Research Paper No. 07082001

Growth and Structural Change in China's Energy Economy

Fritz Kahrl

David Roland-Holst

August, 2007

CENTER FOR ENERGY, RESOURCES, AND ECONOMIC SUSTAINABILTY

338 GIANNINI HALL
UNIVERSITY OF CALOFORNIA
BERKELEY, CA 94707
PHONE: (1) 510-643-6362

Research Papers in Energy, Resources, and Economic Sustainability

This report is part of a series of research studies into alternative energy pathways for the global economy. In addition to disseminating original research findings, these studies are intended to contribute to policy dialogue and public awareness about environment-economy linkages and sustainable growth. All opinions expressed here are those of the authors and should not be attributed to their affiliated institutions.

Growth and Structural Change in China's Energy Economy

Fredrich Kahrl and David Roland-Holst [1]

UC Berkeley

August, 2007

Abstract

China's energy economy underwent significant shifts from 1995-2005. We examine changes in energy demand patterns in China using national input-output and energy input tables from 1997, 2002, and 2004. Our results indicate four overarching trends. First, the energy intensity of the Chinese economy declined significantly from 1997-2004. Second, this longer-term decline masks a minimum in 2002, as more energy intensive domestic consumption and exports drove increases in economy-wide energy intensity from 2002-2004. Third, for urban households embodied energy intensity appears to be rising at lower incomes and falling at higher incomes, suggesting a nascent saturation effect for household energy requirements in China. Fourth, meteoric export growth following China's accession to the WTO has led to a convergence of total energy embodied in domestic (household) and foreign (export) consumption.

Keywords: Chinese energy policy, energy intensity, energy transition

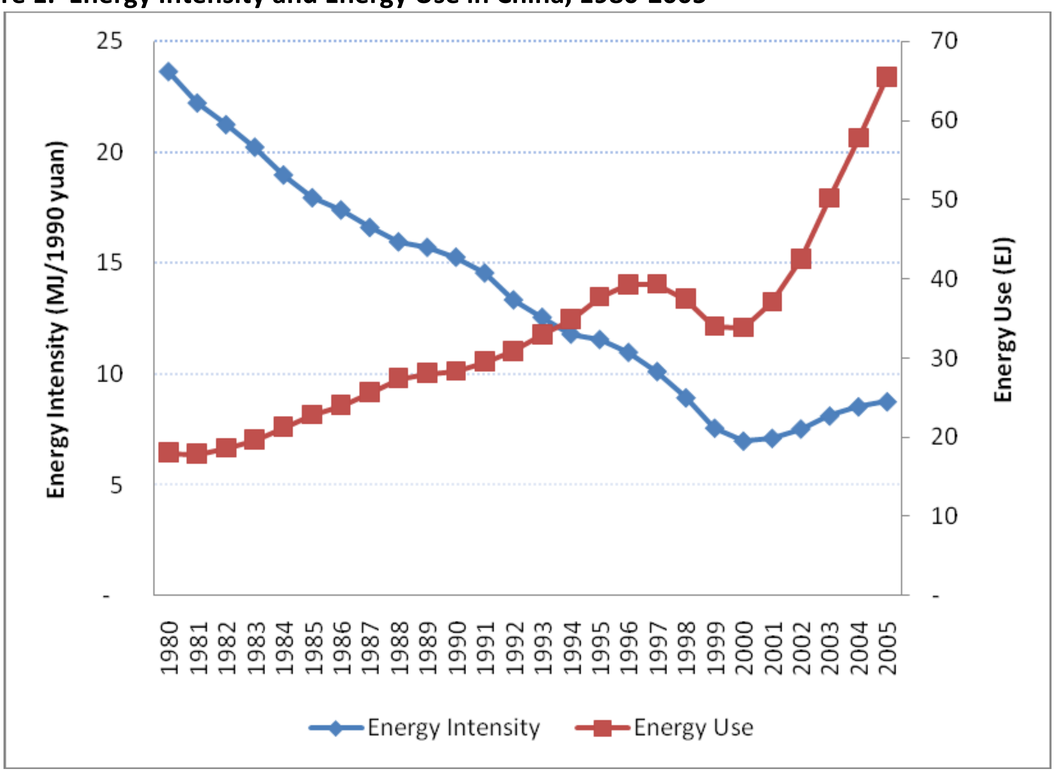
[1] Energy and Resources Group and Department of Agricultural and Resource Economics, respectively. Correspondence: dwrh@are.berkeley.edu.

1. Introduction

China has been the world's most vibrant economy and its largest source of energy demand growth over the past two decades, accounting for more than one quarter of net growth in global primary energy consumption from 1980-2004 (EIA, 2006). To sustain economic growth and rising living standards, China needs effective policies that anticipate and shape the country's future energy requirements. In this paper, we use energy supply chain analysis to examine detailed official data over the last decade for insights into China's changing energy use patterns. Our results indicate that incipient structural changes in the Chinese energy economy and sustained economic and energy demand growth in China will pose important, and different, challenges for policymakers.

Growth and Structural Change

Figure 1. Energy Intensity and Energy Use in China, 1980-2005



Sources: Energy and GDP data are from NBS, various years; GDP data are in 1990 yuan, using the IMF's deflators for China

China's energy economy has undergone significant changes since the turn of the millennium. A combination of sustained absolute growth (i.e., higher economic growth inducing higher energy demand growth) and structural shifts (i.e., rising energy intensity requiring more energy per unit of economic growth) is responsible for these changes. From 2001-2005 China's primary energy demand growth (23.5 EJ, 9% annual growth) exceeded 1980-2000 primary energy demand growth (22.9 EJ, 4% annual growth) (NBS, 2006). After declining steadily from 1980-2000, the Chinese economy's energy intensity began to increase in 2001 (Figure 1). The externalities associated with changing energy demand patterns in China are considerable. From 1990-2000 China accounted for 16 percent of the gross growth in global energy-related CO_2 emissions; from 2001-2004 this share rose to 41 percent (EIA, 2006).

While we do not attempt to separate out the effects of absolute growth and structural change, it is important to note that these two effects have different implications and pose different challenges for Chinese and OECD policymakers. The interplay between growth and intensity is particularly important in the context of international climate negotiations. Rapidly growing countries like China have high uncertainty in economic and attendant energy demand growth. Thus they are less likely to commit to binding, absolute reduction targets that do not account for growth uncertainty. Chinese government proposals to reduce carbon dioxide (CO_2) emissions, to the extent that they have mentioned targets, have indeed focused on CO_2 intensity targets rather than absolute reduction targets.[2] Quite apart from international climate negotiations, in response to the huge surge in energy demand during its 10th Five-Year Plan (2001-2005) the Chinese central government set a binding goal of reducing the energy intensity of the country's GDP by 20 percent during its 11th Five-Year Plan (2006-2010). However, without a clearer understanding of the drivers of rising energy intensity in China, it remains unclear what kinds of policies will be most effective for reducing it.

Explanations for the 2001-2002 shift in the Chinese economy's energy intensity have thus far focused on supply-side forces, including a marked increase in the share of heavy industry in

[2] The draft of China's *First National Climate Change Assessment* reportedly includes a goal of reducing the energy intensity of the Chinese economy by 40% by 2020 and 80% by 2050 (Herzog, 2007). The final draft of *China's National Climate Change Programme* (NDRC, 2007) contains no mention of any targets.

China's economic output since 2002 (Rosen and Houser, 2007). While not disputing heavy industry's role among supply-side forces, attention to demand-side drivers of energy consumption throughout the Chinese economy is equally, if not more, important for designing forward-looking, macroeconomic policies that reduce the energy intensity of China's economic growth. This paper examines the domestic energy consumption embodied in China's final demand — the sum of all energy used domestically to create the goods and services consumed by domestic households, government, capital investment, and foreigners (through exports).

The next section explains the data sources and estimation methods used in the paper. Section 3 presents the basic empirical findings, followed by concluding comments in Section 4.

2. Methods

This analysis is based on data from China's national input-output (I/O) tables and energy input tables, both of which are compiled by the National Bureau of Statistics (NBS). China's I/O tables are assembled every five years (1992, 1997, 2002), and are often updated every two to three years after (1995, 2000, 2004) based on the underlying structure of the five-year tables. We use the 1997, 2002, and 2004 tables in this paper. The structure of the 1997 and 2002 tables reflect longer-term growth patterns in the Chinese economy; the 2004 table reflects changing patterns of final demand after China's accession to the WTO in December 2001.

Energy input tables for China are compiled every year for major energy consuming sectors and published online in China's main statistical yearbook, with a two-year lag between the date of release and the date of the data (i.e., 1997 data are available in the 1999 statistical yearbook). To match I/O tables, we use the 1997, 2002, and 2004 energy input tables.

In tandem, China's I/O and energy input tables provide insight into the flows of energy throughout its economy, as these extend over long supply chains from extraction and processing to intermediate consumption and eventually into final goods and services. Combining the two tables through energy I/O analysis integrates the economic structure of I/O tables with the energy consumption patterns characteristic of different sectors. In the present analysis, we use a sectoral energy intensity technique common in energy I/O analysis (e.g., Casler and Wilbur, 1983).

An I/O table is essentially a double entry tabular accounting ledger that records transactions within an economy. For our purposes, the two key components of an I/O table are the transactions and final demand matrices. The former is an $n \times n$ matrix where each entry x_{ij} records inputs from sector i to sector j. The latter is an $n \times T$ matrix where T includes the components of final demand, Y_i: household consumption, government expenditure, capital investment, inventory changes, imports, and exports. Summing across each row in the table gives gross output for sector i, X_i

$$\sum_{i=1}^{m} x_{ij} + Y_i = \qquad (1)$$

I/O analysis is based on the identity

$$x_{ij} = a_{ij} x_j = Ax \qquad (2)$$

where A is the matrix of direct coefficients, or the A matrix. Each entry a_{ij} in the A matrix is sector *i's* input to sector *j* normalized by the total inputs to sector j. Put differently, a_{ij} is the quantity of sector *i* required to produce one unit of sector *j*. Substituting and rearranging, equation 1 can be rewritten as

$$X = Y(I - A)^{-1} \qquad (3)$$

where $(I-A)^{-1}$ is the multiplier matrix. Each coefficient in the multiplier matrix reflects the total demand induced in sector a_{ij} by a one unit change in final demand for sector *j*. Multipliers thus capture induced supply chain linkages throughout the economy.

Energy I/O analysis is based on an assumed proportionality between transactions in the I/O table and sectoral energy inputs, which are linked through sectoral energy intensities. In other words, if an increase in the demand for processed food increases the demand for agriculture by

0.4 units, the demand for energy in the economy increases by a proportional amount that is determined by the energy intensity (e.g., in joules/unit) of agriculture. The energy intensity (α) of each sector is that sector's total energy input (E_i) divided by its total output, or, in matrix notation

$$\alpha = EX^{-1} \qquad (4)$$

where X^{-1} is the diagonalized matrix of sector output.

The total embodied energy in each sector is the transpose of α multiplied by the multiplier matrix, or

$$\varepsilon = \alpha'(I - A)^{-1} \qquad (5)$$

where ε is an embodied energy intensity row vector that reflects the embodied energy induced from sector *j* by a unit change in final demand. The energy embodied in final demand can be calculated by multiplying ε by the components of final demand, which here include household consumption (C), capital investment (I), government spending (G), and exports (EX).

$$E = \varepsilon \times (C + I + G + EX) \qquad (6)$$

For total household embodied energy consumption H_T, we include direct primary energy consumption as an additional term

$$H_T = C + E_R \qquad (7)$$

where E_R is residential primary energy consumption. This approach allows us to capture the energy embodied in household consumption of primary energy (i.e., through household payments to the coal mining sector and its economy-wide links) and the actual energy in primary energy consumption (e.g., the energy contained in a ton of coal consumed by households) separately, which is important for maintaining consistency between direct and indirect energy consumption. Whether direct residential energy consumption should be considered part of 'embodied energy consumption' is an open question, but is not critical to the argument here. Direct residential primary energy consumption is below six percent of total primary energy consumption in all years that we examine.

Because we focus on energy consumption within the Chinese economy, we do not include imports in final demand. Imports reflect embodied energy entering the Chinese economy rather than the energy embodied in goods and services through domestic energy consumption. We do, however, include primary energy imports in our sectoral energy intensity calculations as these are part of domestic primary energy consumption and are included in the NBS energy input tables.

In sectors that are import dependent, direct primary energy consumption will be low. Indirect energy consumption, both in terms of secondary and embodied energy consumption will also be low because imports do not have linkages in the transaction matrix (i.e., the construction sector's purchase of imported steel does not induce demand for electricity). However, by normalizing domestically consumed primary energy inputs by gross output, we implicitly assume that imports are on average homogeneous across sectors. In other words, we assume that, for instance, nonferrous metals consuming sectors on average have the same proportion of imported nonferrous metals in their total nonferrous metal inputs. While heterogeneity may be significant in one or two sectors (e.g., steel), these differences (e.g., between crude and rolled steel) cannot be captured at the 43 sector level and the import homogeneity assumption is, we argue, reasonable.

Two further methodological points are important to note. First, since we are comparing three I/O tables over time sectoring issues and accounting for inflation are important. For the former, we aggregate the 56-sector 2004 table and disaggregate the 42-sector 2002 table into 43 sectors to match the sectoring scheme in the 1997 table. Aggregation and disaggregation are relatively straightforward; in cases where our 43-sector I/O tables have more detail than the energy input tables we use shares of energy payments for coal and oil and gas in the I/O tables to disaggregate sectoral energy consumption. To account for the effects of inflation we use 2000 yuan as a base year and deflate sectoral energy intensity and final demand for each year based on the IMF's deflators for China; multipliers are unit free and thus do not require deflation.

Second, to avoid double counting primary and secondary energy, we confine our sectoral energy intensities to the primary energy inputs into each sector, including coal, crude oil, and natural gas. Hydropower, nuclear, and wind energy are included as inputs into the 'Production and Supply of Electricity and Heat' sector, based on data from EBCEPY (1998; 2003; 2005). Note that this method differs from but is ultimately consistent with an approach where all energy inputs are allocated to the extractive sectors and all other sectors have an energy intensity of zero. To harmonize energy inputs across sectors and we convert the physical units listed in the energy input tables to energy units using the lower heating values used by the Intergovernmental Panel on Climate Change (IPCC, 2006).

To ensure that our results are consistent, we compare both our energy inputs and our embodied energy results against the total energy use estimated by the NBS. Some discrepancy between our intensity figures and NBS data is to be expected because we use different lower heating values than the NBS. A second reason for potential discrepancies is that some energy inputs, in particular "other petroleum products," are not included in sectoral energy inputs in the tables but are included in total energy. This latter factor is more minor and we do not attempt to correct for it. For intensities, these two factors lead us to a lower estimate of total energy demand, but one that is within one percent of the NBS estimate.

By definition, the total embodied energy that we obtain from equation 6 should be equivalent to energy inputs into sectoral intensities. More intuitively, the E's on both sides of equation 8 are, in theory, identical.

$$E = E\hat{X}^{-1} \times (I - A)^{-1} \times Y \qquad (8)$$

In reality, because of small inconsistencies in the I/O tables, and thus the relationship between gross output, the multiplier matrix, and final demand, there will be some degree of error between the input and output E terms. For 1997 and 2002, our estimates of embodied energy output (LHS in 7) are within 1 percent of our energy inputs (RHS in 7); for 2004 our embodied energy output is 7 percent higher than our energy inputs. The higher error in 2004 likely reflects the preliminary nature of these industry statistics, which have not yet been released officially.

3. Results: Sources of Emergent Energy Demand in China

Our analysis of the changing structure of energy flows in the Chinese economy over 1997, 2002, and 2004 reveals four overarching conclusions. First, the energy intensity of the Chinese declined significantly over 1997-2004, as the embodied energy intensity of final demand decreased across all sectors during this time period. Second, declines in energy intensity over 1997-2004 mask a minimum in 2002, where to a combination of background and structural changes. Third, saturation effects are beginning to emerge at higher income levels in the Chinese economy, with embodied energy intensity rising and falling inversely with income. Fourth, rapid growth in exports led to a convergence in embodied energy demand from domestic (households) and foreign (export) sources over 1997-2004. More detailed discussion of each of the main findings follows.

Improvements in Overall Energy Efficiency

For the three periods considered, Table 1 presents results on the growth in the main components of final demand and their embodied energy intensity. As Table 1 shows, all four components of final demand in China enjoyed rapid and sustained growth over the period 1997-2004 (second row), with real GDP before imports rising an average of 13 percent annually. In contrast, although the energy embodied in demand for domestic output grew significantly from 1997-2004, it was 6 average annual percentage points slower than real demand expansion (first row). This improvement in energy intensity (third row, Energy per FD), was unevenly distributed across demand sources. Still, it represents broadly-based and sustained progress toward greater aggregate energy efficiency in the Chinese economy.

A significant portion of the intensity reductions in our results derive from a sharp decline in direct energy intensity in all primary and secondary energy sectors from 1997-2002, and in the electricity and oil and gas sectors from 1997-2004. These declines can be thought of as "background" energy intensity reductions because their effects on embodied energy intensity are so pervasive and because they are not related to compositional shifts. Compositional shifts are responsible for the differences in embodied energy intensity reductions between investment and households and exports from 1997-2004. Declines in the embodied energy intensity of investment were driven by a shift away from construction, which fell from 65 to 45 percent of total investment from 1997-2004, and toward less energy-intensive investment (e.g., capital equipment). Larger embodied energy intensity reductions in government spending are likely the result of a data anomaly, as the 2004 table includes agricultural spending while the 1997 table does not.

Table 1. Annualized Growth of Embodied Energy, Final Demand, Embodied Energy Intensity, and Share of Embodied Energy (percentages)

		Household	Government	Investment	Exports	Total
1997-2004	Energy	4	6	7	12	7
	FD	8	14	14	17	13
	Intensity	-4	-7	-7	-4	-5
	Energy Share	-3	-1	0	5	0
1997-2002	Energy	4	1	1	3	1
	FD	9	18	13	13	12
	Intensity	-8	-12	-11	-9	-10
	Energy Share	-1	3	-1	2	0
2002-2004	Energy	12	11	23	39	22
	FD	5	5	18	27	14
	Intensity	6	5	4	10	7
	Energy Share	-8	-9	1	14	0

Notes: 'Energy' is embodied energy; 'FD' is final demand; 'Intensity' is embodied energy intensity; 'Energy Share' is the share of embodied energy

WTO Accession and Structural Transitions

Punctuating the longer-term efficiency trend is a minimum in energy intensity between the two periods bracketed by the years being considered: 1997, 2002, and 2004. Substantial reductions in embodied energy intensity from all demand components from 1997-2002 summarily reverse from 2002-2004 (Table 2), coincident with China's entry into the WTO in December 2001. A significant portion of the increase in aggregate energy intensity stems from an increase in the primary energy intensity of heavy industry, which occurred against the backdrop of structural shifts in household, foreign, and investment consumption.

Table 2. Embodied Energy, Final Demand, Embodied Energy Intensity, and Share of Embodied Energy

		HH	GOV	INV	EX	Total
1997	**Energy (EJ)**	**14.1**	**2.6**	**13.2**	**7.0**	**36.9**
	FD (10^{12} RMB)	**3.2**	**0.8**	**2.4**	**1.6**	**7.9**
	Intensity (MJ/2000 RMB)	**4.2**	**3.1**	**5.3**	**4.2**	**4.1**
	Energy Share (%)	**38**	**7**	**36**	**19**	**100**
2002	**Energy (EJ)**	**14.5**	**3.2**	**13.7**	**8.3**	**37.9**
	FD (10^{12} RMB)	**5.3**	**1.9**	**4.6**	**3.1**	**14.6**
	Intensity (MJ/2000 RMB)	**2.8**	**1.7**	**3.0**	**2.7**	**2.7**
	Energy Share (%)	**32**	**7**	**35**	**27**	**100**
2004	**Energy (EJ)**	**18.2**	**3.9**	**20.5**	**15.9**	**58.5**
	FD (10^{12} RMB)	**5.8**	**2.1**	**6.3**	**5.0**	**19.2**
	Intensity (MJ/2000 RMB)	**3.1**	**1.8**	**3.3**	**3.2**	**2.9**
	Energy Share (%)	**31**	**7**	**35**	**27**	**100**

Notes: 'Energy' is embodied energy, in exajoules; 'FD' is final demand, in 2000 RMB trillions; 'Intensity' is embodied energy intensity (Energy/FD); 'Energy Share' is the share of embodied energy, in percentages. HH, GOV, INV, and EX are households, government, investment, and exports, respectively. Household includes primary energy consumed by households.

By definition, increases in the embodied energy intensity of final demand result from: 1) more energy intensive inputs to production, 2) increases in primary energy intensity in individual sectors, or 3) changing composition of final demand. Because the 2004 I/O table is based on the structure of the 2002 table, 1) can be largely disregarded here. In the remainder of this section, we highlight changes in 2), and explore 3) in greater detail for households, exports, and investment. The structure of government spending does not change significantly over the 1997, 2002, and 2004 tables, and we do not examine it in greater depth.

Changes in sectoral primary energy intensity are shown in Table 3. The mining, heavy industry, and secondary energy industries accounted for nearly 94 percent of China's primary energy consumption in 2004. While the mining and secondary energy industries saw continued declines in intensity from 2002-2004, heavy industry's primary energy intensity rose by 5 percent. This increase was not necessarily driven by a reversal or leveling off of the efficiency gains from technology improvements. Instead it may be the result of import substitution for more energy-intensive heavy industrial products in China since 2001 (Rosen and Houser, 2007).

Table 3. Percent Consumption and Percent Intensity Change for Embodied and Primary Energy, 2002 and 2004

	% Total Embodied Energy Consumption (2004)	% Change Embodied Energy Intensity 2002-2004	% Total Primary Energy Consumption (2004)	% Change Primary Energy Intensity 2002-2004
Agriculture	**3%**	**-2%**	**1%**	**+15%**
Mining	**1%**	**+2%**	**6%**	**-24%**
Electricity, Refined Oil, Gas	**9%**	**-4%**	**67%**	**-16%**
Heavy Industry	**11%**	**+16%**	**21%**	**+5%**
Manufacturing	**35%**	**+21%**	**4%**	**+10%**
Construction	**20%**	**+10%**	**0.2%**	**+8%**
Trade, Transport, Telecom	**6%**	**+29%**	**1%**	**-36%**
Services	**14%**	**-3%**	**1%**	**+28%**

Notes: Heavy industry here includes chemicals, ferrous and nonferrous metals processing, and nonmetal minerals processing.

China's exports experienced two major aggregate compositional changes from 2002-2004. First, the value and embodied energy shares of manufacturing rose significantly, accompanied by a slightly lower rise in the shares of heavy industry. Second, these increases were attendant with a decline in the shares of services. While China is widely known to be a manufacturing-intensive exporter, the fact that rapid growth in industrial exports exceeded growth in service-intensive exports in the wake of China's WTO entry should send a warning signal to Chinese policymakers. The large decrease in Trade, Transport, Telecom in Table 4 is likely the result of a different classification of "Trade" used in the 2004 table vis-à-vis the 2002 table. The compositional shifts outlined here are consistent regardless of whether Trade, Transport, Telecom is included.

Table 4. Percent Total Exports and Percent Total Export Embodied Energy by Sector, 2002 and 2004

	% Total Exports by Value 2004	% Total Export Embodied Energy 2004	% Total Exports by Value 2002	% Total Export Embodied Energy 2002
Agriculture	2%	1%	2%	1%
Mining	1%	3%	1%	3%
Electricity, Refined Oil, Gas	1%	6%	1%	7%
Heavy Industry	12%	23%	10%	20%
Manufacturing	73%	58%	65%	52%
Construction	0%	0%	0%	0%
Trade, Transport, Telecom	4%	5%	13%	12%
Services	6%	3%	8%	5%

Notes: Heavy industry here includes chemicals, ferrous and nonferrous metals processing, and nonmetal minerals processing.

For households, the story is significantly different. From 2002-2004, aggregate changes in household embodied energy consumption were dominated by parallel reductions in the share of agriculture and increases in secondary energy consumption — electricity in this case. This pattern is consistent with a longer-term trend over the period 1997-2004. Residential electricity consumption (10 percent annualized growth) (EBCEPY, 2006) grew 1.5 times faster than total household consumption (6.5 percent annualized growth) (NBS, 2006) from 1997-2004. Again, potential reclassifications in Trade may obscure the magnitude of some of the shifts in Table 5, but additional one longer-term trend is noteworthy. The value share of services increased significantly between both 1997-2002 and 2002-2004, while its embodied energy share remained relatively constant. Increases in the value and embodied energy shares of heavy industry from 2002-2004 do not appear to be part of a longer-term pattern, and are driven by household consumption of chemical industry products.

Table 5. Percent Total Household Consumption and Percent Total Household Embodied Energy by Sector, 2002 and 2004

	% Total Household Value 2004	% Total Household Embodied Energy 2004	% Total Household Value 2002	% Total Household Embodied Energy 2002
Agriculture	13%	7%	20%	12%
Mining	1%	1%	1%	1%
Electricity, Refined Oil, Gas	4%	26%	3%	21%
Heavy Industry	6%	13%	4%	9%
Manufacturing	30%	26%	29%	25%
Construction	0%	0%	0%	0%
Trade, Transport, Telecom	5%	6%	11%	10%
Services	41%	20%	33%	21%

Notes: Heavy industry here includes chemicals, ferrous and nonferrous metals processing, and nonmetal minerals processing.

Although annualized investment growth rates increased from 14 percent over 1997-2002 to 18 percent over 2002-2004, compositional shifts tempered the energy requirements of investment demand growth. Again treating Trade, Transport, Telecom patterns with caution, the key change in the composition of investment over 2002-2004 was a shift from construction to manufacturing (i.e., equipment). From 1997-2004, construction's share of embodied energy intensity fell nearly 10 percentage points. Despite this decrease, and despite the fact that it consistently accounts for less than 1 percent of primary energy consumption, construction still accounted for 20 percent of China's total domestic energy consumption in 2004 (Table 3).

Table 6. Percent Total Investment and Percent Total Investment Embodied Energy by Sector, 2002 and 2004

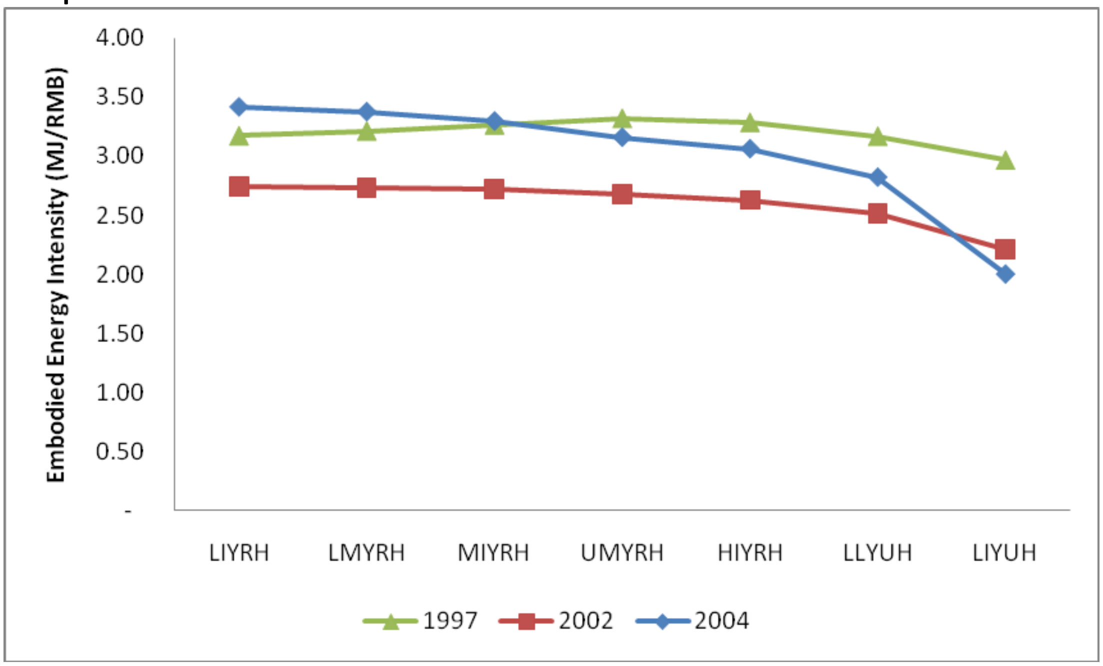
	% Total Exports 2004	% Total Export Embodied Energy 2004	% Total Exports 2002	% Total Export Embodied Energy 2002
Agriculture	4%	1%	2%	1%
Mining	0%	0%	0.4%	1%
Electricity, Refined Oil, Gas	0.1%	1%	0%	0%
Heavy Industry	2%	3%	0%	0%
Manufacturing	37%	32%	31%	24%
Construction	45%	55%	60%	71%
Trade, Transport, Telecom	10%	8%	3%	2%
Services	2%	1%	2%	1%

Notes: Heavy industry here includes chemicals, ferrous and nonferrous metals processing, and nonmetal minerals processing.

Household Energy Use and the Saturation Effect

Household consumption in the 1997 and 2004 I/O tables is disaggregated into 12 categories, 5 rural and 7 urban. Based on an annualized average of these two tables we disaggregate rural and urban consumption in the 2002 table into these same 12 categories, but we use the 2002 breakdown with some caution. Detailed inspection of these categories in our results supports the notion of a saturation effect in embodied household energy use — that the energy intensity of consumption first rises with income and then declines. By taking account of the heterogeneity among households, this process can be seen to be emergent in China, yet its ultimate implied benefits can only be inferred at this stage.

Figure 2. Embodied Energy Intensity of Urban Household Consumption by Urban Income Group



To better understand the forces at work, Figure 2 presents two sets (1997 and 2004) of energy intensity series, and seven urban household types. As the shift of trend from 1997 to 2004 in Figure 1 shows, China's urban economy is currently transitioning from lower income, industrial-intensive demand to higher, tertiary-intensive demand. In 1997 this transition was only just beginning to take shape at a household level, as embodied energy intensities (e.g., appliances and apartments) were fairly uniform across incomes but begin to decline at higher incomes. Economy-wide decreases in energy intensity shift the curve downward by 2002, but do not change its shape.

By 2004 a more distinct trend toward saturation has emerged, where the steeper slope of the 2004 curve shows a situation in which, for instance, lower income households are increasing their demand for appliances while higher income groups, having met these needs, progressively reduce such purchases as a share of income. In other words, whereas from 1997-2002 declines in household embodied energy intensity were driven by background effects, as noted previously from 2002-2004 increases in household embodied energy intensity were driven in part by compositional shifts. Whether the embodied energy intensity of household consumption will rise or fall in the future will depend on the combined effects of trend reduction and rotation observed here.

Exports and Energy Sustainability

The resource implications of China's post-WTO export success are only beginning to be more fully understood. Export growth rates increased from 13 percent annual growth to 27 percent annually across the two periods that we examine, making an important contribution to China's national economic growth and income gains. Table 7 reveals the energy implications of this rapidly rising foreign demand, with exports' share of China's total domestic energy use rising from 19 to 27 percent and households' share falling from 38 to 31 percent from 1997-2004 (first two columns, Table 7). Domestic and foreign consumption of energy embodied in the production of goods and services in China's economy (i.e., subtracting household primary energy use from domestic consumption) converged to near parity by 2004 (second two columns, Table 7).

Table 7. Percent Shares of Embodied Energy by Final Demand Source

	% Total Domestic Energy Consumption 1997	% Total Domestic Energy Consumption 2004	% Total Production Embodied Energy Consumption 1997	% Total Production Embodied Energy Consumption 2004
Domestic (Households)	38	31	34	29
Foreign (Exports)	19	27	20	28

This convergence between household and export embodied energy consumption has important implications for Chinese energy and climate policy. As these two sources of demand continue to grow their competition for supply constrained energy resources, particularly coal, will push up domestic energy prices, reduce domestic purchasing power, and may ultimately affect China's export competitiveness. Managing the transition between an export-driven and a consumer-driven economy will require energy and macroeconomic policies that anticipate possible interactions between these two forces. Convergence in household-export embodied energy consumption in China also makes more ambiguous the notion that developing countries are, or should be held, singularly responsible for their greenhouse gas emissions, as these are closely tied to fossil fuel energy use.

4. Conclusions

China's economic growth experience has been remarkable and in many ways unprecedented. The speed and demographic scope of sustained domestic growth in China portend ever-increasing resource requirements, and energy will be at the forefront among these essential commodities. As China continues its rapid transition from an industrializing to a mature, more service-intensive economy, a new generation of structural adjustments will change the composition and intensity of energy requirements. This paper examines recent history for lessons about how growth and structural change will drive China's energy needs in the future.

Based on detailed official data sources for 1997, 2002, and 2004, a few salient trends are apparent in China's energy requirements. First, China achieved notable aggregate reductions in the energy intensity of demand from 1997-2004, averaging about 5 percent per year. This rate is, of course, slower than the Chinese economy's annual demand growth, and thus China's energy needs have continued to grow. In addition, efficiency gains over 1997-2004 mask a minimum in 2002, where the embodied energy intensity of final demand began to increase. Intensity increases occurred across final demand sectors, but were driven in particular by foreign (export) and domestic (household) demand.

The rise in embodied energy intensity in final demand can be attributed to an increase in the intensity of "background" primary energy consumption in heavy industry, which explains the intensity increase across sectors, and changes in final demand compositions, which explain variation in intensity increases among sectors. Increases in primary energy intensity in heavy industry are not well understood, and should be the subject of further research. We document three major compositional shifts. Exports shifted away from services and toward manufacturing and heavy industry from 2002-2004. Household consumption shifted away from food and toward services and electricity. Investment shifted away from construction and toward manufacturing, which served to lower the energy requirements of investment growth. Further analysis is needed to better separate and quantify these effects.

Examination of detailed urban household energy requirements in China reveals an income profile that suggests higher energy intensity at lower incomes and a process of saturation attenuating the energy intensity of consumption at higher income levels. The magnitude of China's future energy needs will be determined in significant measure by this process of rotation and reduction seen here in the embodied energy of urban household consumption. While there is an obvious role for government in shaping this process, household energy consumption in China, particularly at the demographic intersection between rural and urban areas, remains poorly understood.

Foreign demand has been the largest driver of absolute energy consumption in China since the country's accession to the WTO in 2001. The share of domestically consumed energy induced by exports grew from 19-27 percent from 1997-2004. Foreign demand accounted for nearly the same share of total embodied energy consumptions as domestic households in 2004. This convergence in embodied energy demand between households and exports raises questions about, inter alia, how energy trade-offs between the two might influence the domestic prices, real incomes, and China's international competitive position.

5. References

Casler, S. and Wilbur S., 1984. Energy Input-Output Analysis: A Simple Guide. Resources and Energy 6: 187-201.

Editorial Board of the China Electric Power Yearbook (EBCEPY), 1993-2004. China Electric Power Yearbook. China Electric Power Press, Beijing.

Energy Information Administration (EIA), 2006. Annual Energy Outlook. DOE/EIA, Washington, DC.

Herzog, Timothy, 2007. China's Carbon Intensity Target. World Resources Institute website. Online at: http://www.wri.org/newsroom/topic_content.cfm?cid=4234.

Intergovernmental Panel on Climate Change (IPCC), 2006. 2006 Guidelines for Greenhouse Gas Inventories.

National Bureau of Statistics (NBS), 1995-2006. China Statistical Yearbook. China Statistics Press, Beijing.

Rosen, DH and Houser T, 2007. China Energy: A Guide for the Perplexed. Peterson Institute for International Economics, Washington, DC.