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# Past as Prologue? Understanding energy use in post-2002 China

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ABSTRACT

From 2002 to 2009, China's energy use nearly doubled, making it the world's largest emitter of carbon dioxide more than a decade ahead of forecasts. Why did energy use in China rise so rapidly after 2002? Using index decomposition analysis, we find that the vast majority of growth in energy consumption in China over the 2000s was due to GDP growth, with a small but important amount due to structural change as a result of China's emergence as a net metals exporter. Changing prices and data anomalies make energy intensity and structural change appear to be more important drivers of energy consumption than they actually were; the infamous reversal in energy intensity in China from 2002 to 2004 may simply be an artifact of difficulties in accurately deflating value added. About half of the growth in energy consumption in China from 2002 to 2007 was driven by heavy industry. Using structural decomposition analysis, we find that growth in heavy industrial output was due primarily to growth in construction and equipment investment, with a small amount due to an increase in net metal exports. In tandem, these two findings suggest that the primary driver of energy consumption in China after 2002 was an acceleration of the country's investment-dominated model of GDP growth. Without rebalancing the economy toward consumption, there are limits to what improvements in energy conversion efficiency and end use energy efficiency can achieve in moderating growth in China's energy use.



## 1. Introduction

From 2002 to 2009, energy consumption in China grew by 43 exajoules (EJ, 1 EJ = $10^{18}$ joules), from 47 to 90 EJ, an increase that required nearly 30 years in the U.S. (Fig. 1). Growth in energy use on this scale is without any comparable precedent, having consequences for global geopolitics, energy markets, and the global environment. It was also unanticipated. The International Energy Agency (IEA) forecast in 2002 that, by 2020, energy consumption in China would still be below U.S. 2000 levels (International Energy Agency, IEA, 2002), but in mid-2010 the IEA estimated that China had already eclipsed the U.S. as the world's largest energy consumer.[1]

China's surge in energy consumption coincided with major changes in its energy intensity and economy. A momentary increase in energy intensity, from 2002 to 2004, reversed more than two decades of significant intensity declines that brought China closer to international levels (Fig. 2). The year 2001 inaugurated China's membership in the World Trade Organization (WTO), spurring an intense new cycle of growth in consumption, investment, and exports, with the Chinese economy expanding at double digit annual growth rates from 2003 to 2007 (NBS, 2010).

In response to rising energy use and intensity, the Chinese government set a binding goal of reducing economy-wide energy intensity by around 20% from 2005 levels by 2010. Measures to achieve this goal focused on improving the energy efficiency of industrial equipment and processes, mandatory closures of small industrial plants, and, to a lesser extent, building and appliance efficiency (Andrews Speed, 2009; Price et al., 2010, 2011; Zhou et al., 2010). Despite widely publicized difficulties in meeting the 2010 energy intensity target, the approach to managing energy use in China's 12th Five-Year Plan (2011–2015) appears to be a continuation of the 11th Plan, with a new target and a new suite of energy efficiency mandates, programs, and incentives. This staying of the course raises an important question: Are industrial sector energy efficiency policies, as the Chinese idiom goes, the right medicine for the ailment (对症下药)? More to the point, perhaps, what was the ailment? What factors led to such rapid growth in energy demand?

This paper analyzes both the proximate and root causes of the rapid growth in energy consumption in China from 2002 to 2007, focusing on what this period implies for the future of energy and climate policy, in China and globally. Section 2 develops our framing questions, building on a review of available energy data and the literature on energy use in China during this period. Section 3 discusses our methods and data sources. Section 4 describes the results, followed by a final, concluding section.

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[1] IEA, "China overtakes the United States to become world's largest energy consumer," 20 July 2010, http://www.iea.org/index_info.asp?id=1479.

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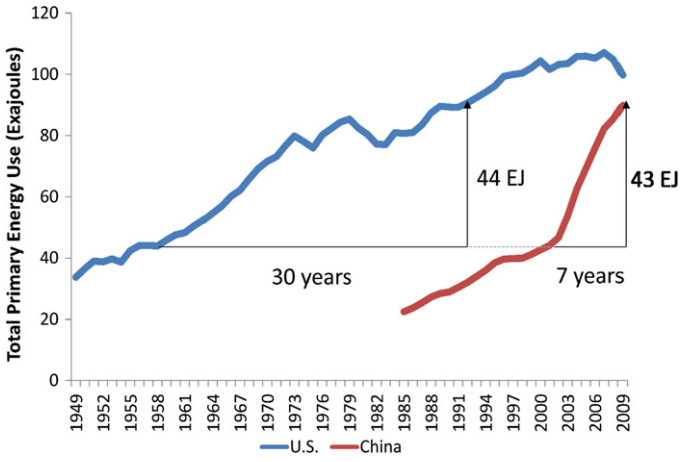


**Fig. 1.** Growth in energy use from 2002–2009 in China required 30 years in the U.S. Sources: China data are from NBS (2010); U.S. data are from EIA (2011).

## 2. Background

Given the gravity of the issues associated with rapid energy demand growth in China since 2002 — from energy security to climate change — there has been surprisingly little analytical work on what factors led to this rapid growth, how likely it is to continue, and what kinds of policy interventions could effectively address it. In this section we describe available evidence on physical energy use trends (i.e., in energy units) and energy–economy linkages in China since 2002.

### 2.1. Energy use trends

Heavy industry has driven much of the growth in China's physical energy consumption since 2002. From 2002 to 2007, the chemical, steel, non-ferrous metal, and non-metal minerals sectors[2]accounted for 17 EJ (49%) of the 34 EJ of growth in primary energy consumption.[3]The energy industry itself (coal mining, petroleum extraction and refining, coking, and electricity generation) and transportation services contributed another 7 EJ (21%) of growth, while residential use added just 3 EJ (8%). Heavy industry's share of total primary energy use increased from 42% in 2002 to 49% in 2007.

A second important change since 2002 has been the rise of coal, and the fall of oil, in China's primary energy mix (Fig. 3). The shares of coal and oil consumption, in fact, reached historical low and high points, respectively, in 2002. Coal and oil are typically more readily substitutable in the industrial sector than in the energy sector, but there is little evidence suggesting larger-scale oil-to-coal substitution in the industrial sector.[4]An alternative explanation is that the shift to coal was driven by higher growth in coal-dominant sectors relative to oil-dominant ones.

[2] By value added, the non-ferrous metals sector is mostly copper, lead, zinc, and aluminum smelting and pressing. The non-metal minerals sector is largely cement, cement products (e.g., concrete), bricks, and glass. Data are from China Data Online's Yearly Industrial Data dataset.

[3] All of the data in this and the next paragraph are from the Consumption of Energy by Sector tables in the China Statistical Yearbook series.

[4] No sectors saw declines in petroleum product use that were large relative to the 1.2 petajoule (1 PJ = $10^{15}$ J) equivalent decline in oil share from 2002 to 2007. Of the sectors that had large increases in coal use, none are major petroleum product consumers except for the processing of petroleum, coking, processing of nuclear fuel sector, and the large shift in the shares of coal and oil in this sector is likely the result of the petroleum processing and coking sectors being aggregated into a single sector. Data are from the NBS Consumption of Energy by Sector tables.

### 2.2. Changes in energy–economy linkages

Though their relationship is still unclear, emergent economic trends have clearly been an important driver of both the magnitude and composition of energy use in China since 2002. Previous analyses of energy–economy linkages that cover this time period implicate a broad range of policy issues, which we divide generically into supply-side (production) and demand-side (consumption) perspectives. To elucidate the determinants of aggregate energy use, we adopt the concept of a three-fold conceptual decomposition of energy use in both our discussion and analysis below. Simply put, aggregate energy demand is determined by aggregate economic growth, economic structure (sector composition), and technology (sector energy efficiency). Together, these components interact to determine total energy requirements for the overall economy. All three evolve concurrently, to some extent independently, and can interact in both reinforcing and offsetting ways. In dynamic emerging economies like China they might all be significant.

Much of the supply-side analysis has focused on the role of the industrial sector. Ma (2010) argues that, using sector price indices rather than an economy-wide deflator, the increase in total energy intensity from 2002–2004 disappears, and that changes in nominal prices made the economy look more heavy industry-oriented in value than it was in real terms. Decomposing energy use in the industrial sector over 1998–2006, Zhao et al. (2010) argue that changes in industrial structure and sub-sector energy intensity both reduced baseline intensity of industrial energy demand, and that virtually all of the increase in industrial energy consumption over 1998–2006 can be accounted for through aggregate increases in output. Looking at the economy as a whole, Price et al. (2011) argue that energy consumption growth over 2002–2008 was mainly the result of aggregate growth in economic output. Focusing on 2002–2004, Chai et al. (2009) make a structural argument, that higher energy use was the result of growth in residential consumption and more rapid growth in heavy industry vis-à-vis light industry. Liao et al. (2007) argue, qualitatively, that the rapid growth in energy-intensive sectors relative to energy efficiency improvements led to the 2002–2004 increase in energy intensity.

A more limited number of analyses have examined final demand (consumption, investment, net export) drivers of energy use. Chai et al. (2009) argue that the shift toward heavy industry from 2002–2004 was caused primarily by changes in the structure of final demand, but do not specify what those changes were. Karl and Chen (2010) argue that government consumption was a significant driver of energy intensity since 2002. Previous work by the present authors (Kahrl and Roland-Holst, 2009) argues that investment and exports are the largest energy demand growth drivers in China, but that household consumption drove the increases in energy intensity from 2002 to 2004. Liao et al. (2007) argue that increases in energy consumption were driven by investment and urbanization, but give no evidence to support the role attributed to the latter.

Taken together, these analyses leave a number of important questions unanswered, two of which we focus on in this study. First, from a supply-side perspective, what were the relative contributions of structural change and energy intensity to growth in energy consumption, what sub-sector level changes shaped these contributions, and was either a meaningful contributor to energy demand growth? Second, from a demand-side perspective, how did changes in technology, final demand structure, and growth in final demand across households, government, investment, and net exports affect economic activity in energy-intensive sectors?

## 3. Methods and data

To address these questions, we use a combination of decomposition techniques. For supply-side analysis, we use index decomposition