Title
Taking out one billion tones of carbon: the magic of China's 11th Five-Year Plan

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Taking Out One Billion Tons of CO2: the Magic of China's 11th Five Year Plan?

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Abstract

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 is the first time that a quantitative and binding target has been set for energy efficiency, and signals a major shift in China's strategic thinking about its long-term economic and energy development. The 20% energy intensity target also translates into an annual reduction of over one billion tons of CO2 by 2010, making the Chinese effort one of most significant carbon mitigation effort in the world today. While it is still too early to tell whether China will achieve this target, this paper attempts to understand the trend in energy intensity in China and to explore a variety of options toward meeting the 20% target using a detailed end-use energy model.

Introduction

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 is the first time that a quantitative and binding target has been set for energy efficiency, and 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 and, as a result, energy use per unit of GDP (energy intensity)[1] has increased. This recent trend in energy intensity stands in sharp contrast to the trend observed from 1980 to 2000, when energy demand grew less than half as fast as GDP and energy intensity declined steadily. China's long-term development plan, which calls for a quadrupling of GDP and doubling of energy use from 2000 to 2020, was based on this earlier experience, as are projections of China's energy consumption by major international institutions (IEA, 2004; Zhou et al., 2003). However, if the recent trend continues, not only will it jeopardize China's development goals, but it will also create significantly greater adverse 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 of reducing energy intensity.

This analysis attempts to understand recent trends in energy intensity in China and to explore a variety of options China may adopt in order to meet the 20% target based upon a detailed end-use energy model. The results are presented in three sections in this report. The first section provides a detailed analysis of energy intensity trends in China during the last ten years, highlighting that the shift in industrial structure toward energy intensive sub-sectors such as steel and cement is the leading cause of the recent rebound in energy intensity in China. The second section

[1] We note that this term is used to describe *economic* energy intensity in this report. *Physical* energy intensity (energy use per physical unit) can also be used at the sectoral level to understand trends in specific sub-sectors (e.g. energy use/ton steel; energy use per cubic meter of built space).

provides an explorative analysis of possible scenarios through which efficiency gains could be achieved to reach the 20% target. Finally, a set of policy recommendations is presented.

Recent Trends in Energy Consumption in China

Between 1980 and 2000, China achieved a quadrupling of its GDP with only a doubling of energy consumption (Figure 1), effectively decoupling the relationship between economic growth and energy consumption (Sinton et al., 1998; Lin, 2005). This was a remarkable achievement, since it is widely accepted that growth in energy use is likely to be faster than economic growth in the early stage of economic development (Galli, 1998). In fact, no other major developing country has witnessed declining energy intensity (or an energy elasticity less than one) until much later in their development process. In the early stage of economic development, industrialization and urbanization tend to lead to extensive infrastructure and housing development: both are energy- and material-intensive activities. As a result, energy intensity tends to increase. In the later stage of economic development, demand for services often grows faster than demand for goods, leading to a shift in economic structure toward the service sector, which has much lower energy and material intensity. In addition, efficiency of energy and material use also tends to increase as better technology and materials become available. Thus, energy intensity tends to decline. This is a pattern observed across economies (Quah, 1997; Janicke et al., 1989; and Ausubel et al., 1993).

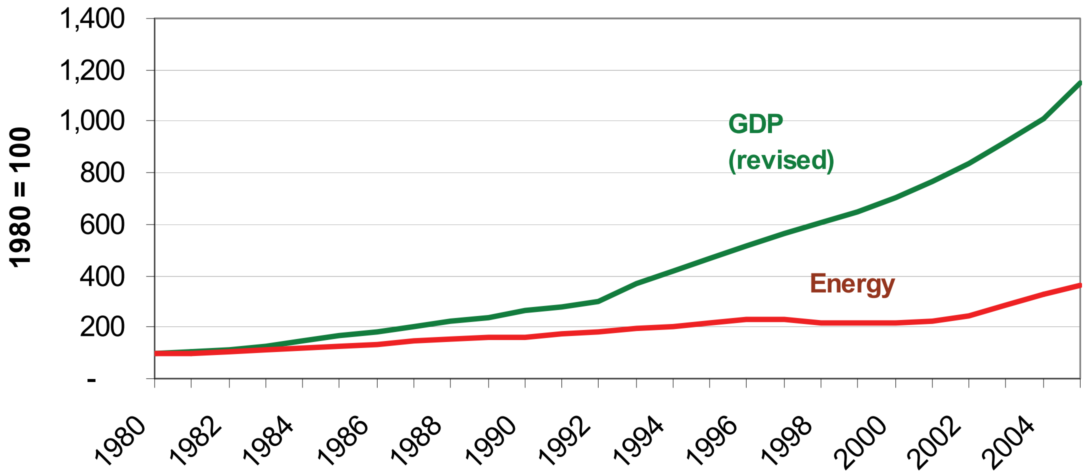

Figure 1: Energy consumption and GDP growth in China, 1980-2000

China's experience from 1980 to 2000 was an exception. However, energy and economic development in China over the last few years suggests that the relationship between energy and economic growth in China may have returned to the expected range of a typical industrializing country. Since 2001, China has experienced much faster growth in energy use than economic growth, with an elasticity reaching 1.6 in 2004. While the growth in energy has moderated to some extent in 2005, the growth rate of energy consumption from 2000 to 2005 maintained a high 9.5% annual average, slightly higher than that of GDP, resulting in an elasticity of just under one (NBS 2006).

This development, while not entirely surprising, nonetheless has alarming implications. At the current rate, China's energy growth could be much faster than anticipated, leading to energy shortages and mounting environmental problems that could undermine China's own development goals for 2020. The consequences for the global energy market could be equally dramatic, since China's energy demand in 2020 would be easily twice as large as expected. Given China's reliance on coal, China's emissions of greenhouse gases (GHG) are likely to be much larger than anticipated as well, further exacerbating the problem of global warming.

In this context, it is timely that China has set a target of reducing energy intensity by 20% within the next five years. Historical evidence suggests that such a target is extremely ambitious and may be very challenging to meet. A thorough analysis of factors affecting energy intensity over the last ten years may help shed some light on what would be the best ways to achieve such a goal.

Energy Intensity Trends

Figure 2 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. 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.

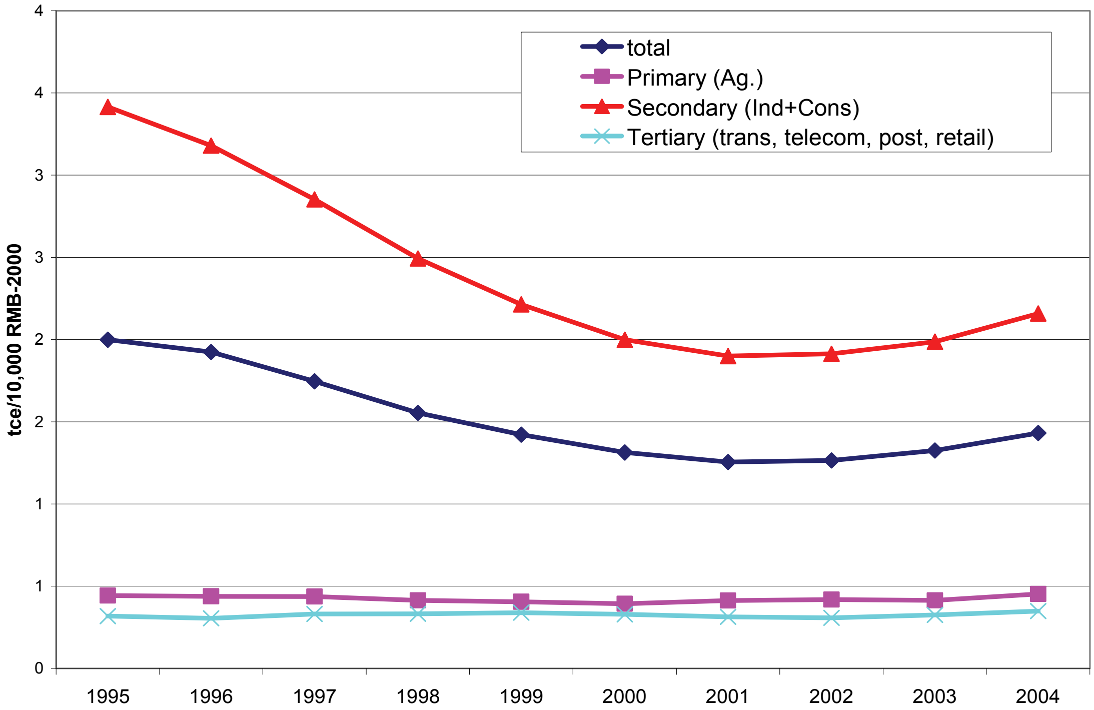

Figure 2: Energy intensity trends in China by three main sectors, 1995 to 2004[2]

Structural Trends

The dominance of the industrial sector in China is not surprising, since industrial energy intensity 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% (Figure 3). The service sector share in China is not only much lower than developed countries but also lower than 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 20% reduction target for energy intensity.

[2] China classifies energy use by agriculture, industry, tertiary, and residential sectors. Commercial building energy use is included in the tertiary sector.

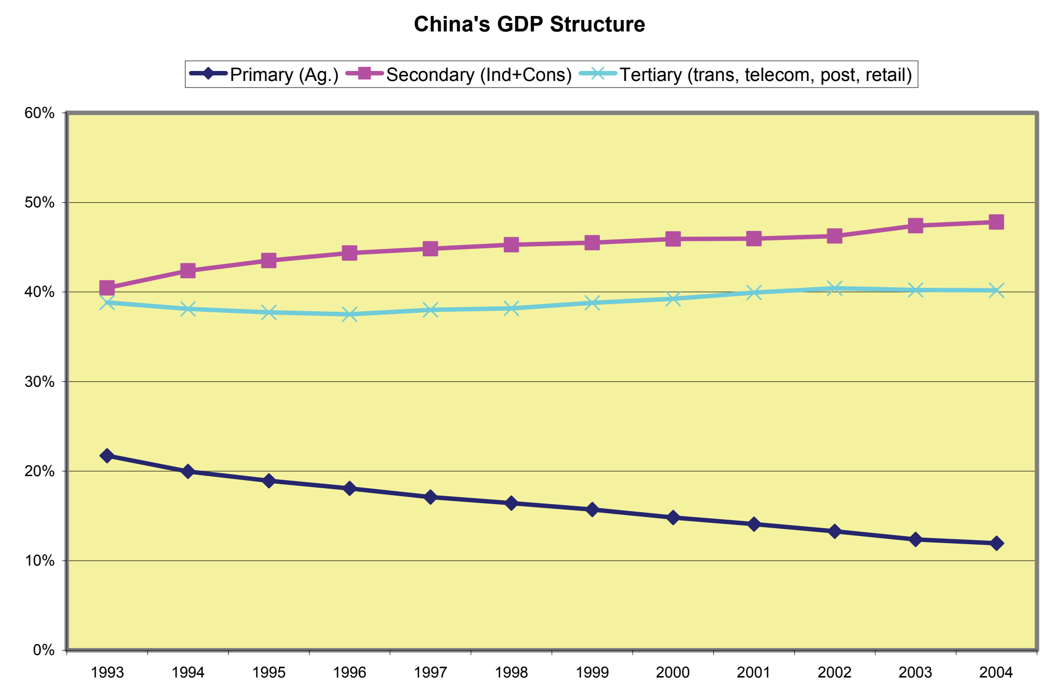

Figure 3: Sectoral shares of GDP in China, 1993-2004

Understanding Energy Intensity and Structural Shift Trends

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. We used a variation of Laspeyres decomposition method presented in Sinton and Levine (1994), with a minor modification. Instead of using a constant base year, we use the preceding year as the base year to minimize the error introduced in the analysis. The modified equation is expressed as follows,

$$E^t = Q^t I^{t-1} + Q^t \sum_{i=1}^{N} S_i^{t-1} \Delta I_i + Q^t \sum_{i=1}^{N} \Delta S_i I_i^{t-1} + Q^t \sum_{i=1}^{N} S_i \Delta I_i$$

Where

E^t = energy actually consumed by industrial sector (in Mtce) in year t

Q^t = GDP or Value-Added (in 2000 yuan)

I_i = intensity of energy use in the ith subsector in year t

S_i = the ith sebsector's share of GDP

i = reference number for subsector

t = the time period

= number if subsectors

$\Delta I_i = I^i_t - I_i^{t-1}$

$\Delta S_i = S^i_t - S_i^{t-1}$

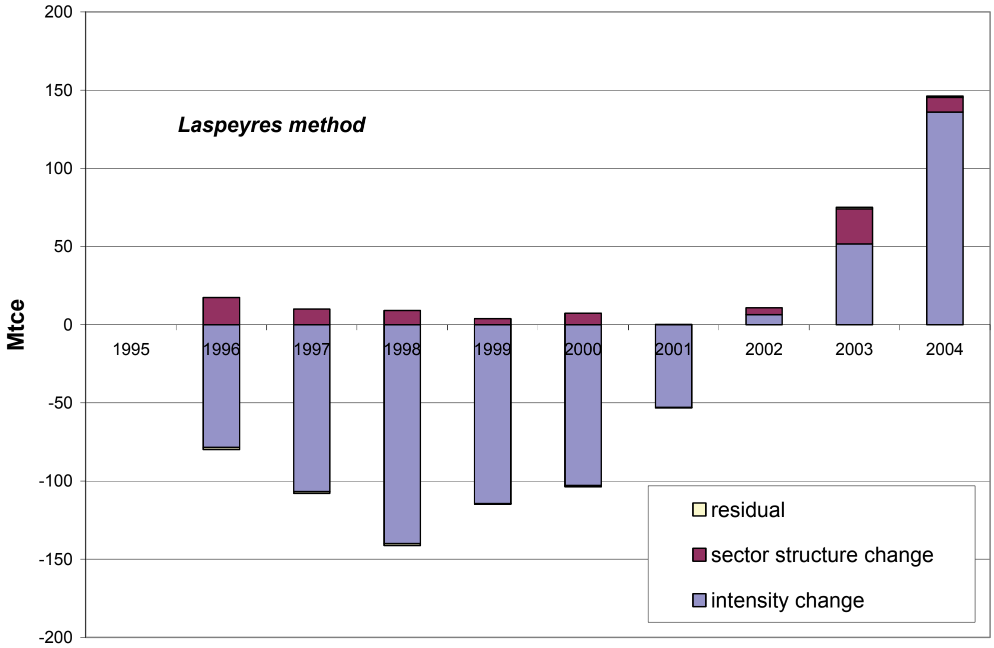

Figure 4: Inter-sector structural change versus energy intensity change

We first apply this methodology to aggregate data using only three sectors: the primary, the secondary, and the tertiary. Figure 4 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 1990s, 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 2). 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 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 could 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.

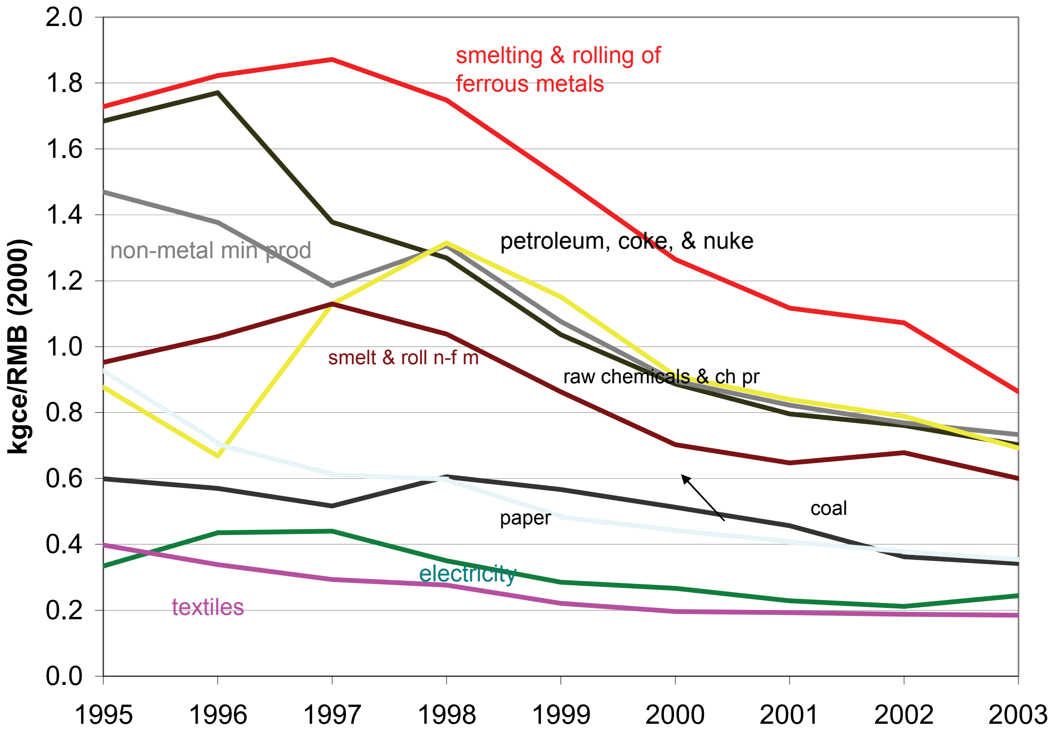

Figure 5: Energy intensities for major industry sub-sectors in China.

Figure 5 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 were widespread electricity shortages, and the fact the profit margins could be eroding in the electric generation industry since the tariff has been held artificially low while fuel prices have gone up tremendously.

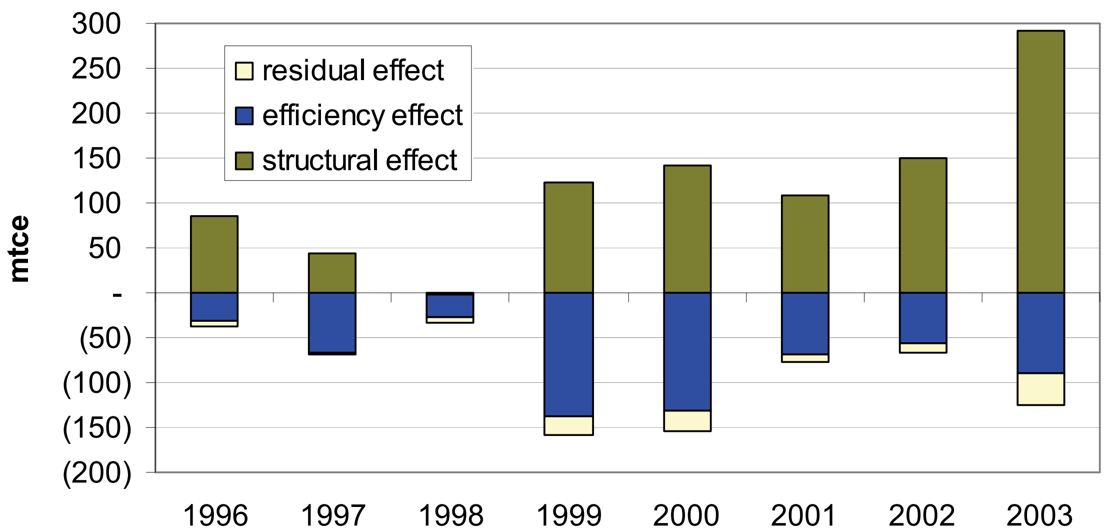

Figure 6: Effect of efficiency changes and structural shift among industry sub-sectors

Further analysis of the effect of efficiency changes and structural shift 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 6:).

In the meantime, the effect of structural shift within industrial sub-sectors – rapid growth in cement and steel production - increased in recent years, and since 2001 has overwhelmed the effect of efficiency gains. Since 2001 efficiency gains alone have not been nearly sufficient to compensate for the effect of heavy industrialization. For example, in 2003, the effect of efficiency gains in industries on energy use is about 30% of that due to structural shift among industrial sub-sectors. As a result, the overall energy intensity of industries is higher today than its recent low point in 2001.

Summary

In summary, the recent increase in energy intensity in China can be largely attributed to three main factors:

1. Rapid growth in production of commodities in heavy industries (iron and steel, chemicals, cement, etc.).
2. Overall growth of the industrial sector, relative to services and agriculture.
3. Slow down in energy efficiency improvement relative to structural changes.

The results of this analysis are consistent with the traditional understanding of economic development where energy intensity tends to rise in the early stage of industrialization due to rising demand for energy-intensive products, extensive infrastructure development, and urbanization. China simply has returned to normalcy in this regard, after two decades of exceptional experience.

This return to a more traditional development pattern represents a tipping point in the relationship between energy and economic development in China, and suggests that without major policy interventions both to boost efficiency gains and to accelerate the development of service industries, energy intensity of the Chinese economy could continue to rise or stay at the current level for some time to come. The rapid decline in energy intensity observed in the 1980s and 1990s is unlikely to return any time soon without such intervention. This calls for a major revision of current understanding of energy demand growth in China in the immediate future, since most projections of China's energy demand were based on a continuation of the trend experienced from 1980 to 2000. In other words, China's energy demand in the future could be much higher than projected.

An Analysis of Possible Scenarios Toward 20% Energy Intensity Target

In this section, we develop a series of scenarios to assess the feasibility of achieving the 20% target for energy intensity reduction from 2005 to 2010. The analysis is based on the China End-use Energy Model developed by the China Energy Group of the Lawrence Berkeley National Laboratory (LBNL). China's current development plan forms the basis of the baseline policy scenario (BPS) in the study. In addition to BPS, we develop several policy scenarios targeting efficiency opportunities in industries, appliances, and the power sector.

China's 11^th^ Five Year Plan Energy Intensity Target

China's 11th Five-Year Plan (FYP) has set a binding target for energy efficiency: energy intensity of GDP should be reduced by 20% from 2005 to 2010. China's GDP grew at an average annual rate of 9.9% from 2000 to 2005. The 11th FYP aims for an average GDP growth rate of 7.5% from 2005 to 2010. Thus, a 20% reduction in energy intensity implies an annual growth rate (AGR) of 2.8% in energy use. However, both GDP and energy use have been growing much faster recently. In 2005, total energy consumption reached 2,225 million tons of coal equivalent (Mtce) (NBS 2006), a 9.5% increase from 2004, while the GPD growth rate was 9.9%. If China's energy/GDP elasticity remains at 1 and economic growth unfolds as forecast, total energy consumption in 2010 would reach 3,192 Mtce. To reach the 20% energy intensity target, it has to be reduced to 2,552 Mtce, or a reduction of 640 Mtce. Figure 7: presents two possible levels of energy consumption in 2010: 1) if GDP grows an average of 7.5%

with an energy/GDP elasticity of 1 based on recent trends, and 2) if GDP grows an average of 7.5% and the 20% energy intensity reduction target is met.

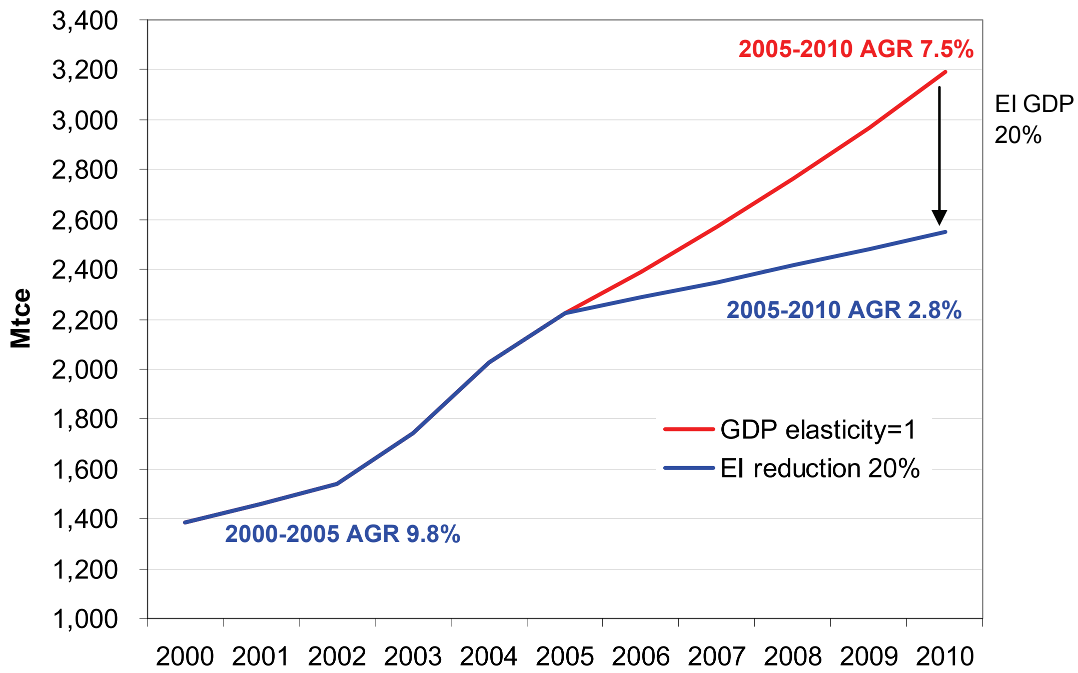

Figure 7: Energy Consumption Implied by the 11th Five Year Plan Energy Intensity Target

Baseline Policy Scenario (BPS)

LBNL's Baseline Policy Scenario (BPS) 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). For a more detailed description of the model and key assumption, please refer to Lin (Lin et al 2006).

The BPS analysis shows that moderate technology improvement and restructuring of China's economy could lead China's energy demand to grow considerably slower over the next 5 years. Figure 8:illustrates the differences in 2010 primary energy consumption among three scenarios: 1) GDP growth of 7.5% with an energy/GDP elasticity of 1%, which approximates the business-as-usual scenario, 2) GDP growth of 7.5% and attainment of the 20% energy intensity reduction goal (EI reduction 20%), and 3) the BPS with energy demand growing at 5.0% and an elasticity of 0.67. The BPS energy demand growth rate exceeds the implied 11th Five Year Plan target of a 2.8% AGR for energy, so additional measures will need to be taken and more aggressive energy efficiency improvements will need to be implemented to bring the growth down further.

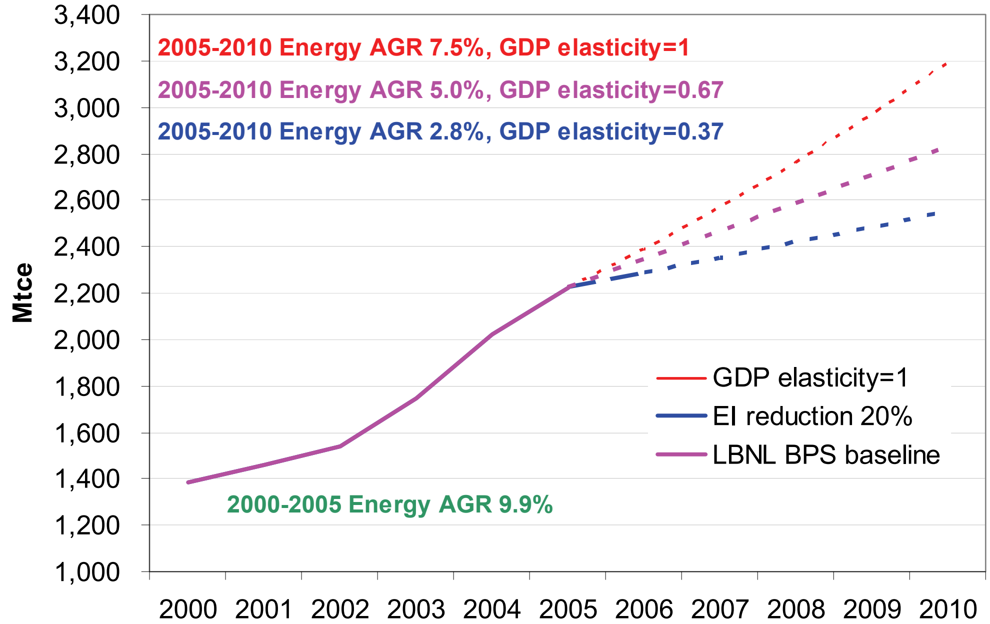

Figure 8: Energy Consumption Implied by the 11th Five Year Plan Energy Intensity Target and the BPS Scenario.

Policy Scenarios

The BPS scenario offers a systematic and complete interpretation of the social and economic goals proposed in China's national plan, and incorporates moderate energy efficiency improvement in all sectors. Building upon the BPS scenario, three additional policy scenarios were prepared to explore the potential approaches that might lead to achievement of the 20% energy intensity reduction goal. A rapid physical intensity decline in heavy industrial sub-sectors (moving 2020 targets to 2010) was addressed in the Aggressive Industrial Efficiency scenario. The Aggressive Industrial and Appliance Efficiency Aggressive scenario explores the additional possibility of further incorporating accelerated efficiency improvements in the building sector, particularly in appliances. The additional impact of a reduction in transmission and distribution losses and further thermal efficiency improvement is covered in the Aggressive Industrial, Appliance and T&D Efficiency scenario[3].

[3] Due to space limitation, detailed assumptions for these scenarios are not presented here. Interested readers should refer to Lin et al, 2007.

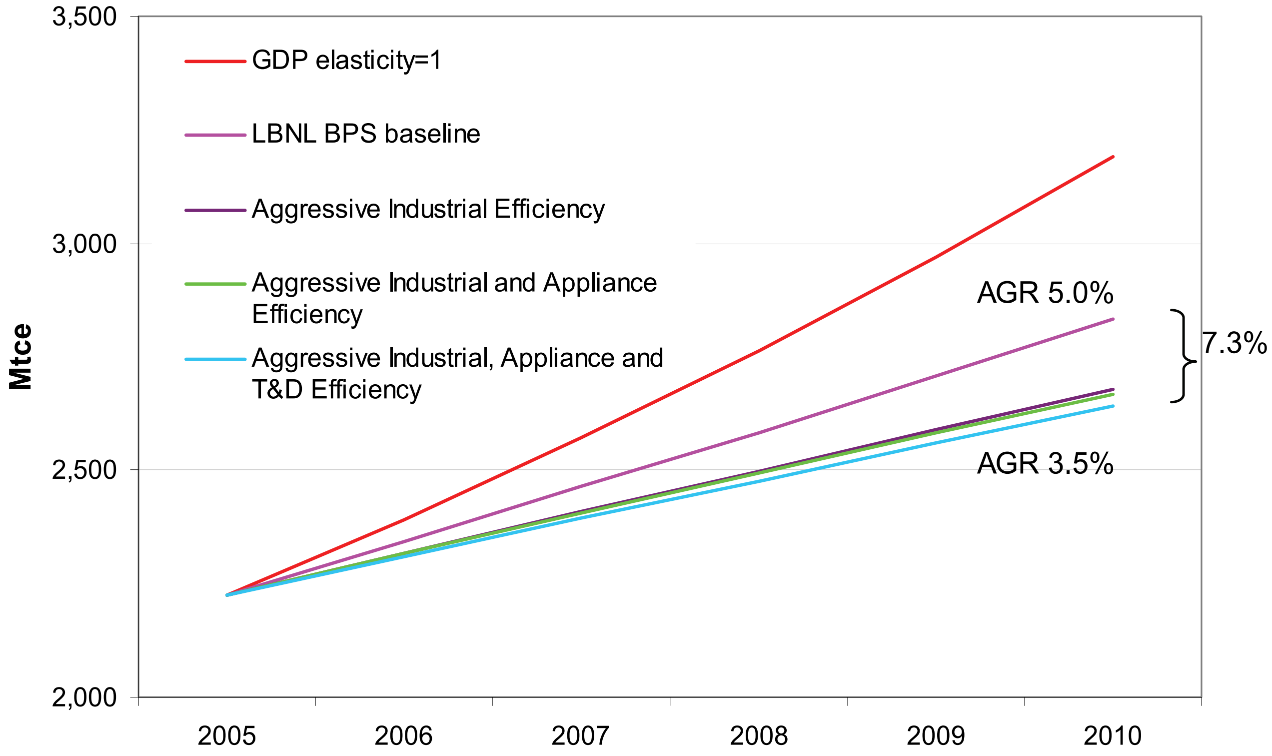

Figure 9: Additional improvement in T&D losses and thermal efficiency of power generation would reduce energy growth to a 3.5% annual average rate

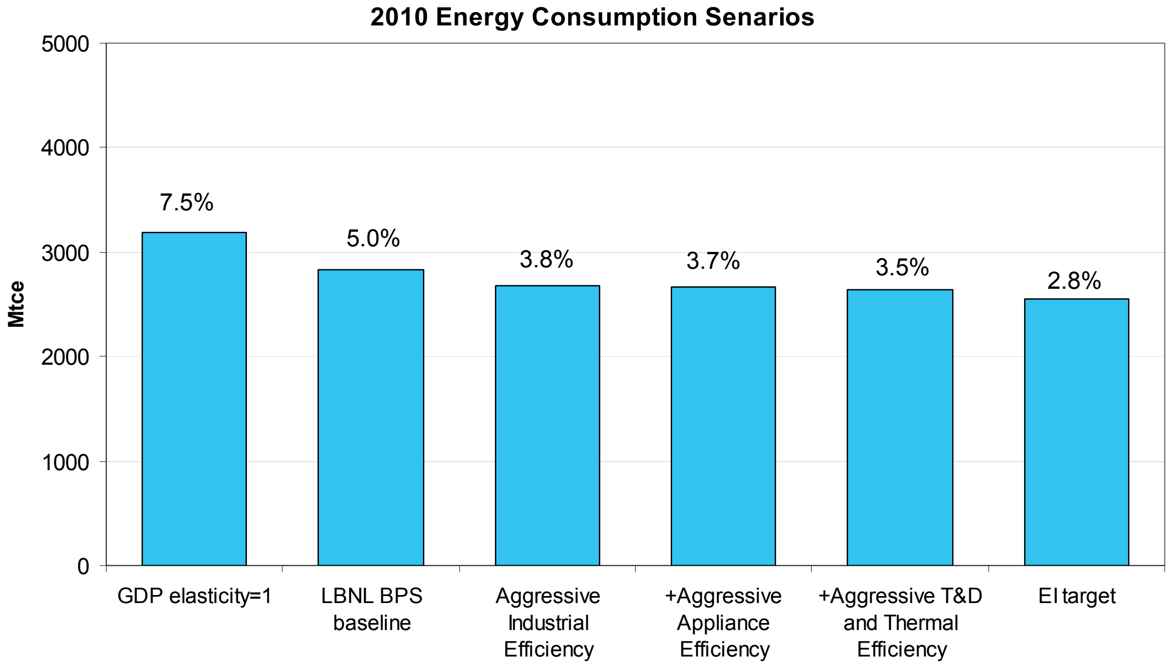

Figure 10: Efficiency can make a big difference

The cumulative impact of the three policy scenarios reduces the growth rate of China's energy use from 5% per year in the BPS scenario to 3.5%, which in aggregate provides 85% of the reduction that is necessary to reach the goal of reducing the energy intensity of GDP by 20% in 2010. The results suggest that energy efficiency improvement can play a critical role in reaching the energy intensity target; however, other macro-economic approaches are also necessary to shift the Chinese economy to more productive activities and sectors.

Total energy consumption, energy savings and the major assumptions of each scenario are summarized in Table 1 below.

Table 1 Energy Consumption and Major Assumptions of the Scenarios

Scenario	Average Energy Demand Growth Rate	2010 Energy Consumption (Mtce)	Incremental Energy Savings (Mtce)	Cumulative Energy Savings (Mtce)	Major Assumptions
Business As Usual	7.5%	3200	(none)		
BPS	5.0%	2833	367	367	• GDP target • "moderate" improvement in energy efficiency
Aggressive Industrial Efficiency	3.8%	2677	156	523	• move 2020 target to 2010 in industry sector
Aggressive Industrial and Appliance Efficiency	3.7%	2668	9	532	• move 2020 appliances efficiency target to 2010
Aggressive Industrial, Appliance and T&D Efficiency	3.5%	2641	27	559	• +1% in coal fired plant efficiency • -1% in T&D loss
20% target achieved	2.8%	2552	89	648	

Conclusions

China's 11th FYP set an extremely ambitious target of reducing the energy intensity of GDP by 20% by 2010. This is a particularly challenging goal in light of the recent increase in energy intensity in China. The results of this analysis show that this increase is caused by rampant growth in industries, especially energy-intensive industries such as cement, steel, and chemicals; and by a slowdown in energy efficiency improvement in recent years.

Thus, achieving the 20% target requires major policy changes that would both revitalize investment in energy efficiency throughout the Chinese economy and encourage the shift to less energy intensive and more economically productive sectors. Without major incentives to support energy-efficient technologies and discourage wasteful practices, it is almost certain that the target won't be met, as illustrated by energy and GDP statistics from China in the first half of 2006.[4]

However, meeting the 20% target is still feasible. The efficiency potential explored in this report indicates that efficiency improvements in the industrial and buildings sectors could contribute substantially toward the 20% energy intensity reduction target, while structural changes in the economy also seem necessary. However, realizing such a potential requires adoption or vigorous implementation of a host of policies to promote energy efficiency improvement.

[4] Reuters, "China unlikely to meet energy efficiency goal," 12/19/2006.

For the industrial sector, energy performance targets for energy-intensive industries should be used as a tool to spur innovation (Price et al., 2003) and to increase enterprise competitiveness. Promoting industry best practices and benchmarking could provide valuable information to enterprises to identify areas of improvement within their facilities. Financial and non-financial incentives should be provided to induce industrial firms to pursue such retrofit potentials. Equally, if not more, important is to ensure that all new and expanded facilities conform to industry best practices. In particular, the 1,000 Enterprise Energy Savings Program, which commits about 1000 large state-owned enterprises to specific energy saving targets, provides an excellent opportunity to showcase the potential to improve industry energy efficiency. Given sub-national developmental disparities in China, the central government could further improve aggregate energy efficiency by forbidding the transfer of old, inefficient equipment from coastal to inland areas.

For the building sector, China has developed an extensive set of building energy codes and minimum efficiency standards for appliances. However, local government agencies need to significantly increase the resources for enforcement actions in order to realize the full impact of the building energy codes. For appliances, national testing programs need to be instituted, and penalties for violations need to be raised significantly to ensure compliance to the existing appliance efficiency standards. In addition, these standards should also be tightened over time as more efficient technologies are developed, in order to deliver greater amount of societal and consumer savings.

Government agencies at all levels should take the lead in purchasing energy-efficient products and ensuring that all government-funded buildings meet the best energy performance code.

For the transportation sector, priority should be given to the development of efficient mass transit systems including bus rapid transit (BRT). An efficient and comfortable mass transit system is critical in stemming the switch to private cars, which could lock in high energy usage for years to come. At the same time, fuel economy and emissions standards for vehicles should be raised to mitigate the impact of rapidly rising vehicle sales on energy use and air quality.

To implement these programs, China needs to attract huge investment for the adoption of energy efficiency technologies and practices. China was successful in stimulating investment in energy efficiency in the past through a combination of low-interest loans, interest subsidies, and tax credits. It is time for China to re-vitalize these incentive programs.

Another source of funding for energy efficiency could be utility-based DSM programs, which has been extremely successful in the North America in slowing down demand growth. In the on-going utility sector reform, China should incorporate the principles of integrated resource planning (IRP) to put demand-side solutions on the equal footing with supply-side resources, and reward utilities for energy saved.

Setting energy prices to reflect costs of extracting, delivery, and use of energy would also help both China's effort to reduce energy intensity in the near future and to move toward a sustainable energy future. Maintaining artificially low prices not only encourages wasteful consumption of energy, but also deters the development of more efficient technologies and renewable energy.

The policy options outlined here have all been successfully implemented individually elsewhere in the world. They all aim to align the interests of energy consumers (such as steel mills) and providers (such as utilities) with societal interests of energy conservation, environment protection, and economic development. Once combined, they could unleash tremendous societal and market forces toward meeting China's goals of energy intensity reduction in the short term and sustainable development in the long term. China has demonstrated to the world in the 1980s and 1990s that it is capable of initiating path-breaking policy reforms with great success. Once again, with the new call for the development of "a harmonious society", China has the opportunity to lead a new path for the world.

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