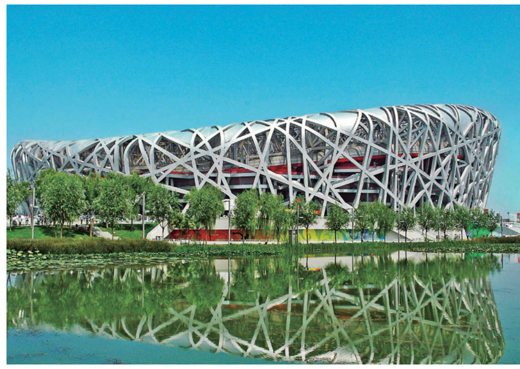
Resource Efficiency: Economics and Outlook for China



Resource Efficiency: Economics and Outlook for China

James West, Heinz Schandl, Sonja Heyenga

Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Shaofeng Chen

Institute of Policy and Management (IPM), Chinese Academy of Sciences (CAS)

Citation

West J, Schandl H, Heyenga S and Chen S (2013). Resource Efficiency: Economics and Outlook for China. UNEP, Bangkok, Thailand.

ISBN : 978-92-807-3318-1
Job No: DEW/1632/BE

Disclaimer

The content and views expressed in this publication are those of the authors and do not necessarily reflect the views or policies, or carry the endorsement of the contributory organizations -the Commonwealth Scientific and Industrial Research Organisation (CSIRO) or the United Nations Environment Programme (UNEP).

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of UNEP concerning the legal status of any country, territory or city or its authorities, or concerning the delimitation of its frontiers and boundaries. Reference to a commercial company or product in this publication does not imply the endorsement of UNEP.

Cover images (clockwise from top left): nipic

Reproduction

Production

UNEP Division of Early Warning and Assessment
United Nations Environment Programme
Regional Office for Asia and the Pacific
U.N. Building 2nd floor, Rajdamnern Nok Avenue
Bangkok 10200, Thailand
Tel: +662-288-2617/1133, Fax: + 662-280-3829
E-mail: uneppub@unep.org
Web: www.unep.org/roap

Resource Efficiency: Economics and Outlook for China
Published: July 2013
Website: www.unep.org
Project coordinator/editor: Jinhua Zhang, Anna Stabrawa/UNEP
Cover design and layout by Yi Zhang
Printed in China by Qiushi Printing
Translated into Chinese by Shaofeng Chen, Liyang Su, Haibo Qin, Lihua Liang, Yang Liu, Wenjing Yue, Hongxia Zheng, Mingqi Pan, Qian Chen, Mingjing Qiu

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on 100% recycled paper, using vegetable-based inks and other eco-friendly pratices. Our distribution policy aims to reduce UNEP's carbon footprint.

Foreword

China's dramatic economic growth over the past few decades has increased demands for natural resources within and beyond the country itself in ways that are unprecedented in human history.

While that growth has lifted millions out of poverty it has also come with rising environmental challenges linked to the extracting, processing and use of those natural resources in areas from construction to power generation.

But as this report shows, there are other ways of looking at this development trajectory including the fact that when compared with the global and regional picture, China's track record in improving resource efficiency has been in some cases among the best on the globe.

China's energy efficiency for example, improved over the 1970 to 2009 period at an annual compound growth rate of just over 3.9%, exceeding the global performance of just under 0.7% and that for the Asia Pacific region as a whole which was 0.13%.

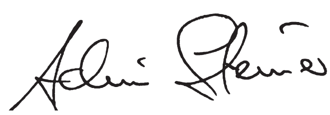
These are among the findings of the Resource Efficiency: Economics and Outlook for China which is a joint report of UNEP and its regional partners, the Commonwealth Scientific and Industrial Research Organisation (CSIRO)/Australia and the Institute of Policy and Management (IPM), Chinese Academy of Sciences (CAS).

It underlines that China has in the past few years introduced a considerable number of policies in areas from renewable energies to vehicle emissions standards that are contributing to boosting resource efficiency and assisting towards a transition to green economy and an ecological civilization. The effects of many of these policies will however only become apparent in the years ahead.

The report also underlines that China, in common with other emerging economies needs to make significant investments not only in more resource-efficient infrastructure such as energy saving buildings, but also in human capital and governance capacity if far greater resource efficiency and a transition to a sustainable economic model is to be truly realized.

China's development path is also in part the world's development path given the country's influence on markets and sustainability across the globe.

This report can contribute to greater understanding of what China has already achieved and the challenges and opportunities for improving resource efficiency and 'decoupling' of economic growth from natural resources use in the years and decades to come.



Achim Steiner
United Nations Under-Secretary-General and Executive Director
United Nations Environment Programme

Contents

Acknowledgements

This report results from a collaborative project between the CSIRO and the United Nations Environment Programme (UNEP) Regional Office for Asia and the Pacific.

The authors would like to thank Anna Stabrawa, Jinhua Zhang and Panvirush Vittayapraphakul (UNEP Asia and the Pacific, Bangkok), for their contributions and review of this document. They are also grateful to Tommy Wiedmann and Karin Hosking (CSIRO Ecosystem Sciences), Ananda Dias, Nanqing Jiang, Shaoyi Li, Stefanos Fotiou and Janet Salem (UNEP), Yang Liu, Borong Huang , Yingming Li, Dunjiang Song, Mingqi Pan, Liyang Su (Institute of Policy and Management, Chinese Academy of Sciences (IPM-CAS) and Anthony Chiu (the Philippines) for respectively reviewing and editing the report.

1 Main Messages

- China's great advances in economic development over the last decades have greatly increased China's demand for natural resources, and so the environmental pressures associated with extracting, processing, and using those natural resources.
- Increasing affluence is by far the most important driver of resource pressures in China, far more important than population growth.
- Relative both to its region, and to the World, China's performance in improving resource efficiency has been exceptionally good. Unfortunately these improvements have not been sufficient to offset the additional resource demands created by increasing per capita income. Furthermore, the rate of improvement has slowed somewhat in recent times.
- China is no longer a country of low resource requirements in per capita terms, with demand levels equivalent to or higher than many industrialized countries. This fact should, however, be viewed in context with its role as a major supplier of goods for final consumption in other countries.
- The magnitude of the effect of China's industrial transition on global demand for resources is, in absolute terms, unprecedented. This stems from the sheer number of people involved. China's economic transition was responsible for most of the annual growth in global materials consumption by the turn of the millennium.
- Despite massive increases in material requirements, China still continued to meet the great majority of new demand overall from domestic sources of supply. Its reliance on imports for some key materials is, however, increasing rapidly.
- The extremely high apparent resource efficiencies achieved by some advanced industrialized nations are not likely to be realistic benchmarks for China while it continues to supply most of its own resources requirements.
- China has in recent years introduced a large number of policy initiatives relevant to increasing resource efficiency. The effects of many of these policies will only become apparent in the years to come.

2 Summary

China's rate of economic development and social progress in recent decades has been extraordinarily rapid. As is generally the case when a nation industrializes and urbanizes, China's rapidly improving material standards of living have come with a greatly increased per capita demand for natural resources, and a corresponding increase in the environmental pressures associated with extracting, processing, and using these natural resources.

While other countries have developed rapidly in the past, China's industrial transition is unprecedented in the sheer number of people it affects. The combination of rapid per capita increases in material consumption combined with massive total population numbers has led to China being transformed from a relatively modest consumer of natural resources in the 1970s, to accounting for most of the annual growth in global materials consumption by the turn of the millennium. China's impact on global energy demand has also been very large, but less profound.

This huge new requirement for resources has come about in spite of the fact that, relative both to its region and to the World, China's performance in improving the efficiency with which it converts materials and energy to income has been exceptionally good. It has made huge gains in resource efficiency over recent decades, especially with regard to energy intensity. It is thus of considerable concern that over the most recent period studied, the rate of improvement in materials intensity has slowed greatly, although it remained superior to the corresponding regional and global rates. It remains to be seen whether the large number of policies relevant to improving resource efficiency recently introduced will serve to restore the earlier rapid rates of improvement.

Great gains in resource efficiency, however, have always been and remain far below the levels required if stabilizing or reducing environmental impacts from current levels is a policy goal. China's total materials and energy consumption increased at rates higher than global averages over the full period of this study. If the most recent policy initiatives do not prove sufficient to return China to rapidly improving resource efficiency, and actually increase those gains at a rate faster than the fastest rate experienced to date, environmental pressures can be expected to continue increasing rapidly. It is difficult to envisage a business as usual approach which will yield the magnitude of resource efficiency required. This implies that an unprecedented level of innovation in the major production and infrastructure systems underpinning China's modernization will be required, if high levels of economic growth are to be maintained while simultaneously averting further and massive degradation of China's natural environment.

In trying to assess China's overall performance on resources use and resource efficiency, there are some special or unusual circumstances to be considered. Firstly, the model used for China's recent development has been highly export oriented, so a significant share of materials "consumption" attributed to China is actually used to produce goods for final consumption in other countries. Also, unlike many long industrialized countries, China still meets most of its demand for natural resources from domestic extraction, although its reliance on foreign supplies of metal ores and some fossil fuels was increasing rapidly. This relatively high degree of self reliance has some important advantages, especially with regard to ensuring security of supply, but also has marked disadvantages. Perhaps the most important disadvantage lies in having the high environmental pressures associated with extraction and processing accrue within China's densely populated domestic territory.

Another effect of China's relative high materials self sufficiency, is a similarly high level of "apparent" materials consumption. Because China meets its primary material and energy requirements domestically all the relevant pressures occur in China. An important implication of this is that it is unrealistic to expect China to achieve the extremely high apparent resource efficiency levels of those countries which have transferred most of their materials and energy intensive production processes to external jurisdictions (unless and until China does the same).

3 Introduction

A detailed report dealing with resource efficiency in China is timely, as from previous work (UNEP 2011), it became apparent that resource efficiency trends in China now dominate resource efficiency trends for the whole Asia-Pacific region, and it is the trajectory of the Asia-Pacific region which now determines global resource use trajectories. The impact that China's resource demands have had on global resource flows are already profound, and it has not yet completed its industrialization and urbanization. GDP per capita remains a fraction that of the most advanced economies within its own region, and it should be expected that China will continue to press ahead with its modernization, and in delivering higher material standards of living to its people. That being the case, it is important to understand the magnitude of the challenges that continued growth will pose to maintaining the quality of China's environment, and to China's ability to meet its ongoing requirements for natural resources. A detailed treatment of resource efficiency trends and the underlying drivers of those trends is an essential component in understanding of those challenges.

This report provides more detailed data and analysis, specific to China, over that provided in (UNEP 2011). It can be thought of as a single country focus version of that report, and so the structure is broadly similar. For most sections the base data used is simply the China specific data assembled for the production of (UNEP 2011), and so covers the same time period of 1970 to 2005. The exception is the material flows data, which has had a major update and revision performed. The time series for material flows data has been extended to cover 1970 to 2008.

4 Material use patterns and material efficiency in China, 1970 – 2008

The use of natural resources (materials, energy, water, and land) underpins all of humanity's economic and social activities. Natural resources are extracted, concentrated, and transformed to enhance their value for a vast range of consumptive activities. Some natural resources are used up in the process of consumption (e.g. food, feed, and fuels) while others are transformed into durable artefacts (e.g. buildings, infrastructure, machinery, and consumer goods), which last much longer. Waste and emissions occur at all stages of the production–consumption process and, ultimately, at the end of its useful lifetime, every primary resource is discharged into the environment as a waste or an emission.

Historically most of the global growth in resource use has occurred in high-income OECD countries, but recently the Asia and the Pacific region has emerged as a major global resource consumer, such that by the end of the 20th century, it had overtaken the rest of world in overall material use. Since the 1990s China has been central to the region's extremely high growth trajectory (UNEP 2011).

Box 1. Database preparation methodology and sources

A detailed technical annex describing the methodology and all base data sources behind the construction of the new database upon which this report is based is available at (annex website reference). Key points from that annex are summarized here.

All major base data sets used are available from publically accessible (although often not free) sources. These sources included (EIA 2011, FAO 2011c, FAO 2011d, FAO 2011a, FAO 2011b, IEA 2011b, IEA 2011a, IEA 2011c, IEA 2011d, UN Statistics Division 2011a, UN Statistics Division 2011b, USGS 2011). A number of smaller countries in the region were excluded from the database, due to issues with base data availability, consistency, and reliability. The 29 nations retained in the database include: Australia, Bangladesh, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, Fiji, India, Indonesia, Japan, Kazakhstan, Kyrgyzstan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Singapore, Sri Lanka, Tajikistan, Thailand, Turkmenistan, Uzbekistan, Viet Nam. The categories of materials covered are those considered primary materials in the material flows accounting framework described in (Eurostat 2011), i.e. biomass, construction minerals, fossil fuels, metal ores, and industrial minerals. Importantly, while the base data sets used were generally of high quality, they were often specified in terms of a material of value extracted, while the new database requires that they be specified on an "as extracted" or similar basis. For example, (USGS 2011) generally gives data on mining production in terms of contained metal, whereas mine production in the new database needs to be specified in terms of ore extracted. This requires, as a minimum, the application of different assumed ore grades for different metals. For some sub-categories of materials there was little or no direct base data of any sort, so tonnages had to be determined via modeling and inference. A notable example of this is the modeling of grazed biomass.

The methodology used to compile the database complied as nearly as practicable to the guidelines set out in Eurostat2011, however where there have been significant departures from these guidelines the rationale behind them and their implementation is described in detail in at http://www.cse.csiro.au/forms/files/MFA-Technical-Annex.pdf .

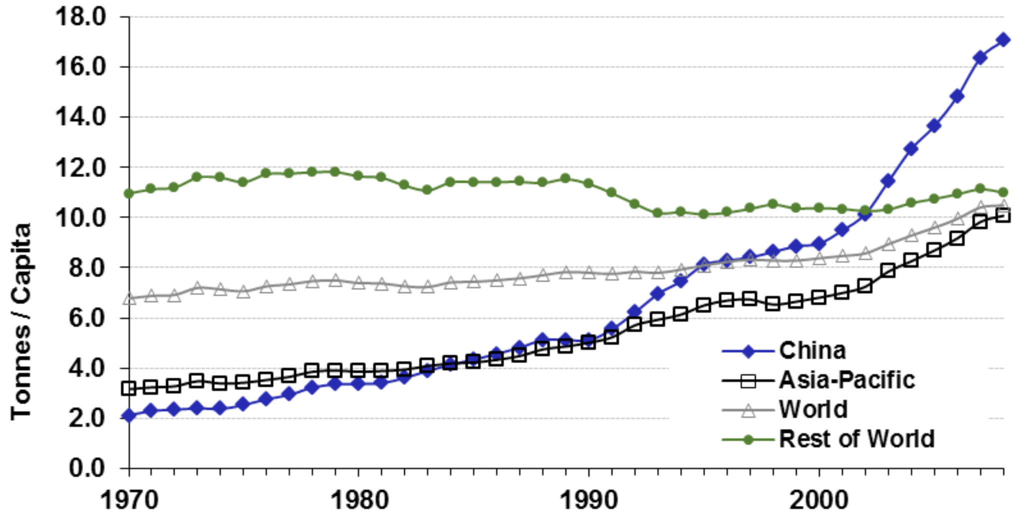


Figure 1 Domestic material consumption per capita, comparison between China, Asia and the Pacific, World, and Rest of World (i.e. World excluding Asia and the Pacific), from 1970 to 2008.

The rapid growth trajectory in China's use of materials is put into a global context in Figure 1. China's consumption of primary materials per capita has increased from 31% of the world average levels in 1970 to over 162% of the world average in 2008. Even within the highly dynamic Asia-Pacific region, China's rapidly increasing domestic material consumption (DMC) per capita stands out, growing at 5.6% p.a. over the full period 1970 to 2008, which is nearly twice the regional average growth rate. Furthermore, China's exceptional growth rate in DMC/capita accelerated from around 2000 on, to average over 9% for the first decade of the 21st Century.

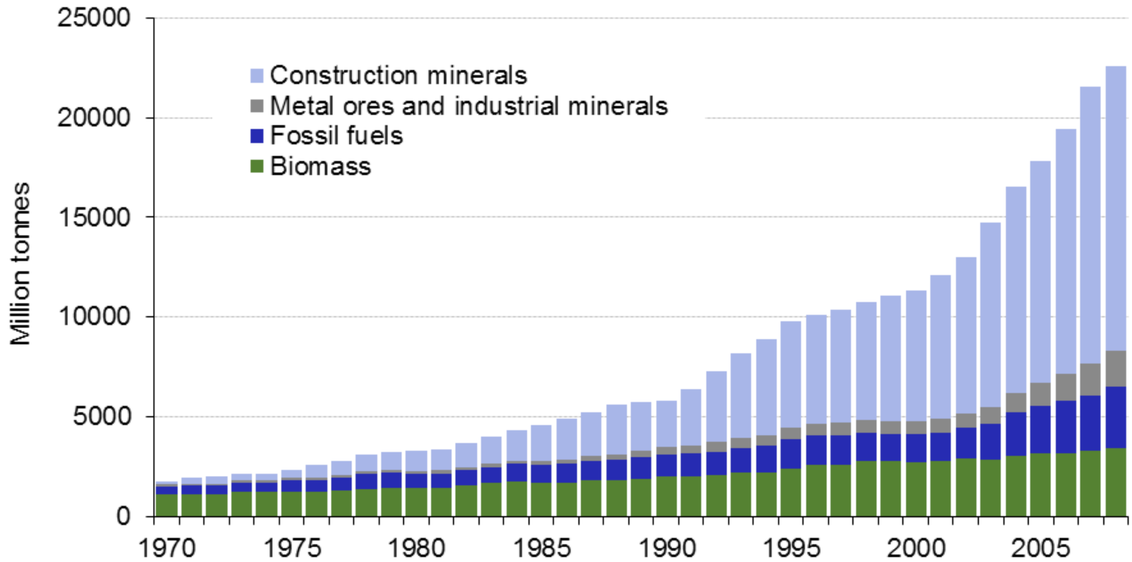


Figure 2 China's domestic material consumption by major material group, from 1970 – 2008.

Figure 2 shows the composition of China's DMC by four major materials categories. This brings into focus the enormous overall magnitude of China's DMC, and change in the relative importance of different categories of materials as China passes through the socio-metabolic transition from an agrarian society to an industrialised one. China's total DMC of 1.7 billion tonnes in 1970 constituted around 7% of the world total for that year, and had China ranked third globally in terms of total DMC. By 2008, China's total annual DMC of 22.6 billion tonnes accounted for 32% of the world total, and made it by far the world's greatest consumer of primary materials, nearly fourfold the consumption of the USA, which was the second ranked consumer.

The relative shares of the four major materials categories underwent a major shift over the study period, with biomass decreasing from 63% of the total in 1970 to only 15% of the total in 2008, while construction minerals share increased from 8% to 63%, underlining the massive scale of urbanization and emphasis on investment in major infrastructure which has taken place in the latter part of the period. Metal ores and industrial minerals also roughly doubled their share, from 4% to 8%, while fossil fuels share decreased from 25% to 14%, although even as fossil fuels' relative share decreased, the total level of consumption of fossil fuels actually increased more than sevenfold between 1970 and 2008, a compounding annual rate of growth of 5.3%.

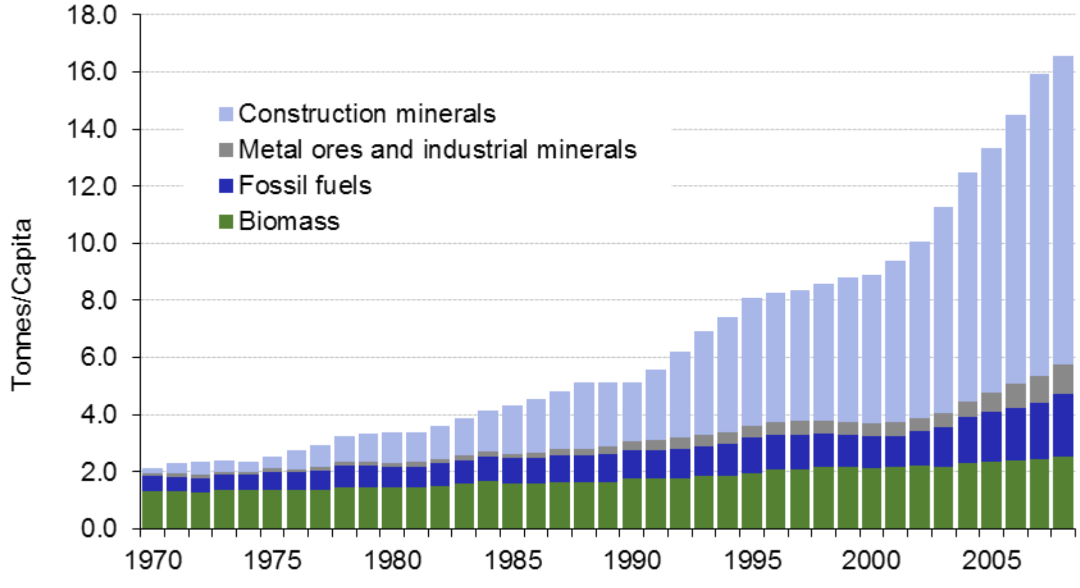


Figure 3 China's domestic material consumption per capita, by major material group, from 1970 – 2008.

Figure 3 the gives the breakdown of DMC for each of the four major materials categories on a per capita basis, while Figure 4 shows China's total domestic extraction (DE) per capita. The degree to which China remains relatively self sufficient for most of its overall materials requirements is highlighted by the strong similarity of these two graphs. Even after the extended period of extremely strong growth in DMC from 1990 to 2008, total DMC only exceeds total DE by less that 3%, i.e. China has been able to increase rates of extraction sufficiently to almost meet demand. While this is an encouraging result, emerging import dependency becomes apparent upon examination of individual materials categories.

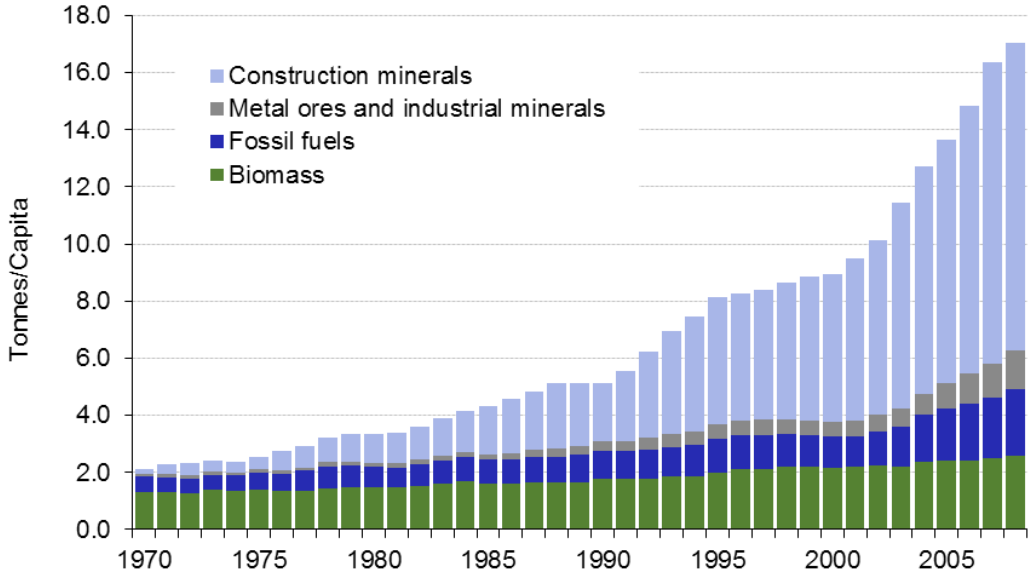


Figure 4 China's domestic material extraction per capita, by major material group, from 1970 – 2008.

Figure 5 shows physical trade balance per capita, which is equivalent to DMC – DE, and shows where China is becoming more import dependant. The most obvious feature in this graph is the rapid growth in net imports of metal ore and industrial minerals. By 2008, China's net imports of metal ore and industrial minerals accounted for 25% of DMC in this category, where only one decade before the corresponding figure was only 9%. Furthermore, China's dependency on foreign suppliers in this category is almost definitely much higher than the raw figure of 25% would indicate. This is because the traded commodities in this category are often highly concentrated compared to the form in which they are initially extracted. For example, it is copper concentrates and metal which are generally traded internationally, not ore as extracted. As these products typically contain tens to hundreds of times the metal per unit weight of the ore initially extracted, an imported tonne will substitute for many tonnes of domestically extracted ore.

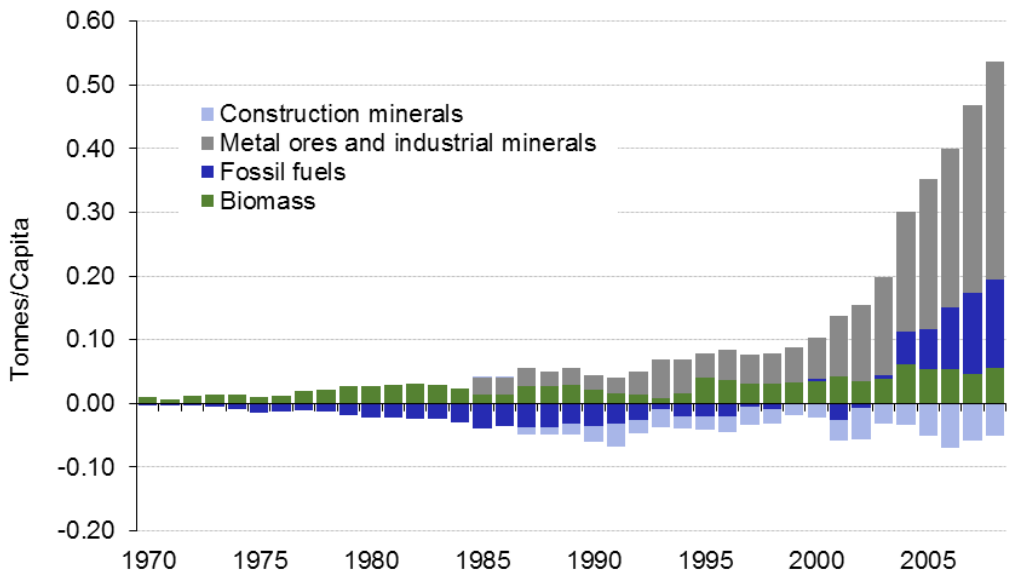


Figure 5 China's physical trade balance per capita, by major material group, from 1970 – 2008.

Given this, it seems probable that the Chinese economy is already more dependent on foreign production of metals than on domestic extraction. The degree to which this concentration effect operates varies widely across the different major categories of materials (Schandl and West 2012).

The other major feature to note in Figure 5 is China's transition from net exporter of fossil fuels to net importer. Net imports remain relatively small compared to domestic extraction, at around 6%, however the rate of growth over the period 2004 to 2008 was 22% p.a. compounding. Also of concern is that when the data underlying the aggregated fossil fuels category is broken out into components, we find that the great majority of imports in this category are of petroleum. Petroleum is commonly identified as the fossil fuel most likely to encounter constraints on production, and so experience upward pressure on prices, earliest out of the three main underlying categories (coal, natural gas, petroleum).

China's net imports of biomass are growing, but the share of net biomass imports relative to that domestically extracted remains very small, at less than 3%, with a growth rate of less than 3% compounding for the period 1970 to 2008.

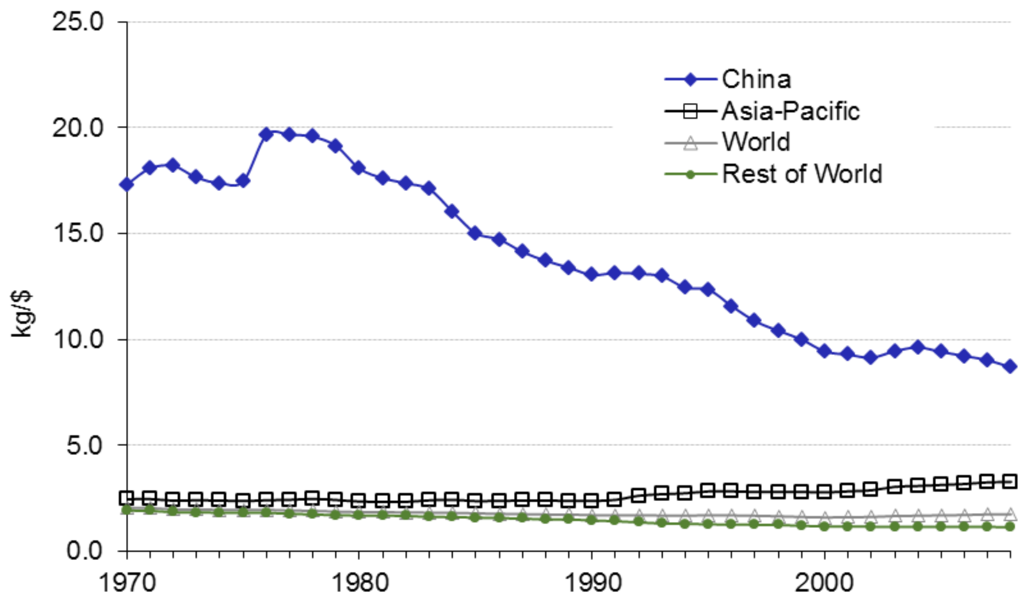


Figure 6 Materials intensity, comparison between China, Asia and the Pacific, World, and Rest of World (i.e. World excluding Asia and the Pacific), from 1970 to 2008.

Figure 6 shows how the materials intensity (MI) of the Chinese economy, calculated as DMC / GDP, has evolved. MI is a very important indicator in that it indicates the extent to which an economy has managed to decouple its growth from ever increasing inputs of raw materials. For most of the period 1970 to 2008 China exhibited a clear trend toward decreasing (improving) MI, decreasing by around 2% p.a. compounding, between 1970 and 2000. While this rate of improvement was not sufficient to neutralize the growing environmental impacts of economic growth over the period, it did moderate these effects somewhat. Unfortunately, since the year 2000, coinciding with a period of extremely rapid economic growth in China, the ongoing improvement in MI has almost stagnated, with MI decreasing by less than 1% p.a. As a result, China appears likely to be increasing those environmental pressures associated extracting raw materials at a rate similar to its very rapid economic growth rate. There is certainly no indication of any environmental Kuznets curve developing with regard to extractive pressures in the Chinese context i.e. as per capita incomes increase, per capita DMC continuing to increase rapidly as well. One cause for optimism here may be that, as is evident from Figure 3, the largest factor in increasing DMC has been growth in construction minerals. As construction minerals (unlike fossil fuels, most biomass, and some metal ore), are used almost exclusively in building stocks of long lived infrastructure and buildings, rather than as consumable inputs to production and services, much current DMC will not be ongoing in nature. Much of it is likely to contribute to increasing the resource efficiency of the Chinese economy over the longer term. Increases in resource efficiency could be expected, for example, from the construction of more direct and efficient transportation and communications networks, and better quality, more energy efficient building stock, to the replacement of older and less efficient energy generation technologies and industrial plant. The extent to which this optimistic outcome materializes will only become apparent over the longer term, and must be tempered by the rapid growth observed of other factors linked to higher ongoing consumption, such as rapidly increasing car ownership, which grew at over 18% p.a. compounding from 2003 to 2008 (World Bank 2012).

5 Drivers of material use in China, 1970 – 2008

An economy's level of resource consumption is driven by various factors. One widely used analytical framework, the I = P × A × T equation (IPAT) formulated in (Ehrlich and Holdren 1971), conceptualizes the drivers behind any specific environmental impact (I) as the product of population (P), multiplied by the level of affluence (A) of that population (calculated as GDP / population), multiplied by a technological coefficient (T). It should be stressed that the technological coefficient T is simply the intensity with which the economy being studied produces the environmental impact under consideration, per unit of economic output, and has no simple linkage with the concept of more or less advanced technology. In this case, as the environmental impact under consideration is DMC, so T is defined as DMC / GDP, i.e. materials intensity (MI). In this section both DMC and MI are subscripted with the IPAT variable they correspond to i.e. $DMC_{(I)}$ and $MI_{(T)}$.

Using this framework in its original form, determining the effect on I of changing an individual driver in isolation is straightforward. A 10% increase in population will, all other things being equal, lead to a 10% increase in I. The situation becomes less clear where two or more of the drivers vary simultaneously, due to the multiplicative nature of the equation, and even more so if we wish to allocate proportional 'responsibility' for the change in $DMC_{(I)}$ to the different drivers, and have the components sum to 100%. One solution to this allocation problem is via a transformation of the IPAT factors to logarithmic form, which gives an additive form of the IPAT equation, and which is amenable to allocating percentage contributions to the different drivers which will sum to 100%. 8 The results of applying this technique are shown in the last three columns of Table 1.

Table 1 shows how the relative importance of population, affluence, and $MI_{(T)}$ in driving growth in $DMC_{(I)}$ has changed over the last four decades for China, Asia and the Pacific, and for the world as a whole. In Table 1 it is apparent that for each of the decades studied, China's $DMC_{(I)}$ increased at a rate much higher than the world average, and considerably higher than the region as a whole. Importantly, the relative importance of the individual drivers was very different for China, the region, and globally. While increasing population was of comparable importance to increasing affluence at both the regional and global scales, for the first three decades studied, for China increasing affluence was a much stronger driver in all periods. In China, from 1970 to 1980, increasing affluence was already responsible for more than twice the increase in $DMC_{(I)}$ as population growth, and by the latest period, 2000 to 2008, affluence had over twenty times the influence that population growth had. Changing $MI_{(T)}$ has served to moderate the rate of growth in $DMC_{(I)}$ in all but the first decade for China, when it slightly exacerbated growth in $DMC_{(I)}$. From 1980 to 2000 the moderating effect was quite strong, offsetting two to three times the growth in $DMC_{(I)}$ caused by increasing population, but dwarfed nevertheless by the effects of increasing affluence.

In all but the period 1970-1980, China's $MI_{(T)}$ has improved more rapidly than for Asia and the Pacific, or the world. China's improvement in $MI_{(T)}$ is especially notable in comparison to the marked deterioration for Asia and the Pacific overall over the periods 1990 to 2000, and 2000 to 2008. The main reason underlying the deterioration in regional MI has been the rapid economic growth of China. This somewhat ironic result comes from the fact that even after the large improvements China has achieved in $MI_{(T)}$, its $MI_{(T)}$ is still much higher than the Asia and Pacific region's other major economies, most notably Japan, which has perhaps the world's lowest $MI_{(T)}$. As China's relative share of the regional economy grows, average regional $MI_{(T)}$ moves closer to that of China i.e. increases.

An important point here is that while China can, and should pursue policies aimed at decreasing $MI_{(T)}$ and improving resource efficiency, especially in light of the slower rate of improvement seen from 2000 to 2008, it is unlikely to approach the levels of $MI_{(T)}$ achieved by Japan. The reason for this is that a major factor behind Japan's extremely low $MI_{(T)}$ is that it has off-shored many of the most materials intensive industries, especially primary extraction of metal ores and industrial minerals. This means that only the relatively small tonnages of internationally traded crude metals and metal concentrates are counted in Japan's $DMC_{(I)}$. China, in contrast, still has a very large mining sector, and extractive sector in general. A detailed discussion of the effects of the concentration of primary materials in internationally traded commodities, on the apparent materials consumption of countries which extract primary materials rather than import them, is given in (Schandl and West 2012). In short, while importing concentrated primary materials may decrease an individual nation's $DMC_{(I)}$, this apparent improvement just reduces the performance of another country, and so may achieve little from a sustainability standpoint.

						Share contribution using log transforms		
	$DMC_{(I)}$%	$DMC_{(I)}$ (tonnes)	P	A	$MI_{(T)}$	P	A	$MI_{(T)}$
1970 - 1980								
China	91%	1,573,721,266	20%	53%	4%	28%	65%	6%
Asia-Pacific	50%	3,114,312,314	23%	28%	-4%	50%	60%	-11%
World	32%	7,919,652,804	21%	21%	-10%	68%	70%	-38%
1980 - 1990								
China	76%	2,498,626,023	16%	110%	-28%	26%	132%	-58%
Asia-Pacific	58%	5,445,357,573	22%	31%	1%	41%	56%	3%
World	26%	8,544,041,368	19%	14%	-8%	76%	60%	-36%
1990 - 2000								
China	95%	5,512,745,379	11%	142%	-28%	16%	133%	-49%
Asia-Pacific	57%	8,397,112,868	15%	18%	17%	31%	35%	34%
World	24%	9,797,934,834	15%	15%	-6%	66%	64%	-31%
2000 - 2008								
China	100%	11,266,439,041	5%	107%	-8%	7%	105%	-12%
Asia-Pacific	61%	14,248,243,163	9%	26%	18%	18%	48%	34%
World	37%	19,074,496,272	10%	14%	10%	30%	42%	28%

Table 1 Comparison of the major drivers of growth in domestic material consumption over four periods (1970 to 1980, 1980 to 1990, 1990 to 2000, and 2000 to 2008), for China, Asia and the Pacific, and the World.

6 Energy use patterns and energy efficiency in China, 1970 – 2009

The importance to modern societies of access to abundant energy is hard to overstate. Virtually all major industrial processes are reliant on significant to extremely large inputs of energy. The process of modernizing and increasing labour productivity in the agricultural sector can to a large extent be thought of as the substitution of fossil fuel energy inputs for human and animal labour and, more indirectly, for other inputs such as natural (manure) type fertilizers (in the form of fossil energy intensive chemical fertilizers). The large size of services sectors, so characteristic of the most developed economies, is only made possible by huge increases in labour productivity that have been achieved over the last 200 years in the extraction, transformation, and distribution of natural resources to end consumers. All of this relies on massive inputs of energy from concentrated energy sources, mainly fossil fuels (UNEP 2011).

China has been undergoing a period of rapid industrialization for several decades, with a very pronounced acceleration since the turn of the millennium. China's per capita energy consumption, as measured by total primary energy supply (TPES), has increased from 31% of the world average levels in 1970 to over 74% of the world average in 2005 and 95% in 2009 while this growth is considerable, it is markedly lower than that seen in the previous chapter for materials. Figure 7 shows that per-capita energy use in China has roughly been in line with that for Asia and the Pacific as a whole until about 2000. It appears that China has since moved to a regime characterized by much faster growth in TPES from 2001 on. TPES per capita grew at 2.1% yearly from 1970 to 2000 but accelerated to 8.5% yearly average growth between 2000 and 2005 and 6.5% yearly average growth between 2005 and 2009.

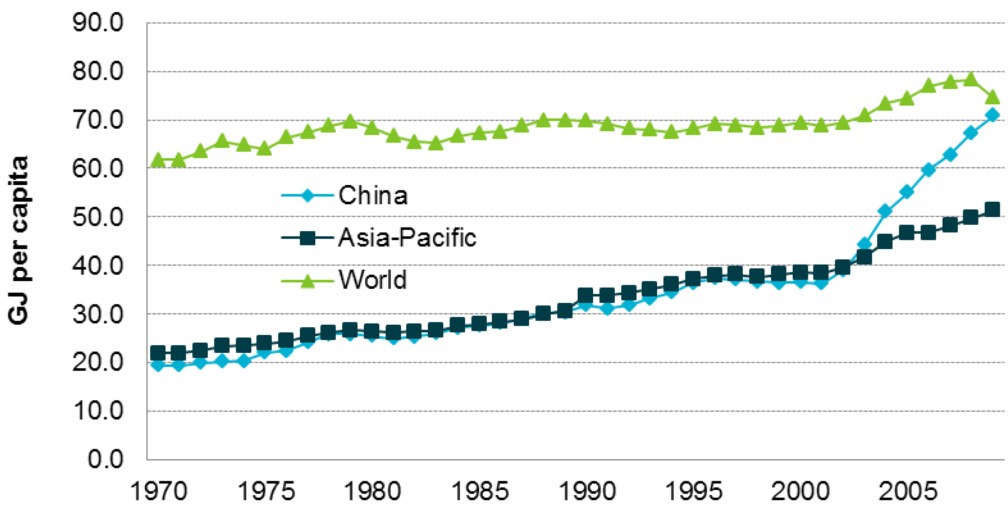


Figure 7 Total primary energy supply per capita. Primary data sources (IEA 2007b, IEA 2007a, World Bank 2012)

Figure 7 shows total TPES[1] for China, from six major source categories. Again, while growth in total TPES has been quite strong, it has been much lower than that of materials. This implies either that the Chinese economy has been moving towards using less energy intensive materials, and / or that it is benefitting from strong improvements over time in the energy efficiency of major production processes. TPES grew by a yearly 4.6% on average between 1970 and 2009.

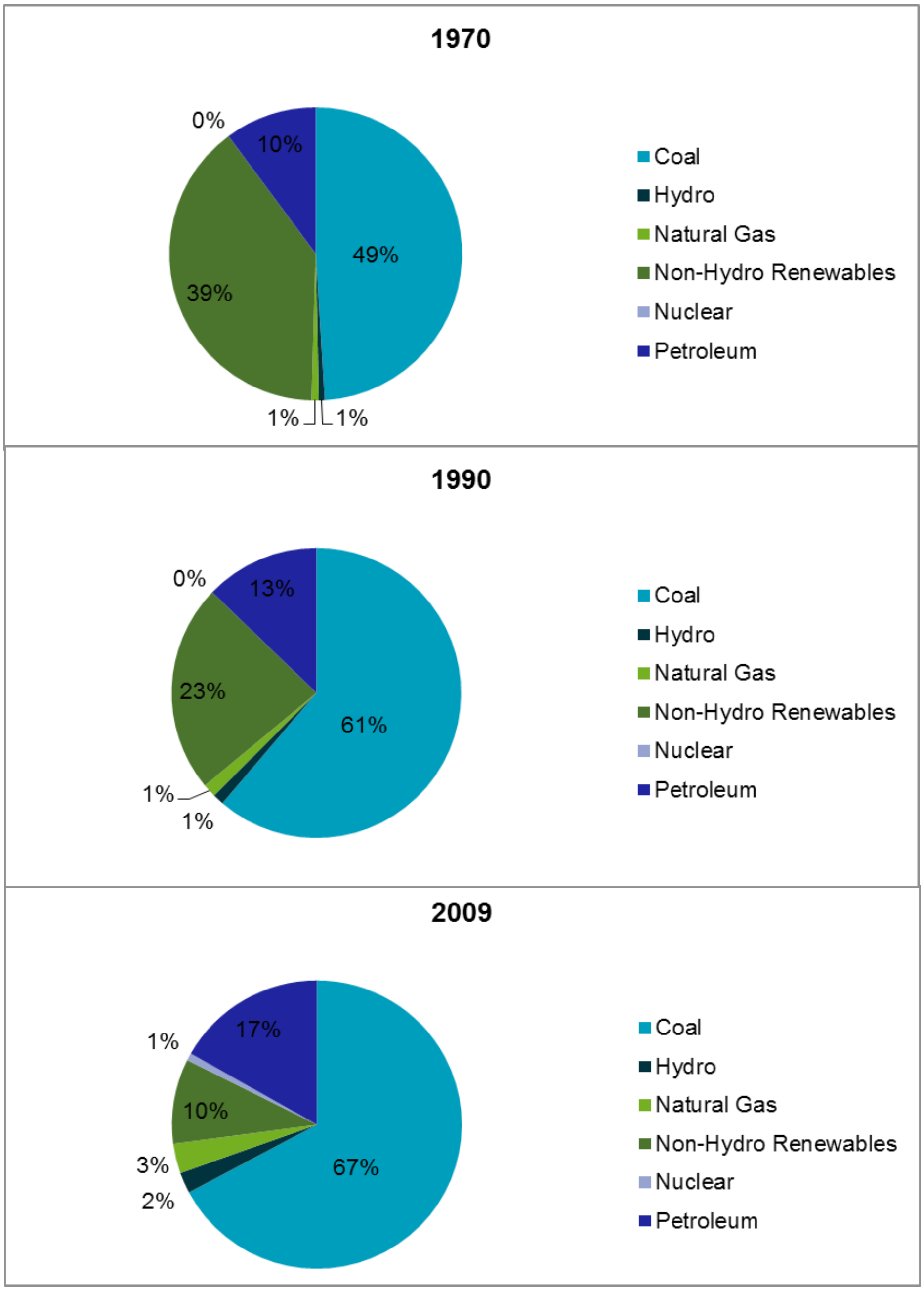


Figure 8 Change in shares of TPES by source between 1970, 1990 & 2009. Sources: (IEA 2007a, IEA 2007b, IEA 2011c)

1 The sources of base data used for this section are much less diverse than those used for materials, with virtually all of the data for energy flows derived from the International Energy Agency (IEA) publications (IEA 2007a, 2007b, 2007c, 2007d) and World Bank data for information on GDP and value added (World Bank 2009).

As TPES grew, the relative importance of the different sources of energy also changed markedly. Figure 8 shows how these shares changed between 1970, 1990 and 2009. The large observed decrease in the share of non-hydro renewable energy sources (mainly bio-fuels and waste) from 39% in 1970 to 10% in 2009 and the strong increase in share met from all fossil fuel sources, is consistent with the socio-metabolic transition from a biomass based economy to a largely minerals based industrialised society taking place over the study period. Coal shows the largest increase since the 1970's and has now a share of 67% in total primary energy supply. Oil contributes 17% and natural gas is still very small at 3% of overall TPES. The large an increasing share of coal also contributes to fast rising carbon dioxide emissions.

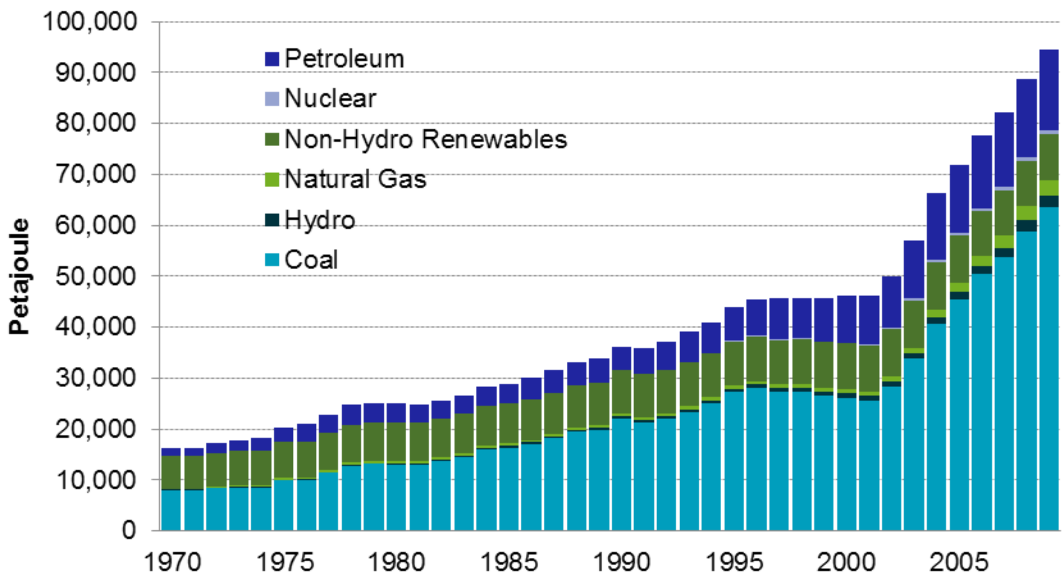


Figure 9 Total primary energy supply by type. Sources (IEA 2007a, IEA 2007b, IEA 2011c)

The trajectory of coal in the overall TPES mix revealed by the time series in Figure 9 is of particular interest. After growing reasonably consistently from 1970 on, coal consumption decreased consistently from the mid 1990s to 2001, at a time when other sources either plateaued or continued to grow. This was followed by a period of extremely rapid growth in coal consumption, which increased by almost 2.5 fold in eight years. This renaissance of coal may be explained in part by reference to Figure 10, where we see that China was able to more than match its coal requirements by massively expanding domestic extraction of coal, with the energy content of domestically extracted coal being around 105% of that consumed. In contrast, domestic extraction of petroleum, the second component of TPES, was only equal to 57% of consumption. By expanding the share of coal in its energy mix, China maintained a relatively high level of self sufficient in energy.

Figure 11 shows that the efficiency with which China converts energy into economic output, as measured by TPES/GDP (energy intensity), improved greatly over the period 1970 to 2009. Over the full period, energy intensity (EI) decreased at an average rate of 3.91% p.a. compounding. The Chinese improvement in energy efficiency by far exceeded the improvements for the world (0.68% per annum) and for Asia and the Pacific (0.13% per annum). Even with this rapid improvement, China's energy efficiency is still below global and regional standards. In 2009, China required nearly 2.5 times the global average of energy per unit of economic output, and about twice that of Asia and the Pacific. Nevertheless, China's achievements in reducing EI largely forestalled a rapid increase in regional EI as China's relative share of the regional economy grew. This contrasts with the situation with regard to materials intensity. Unfortunately, this situation appears to have changed, as EI slowed improving from 2000 on, while China's share of Asia and the Pacific's aggregate GDP continued to increase.

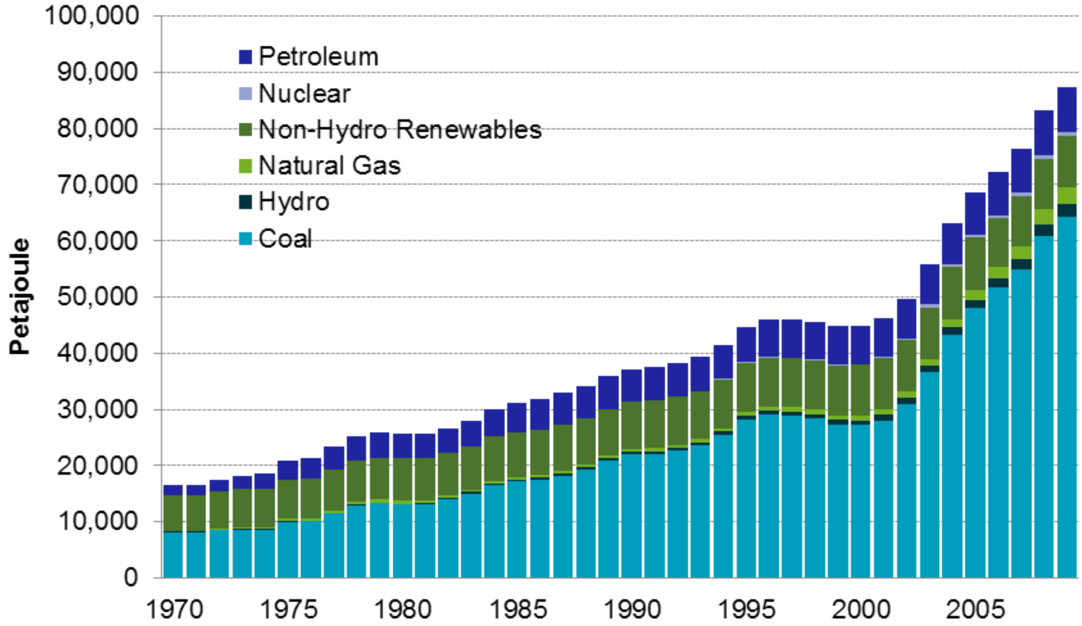


Figure 10 Domestic primary energy production by type. Sources: (IEA 2007b, IEA 2007a, IEA 2011c)

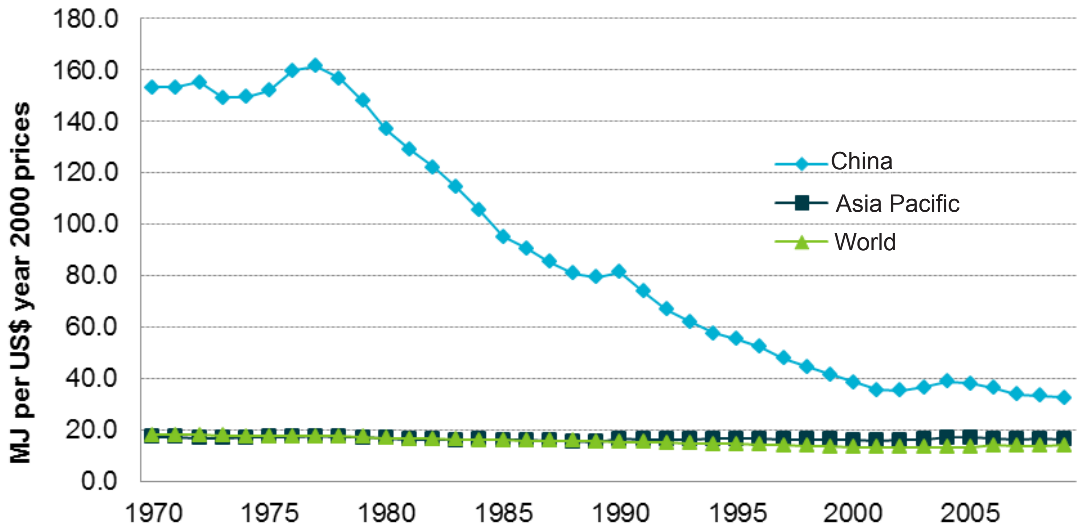


Figure 11 Energy intensity of the Chinese economy compared to world and Asia and the Pacific averages. $US are constant year 2000, exchange rate based. Sources: (IEA 2007b, IEA 2007a, World Bank 2012)

Figure 12 provides detail on the energy efficiency of three major sectors of the Chinese economy. It can be seen that while the greatest improvements in energy efficiency have been made in the industrial sector, it remains by far the least efficient at converting energy to income. Furthermore, the turnaround in trend, towards increased EI in the new millennium suggests that the economic model which has provided extremely rapid growth in the Chinese industrial sector over the same period, does little by itself to improve energy efficiency. The sustained improvement which took place from the late 1970s to 2000 may have been be one off gains resulting from the combination of institutional reform and technological modernization which took place over that period. If so, further gains going forward may be much harder to achieve, as the process efficiency gaps between new plant and the existing plant it replaces or augments becomes less, and large scale inefficiencies in the deployment of economic resources become more difficult to identify. If this does prove to be the case, then future improvements in energy efficiency may need to be achieved largely by the growing less energy intensive sectors, such as services, relative to industry.

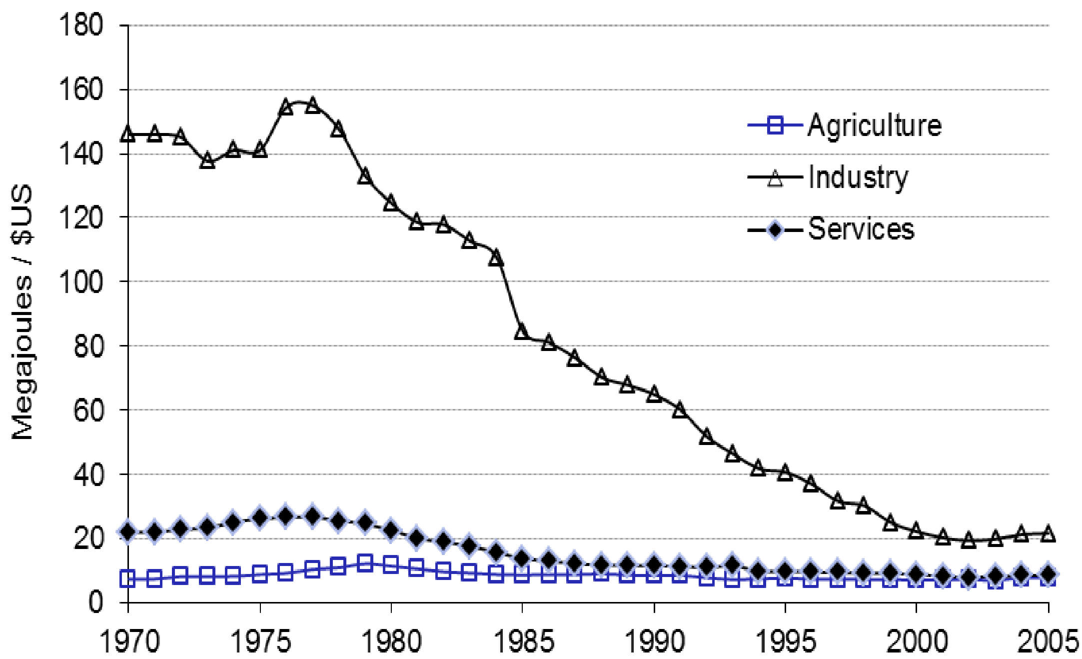


Figure 12 Energy intensity of the agricultural, industrial, and services sectors of the Chinese economy. $US are constant year 2000, exchange rate based. Sources: (IEA 2007b, IEA 2007a, World Bank 2012)

7 Drivers of energy use in China,1970 – 2005

						Share contribution using log transforms		
	$TPES_{(I)}$%	$TPES_{(I)}$ (Petajoules)	P	A	$EI_{(T)}$	P	A	$EI_{(T)}$
1975 - 1985								
China	43%	8,710	15%	99%	-37%	38%	193%	-131%
Asia-Pacific	40%	21,368	20%	26%	-7%	54%	68%	-22%
World	25%	64,653	19%	15%	-9%	77%	64%	-41%
1985 - 1995								
China	51%	14,889	15%	127%	-42%	33%	198%	-131%
Asia-Pacific	61%	45,222	21%	28%	4%	39%	52%	8%
World	19%	61,752	17%	13%	-10%	92%	68%	-60%
1995 - 2005								
China	64%	28,029	8%	120%	-31%	16%	160%	-76%
Asia-Pacific	42%	50,638	13%	22%	3%	35%	57%	8%
World	24%	92,548	14%	19%	-8%	59%	79%	-39%

Table 2 Comparison of the major drivers of growth in total primary energy supply over three periods (1975 to 1985, 1985 to 1995, and 1995 to 2005), for China, Asia and the Pacific, and the World.

The factors driving the growth in China's energy TPES are analysed here using the IPAT framework, which was discussed previously with regard to materials consumption. The reader is referred to the initial paragraphs of that section for an explanation of IPAT. The only difference here is that the environmental impact (I) of interest is TPES, and so the corresponding technological coefficient (T) is energy intensity (EI). In this section both TPES and EI are subscripted with the IPAT variable they correspond to i.e. $TPES_{(I)}$ and $EI_{(T)}$.

Table 2 shows how the relative importance of population, affluence, and $EI_{(T)}$ in driving growth in $TPES_{(I)}$ has changed over each of the three decades between 1975 and 2005, for China, Asia and the Pacific, and for the world as a whole. China's TPES increased at a rate roughly two to three times faster than the world average in each of the three decades studied, however China's increase was broadly comparable with the rapid growth rates for Asia and the Pacific as a whole, with China's TPES only growing appreciably faster than the regional average over the final decade studied, from 1995 to 2005. As seen previously for materials, the relative importance of the individual drivers was very different between China, the region, and globally. Where increasing population was of comparable importance to increasing affluence at both the regional and global scales in each decade (always making a contribution between 60% and 140% that of affluence), for China the contribution of increasing affluence was always greater than fivefold that of population.

China's achievements in lowering $EI_{(T)}$ had a much larger effect on moderating growth in $TPES_{(I)}$ than seen previously for materials. Over the two earlier periods, from 1975 to 1995, decreasing EI counteracted around two thirds of the increase in TPES attributable to increasing affluence, and for 1995 to 2005 it was still offsetting nearly half the affluence effect. In all periods it offset several times the increase in TPES attributable to population increase. Improvements in China's EI clearly had a strong effect on restraining energy use at the national level, however the rate of improvement was not fast enough to avoid marginal increases in regional EI as of China's share of the regional economy increased. Where Asia and the Pacific's EI decreased from 1975 to 1985, it increased in both decades from 1985 to 2005 as a rapidly growing share of regional economic activity shifted from the region's low EI economies to those with higher EI, above all China. This is the same effect seen earlier for materials intensity. While much less pronounced than that seen for materials, the effect has been been powerful enough to outweigh the improvements made by countries on an individual basis. As with materials, the means by which some of the more energy efficient countries in the region achieved low EI , notably off-shoring of energy intensive processing of primary materials, may not provide a particularly meaningful model for China's future development. Even if China did achieve low EI by this means, many of the major issues manifest at the global scale e.g. those associated with resource depletion and greenhouse gas emissions. This being the case, it is not clear that much is achieved via outsourcing, beyond relieving local environmental pressures. Improved process efficiencies are another matter entirely, and represent real gains in that they make it possible to support a given standard of living using fewer resources. Improving process efficiencies, whether in industry or in the delivery of services, is fundamental to the ability to maintain or improve living standards for a population while simultaneously reducing their environmental impact. While there is good evidence that increasing process efficiencies do not deliver the reductions in resources which might initially be expected, due to the operation of the "rebound effect" (Jenkins, Nordhaus and Shellenberger 2011), the existence of this phenomenon does not constitute a viable argument against the desirability of pushing for ever higher process efficiencies. This is because the rebound effect is secondary, and assumes that the efficiency gains will be re-invested in securing ever higher material standards of living. While this may be a reasonable assumption for most current economies, it is entirely within the realm of policy to dramatically influence the extent to which this effect operates. Conversely, it is difficult to envision policies which can deliver higher aggregate material standards of living in an economy with decreasing process efficiencies.

8 Water use patterns and water efficiency in China, 1980 – 2005

In addition to being fundamental to all life, water resources are closely linked to the economic use of resources, as a material input to production and consumption activities, and as sinks for waste material. Unfortunately, perhaps due to low unit values, and to difficulties in establishing rigorous and consistent water accounts, statistics on water can be rather poorly compiled, and sporadic in nature, and subject to major revisions. There appears to have been a major revision of key water statistics for China itself in recently[2]. In view of this, this section of the report has been kept short and the analysis conducted limited.

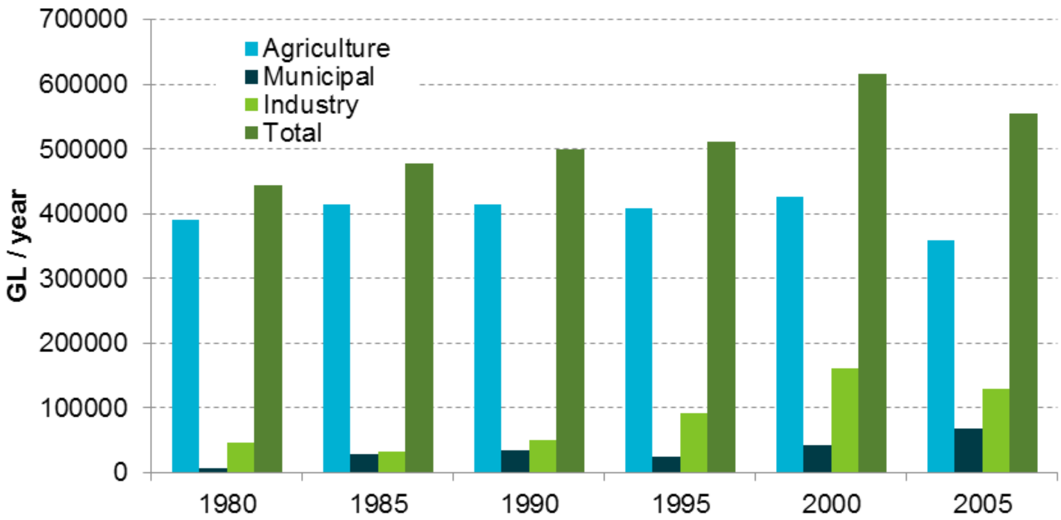


Figure 13 Annual water withdrawals by major sectors of the Chinese economy, for the period 1998 to 2002. Sources: (FAO 2010, World Bank 2010)

Figure 13 shows that China's growth in total water withdrawals was subdued over the period 1980 to 2005, when compared to the extremely rapid rates of growth in consumption of materials and energy. Furthermore, this growth appears to be approximately linear over time, rather than compounding, as seen previously for materials and energy. The sectoral detail in Figure 13 shows that growth between the different sectors is very uneven. A clear decrease in water used in the agricultural sector has been more than offset by growth in industry and municipal withdrawals. The total changes for the three sectors over the full twenty five year period were: agriculture -8%, industry +81%, municipal +797%, total + 25%.

2 The data used here is derived from either the FAO Aquastat or WDI data bases, as available online in early 2010. Since that time, the values from both sources have changed, and most importantly, no estimate of agricultural use (or total use) is now provided for China for any year in the period 1998 to 2002, suggesting poor reliability for this period. Data has been retained for this interval in graphs and tables both for completeness and because the regional aggregates done in the original REEO report were for this period.

	Agriculture (GL)	% of Total	Industry (GL)	% of Total	Municipal (GL)	% of Total	Total (GL)
China	426,900	69.2%	162,000	26.3%	41470	6.7%	617,000
Asia and the Pacific	1,848,041	81.5%	259,385	11.4%	161260	7.1%	2,268,726

Table 3 Water withdrawals by industry sector, averaged for the years 1998 to 2002, for China and Asia and the Pacific. Sources : (FAO 2010, UNEP 2011)

Table 3 indicates that for the period 1998 to 2002, China used a smaller share of its water for agriculture than typical for Asia and the Pacific, whereas industry's share was over twice the regional average, and the share of municipalities near average for the region. The sectoral shares for China for the period 2003 to 2007 (not shown here) were broadly similar with the exception of municipal withdrawals, which almost doubled to 12%. This increased share was at the expense of agriculture, which declined marginally to 65%, and industry, which declined to 23%.

	All Economy (Litres/$US)	Agriculture (Litres/$US)	Industry (Litres/$US)	Households[3] (Litres/$US)
China	515	2,365	294	75
Asia and the Pacific	273	3,454	93	35

Table 4 Water intensity per $US of GDP by sector, averaged over the interval 1998 to 2002, for China and Asia and the Pacific. Sources : (FAO 2010, UNEP 2011)

Table 4 indicates that for the period 1998 to 2002, the Chinese economy was only around one half as efficient as the Asia and Pacific region at converting inputs of water to income. China's sectoral performance varied greatly, with its agricultural sector less water intensive than the regional average, while its industrial and municipal sectors were twice to three times more water intensive than the regional average. Sectoral withdrawals for China for the period 2003 to 2007, and GDP for 2005, indicate that China's average water intensity for the economy as a whole decreased greatly over the subsequent five year period, to 290L/$US.

With renewable internal freshwater resources of 2,813,000 GL, China's total withdrawals for the period 2003 to 2007 of 554,000 GL give it a Water Exploitation Index (WEI) of 19.7%, and so remains just below the 20% threshold generally accepted e.g. in (Marcuello and Lallana 2003), as indicating that a country is water stressed[4]. This encouraging result must be tempered by the knowledge that water stress is likely to be highly variable for different Chinese regions. In (UNEP 2011), most of the Asia and Pacific region's most water stressed nations occurred on China's western border, while those to its southeast exhibit little or no water stress. It might be expected that China's regions follow a broadly similar pattern.

3 The water intensity cited for "Households" is calculated from "Municipal" water withdrawals from the Aquastat database, divided by the value added in the "household" sector in WDI statistics (in exchange rate based, constant year 2000, $US). As a result there will be some degree of boundary mismatching.

4 WEI less than 10% - non-stressed; WEI between 10 and 20% - low stress; WEI greater than 20% - stressed; WEI greater than 40% - severely stressed.

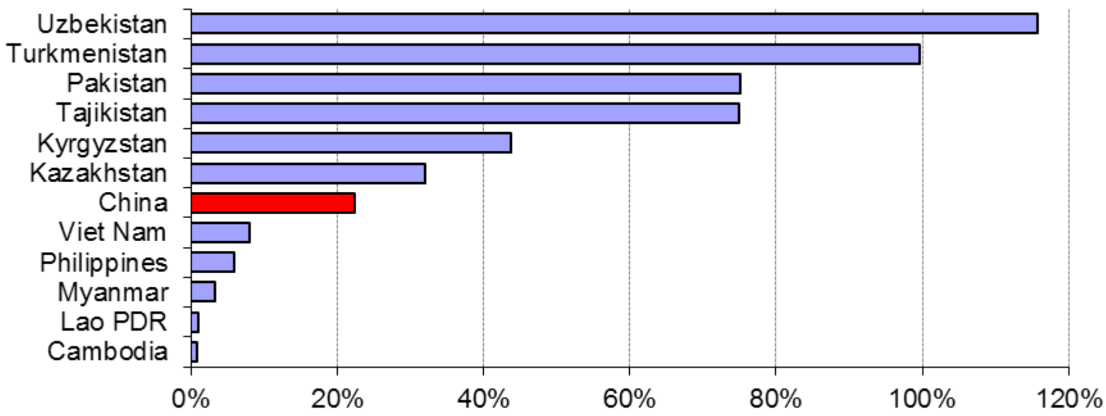


Figure 14 Water exploitation indices for China and a selection of nearby countries to its west and southeast.

9 Greenhouse gas emissions in China, 1970 – 2005

Figure 15 provides a summary overview of important trends with regard to China's Greenhouse gas (GHG) emissions and GHG intensity. China clearly achieved major decreases in its GHG intensity over most of the period 1970 to 2005, notably from the late 1970s to the early 2000s. Emissions of carbon dioxide decreased on average by 2.7% p.a. compounding for the whole period. This improvement is evident for both carbon dioxide emissions, and for the broader measure (here labelled 3GHG) which aggregates the carbon dioxide equivalent effects of emissions carbon dioxide, methane, and nitrous oxides. The 3GHG measure is available only post 1990. Despite these improvements in GHG intensity, GHG emissions per capita grew rapidly over the same period, by an average of 4.1% p.a. compounding, with growth accelerating from the turn of the millennium. This acceleration in per capita emissions coincides with a turning point in GHG intensity, which actually increases for the first time since the late 1970s. The turning point coincides with the rapid share increase of coal in China's energy mix, discussed earlier in the energy section.

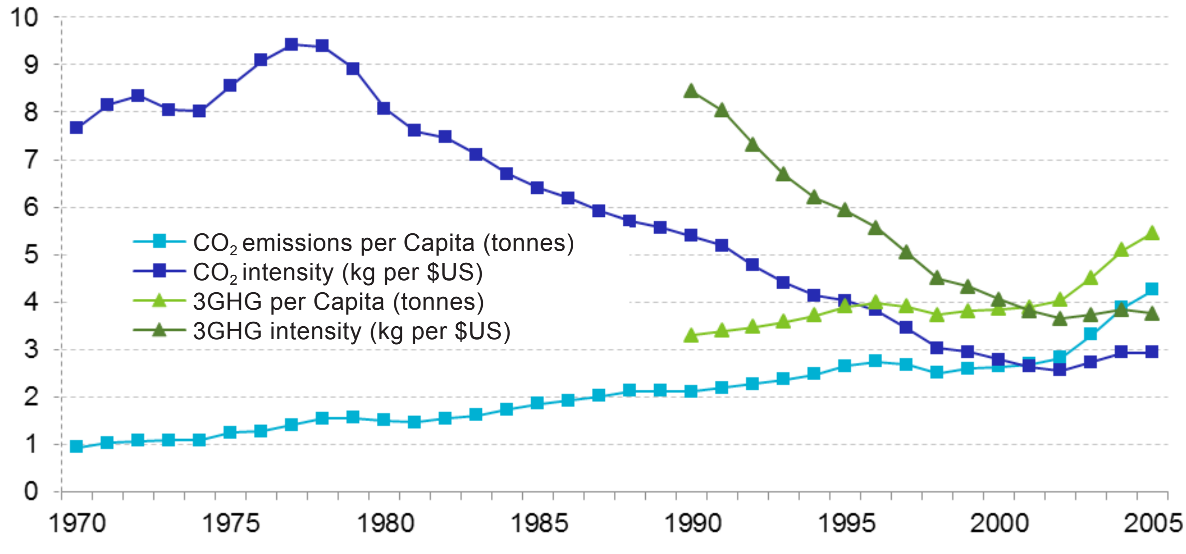


Figure 15 China's greenhouse gas intensities and emissions per capita for 1970 to 2005. 3GHG refers to CARBON DIOXIDE equivalent summing the emissions of carbon dioxide, methane, and nitrous oxides given in (World Bank 2009)

Table 5 compares China's GHG intensity trajectory to Asia and the Pacific as a whole, and to the Rest of World (i.e. excluding Asia and the Pacific). China's GHG intensity has improved much faster than either the Rest of World, or Asia and the Pacific, the later region showing little improvement at all over the fifteen year period examined. Even after the rapid gains made in GHG intensity, China's economy remained very GHG intensive, emitting over four times the GHG per unit of economic output as the Rest of World, and more than twice that of its region, Asia and the Pacific. As discussed previously for both materials and energy, much of the Asia and the Pacific's regions failure to decrease GHG intensity significantly can be attributed to the rapid growth of China's share of the regional economy.

	1990	1995	2000	2005
China	8.43	5.93	4.06	3.75
Asia-Pacific	1.66	1.65	1.55	1.62
Rest of World	1.23	1.07	0.95	0.91

Table 5 Greenhouse gas emissions intensity for China, Asia and the Pacific, and the Rest of World, for 1990 to 2005. Greenhouse values indicate carbon dioxide equivalent of direct emissions of carbon dioxide, methane, and nitrous oxides. Source: (UNEP 2011, World Bank 2009)

Table 6 compares China's GHG emissions per capita with a selection of other countries from the Asia and the Pacific, in 2000/2001. While this table shows that China still exhibited relatively low GHG emissions per capita at that point, the main point to note is the difference between direct GHG emissions per capita, and GHG footprint, which adjusts for emissions embodied in trade. In China's case, the difference between the two measures indicates that over 25% of its GHG emissions were actually attributable to products consumed elsewhere in the world. This stands in contrast to a country like Japan, which imports many products after GHG intensive processes have been performed elsewhere. In Japan's case, only 78% of the GHGs embodied in its consumption were accounted for in its direct emissions. This is an important point to be taken into account when making country to country comparisons based on apparent per capita consumption or emissions, and should temper the degree to which the success of some countries in lowering their materials/energy/emissions intensities can be used as a guide to what is practicable at the larger scale. Specifically, to where should China outsource its emissions intensive production processes, and what would be achieved, in sustainability terms, by it doing so?

	Direct GHG emissions (tonnes CARBON DIOXIDE-e)	GHG footprint (tonnes CARBON DIOXIDE-e)
China	3.9	3.1
Japan	10.7	13.8
India	2.1	1.8
Australia	28.9	20.6
Indonesia	2.8	1.9
Republic of Korea	10.4	9.2

Table 6 Comparison of direct greenhouse gas emissions to greenhouse gas footprint, on a per capita basis, for China and five other countries in Asia and the Pacific, for 2000/2001. Sources: (Hertwich and Peters 2009, World Bank 2009)

10 Resource efficiency policy in China

China is home to approximately one-fifth of the world's population. The nation is also experiencing a rapid process of urbanization. The urbanization rate reached 51 per cent in 2011 (CNSB 2012). By 2030, urban populations are expected to grow by more than 300 million, with nearly 60% of the population living in urban areas (Laquian, 2006). China's rapid economic growth in recent decades has been accompanied by substantial depletions of natural resources, degradation of major ecosystems and serious environmental pollution. Some of the more pressing environmental issues include water resource depletion and pollution, soil erosion, desertification, acid rain, sandstorms and forest depletion. A large share of the pollution originates from industrial production (Hicks and Dietmar, 2007).

Five-Year Plans for Social and Economic Development

Environmental objectives are integrated into several national policies and regulations, including the *Circular Economy Promotion Law and the Cleaner Production Promotion Law*. Sustainable consumption and production (SCP) principles are also integrated into China's Five-Year Plans for Social and Economic Development. The Five-Year Plans for Social and Economic Development (FYPs) form the basis for coordinating Chinese national public policy priorities. They are developed by the National Development and Reform Commission (NDRC) and approved by the National People's Congress. SCP principles are integrated through quantified pollution emission targets as well as quantified resource efficiency targets.

The 11^{th} FYP (2006-2010) marked a major shift from previous plans in terms of the objectives of economic policy. It had an increased focus on more balanced and sustainable growth, greater resource efficiency, better living standards and balanced rural-urban development. A key task and strategic priority of the plan is to 'build a resources-saving and environment-friendly society' (World Bank, 2008, page7). The most important SCP-related targets to be achieved over the five year period include:

- 20% reduction in energy intensity
- 10% reduction in annual SO_2 and COD emissions
- 30% reduction of water consumption per unit of industry value added
- Increasing the recycling rate for industrial solid wastes to 60%

By the end of 2010, China had basically realized the targets of energy conservation and emissions reduction set up in the 11^{th} FYP, including reducing accumulated CO_2 by 1.46 billion tons, energy intensity by 19.1%, annual SO_2 by 14.29% and COD emissions by 12.45%.

The 12^{th} FYP (2011-2015) is continuing the broad policy direction of the previous plan. Major themes in the current plan are sustainable growth, economic restructuring, social equality and environmental protection. The Chinese government seeks to move the economy up the value chain to more service and high-tech oriented business. For the first time in a FYP, China has set a carbon-intensity reduction target of 17 per cent and intends to reduce energy intensity by a further 16 per cent by 2015. Other legally binding targets include (Lommen, 2011):

- Increase the proportion of non-fossil fuel by 3.1%
- Increase forest coverage by 1.3%
- Reduce annual SO_2 and COD emissions by 8%
- Reduce annual NO_x and ammonia nitrogen emissions by 10%
- Reduce water consumption per unit of industry value added by 30%
- Eliminate the loss of arable land

Seven industries have been selected as priorities for development, consistent with the 12th FYP's goals of sustainable growth and moving up the value chain[5]. Their contribution to GDP is set to rise from 2% in 2010 to 8% in 2015 (KPMG, 2011a).

Circular Economy Promotion Law

China is one of the first countries to embrace the circular economy (CE) approach as a new paradigm for economic and industrial development. The CE concept seeks to change the economic growth model by radically increasing material use efficiency and sharply reducing pollution discharges. The ultimate objective of the CE approach is to achieve decoupling of economic growth from natural resource depletion and environmental degradation (World Bank, 2009). The Chinese government has been promoting CE on a number of fronts, including legislation, policy reform, pilot projects, and monitoring and evaluation activities. The *Circular Economy Promotion Law* came into force in 2009. It is a comprehensive framework law which aims to improve resource efficiency, protect the environment and achieve sustainable development. The *CE Promotion Law* is very broad and far-reaching. Its enforcement therefore requires supporting regulations to be developed. The Chinese government is currently in the process of drafting the *CE Development Plan*, which will outline the major tasks and measures necessary for achieving more effective implementation.

Several barriers have been identified that affect the successful implementation of the *CE Promotion Law*. These include the difficulty of changing current industrial structures, the lack of funding, advanced technologies and information support, the poor environmental awareness of the public and private sector, and the lack of effective enforcement mechanisms (Geng, 2009; Xue et al., 2010).

Cleaner Production Promotion Law

China began to implement cleaner production (CP) in the early 1990s as a way of confronting the country's serious environmental problems. A network of national and local CP policies incorporated CP

5 The seven priority industries are New Energy (nuclear, wind and solar power), Clean Energy Vehicles, Energy Conservation and Environmental Protection, Biotechnology, New Materials (rare earths and high-end semiconductors), New IT (broadband networks, internet security infrastructure), and High-end Equipment Manufacturing (aerospace and telecom equipment)

activities such as demonstration projects, training and promotion centres and the creation of the National Cleaner Production Centre (CNCPC) (Hicks and Dietmar, 2007). Today, the *Cleaner Production Promotion Law* (2003) governs the implementation of all CP activities in the country. It seeks to promote cleaner production, increase resource efficiency, and reduce and avoid the generation of pollutants. This law not only encourages CP at the individual company level, but also supports broader CP efforts at inter-firm level and regional levels through eco-industrial development. Compulsory CP audits are carried out for key polluting enterprises. Enterprises are also encouraged to reach voluntary agreements with local governments to improve their energy and environmental performance beyond compliance with national and local standards (Andrews-Speed, 2009).

Despite China's relatively long experience with CP, several implementation challenges remain. Overall, it has proven difficult to encourage enterprises to undertake CP measures and to provide adequate resources to ensure CP adoption (Hicks and Dietmar, 2007). Lack of awareness, the absence of an adequate institutional framework and the difficulty of creating a market for CP services have also been recognized as common barriers to CP implementation (Geng *et al*., 2010). For small- and medium-sized enterprises (SMEs) the most prominent barriers to CP adoption are the absence of economic incentive policies, lax environmental enforcement and high initial capital costs (Shi *et al*., 2008).

Policies relating to food and agriculture

Since the mid-1990s, the Chinese government has been concerned with its ability to continue feeding a growing population. More than 12% of cultivated land is believed to have been lost in the last decade due to urbanization and industrialization (OECD, 2010). These losses of cultivated land have largely been concentrated in the most productive farming areas of the country; the coastal and central provinces, which also have more fertile soils than the remainder of the country (Lichtenberg and Ding, 2008).

The central government places a high priority on the conservation of agricultural land, largely for food security reasons but also to protect farmers from being forced off their landholdings by local governments trying to convert collectively-owned land for industrial and residential purposes (Kamal-Chaoui *et al.,* 2009). The *Land Administration Law* was implemented in 1999 to protect environmentally sensitive and agricultural land, and to coordinate the planning and development of urban land. The law reinforces farmland preservation efforts by stipulating that the total amount of cultivated land within each administrative area needs to remain unreduced (Lichtenberg and Ding, 2008).

The *CE Promotion Law* contains provisions for developing ecological agriculture and for achieving greater overall efficiency in China's agricultural sector. For instance, agricultural producers are encouraged to adopt planting, breeding and irrigation technologies that reduce the use of water, fertilizers and pesticide. Agricultural departments are also advised to promote the use of energy-saving agricultural machinery.

The modernization of the agricultural sector is also one of the major priorities of the *12th FYP*. Key agricultural targets include reaching an annual grain production capacity of no less than 540 million tonnes, and ensuring the maintenance of farmland reserves at no less than 1.212 million square kilometres. The agricultural sector is to be modernized and made more efficient through various approaches including building logistical support structures, modernizing supply chains, standardizing production and quality control, increasing rural development funding and ensuring consumer safety (NZTE, 2011).

Policies relating to buildings and construction

China's rapid rate of economic development and urbanization presents a significant challenge to the building and construction sector in terms of energy supply and carbon emissions. China is the world's largest market for new construction projects with around 2 billion m^2 of floor space added annually, mostly in urban areas (Li and Colombier, 2009). While 60% of these new buildings are classified as residential, 30% are public buildings[6] and the remaining 10% are used for industrial purposes (Shui *et a*l., 2009). Buildings are a priority area for policy development by the Chinese government due to the large amount of energy wasted for their heating or cooling purposes. At present, the building sector accounts for nearly 30 per cent of China's total energy consumption, and this proportion is growing steadily (Li and Yao, 2009).

The *11th FYP* established an energy-saving target for buildings of 100 Mtce in primary energy units (Levine *et al.*, 2010). Energy savings were meant to be achieved through better enforcement of building energy efficiency codes and standards, retrofitting existing buildings and reforming heat supply systems, and improving energy management of government office buildings and large scale public buildings (Price et al., 2011). The *12th FYP* has also introduced ambitious energy saving targets for the building sector. [7] In addition, the CE Promotion Law contains provisions for the adoption of more efficient building and construction technologies and processes so that savings in energy, water, land and materials can be realized.

In recent years, China has adopted building codes for residential and public buildings, focusing on heating, ventilation and air conditioning, as well as lighting, hot water and power use. National energy design standards for residential and public buildings were developed in 2005. The Ministry of Housing, Urban and Rural Development (MOHURD) regulates the building industry in China and coordinates the country's building energy codes. Regulations, policies and programs issued by MOHURD to promote energy efficiency in buildings are listed in Table 7 below.

Implementation challenges in the building and construction sector still exist. For instance, the building codes compliance rate remains unclear for small cities and in rural areas. It is, however, considered accurate in larger cities, where compliance is enforced through regular and random inspections carried out by the local government (Zhou *et al*., 2011).

6 Public buildings in China refer to non-residential buildings including commercial, educational and governmental buildings

7 The details of the 12th FYP for energy conservation of the building industry were not yet published at the time of writing.

- National Green Building Innovation Awards (2004-2007)
- Notice on Enforcement of Building Energy Standards for New Residential Buildings (2005)
- Notice on Conducting Building Energy Conservation Inspections (2006)
- Green Building Technology Guidance (2005)
- Management of Energy Conservation in Civic Buildings (2005)
- Guidance on Building Energy Efficiency Evaluations and Labelling (2006)
- Guidance on Energy Audits for Governmental Buildings and Large-scale Public Buildings (2007)
- Green Building Evaluation Labelling (2008)
- Management and Technical Guidance for Energy-efficient Campuses in Universities and Colleges (2008)
- Civil Building Energy Conservation Ordinance (2008)

Table 7 Recent Building Energy Efficiency Regulations, Policies and Programs. Source: (Shui et al. 2009, Levine et al. 2010)

Policies relating to mobility and transport

China has experienced rapid motorization since the early 1990s, when the Chinese government designated the automotive industry as one of the pillar industries of the national economy. Today, China is the leading producer of motor vehicles and it has overtaken the United States as the biggest automobile market in the world (Cao and XU, 2010; Pan, 2011). Although per capita car ownership levels are still low, they are progressing quickly. The number of registered cars increased from around 1 million in 1994 to nearly 33 million in 2008 (Pan, 2011). The government has therefore put great efforts into expanding roadway capacity to accommodate the increased volumes of private motor vehicles.

The Chinese government has adopted a number of regulations to reduce the negative environmental and health impacts of motor vehicles. The revised *Energy Conservation Law* (2007) promotes the use of clean, alternative fuels and provides incentives for the development and use of high-efficiency vehicles, including alcohol-fuelled, hybrid, electrical and compressed natural gas vehicles (Prakash, 2008). Mandatory fuel economy standards have been instituted to achieve emission reductions in private vehicle use.

Demand for public transport services has also increased rapidly, particularly in urban areas. The *12th FYP* prioritizes the development of public transportation. For instance, plans include building up a 45,000 km high-speed railway network and improving subway and light rail coverage (Pew Centre, 2011). However, the *12th FYP* also seeks to extend China's road network by constructing seven new freeways originating from Beijing and nine new expressways running north to south (KPMG, 2011b).

Policies relating to manufacturing and consumer goods

China is one of the world's largest producers and consumers of household appliances (Price *et al.*, 2011). Under the *11th FYP*, national policies on household appliance standards and energy efficiency labels were strengthened to achieve a reduction in energy intensity. Minimum energy performance standards now exist for 30 types of appliances and equipment, mandating an average 10% reduction in energy consumption over previous levels (Price *et al.*, 2011). A mandatory energy information label known as the China Energy Label (CEL) has been established for 13 types of appliances to promote consumer awareness and facilitate market transformation.

Under the *12th FYP*, the manufacturing sector is required to reduce energy intensity. Industrial facilities that fall short of energy reduction targets are in danger of being shut down. Another cornerstone of the *12th FYP* is to increase domestic consumption. A key goal here is to continue establishing an environment that encourages domestic spending. Total retail sales of consumer goods are targeted at a 16% increase (KPMG, 2011a). It is expected that individual income tax will undergo major changes and be lowered so that workers have more disposable income.

Policies relating to urban development and land use

China is undergoing a massive process of urban development. In 2008, more than 600 million people were living in 655 cities, pushing the urbanization level to 45.7 per cent (Woetzel *et al.*, 2009). The urbanization rate is expected to reach 55 per cent in 2020 and 58 per cent in 2030 (Li and Colombier, 2009). With the process of urbanization continuing at such a rapid rate, a further 300 million to 400 million rural residents are expected to move to urban areas in the next 20 years. Urbanization in China has led to urban sprawl, the loss of arable land and increasing demand for energy and natural resources, as well as contributing to the challenge of providing social services.

The 11th FYP placed a much stronger emphasis on the development of metropolitan regions across the country. It also included measures to better integrate strategic towns into metropolitan economies.

The 11th FYP called for China's urbanization level to reach 47% by the end of 2010. It also promoted urbanization through the 'balanced development' of cities and towns (Kamal-Chaoui *et al*, 2009). The 12th FYP has set the target of increasing the urbanization rate to 51.5% by 2015 (KPMG, 2011a). Around 8 million rural workers are to be transferred to urban areas each year. At the same time, more than 45 million jobs are to be created in urban areas, while keeping the urban registered unemployment rate at no higher than five per cent. Urbanization is to be particularly accelerated in the central and western regions of the country. This is meant to be achieved through the liberalization of China's *hukou* system, which has controlled and limited rural-urban migration in the past. The overall goal is to reduce the attraction for the rural population to move to the eastern seaboard. Instead, urban centres are to be developed across inner China in areas such as Inner Mongolia, the Xi'an region, Chongqing and Chengdu, and Kunming and Guizhuo (NZTE, 2011).

Policies relating to energy, water and waste

China is the world's second-largest energy consumer after the United States and has one of the world's fastest-growing energy sectors (Yang, 2010). The majority of China's energy is generated from carbon-intensive fossil fuels, with coal dominating the country's energy supply (Chai and Zhang, 2010). The Chinese government has made great efforts to reduce energy intensity and to improve energy efficiency. Industry has been the key focus of energy conservation efforts in recent years, with old, small-scale and inefficient plants being closed down (Andrews-Speed, 2009).

China's *11th FYP* required a 20 per cent reduction in energy intensity by 2010 from 2005 levels. Preliminary assessments show that the country fell short of this target by just under one per cent, achieving a reduction in energy intensity of 19.1 per cent (Chow, 2011). The closure of inefficient power and industrial facilities is believed to have contributed to the decline in energy intensity during this period, with a reported 72.1 GW of thermal capacity closed (Lewis, 2011). Following the announcement of the 20 per cent energy reduction target as stated in the *11th FYP*, a series of policies were put in place to support the realization of this goal (see Table 8 below).

Policy	Key Component
Law on Energy Conservation 2007	• Codifies the major elements of the Medium and Long-Term Plan for Energy Conservation • Places great importance on the behaviour and performance of the government itself with regards to energy conservation
Medium and Long-Term Development Plan for Renewable Energy in China 2007	• By 2010, the share of renewable energy in total primary energy consumption will be raised to 10 per cent, and by 2020 to 15 per cent
Renewable Energy Law 2006	• Promotes the development of renewable energy • Provides a framework for pricing, special funding, special import facilities for equipment and provisions for grid management
Medium and Long-Term Plan for Energy Conservation 2004	• Sets out specific energy conservation targets for industrial, transportation and building sectors • Calls for a revision of existing energy policies and recognizes the importance of economic incentives

Table 8 Policies for reducing energy intensity in China. Sources: (UNDP 2010, Cao and Xu 2010, ADB 2010)

The *12th FYP* also includes a legally binding energy intensity reduction target of 16 per cent, slightly lower than the target of the previous FYP. The Chinese government is also in the process of developing a range of market mechanisms to complement existing regulations and standards in the energy sector. They key market mechanisms proposed in the *12th FYP* include a carbon tax, a natural resources tax and a carbon emissions trading scheme.[8]

Water resources in China are in short supply, severely polluted, and often wasted (Chunmei and Zhaolan, 2010). Water pollution of major lakes and rivers is one of the most pressing national environmental concerns in the country. More than 60% of large lakes are eutrophic and more than 75% of the water in rivers flowing through China's urban areas is unsuitable for drinking or fishing (Wang, 2011). In addition, nearly 40 per cent of the population lives in regions facing water scarcity (UNDP, 2011). The over-exploitation of water resources has led to serious environmental consequences, including ground subsidence, salinity intrusion, and ecosystem deterioration (Jiang, 2009).

8 A new Climate Change Law is expected in the next two to three years to draw together existing climate-related policies and to lay a legal foundation for future institutions.

The Chinese government has recognized the water resources issues and has taken numerous steps to promote sustainable water use. There are a number of policy goals and priorities for water resources management in its *11th* and *12th FYP*. A compulsory 30% reduction target for water consumption per unit of industry value added has been incorporated into both FYPs. Other policy objectives include strengthening river basin management, protecting drinking water sources, combating transboundary water pollution, enhancing water saving in agriculture, and increasing the treatment of urban sewage (Jiang, 2009). The *CE Promotion Law* outlines several provisions for more sustainable water use. These include using reclaimed water for road cleaning, greening and landscaping, developing water-efficient agricultural irrigation facilities, formulating water use quotas for government agencies, and developing advanced technologies for wastewater recycling by enterprises. China is also actively investing in projects to augment the water supply. The most prominent example is the $62 billion South-to-North Water Transfer Project. It will provide water for domestic and industrial uses in the arid north and is set to divert up to 45 billion m^3 of water annually (Jiang, 2009).

Driven by urbanization and increasing affluence, China recently surpassed the United States as the world's largest municipal solid waste generator. Yet compared to other environmental issues such as air pollution and water sanitation, the issue of solid waste management in Chinese cities has attracted little attention (Wang, 2011). Policy efforts have focused largely on improving the treatment of solid waste. The Chinese government has issued a series of policies to encourage investment in incinerators. These incentives include tax refunds, prioritized bank loans, subsidized loan interest, and subsidized prices for purchase of electricity (Wang, 2011). Several policies have been implemented to address the serious waste problems in China. These include the *Law on the Prevention and Control of Environmental Pollution Caused by Solid Waste* (1995), the *Measures for the Management of Municipal Domestic Waste;* and the China WEEE Regulation (2011).

Economic and market instruments

The Chinese government has adopted a range of economic instruments aimed at both strengthening the economy and conserving resources. Following the 2008 global financial crisis, the Chinese government announced an economic stimulus package with a significant 'green' focus. Overall, US$586bn was to be spent over a two year period in ten major areas, including electricity, health, water and rural infrastructure (UNEP, 2009). Projects to support the growth of a green economy form a significant part of the stimulus package; for instance more than US$50bn was allocated for direct energy efficiency projects (World Resource Institute, 2008).

The Chinese government launched a financial subsidies fund in 2008 to promote energy efficient lighting products. While bulk users receive a subsidy of 30% on each highly efficient lighting product, residential users receive a subsidy of 50% (Wei, 2009). The country has also made progress toward environmental tax reform (ETR). It recently adopted a new law on corporate income tax that grants preferential tax treatment for investment in energy saving and environmentally friendly products and equipment. In addition, China's consumption tax was revised in 2006, putting a higher tax burden on larger, less efficient vehicles (Zhou et al., 2010).

Voluntary initiatives with industry are also part of China's energy conservation efforts. Under the Top-1000 Energy-Consuming Enterprises Programme (NDRC, 2008) participating enterprises sign energy conservation agreements with local governments, and are expected to formulate energy conservation plans and efficiency goals, establish reporting and audit systems, and conduct training. The programme aimed save 100 million tonnes of coal equivalent between 2005 and 2010.

Policy challenges

The Chinese government is committed to building a resource-saving and environmentally friendly society and it has successfully developed a large number of policies with environmental objectives. Most noteworthy is the adoption of the Circular Economy (CE) approach, with the vision of achieving the decoupling of economic growth from natural resource depletion. The *CE Promotion Law* is the world's first national law to make the circular economy a national strategic focus of economic and social development, thereby differing greatly from the traditional linear economic model.

A further encouraging development is that sustainability objectives have been successfully mainstreamed into China's national development plans. The *11th FYP* contains binding targets for achieving greater energy efficiency and the reduction of major pollutants. The *12th FYP* builds on previous achievements and sets a binding carbon-intensity reduction target. At the same time, officials are increasingly being measured for their performance in achieving centrally laid out environmental targets from the *12th FYP*.

However, while comprehensive national policies exist, implementation remains difficult. Several policies lack supporting regulations that outline more detailed implementation activities. For example, the *CE Development Plan,* which will outline the more practical tasks and measures necessary for achieving the implementation of the *CE Promotion Law,* was only adopted in late 2012. This delay has hindered the effective implementation of the *CE Promotion Law,* which came into force in 2009.

Where policies have been implemented they are often not properly evaluated and monitored due to a lack of technical, financial and human resources. Deficient enforcement mechanisms have also led to poor compliance rates in some sectors and regions of the country. The development of national indicator systems is essential so that policy makers can assess the effectiveness of policy initiatives and strengthen enforcement.

The difficulty of implementing and enforcing resource efficiency policies at the local level of government is one of the major policy challenges to be overcome. In China, the responsibility for environmental compliance and enforcement lies principally at the local level. However, financial and human resources as well as technical equipment at the local scale are often insufficient. Capacities of local government officials need to be strengthened through continuous training and regular information provision on new regulations.

References

Andrews-Speed, P, 2009. China's ongoing energy efficiency drive: Origins, progress and prospects, Energy Policy, 37, 1331-1344.

Cao, M. And Xu, Y., 2010. Climate protection and motor vehicle regulations: Evaluation of motor vehicle regulations in China in the context of greenhouse gas management, Natural Resources Forum, 34, 266-274.

Chow, G.C., 2011. Economic Planning in China, CEPS Working Paper No. 219, Center for Economic Policy Studies, Princeton University, United States.

Chunmei, W. And Zhaolan, L., 2010. Environmental Policies in China over the Past 10 Years: Progress, Problems and Prospects, Procedia Environmental Sciences, 2, 1701-1712.

CNSB. 2012. Statistical Communique on 2011 National Economic and Social Development of China. Beijing: China National Statistics Bureau.

Ehrlich, P. R. & J. P. Holdren (1971) Impact of Population Growth. Science, 171, 1212-1217.

EIA. 2011. International Energy Statistics. U.S. Energy Information Administration.

Eurostat. 2011. Economy Wide Material Flow Accounts (EW-MFA): Compilation Guidelines for Eurostat's 2011 EW-MFA questionnaire

FAO. 2010. Aquastat. Food and agriculture organization of the United Nations.

FAO. 2011a. Subscribers section - Bulk downloads - Food balance sheets. Food and agriculture organization of the United Nations.

FAO. 2011b. Subscribers section - Bulk downloads - Forestry. . Food and agriculture organization of the United Nations.

FAO. 2011c. Subscribers section - Bulk downloads - Production. . Food and agriculture organization of the United Nations.

FAO. 2011d. Subscribers section - Bulk downloads- Trade. Food and agriculture organization of the United Nations.

Geng, Y., 2009. Circular economy policy of China: Role of policy research towards a shift from institution building to implementation, Presentation, Chinese Academy of Sciences, UNEP.

Geng, Y., Xinbei, W., Qinghua, Z. And Hengxin, Z., 2010. Regional initiatives on promoting cleaner production in China: a case of Liaoning, Journal of Cleaner Production, 18, 1502-1508.

Hertwich, E. G. & G. P. Peters (2009) Carbon Footprint of Nations: A Global, Trade-Linked Analysis. Environmental Science & Technology, 43, 6414-6420.

Hicks, C. and Dietmar, R., 2007. Improving cleaner production through the application of environmental management tools in China, Journal of Cleaner Production, 15, 395-408.

IEA. 2007a. Energy balances of Non-OECD countries. Paris: International Energy Agency.

IEA. 2007b. Energy balances of OECD countries. Paris: International Energy Agency.

IEA. 2011a. Energy balances of Non-OECD countries. Paris: International Energy Agency.

IEA. 2011b. Energy balances of OECD countries. Paris: International Energy Agency.

IEA. 2011c. Energy statistics of Non-OECD countries. Paris: International Energy Agency.

IEA. 2011d. Energy statistics of OECD countries. Paris: International Energy Agency.

Jenkins, J., T. Nordhaus & M. Shellenberger. 2011. Energy Emergence: Rebound and Backfire as Emergent Phenomena. Breakthrough Institute.

Jiang, Y., 2009. China's water scarcity, Journal of Environmental Management, 90, 3185-3196.

Kamal-Chaoui,L., Leman, E. and Rufei, Z., 2009. Urban Trends and Policy in China, OECD Regional Development Working Papers, 2009/1, OECD Publishing.

KPMG, 2011a. China's 12th Five-Year Plan: Overview, KPMG, China.

KPMG, 2011b. China's 12th Five Year Plan: Transportation and Logistics, KPMG, China.

Laquian, A.A., 2006. People's Republic of China, B. Roberts and T. Kanaley (Eds.) Urbanization and Sustainability in Asia: Case Studies of Good Practice, Asian Development Bank, Philippines.

Levine, M.D., Price, L., Zhou, N. Fridley, D., Aden, N., Lu, H., McNeil, M., Zheng, N. And Yining, Q., 2010. Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five Year Plan,

Lewis, J., 2011. Energy and Climate Goals of China's 12th Five-Year Plan, Pew Center on Global Climate Change, Arlington, United States.

Li, J. and Colombier, M., 2009. Managing carbon emissions in China through building energy efficiency, Journal of Environmental Management, 90, 2436-2447.

Li, B. And Yao, R., 2009. Urbanisation and its impact on building energy consumption and efficiency in China, Renewable Energy, 34, 1994-1998.

Lichtenberg, E. and Ding, C., 2008. Assessing farmland protection policy in China, Land Use Policy, 25, 59-68.

Lommen, Y.F., 2011. Toward Sustainable Growth in the People's Republic of China: the 12th Five-Year Plan, ADB Brief No. 7, Manila, the Philippines.

Marcuello, C. & C. Lallana. 2003. Indicator Fact Sheet - (WQ01c) Water exploitation index. European Environment Agency.

NDRC, 2008. NDRC No. 58 Public Communique. National Development and Reform Commission, Beijing.

NZTE, 2011. Report on the 12th Five-Year Plan: An in-depth overview and analysis of China's policy blueprint for years 2011-2015, New Zealand Trade and Enterprises, Auckland.

OECD, 2010. Trends in Urbanisation and Urban Policies in OECD Countries: What Lessons for China?, Organisation for Economic Co-operation and Development,

Pan, H., 2011. Implementing Sustainable Urban Travel Policies in China, Discussion Paper No. 2011-12, International Transport Forum, OECD.

Prakash, M., 2008. Promoting environmentally sustainable transport in the People's Republic of China, Asian Development Bank, Philippines.

Price, L., Levine, M.D., Zhou, N., Fridley, D., Aden, N., Lu, H., McNeil, M., Zheng, N., Qin, Y. and Yowargana, P., 2011. Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th Five Year Plan, Energy Policy, 39, 2165-2178.

Schandl, H. & J. West (2012) Material Flows and Material Productivity in China, Australia, and Japan. Journal of Industrial Ecology, DOI: 10.1111/j.1530-9290.2011.00420.x.

Shi, H., Peng, S.Z., Liu, Y. and Zhong, P., 2008. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives, Journal of Cleaner Production, 16, 842-852.

Shui, B., Evans, M., Lin, H., Jian, W., Liu, B. Song, B. And Somasundaram, S., 2009. Country Report on Building Energy Codes in China, Pacific Northwest National Laboratory, Prepared for the U.S. Department of Energy.

UN Statistics Division. 2011a. Commodity Trade Statistics Database United Nations.

UN Statistics Division. 2011b. Industrial Commodity Production Statistics Database 1950 - 2008. ed. U. Nations. New York.

UNEP. 2011. Resource Efficiency: Economics and Outlook for Asia and the Pacific. Bangkok: United Nations Environment Programme.

UNDP, 2010. China and a Sustainable Future: Towards a Low Carbon Economy and Society, UNDP, Beijing, China.

UNEP, 2009. Green Economy Fact Sheet. United Nations Environment Programme, Nairobi.

UNDP, 2011. China 2011-2015: Country Programme Document, UNDP, Beijing, China.

USGS. 2011. Commodity statistics and information. USGS.

Wang, R., 2011. Environmental and resource sustainability of Chinese cities: A review of issues, policies, practices and effects, Natural Resources Forum, 35, pp.112-121.

Wei, 2009. Practice and experience of promoting efficient lighting in China. International Conference on Green Industry in Asia, Manila.

Woetzel, J., J. Devan, J, L. Jordan, S. Negri, and D. Farrell. 2009. Preparing for China's Urban Billion. McKinsey Global Institute.

World Bank, 2008. Mid-term Evaluation of China's 11th Five Year Plan, Poverty Reduction and Economic Management Unit, World Bank.

World Bank, 2009. Developing a Circular Economy in China: Highlights and Recommendations, Policy Note, World Bank Technical Assistance Program, World Bank.

World Bank. 2009. World Development Indicators 2009. World Bank.

World Bank. 2010. World Development Indicators 2010. World Bank.

World Bank. 2011. World Development Indicators 2011. World Bank.

World Resources Institute, 2008. A 'green lining' in China's economic stimulus plan. Retrieved 26 April 2012 from www.wri.org/stories/2008/11/green-lining-chinas-economic-stimulus-plan.

Xue, B., Chen, X., Geng, Y., Guo, X., Lu, C., Zhang. Z. And Lu, C., 2010. Survey of officials' awareness on circular economy development in China: Based on municipal and county level, Resources, Conservation and Recycling, 54, 1296-1302.

Zhou, N., Levine, M.D. and Price, L., 2010. Overview of current energy-efficiency policies in China. Energy Policy, 38(11), 6439-6452.

Zhou, N., Mcneil, M. and Levine, M., 2011. Assessment of building energy-saving policies and programs in China during the 11th Five-Year Plan, Energy Efficiency.

This report is intended to supplement the original Resource Efficiency: Economics and Outlook for Asia and the Pacific report (UNEP 2011). It provides more detailed data and analysis specific to China and can be thought of as a single country focus version of that report. The content of this report focusses on deepening analyses specifically relating to resource use pattern, resource efficiency, drivers of resource use, Greenhouse gas emissions and resource efficiency policy in China.

FOR MORE INFORMATION, CONTACT:

United Nations Environment Programme
Regional Office for Asia and the Pacific
U.N. Building 2 floor, Rajdamnern Nok Avenue
Bangkok 10200, Thailand
Tel: +662-288-2617/1133, Fax: + 662-280-3829
E-mail: uneproap@un.org
URL: www.unep.org/roap

Cover photos© nipic.com

www.unep.org
United Nations Environment Programme
P.O. Box 30552 Nairobi, 00100 Kenya
Tel: (254 20) 7621234
Fax: (254 20) 7623927
E-mail: uneppub@unep.org
web: www.unep.org