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AN ASSESSMENT OF CHINA'S 2020 CARBON INTENSITY TARGET

Project Lead: Neil Hirst

Project Team: Alex Dunnett, Mark Faist, Sam Foster, Mark Jennings, Luis Munuera, and Danlu Tong

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Executive Summary

China is a signatory of the Copenhagen Accord, developed at the Copenhagen climate summit in December 2009, which recognised that deep cuts in global emissions were required "with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius"[1].

As part of international mitigation efforts, China said it would endeavour to reduce its carbon dioxide (CO_2) emissions per unit of GDP by 40 - 45 percent by 2020 from 2005 levels and increase the share of non-fossil fuels in primary energy consumption to around 15 percent[2].

This Report assesses the feasibility and ambition of these targets, given the scale of global emissions reductions required to hold the rise in global mean temperatures to 2°C, and identifies some of the key domestic and international policy issues and challenges.

Is the Chinese target feasible?

A continuation of China's historic trend, since 1980, of declining carbon intensity, would be sufficient to enable China to exceed its target range. But this does not mean that achieving the target is easy. This declining trend was reversed during 2003 and 2004 and further progress will not be sustained without strong government policy interventions.

On the basis of existing policies, we estimate that China is set to achieve a 38% reduction in carbon intensity by 2020, a major achievement which would, however, require further effort to reach the (40 – 45%) target range.

How ambitious is it?

The targets that China has set are of major consequence and, if met, will make a significant contribution to international mitigation efforts. By achieving a 45% improvement in CO_2 intensity, the upper end of the target range, China would be eliminating more than two billion tonnes of CO_2 emissions per year by 2020 relative to baseline. This is more than three times the level of UK emissions today.

Even so, the targets may not be demanding enough to deliver the aims of the Copenhagen Accord. The absolute level of China's CO_2 emissions would still have risen from just over 5 billion tonnes in 2005 to over 8 billion tonnes in 2020, an increase of about 70%[3].

What is the savings potential?

The specific options that we have identified for reducing CO_2 emissions are shown in detail in the main part of this brief. However the broad areas with the greatest potential include:

- Further modernisation of the coal power fleet
- Increased investment in low carbon power technologies such as nuclear and renewables
- Rationalising and modernising the less efficient parts of the iron and steel and cement industries
- Setting and enforcing higher efficiency standards for industry, buildings and transport.

Our conclusion is that the targets that China has set are not easy to meet, but that they are within reach. The lower end (40%) of China's target range for the reduction of carbon intensity is attainable through the adoption of measures that would save costs and which we regard as reasonably attainable. However, to reach the higher end of the range (45%), our analysis suggests that China would have either to adopt measures with costs of up to $50 per tonne of CO_2 saved or to extend lower cost and cost saving measures closer to their absolute, theoretical potential.

There are, however, significant administrative, social, and resource barriers that will need to be overcome, even for those measures that we judge reasonably attainable: to be met these measures will require the efforts of government at city and Provincial level, as well as in Beijing.

Looking to 2050

In the longer term all major economies will need to achieve much lower levels of carbon intensity to meet a 2°C target. For this, China will need large-scale adoption of technologies such as Carbon Capture and Storage (CCS), advanced nuclear, solar power, and electric vehicles. Indeed there is a risk that some of the advanced and efficient coal plant needed to moderate the growth of carbon emissions to 2020 might need to be retired early or retrofitted with CCS to meet more stringent carbon targets in mid-century. Given its industrial strength and technological expertise, China could make significant progress in developing, demonstrating and deploying low carbon technologies to 2020 and beyond.

Introduction

China's Commitments

China played a leading role in the Copenhagen Accord, which underlines that "climate change is one of the greatest challenges of our time" and recognises the objective of containing the increase in global temperatures to below 2°C degrees Celsius. The parties to the Accord agreed to co-operate to achieve the peaking of global and national emissions as soon as possible, but with a longer time frame for developing countries. They also recognised that, "social and economic development and poverty eradication are the first and overriding priorities of developing countries"[4]. It can be expected, therefore, that China's climate change policies will continue to be consistent with these development objectives.

It is important to see China's emissions in a historic context and also in relation to population. China has about 20% of the World's population but from 1900 to 2005 contributed only about 8% of the World's energy-related CO_2 emissions. By comparison the United States and EU countries contributed just over half of cumulative emissions[5]. China has now, since 2007, overtaken the US to become the world's largest emitter. However China's emissions per head, in 2008, are still less than half the average for developed countries (OECD)[6].

The next decade is critical for international mitigation efforts. According to the International Energy Agency (IEA) if global emissions do not peak by around 2020 and decline consistently thereafter, the emissions reductions needed to meet a 2°C target will become much more costly or even infeasible[7] (Scenarios with later peaking dates are possible but they require very challenging rates of reduction thereafter[8]). According to *China's Energy Transition; Pathways for Low Carbon Development* a peak in Chinese emissions between 2020 and 2030 is the most plausible way in which China could make a full contribution to global action to stabilise the climate[9].

In November 2009, in the run-up to the Copenhagen climate change meeting, the State Council of China announced a target for reducing the intensity of carbon dioxide emissions per unit of GDP in 2020 by 40 to 45 percent, compared to the level of 2005[10]. The target was announced as a "voluntary action" taken by the Chinese Government "based on our own national conditions" and as a "major contribution to the global effort in tackling climate change". It was widely recognised as representing a major step forward in Chinese climate change mitigation policy and has now been incorporated into the commitments by non-Annex I countries within the Copenhagen Accord.

As a party to the 1992 Framework Convention on Climate Change, China has for many years recognised the importance of stabilising the level of greenhouse gases in the atmosphere. But as a developing country, China did not need to commit itself to any national emission reduction targets under the Kyoto Protocol and, as a matter of policy, China opposes legally binding commitments for developing countries under the Climate Treaty (UNFCCC). China has, nevertheless, pursued a range of policies for improving energy efficiency and promoting renewables which have helped to moderate emissions growth.

Economic Context

China's energy policy has multiple objectives. As explained in China's official statement to Cancun, "As a developing country with per capita GDP of only US$ 3,700 and ranking around 100th place globally, China still has a huge population living in poverty and is confronted with multiple challenges of economic development, poverty eradication, improving people's livelihoods and protection of climate"[11].

China is currently the most populous nation and earth and, economically, one of the most dynamic. China emits more than 6 billion tonnes of energy related CO_2 emissions, about one fifth of the world total and about ten times the figure for the UK[12]. On some estimates China's CO_2 emissions could increase to over 10 billion tonnes per annum by the 2020's[13]. While China's emissions are unlikely to peak before 2020, moderating their rate of growth is of critical importance.

In this Report the Chinese economy is projected to grow at 8.8% per annum from 2009 to 2015 and then at 5.3% from 2015 to 2020. A higher rate of growth, especially if accompanied by a more rapid shift to higher value manufacturing and services would make China's carbon intensity target easier to achieve.

Achievability of China's Targets

In this Paper, we assess the feasibility and ambition of China's voluntary targets, given the scale of global emissions reductions required to hold the rise in global mean temperatures to 2°C, and identify some of the key domestic and international policy issues and challenges.

China's carbon intensity has been declining from 2.45 tonnes of CO_2 per thousand US dollars of GDP (Valuing the Yuan at Purchasing Power Parity) in 1980 to a minimum of 0.71 tonnes per thousand US dollars in 2001[14].

A continuation of this trend over the next decade would be sufficient to enable China to exceed its target range. Assuming a 1% slower growth rate, China would still come within the target range. But this does not mean that achieving the target is easy. This declining trend was reversed during 2003 to 2004 and further progress will not be sustained without strong government policy interventions.

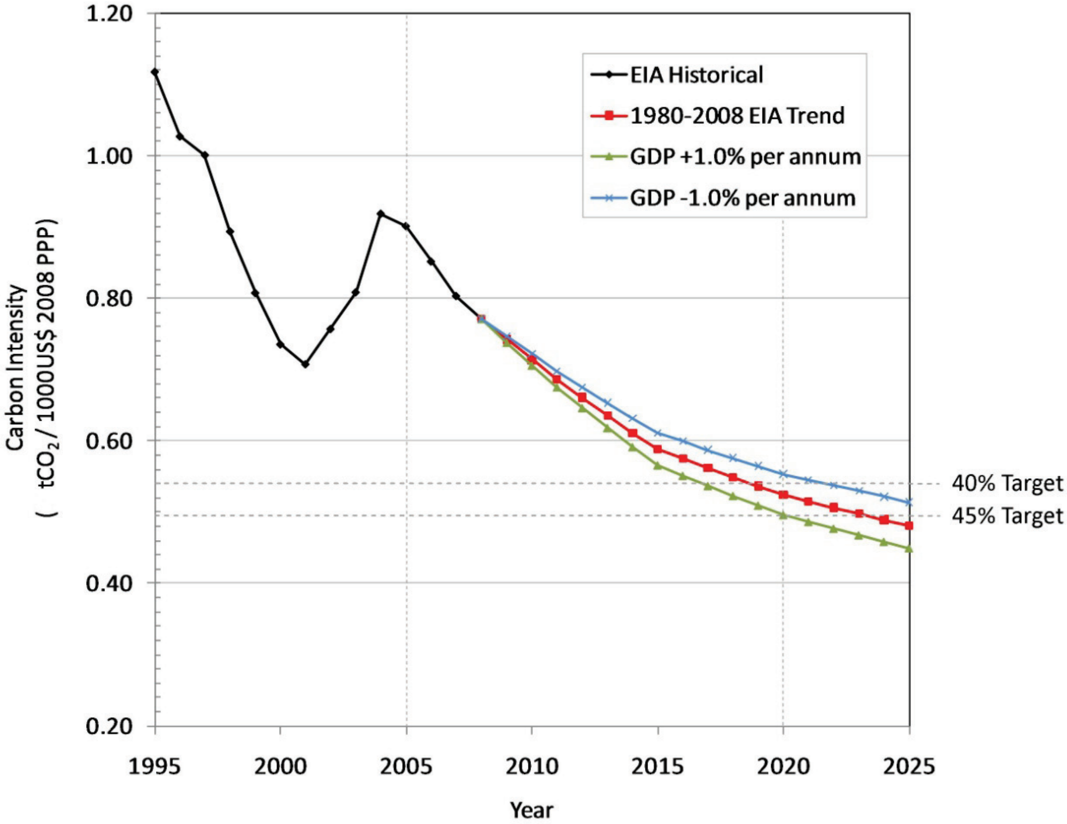

Figure 1: Chinese carbon intensity trend extrapolation. (Trend up to 2008 US Energy Information Administration (EIA) data[14], Projection to 2025, own analysis based on International Energy Agency GDP projections and the average trend in CO_2 /GDP from 1980 - 2008, EIA data.

Moderating carbon emissions represents a particular challenge for China's rapidly developing economy, since coal remains by far the most accessible and lowest cost source of energy. Also some of the "low hanging fruit" for reducing carbon emissions has already been gathered by closing the oldest and least efficient industrial plant during the 11th Five Year Plan from 2005 to 2010.

We have categorised the carbon saving options available to China according to their difficulty of implementation. Our "Green" case is a mid-range estimate of what we judge reasonably attainable. Our "Stretch" case is closer to the absolute, theoretical potential.

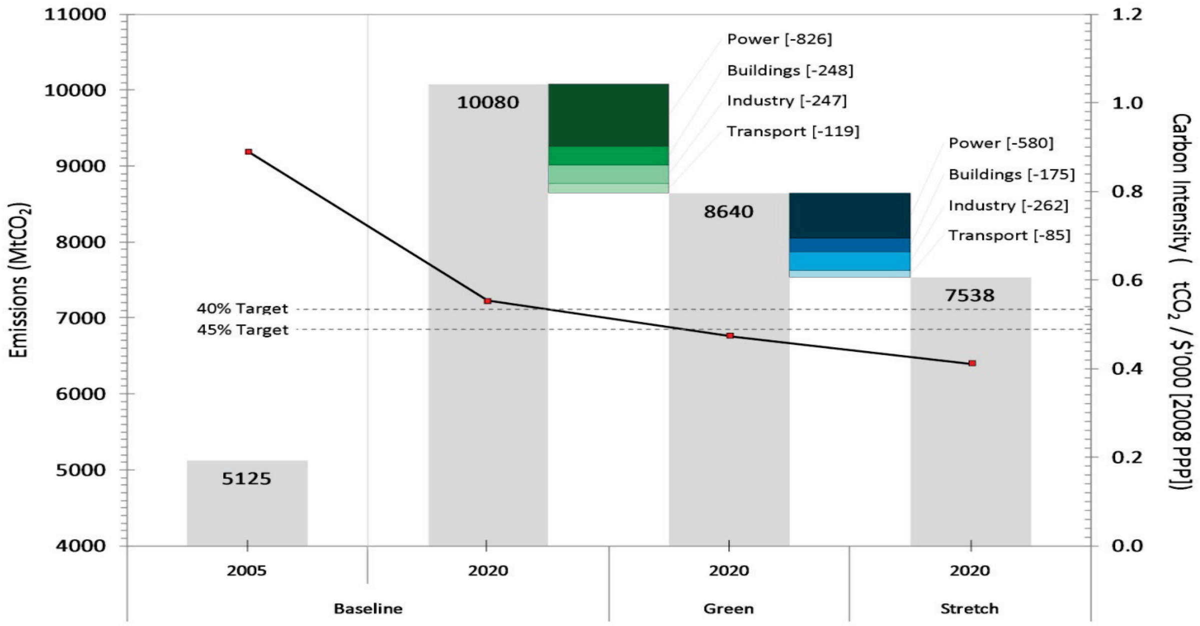

Figure 2: China scenario emissions and carbon intensity metrics (Source: IEA growth projections. Own Analysis, See Annex 1).

Figure 2 shows the impact of the potential savings on China's CO_2 emissions. In the base case these emissions rise from 5.1 billion tonnes p.a. in 2005 to 10 billion tonnes per annum (p.a.) by 2020. The "Green" savings, in power, buildings, industry, and transport, reduce the 2020 emissions to 8.6 billion tonnes p.a. The "Stretch" savings further reduce them to 7.5 billion tonnes. The dark line crossing the Figure shows that in the baseline case China would fall significantly short of the target range of reducing carbon intensity by 40 - 45%. However the carbon savings in the Green case would just be sufficient to exceed the high end (45%) of the target range and the savings in the Stretch case would enable it to be exceeded by a significant margin.

Cost Options	Negative	Low	Medium	High
Baseline	37.9%			
Green	40.2%	42.6%	44.8%	46.8%
Stretch	41.1%	45.9%	50.4%	53.6%

Table1. Reductions in carbon intensity between 2005 and 2020 by cost and difficulty (Source: IEA growth projections, own analysis. See Annex 1).

We have also categorised the savings according to their cost, ranging from Negative to Low (less than $10 per tonne of CO_2 saved), Medium ($10 - 50), and High (over $50). Table 1 shows the reductions in carbon intensity attainable by adopting measures of different cost and difficulty. The lower end of the target range (40%) is reachable with "Green" policies that will also reduce costs. However reaching the higher (45%) end of the range requires *either* the adoption of Green policies with low and medium costs *or* the adoption of Stretch policies with low costs. To some extent, therefore, there is a choice between policies that are more costly and policies that face greater barriers to implementation.

There are, however, significant barriers to the adoption even of some of the lower and negative cost options in the “Green” case. These include the need to enhance China’s administrative capability for energy efficiency monitoring and enforcement, the social and local economic costs of industry restructuring, and the resource bottlenecks that may constrain the very rapid expansion of options such as nuclear power. International collaboration might be helpful, especially at city and provincial level, to enhance China’s ability to develop and enforce energy efficiency standards.

Methodology

The underlying analysis on which this Paper is based was carried out for the UK government as part of the AVOID O Programme[15]. This was a bottom-up detailed technological analysis of the potential for reducing CO_2 emissions from energy consumption in each of the main sectors – power, industry, buildings and transport, which together account for about 70% of Chinese CO_2 emissions.

We have largely relied on published forecasts by the IEA, the EIA, and the IMF, for our assumptions on GDP growth and demand in main sectors of the economy. Details of the methodology are at Annex 1.

China’s Economy and Energy Policy

The Pace of Economic Development

China is the most populous nation on earth with 20 percent of the world’s population. Economically, it is also one of the most dynamic. In terms of purchasing power parity China now accounts for 13% of global GDP. China’s rapid and sustained growth over several decades has been concentrated in the Secondary economic sector, which includes industry and infrastructure (Figure 3), with the result that China now accounts for 24% of global industrial energy consumption.

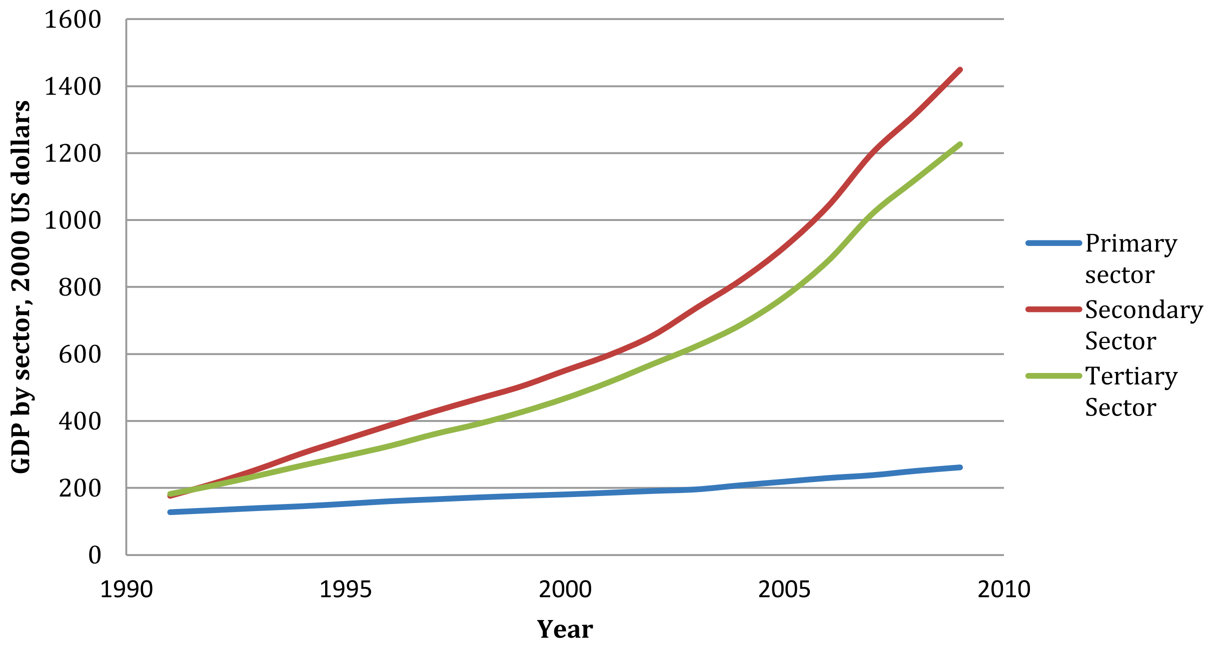

Figure 3: Sectoral Components of China's Growth – GDP by sector 1991 - 2009 (source: IMF 2010) [16]

By sustaining an astonishing growth rate of around 10% per annum over the past decade, China has more than doubled its GDP and has now overtaken Japan as the world's second largest economy[17]. The IEA have announced that, according to their preliminary data, China has overtaken the US to become the world's largest energy user[18]. But China remains a developing country and, as the Copenhagen Accord recognised, for such countries, "social and economic development and poverty eradication are the first and overriding priorities"[19].

China's rapid economic development has generated "the most rapid decline in absolute poverty ever witnessed" according to the UNDP[20], and China has already achieved the goal of halving the number of people in extreme poverty by 2015 set by the UN as one of its Millennium development targets. China's GDP is about $7,000 per head at Purchasing Power Parity, which is still very low by OECD standards[21]. But there is a wide variation between provinces. Guangdong, a Province of nearly 100 million people, has GDP per head in excess of $10,000[22].

There are major centres of population away from the East coast where GDP per head is much less. Remaining rural poverty is now concentrated in remote regions, but China faces a new challenge in the form of urban poverty related to migration to the cities.

Energy Supply and Import Dependency

One consequence of China's rapid economic growth has been that it has moved from being largely self-sufficient in energy as recently as 1980, to importing about half its oil needs today. This oil import dependency is set to increase further with the rapid growth of the private car market. China alone could account for more than half the increase in global oil demand in the coming decades with the risk of driving oil prices to new peaks[23]. Security of oil supply is, accordingly, a major policy concern for China.

China is currently only 5% dependent on imports for its gas supply, but this is expected to increase sharply in future years[24].

Coal is the most accessible, secure, and lowest cost source of energy in China. Coal fuels more than 80% of power generation and contributes 65% of total energy supply[25]. China is largely self sufficient in coal, and has proven reserves equivalent to 45 years of production at current rates. Nevertheless the 3% of coal supply that China currently imports already constitutes about one fifth of global seaborne coal trade[26].This high dependency on coal, which is expected to continue for some decades, represents a problem from the point of view of climate change, because coal is the most CO_2 intensive of major fuels. According to a report by China's Energy Research Institute, however, the growth of coal demand is expected to slow, reaching a peak at perhaps 3.4 billion tonnes per annum in 2020[27].

Steel and Cement

China is the world's largest producer of coal, cement, iron and steel, and aluminium; in fact nearly half of the world's cement is made in China. Chinese Steel production is relatively carbon intensive by international standards, partly because a relatively small share of production (about 10%) is derived from recycled material. The carbon intensity of Chinese cement has been declining fairly sharply in recent years and is around the global average[28]. Of course much of industrial effort is on the manufacture of exported goods consumed in developed countries.

Energy Efficiency and Environmental Policies

China is clearly aware of the need to improve its energy efficiency and reduce its reliance on fossil fuels, which brings not only potential economic benefits such as security of energy supply and a reduced oil import bill, but local and global environmental benefits as well. The government is already pursuing aggressive energy efficiency policies, including the closure of many of the least efficient industrial plants and power stations. However, these are not always easy to achieve in a rapidly growing developing economy with powerful provincial governments. The 11th Five Year Plan (2006-2010) set an ambitious target to reduce energy intensity (energy consumption per unit of GDP) by 20% on 2005 levels. In the event a 19.1% reduction was achieved. But radical measures, including power cuts and plant closures, were reported during 2010 as a part of China's efforts to meet this target.

In announcing the new 12th Five Year Plan (2011-2015) the Chinese Government has clearly signalled a focus on sustainability and the environment. Prime Minister Wen Jibao said, “We must not any longer sacrifice the environment for the sake of rapid growth and reckless rollouts, as that would result in unsustainable growth featuring industrial overcapacity and intensive resource consumption”[29]. The Plan contains an overall economic growth projection, of 7% p.a., significantly lower than actual growth in recent years. It also contains a number of energy and emissions targets including an energy intensity reduction of 16% and carbon intensity reduction of 17%, on 2010 levels. At the same time, the Plan identifies seven strategic emerging industries (SEIs) as being critical to China’s economic development, including electric vehicles, energy efficient products and renewable energy. Investment in these industries will total approximately $1.5 trillion over the course of the Plan. The Plan also includes major increases in non-fossil energy, including a four-fold growth in nuclear power to 40 GW, 63 GW of new hydroelectric capacity, 48 GW of new wind capacity and 5 GW of solar capacity by 2015[30].

A 17% reduction in China’s carbon intensity during the 12th Five Year Plan will still leave a further reduction of around 20% to be achieved during the 13th Five year Plan (2016 - 2020) to reach the lower end of China’s target range (40%). This is broadly consistent with the conclusion of this study that the target is achievable but that there is more work to do.

Although this is not included in the 12th Five Year Plan, the Chinese Government is reported to be considering adopting cap and trade mechanisms in selected regions, and there has even been some exposure of the possibility of setting an absolute national cap on energy consumption[31]. Six municipalities and provinces including Beijing, Chongqing, Shanghai, Tianjin, Hubei and Guangdong are expected to start a carbon trading pilot scheme during 12th Five Year Plan. These are encouraging indications of the possible direction of future policy.

In the following section we assess the potential for CO_2 emissions savings in the four major energy-use sectors of the Chinese economy; electricity generation, industry, buildings (including appliances) and transport.

CO_2 Savings Potential by Sector

Electricity Generation

Our baseline scenario for the Chinese power sector in 2020 is taken from the IEA Reference scenario[32]. China has 700 GW (billions of Watts) of generating capacity, mostly coal fired, and this is expected to approximately double by 2020[33]. By comparison, the UK has a total capacity of 75 GW and the US has 1,000 GW. Generation of electric power is, by far, the main source of energy related CO_2 emissions in China and, although reductions in demand are also important, our study shows that the introduction of more efficient and lower carbon generation technology offers the greatest potential for CO_2 reductions in the period to 2020. Table 1 outlines the technology options available for electricity generation, their carbon saving potential, costs, and barriers.

Improving the efficiency of the fleet of coal power stations

China is expected to have more than 1,000 GW of coal fired power stations by 2020. The most advanced coal power stations, known as supercritical (SC) and ultra-supercritical (USC) operate at higher temperatures and pressures and have significantly greater efficiency than, for instance, existing sub-critical power stations in the UK and the US[34]. China can manufacture SC plant and about 60% of USC components, at costs considerably below those in developed countries[35]. China has a huge programme of deploying SC and USC plant, which now make up 50% of new coal installations[36], and the policy is to require these technologies for all plants over 600 MW[37]. Circulating Fluidized Bed (CFB) technology may also have some potential. China has a major programme of closing its older, smaller, and less efficient power plants. China has set an ambitious target which would require 50% of its total fleet to be SC or USC by 2020.

- *We assume that the penetration of SC/USC will reach 40% of total capacity by 2020 in our Green Scenario and 50% in our Stretch Scenario. Our Stretch Scenario would bring the efficiency of the coal fired fleet into line with the targets of China's National Development and reform Commission (NDRC). The Green and Stretch Scenarios would save 126 and 250 million tonnes of CO_2 per annum, respectively, compared to the base case, at Low cost.*
- *We have also assumed a continuing programme of improving the efficiency of existing sub-critical stations that continue in service, saving 72 - 151 MT CO_2* per annum *through better operation, maintenance, and retrofit, also at Low cost.*

Integrated Gasification Combined Cycle (IGCC)

Integrated Gasification Combined Cycle (IGCC) is an advanced power technology in which coal is gasified before combustion. It offers the potential for very high levels of efficiency and may be exceptionally well suited for CCS. China has several demonstration plants under construction and at least 7 more are planned[38]. With CCS, IGCC may represent a pathway towards very low carbon fossil fired power stations of the future.

- *Depending on plant performance, we assume that IGCC could contribute 6 - 12 MT of CO_2 savings by 2020 at High cost.*

Technology/Option	Mitigation (Mt CO2e)		Marginal Cost of Abatement	Barriers	Domestic Policy Levers
	2020 Green Abatement	2020 Stretch Abatement			
Efficiency Gains from Subcritical Coal Power Plants	72	151	Very Low	Power shortages; Economic constraints	Push cheaper technologies in using RD&D; Internalise environmental cost
Supercritical and Ultra Supercritical Coal Power Plants	126	250	Low	Retirement rate of incumbent power plant	Push cheaper technologies in using RD&D; Eliminate small power plants with very low efficiency
IGCC	6	12	High	Lack of domestic core technology; Sophisticated process; Lack of skilled operators	Investment in R&D; Demonstration of the process; Capacity building both in management and skilled people
Natural Gas	138	182	High	Insufficient gas supply; Natural gas development is prioritized for households and commercial users; particularly in urban areas; Cost disadvantage compared to coal-fuelled electricity	International collaboration on unconventional gas exploration; Investment in LNG stations and natural gas pipe lines; Mature pricing mechanism for natural gas
Hydro – Large scale	108	108	High	Mismatch between resource-rich and energy intensive areas; Environmental and security concerns; Resettlement of residents	Careful planning before construction to address environmental and social issues
Hydro – Small scale	36	36	Medium	Relatively high Cost compared to conventional biomass/coal; Difficulty in combining to grid	Tax incentives, soft loans; Rural Electrification Programmes; Joint ventures and CDM
Onshore Wind	53	152	Medium	Insufficient funding; Higher cost than conventional thermal; Insufficient electricity grid; Low capacity factor	Fossil fuel tax; Reformed concession model; Accelerate electricity grid upgrading; Increase capacity factor by referencing international experiences.

Technology/Option	Mitigation (Mt CO_2e)		Marginal Cost of Abatement	Barriers	Domestic Policy Levers
	2020 Green Abatement	2020 Stretch Abatement			
Offshore Wind	6	15	High	High cost; Technology immaturity; Lack of systematic study on the wind condition and risk management	Demonstration; Further R&D to bring down the cost
Solar PV	1	15	Very high	Lag behind in domestic development of thin-film technology; High cost due to imported raw material, equipment etc.; Lack of on-grid pricing mechanism; Insufficient electricity grid	Enhance R&D; Increase access to international funding; Provide financial incentives through feed-in tariffs/RPS; Accelerate electricity grid upgrading
Solar CSP	0	4	Very high	Technology immaturity; Lack of supporting policy; water requirements	Enhance R&D; International cooperation to break through technology bottlenecks
Biomass – Co-firing	102	142	Very low	Lack of efficient gathering and storage channels for raw material; Transportation difficulties due to large quantity	Supporting policies to encourage the utilisation of biomass; Promote public environmental awareness
Biomass – Biogas	13	17	Low	Lack of efficient gathering and storage channels for raw material; High cost compared to coal-fuelled electricity	Enhance R&D and localize key components to reduce the cost
Biomass – Waste incineration	12	16	High	High cost; Public rejection	Development of more reliable technology
Nuclear Fission	153	306	Medium	Insufficient uranium supply; Backward technology - domestically-mastered Gen II Vs more advanced Gen III or Gen IV designs; Insufficient spent fuel management capacity	Explore international market to ensure uranium supply; Enhance capacity building to deal with nuclear waste; Investment in core technology R&D

Table 1: Technology options potential, cost and barriers for Chinese power

Carbon Capture and Storage

While large CO_2 savings are available in China from improvements in the efficiency of the coal fleet, the only technology that can largely eliminate CO_2 emissions to the atmosphere from coal power stations is Carbon Capture and Storage (CCS), in which the CO_2 is separated from the power station exhaust and stored in geological strata underground (See Box 1). This technology will be crucial, in the longer term, to enable China to develop a low carbon economy while maintaining a significant dependence on coal. However it is not expected to be deployed soon enough to deliver significant carbon savings by 2020.

Box 1: Carbon Capture and Storage (CCS)

CCS has only become an important issue in China very recently, and it remains at the R&D stage. It is not anticipated to play a role in achieving 2020 carbon intensity reduction targets. The relatively high costs and efficiency penalties of CCS hinder its further development, and large-scale deployment is not expected soon unless financial aid from international means can be secured[39]. Although general policies are in place to support the research of CCS technologies, until now, there is no elaborated policy to promote the deployment of CCS.

A number of demonstration projects involving international cooperation are under way. Projects currently committed include the National Development and Reform Commission/Asian Development Bank GreenGen IGCC project in Tianjin and Shenhua's Coal to Liquids project in Ordos, Inner Mongolia. The EU-China NZEC (Near Zero Emissions Coal) project, in which the UK is very active, aims to complete a demonstration CCS plant in China by 2015. Implementation of power and non-power sector CCS has been examined in the EU's GeoCapacity project, with special focus on capacity-building in China[40]. China is also a member of the CSLF (Carbon Sequestration Leadership Forum) and the APP (Asia-Pacific Partnership) on Clean Development and Climate. In November 2009, China and the US launched a joint *Roadmap for US-China Collaboration on Carbon Capture and Sequestration*.

Biomass co-firing

Introducing a proportion of biomass into the fuel of coal stations is an attractive option in China, as is, to a somewhat lesser extent, the burning of gas derived from biomass. The main materials are agricultural wastes, especially bagasse derived from sugar cane, and residues from forest management and wood products manufacturing. By the end of 2007 China had installed capacity of 2.2 GW of biomass generating capacity, of which 1.7 GW was bagasse. This could reach 5 GW by 2010. The main challenge in increasing this is finding raw materials of the right quality and developing cost-effective systems for gathering and storing them[41].

- *We assume 30 GW of new capacity by 2020 which, depending on the capacity factor could yield savings of 115 to 159 MT CO_2, at Low cost.*

Nuclear Power

China has a large nuclear power programme and very ambitious plans for its expansion. China has its own nuclear power technology equivalent to currently operating plant in developed countries, but about a third of its new plants employ more advanced "Generation III" technology imported from Westinghouse[42]. The 12th Five year Plan projects 40 GW of nuclear capacity by 2015 and the previous target of achieving 40 GW by 2020 may well be upgraded to 70 or even 80 GW[43]. Despite the safety review following the Japanese nuclear crisis, the Chinese government has pledged to adhere to the development plan.

We have assumed a possible capacity range of 60 - 80 GW by 2020, which would lead to CO_2 savings of 153 – 306 MT per annum at Medium cost, making nuclear power the single option with the greatest savings potential. Such a programme would almost certainly require a substantial increase in uranium imports. Capacity to handle spent fuel is also an area of concern.

Wind

China has very large wind potential, estimated at 300 GW onshore and 700 GW offshore[44]. Since the Renewable Energy Law of 2005, capacity has grown rapidly, to 25 GW at the end of 2010[45]. The 12th Five Year Plan proposes an additional 48 GW by 2015, a big increase on previous expectations[46]. The main barriers for large-scale wind deployment are the high up-front cost, lack of grid connection in remote, windy, areas and the need for system reinforcement to cope with intermittency.

- *We assume total capacity of 100 – 150 GW in 2020, with availability of 24% onshore and 46% offshore. This would yield CO_2 savings of 53 – 152 MT onshore, at Medium cost, and 6 – 15 MT offshore at High cost.*

Hydro

China has 145 GW of hydro capacity, including the 22.5 GW Three Gorges project, accounting for nearly 15% of total capacity. There is estimated to be 694 GW of hydropower potential. Government plans envisage that capacity will increase to 300 GW in 2020, including 75 GW of small hydro, mainly used to provide electricity for remote rural areas[47]. There is a real possibility that this figure, and hence the carbon savings, could be exceeded. As in other parts of the world, the main barriers to hydro-power are environmental and social.

- *The savings potentials are estimated at 108 MT CO_2 for large hydro, at High Cost, and 36 MT for small hydro, at Medium cost.*

Natural Gas

Gas power stations emit less than half the CO_2 per unit of power than coal stations. Gas contributes only about 2% of Chinese electricity generation, and the government has given priority to the use of gas in urban households and vehicles, where it can contribute most to urban air quality improvement. China is expected to depend increasingly on gas imports from relatively high cost sources such as Liquefied Natural Gas (LNG) shipments and very long distance pipeline transport from Turkmenistan or Russia.

- *Nevertheless the share of gas in power generation may increase to around 8% by 2020, leading to CO_2 savings of 138 – 182 MT at High cost.*

The success of unconventional gas production techniques in the US, including shale gas, coal-bed methane (CBM) and coal-mine methane (CMM), has opened up the possibility of increasing gas production elsewhere in the world. This includes China, although the potential is still very uncertain. There is therefore some possibility that switching from coal to gas might play a much bigger role in moderating Chinese CO_2 emissions in the medium term, as it has done in Europe in recent decades, though probably not until after 2020.

Photovoltaic (PV) and solar thermal

China has been the world's leading producer of solar cells since 2008 and could have around 33% of global production capacity by 2012[48]. However this is mainly for export and domestic deployment is limited by the relatively high cost. There was 105 Megawatts (million Watts) of installed PV capacity in 2007[49]. The NDRC's target is for 1.6 GW of PV and 0.2 GW of Concentrating Solar Power (CSP) by 2020, but this appears relatively conservative and a total capacity of up to 10 GW or even 20 GW has been suggested as possible. The main barrier to increased solar power is cost, and this may be addressed by a planned pricing mechanism for grid supplied solar, due by the end of 2010.

- *The estimated CO_2 savings are in the range 1 – 19 MT CO_2 at High cost.*

The longer term

In the longer term all major nations will need to reduce their emissions from power stations to very low levels in order to meet global climate change objectives. For China, this means either a comprehensive adoption of CCS for coal and gas plant or a wholesale switch to nuclear power and renewables.

Industry

In 2007, Chinese industry accounted for nearly 70% of electricity demand and nearly 60% of China's energy related CO_2 emissions, when one includes indirect emissions attributable to industrial electricity consumption[50]. An exceptionally large share of the Chinese economy is devoted to manufacturing and infrastructure. China is the world's largest producer of iron and steel and manufactures a remarkable 48% of the world's cement.

In our base case, before taking account of the carbon saving options discussed below, CO_2 emissions from industry are expected to grow at 3.3% per annum, significantly less than 7.5% growth of the economy as a whole, as the structure of the economy shifts towards higher value manufacturing and services[51].

While China has some of the most efficient industrial plant in the world, the iron and steel and the cement industries still include significant shares of older inefficient plant. For instance the latest and most efficient steel plants in China require 17 GJ (gigajoules) of energy per tonne of steel, whereas the average is much higher, at 23 GJ, because most of the production is in smaller inefficient plants[52]. Similarly, in 2005, 47% of China's cement was produced in inefficient vertical kilns, a technology almost exclusive to China which requires 5 GJ per tonne of cement clinker, compared to 3 GJ for best practice plant[53]. Both iron and cement production are almost exclusively coal fired, with the exception of the electric power (also likely to be coal derived) used in the production of steel from scrap.

A comprehensive scheme of monitoring, reporting and auditing is needed to identify the areas of industry with the highest savings potential. Targets for individual companies could then be determined by benchmarking with best practice rather than by setting top-down targets[54]. International collaboration with similar schemes employed within the EU ETS or the UK CRC programmes could accelerate implementation.

A concentration of the industry sector through mergers and acquisitions would ease the problem of smaller and inefficient enterprises, but the targets that were set for 2010 are now unlikely to be reached. For example, 50% of steel production was intended to come from the ten largest companies by 2010, but, as of 2007, their share had remained largely unchanged at 33%. In the 12th Five Year Plan the target is 60%[55]. More competitive electricity prices would facilitate restructuring. However Provinces have been allowed to adjust electricity prices according to the level of energy efficiency of individual companies and electricity prices generally remain at a low level, as power generation firms run at a loss and fuel is subsidised.

Government policies for improving energy efficiency in industry

Since 2004 China has introduced a comprehensive program of policies aimed at increasing the energy efficiency of the economy by 20% between 2006 and 2010[56]. These policies include:

- The Ten Key Projects, which targets the retrofitting of process kilns, motor efficiency improvements, and the optimisation of energy use.
- The Top-1000 enterprises program, which comprises a retrofit program for the 1000 most energy consuming enterprises across nine sectors which combined account for 50% of energy demand[57].
- Targets for the closure of small, inefficient plants; and
- Electricity pricing reform.

It is difficult to assess the current progress of these measures because of incomplete data, but the Chinese Government have reported that the economy came very close to meeting the overall target, with an improvement in the energy efficiency of the economy as a whole of 19.1% over the period[58].

Iron & Steel, Cement, Chemicals - Efficient New Plants

In the base case it is assumed that only the largest 10 companies in each sector, accounting for 20% of cement production and 33% of steel and chemicals, build new plant with the most energy efficient available technology.

- *More widespread diffusion of advanced plant designs has the potential to save up to 120 – 192 $MtCO_2$ in 2020 at Negative cost.*

Steel and Cement – Plant Closures

200 million tonnes of relatively inefficient iron and cement production capacity has already been shut-down between 2006 and 2008[59]. Our base case assumes that by 2020 a total of 350 million tonnes will have closed, or about one fifth of the total 2005 production capacity, roughly in line with the planned rate of closure in the 11th Five Year Plan (2006 – 2010). It will be difficult to close more than that, bearing in mind the pressure of demand and the local social and economic impact of closures.

- *Closing an additional 100 million tonnes of iron and steel and 250 million tonnes of cement capacity, phasing out vertical kilns, would lead to a saving of* 43 $MtCO_2$ *at Medium cost.*

Technology/ Option	Mitigation (Mt CO_2e)		Marginal Cost of Abatement	Barriers	Domestic Policy Levers
	2020 Green Abatement	2020 Stretch Abatement			
Iron & Steel, Cement, Chemicals - new best practice plants	120	192	Negative	Fragmented industry. Limited availability of best practice technology for smaller firms.	Minimum technology requirements for new plants. Higher fuel and electricity prices. Promote mergers and acquisitions.
Iron & Steel, Cement - additional small plants closure	0	43	Medium	Local authorities not willing to close plants, social coherence and employment are contradictory to small plants closure. Demand increase could lead to reopening of closed plants.	Increase of electricity prices. Stricter binding of electricity and fuel prices to plant efficiency.
Cement: clinker substitution	39	39	Negative	Cement quality. Limited supply of substitution materials.	Financial incentives (lower duties, taxes).
Iron & Steel: shift to gas-DRI	0	59	High	Limited gas supply. Low priority in central government's natural gas prioritization plans.	N.A.
Cement - use of alternative fuels	26	56	Medium	High capital cost for plant modification. Technical challenges in adapting processes for alternative fuels. Low availability of sorted waste.	Waste management program, waste sorting.
All Industry - Continuation and expansion of Top 1000 retrofit program	36	82	Low	Targets set top-down, not according to benchmarks. Much larger number of companies involved than included in top 1000 program.	Benchmarking against best practice in order to set targets. Monitoring and auditing system to be set up, best-practice guidelines to be created.
Other industry - Industrial motor systems	26	38	N.A.	Top-level estimate. Applies to a large number of companies (excluding top 1000).	Mandatory standards.

Table 2: Technology options and barriers for Chinese Industry

Cement - clinker substitution and use of alternative fuels

The blending of substitutes with cement clinker is an important energy saving option. China is well supplied with suitable materials, such as fly ash and blast furnace slag, and has already reduced its ratio of cement to clinker from 83% in 1994 to 72% in 2005.

- *There is further potential to reduce the ratio to 68%, and this would achieve additional emission savings of 39 MtCO_2, at Negative cost[60].*

Emissions from cement production can also be reduced by introducing alternative, lower carbon fuels. Most of the savings come from biomass, which has a higher carbon reduction factor than waste[61].

- *Using 11% biomass and 22% waste in new plants would save 26 MtCO_2 of emissions and adopting the same ratios in all plants, would save 56 MtCO_2 at Medium cost.*

Iron & Steel – Direct Reduction

The use of gas based direct reduced iron yields significant emissions savings compared to blast furnace/basic oxygen furnace technology. However, Chinese gas supplies are limited, and the government has given priority to using them for purposes that improve urban air quality, especially in buildings and for transport. As a result Gas-DRI technology has not been widely employed. Gas based direct reduced iron yields could reduce CO_2 emissions per ton of steel from 1.7 tonnes for blast furnace/basic oxygen furnace to 1.05 tonnes[62]. However gas supply remains a major constraint.

- *If 100 Mt of steel would be produced using the gas-fired DRI process, 59 MtCO_2 could be saved at High cost.*

Continuation and expansion of Top 1000 retrofit program

It has been announced that the targets of China's Top-1000 enterprises program have already been reached by the end of 2008[63]. Significant barriers remain for the implementation and administration of effective benchmarking and measurement schemes, especially for very large numbers of enterprises. Nevertheless, there is potential for these targets to be strengthened and the 12th Five year Plan includes proposals to increase the coverage to 10,000 enterprises.

- *In the sectors not considered above, this could mitigate a further 36 MtCO_2. If an even more comprehensive approach is taken, covering a much greater number of enterprises, this potential could increase to 82 MtCO_2. All these savings* *would be a Low cost.*

Other Industry – more efficient motor systems

Motor systems currently account for around 60% of all electricity usage in Chinese industry[64].

- *Overall efficiency improvements from 10 - 15% should be possible, equivalent to savings of 38 MtCO_2, at Low cost, at the high end of the range. Additional savings through CHP have been identified and are included in the district heating section of the buildings sector below.*

Longer Term

In the longer term the industrial sector will need to achieve much deeper reductions in CO_2 emissions by fuel switching to low carbon electric power, continued efficiency gains and, where alternatives to fossil fuels are not available, CCS. There are a number of projects for demonstrating CCS technology in China (see Box 1) but it is not expected to achieve significant commercial deployment until well beyond 2020.

Buildings

Emissions from the residential and commercial buildings and appliances are expected to more than double from 1.1 GtCO_2 in 2005[65]. This will be driven mainly by the heating needs of rapidly expanding Chinese cities, and a growing number of households with an increasing variety of appliances per household[66]. We project that 20 billion square metres of floorspace will be built between 2010 and 2020 and that electricity demand for appliances will roughly double in this period.

The theoretical abatement potential in the buildings sector to 2020 is more than a gigatonne of CO_2, and the cost is negative. The 11th Five Year Plan contained initiatives concentrated on building envelopes, lighting and heating, and ventilation. However, the successful administration of energy efficiency standards across China's huge buildings stock is a big challenge and only a small share of that potential is likely to be realised. Abatement potential in the range of 200 – 400 MtCO_2, to 2020, is more realistic. Failure to adopt these measures in the short-term will have the effect of 'locking-in' a less efficient building stock over its whole lifetime. A study by McKinsey in 2009 suggests that a 5 year delay in building sector reform in the period 2010 - 2020 reduces potential for carbon savings by approximately 400 MtCO_2 in 2030[67].

In order to maximise the abatement potential, especially in the period after 2020, a rapid implementation of stricter building codes is necessary. Moreover, monitoring and inspection during and after the construction phase must be improved. International collaboration on a local level, such as the "Sustainable City Initiative", run by UK Trade & Investment, could accelerate the improvement of such monitoring agencies and the setup of local research institutions of building energy efficiency[68]. In district heating and CHP, international collaboration could speed up the development and upgrade of the heating networks towards BPT.

Building codes

The Ministry of Housing, Urban and Rural Development (MOHURD) is currently focusing its efforts on the northeast of the country, where a number of provinces have implemented more stringent building codes. Research institutes have been established which are now extending their focus to the transitional and urban regions further south, where heating and cooling needs can be reduced by more efficient insulation. Compliance in urban areas is close to 100% in the design phase, but enforcement during construction has been less effective, especially for residential buildings and in smaller cities[69,70].

- *Strengthening of residential and commercial building codes in the urban north, to halve the space heating requirements, to a level similar to northern European standards, could save at least 92 to 124 $MtCO_2$ in 2020 at negative cost[71].*

A comprehensive labelling scheme for appliances has been established including minimum energy performance standards (MEPS), and recent testing data indicate high compliance rates[72].

- *However, stricter standards, orientated at the lowest life cycle cost (LCC) for the end-user, could lead to further savings of 71 – 96 $MtCO_2$ at Negative cost with the added benefit of reducing the peak electricity demand[73]. Since China exports around 50% of appliances produced, enhanced domestic standards could induce a spill-over effect to other countries[74].*

For lighting, an accelerated replacement of incandescent light bulbs by CFL and LEDs could lead to 32 $MtCO_2$ savings. At the high end of our range we assume a complete phase-out of incandescent lamps, saving 45 $MtCO_2$. These savings are at negative cost.

Technology/ Option	Mitigation (Mt CO_2e)		Marginal Cost of Abatement	Barriers	Domestic Policy Levers
	2020 Green Abatement	2020 Stretch Abatement			
Building Codes; Residential in urban north	39	46	Negative	Inadequate enforcement of building codes in the construction phase, particularly in residential projects. National building codes do not represent variations in climate. Limited green-building capacity. Principal agent problem.	Adaptation of existing strict local standards on a wider scale, up-scaling of local authorities that control compliance in construction phase
Building Codes; Residential in transitional and south	14	14	Negative	Inadequate enforcement of building codes in the construction phase, particularly in residential projects. National building codes do not represent variations in climate. Limited green-building capacity. Principal agent problem.	Adaptation of existing strict local standards on a wider scale, up-scaling of local authorities that control compliance in construction phase
Building Codes; Commercial	53	78	Negative	Inadequate enforcement of building codes in the construction phase, particularly in residential projects. National building codes do not represent variations in climate. Limited green-building capacity. Principal agent problem.	Adaptation of existing strict local standards on a wider scale, up-scaling of local authorities that control compliance in construction phase
Stricter Appliance Standards	71	96	Negative	Higher up-front costs of appliances for end-user. Reluctance from industry. Dispersed appliance industry, products difficult to control	Expansion of subsidies for appliances, limitation of subsidy to best efficiency category.
Lighting, residential	32	45	Negative	Reluctant end-users, limited awareness of savings.	Phase-out of incandescent lamps, subsidies for CFL.
Retrofit Package; Commercial	0	56	Low	Retrofitting process just in pilot phase. Limited awareness/information.	Pilot projects throughout all provinces, up-scaling of energy service companies, energy performance contracting, pioneer role of public sector (e.g. through procurement)
Retrofit Package; Residential	0	19	Low	Reluctant end-users due to high personal discount factors when considering investment costs. Principal agent problem.	Pilot projects. Low-interest credit programs and subsidies for energy efficient renovation.
District Heating	39	69	Low to Medium	Lack of fiscal/tax incentives for CHP/DH. No targeted policy for small scale CHP. Insufficient monitoring and enforcement of newly built CHP projects. Low efficiency of distribution network limits commercial viability.	Acceleration of heat metering reform (pricing). Incentivise CHP/DH. Encourage ESCOs to enter CHP/DH market

Table 3: Technology options and Chinese Buildings

Buildings Retrofit

The Government has put forward a proposal for the retrofit of existing buildings, but has not so far fully succeeded in implementing it. Finance is a challenge because subsidies are limited and banks do not have experience in energy efficiency technology. An economic retrofit package is considered feasible for 20% of the buildings in the urban north. Barriers should be lower for commercial buildings, due to the smaller number of larger buildings, the existing retrofit pilot projects[75] the possibility of energy performance contracting, and the possible involvement of energy service companies[76]. Retrofit is inherently more difficult than raising standards for new buildings.

- *Savings from retrofit are only considered in the Stretch case, where they account for 75 $MtCO_2$ at Low cost.*

District Heating

District heating is widespread in the urban north, with around 70% of the floorspace covered. However, the efficiency of heat distribution networks is low, ranging between 70 - 75%, compared to 90 - 92% for best practice[77]. Approximately half of district heating networks incorporate combined heat and power (CHP) generation, whilst dedicated heat in the remainder is typically provided by coal-fired boilers operating at low efficiencies (60 - 65%) compared to best practice (80 - 85%).

- *Upgrading dedicated heating boilers to CHP and an increase of the total district heating coverage could save between 39 - 69 2 $MtCO_2$ at Low to Medium cost.*

Longer Term

In the longer term a continuing enhancement of institutional capabilities to draft, enforce, and monitor ambitious building codes, as well as close coordination between regional and central governments, will need to continue, beyond 2020 to achieve very high levels of building efficiency. Low carbon technology for heating, largely through the mass deployment of heat pumps, will play an important role. Strict labelling, testing and monitoring of appliances will be needed to achieve further large efficiency gains.

Transport

Road traffic already accounts for more than 60% of the energy used for transport in China, and it is expected to be the fastest growing transport sector. China is already the largest car market in the world, even though there are only 59 vehicles per 1000 people, well below the world average of 120[78]. The Chinese government is making great efforts, through the construction of railways, to moderate the shift from public transportation to private cars. Nevertheless, with increasing household incomes, urbanisation rates and government support[79], road transport is projected to account for 80% of the overall growth in emissions from transport to 2020, by which time there are expected to be 168 million vehicles on the roads.

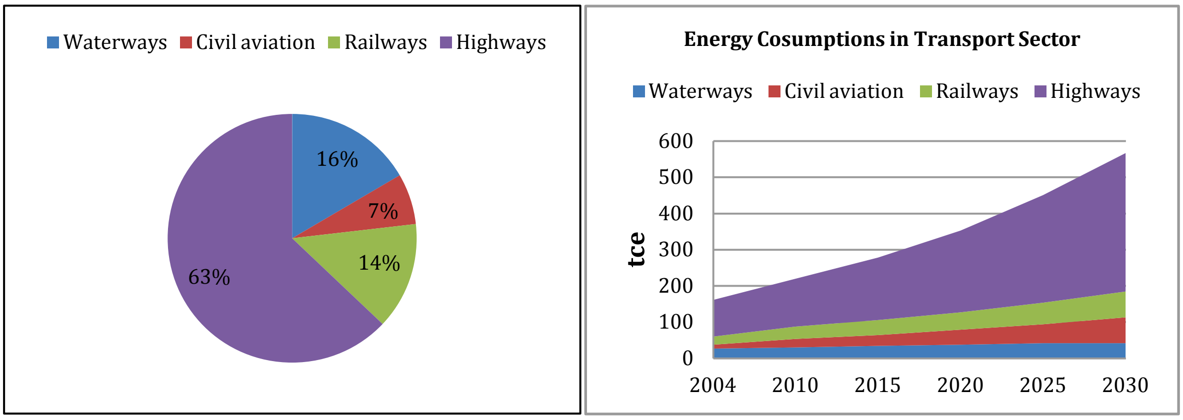

Figure 1: Energy Consumption in the transport sector (left, share in 2004 – right, projection to 2020)[80].

Although in 2005 the Chinese transport sector accounted for small share (7%) of the total CO_2 emissions, our analysis suggests they will be three times greater by 2020, reaching more than a Gigatonne in our baseline.

Advanced Vehicles

Hybrid electric vehicles (HEV), plug-in-electric-vehicles (PIEV), and electric vehicles (EV) are available in China but sales have so far been modest, due to high prices. China's electric vehicle (EV) technology is at an earlier stage, but is relatively advanced by international standards, based on China's strength in battery technology. EVs are seen by the Chinese government as an opportunity to catch up to or even "leapfrog" developed countries[81]. The government has announced new subsidies in its "Automobile Industry Revival Plan"[82] and demonstration is taking place in a number of Chinese cities, while Chinese companies are starting to commercialise electric vehicles[83]. Barriers limiting the uptake of advanced vehicles include high prices, and insufficient supporting policies for the development and deployment of hybrids. Further to this, technical barriers remain in the lack of recharging stations and immaturity of battery technology for EVs.

- *We estimate that an increased share of advanced vehicles in new light vehicle sales from 15% to 40% could save between 16 – 32 $MtCO_2$ at High cost.*

Technology/ Option	Mitigation (Mt CO_2e)		Marginal Cost of Abatement	Barriers	Domestic Policy Levers
	2020 Green Abatement	2020 Stretch Abatement			
HEV/PLEV/EV/ FCV	16	32	High	High upfront cost. Lack of public perception and consumer acceptance. Lack of qualified domestic manufacturers. Insufficient financial incentives. Lack of recharging stations and Immature battery technology for EVs	Improving Chinese technological capabilities and intellectual property, Enhancing R&D investment, Government standardization of parts and components, Stimulating consumer demand through cost incentives.
Public Transportation	36	65	Medium	Relatively high cost and long lead times for urban rail, constrained to large cities; Funding for BRT systems monopsonistic; Road network constraints	Secure funding from more diversified sources, including private sectors. Integrated city design.
Vehicle Fuel Economy Improvements	30	35	Negative to Low	Vehicle fleet inertia; Rebound effect (20 – 40%); Typical low price elasticity of transport demand	Fiscal incentives for replacing older inefficient models. Enhancing domestic R&D capability and institutional infrastructure.
CNG/LNG/LPG	12	23	High	Fuel availability; Low number of gas refuelling stations.	Secure natural gas supply by increasing domestic production capability and exploration of international import market. Increase number of refuelling stations alongside city planning (*i.e.* Integrated whole-system planning).
Bioethanol	19	37	High	Feedstock availability Technology immaturity of 2nd generation biofuels.	Investment in R&D for second generation biofuel crops (*i.e.* Cellulosic biofuel).
Biodiesel	6	12	High	Price disadvantage compared to conventional diesel. Lack of unified, compulsory quality standards for biodiesel. Lack of stable feedstock supply. High regulatory barriers protecting incumbent national oil companies from international competition.	R&D to lower costs and scale up technology. Comprehensive legislation regulating the production and usage of biodiesel.

Table 4: Technology options for Chinese transport

Public Transport

The Chinese government has given priority to developing urban public transport networks. Bus Rapid Transport (BRT) systems are being increasingly recognized as highly cost-effective and have major potential in many Chinese cities in the next decade[84]. According to construction layouts of 15 Chinese cities, including Beijing and Shanghai, urban rail transit routes will expand to 1,700 km by 2015[85]. However, this option has high cost barriers and requires longer lead times.

- *Our analysis shows that strengthening and expanding public transport networks with BRT and urban rail could save 36 – 65 MtCO_2 at Medium cost.*

Fuel Economy Improvements

China has been progressively strengthening Fuel Economy Standards since 2004. The current fleet average standard of 7.9 kilometres per litre is the third most stringent in the world, after Japan and the EU[86]. In 2008 China adopted a modern fuel efficiency labelling system. China also introduced tax incentives to promote small-engine vehicles and efficiency standards for light duty trucks[87]. Meanwhile, the next phase of increasing Fuel Economy Standards is expected to be implemented from 2015 with an additional 18% increase in vehicle efficiency[88].

- *In this study, we considered further improvement in the fuel efficiency of the Chinese light-duty vehicle fleet to Japanese standards together with a range of 30% to 40% improvement in heavy duty vehicles. All these factors together could save 30 – 36 MtCO_2 at Negative to Low cost.*

Alternative Fuels - CNG/LNG/LPG, Bioethanol and Biodiesel

Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) powered vehicles are relatively mature technically[89] and CNG is given priority for the use of natural gas[90]. The major obstacle to the diffusion of these vehicles is not technical but is the availability of gas[91]. Besides, limited gas-refuelling stations also hinder the large-scale deployment of the gas vehicles[92].

- *Our analysis shows 12 - 23 MtCO_2 could be saved, at High cost, by increasing the diffusion of CNG/Liquefied Natural Gas (LNG)/LPG-powered vehicles to between 19.6 million and 40 million tons.*

Under recent government policies 14 provinces have been required to achieve a 10% blending of ethanol in gasoline by 2005[93]. NDRC has projected 3 million tonnes of bioethanol usage by 2010 and 10 million tonnes by 2020[94]. The barriers for such high levels of consumption of bioethanol are high, and concern feedstock availability. Production of bioethanol from food sources has not been allowed since 2007[95] and the technology for second generation biofuels, based on non-food materials, is still immature.

- *We estimate that 19 $MtCO_2$ can be saved in 2020 by reaching national targets, while doubling their stringency could save 37 $MtCO_2$ at High cost.*

Biodiesel does not enjoy similar government support to ethanol and its growth rate is heavily constrained by a low level of fiscal incentives, high production costs, and a lack of a stable supply of feedstock[96].

- *Reaching a projected 2 million tons of transport biodiesel production by 2020 could save 6 $MtCO_2$ at High cost[97]. While this is in line with the projections in the NDRC's renewable plan[98], it implies an ambitious 25% annual rate of growth. The upper end of our range assumes an even more ambitious rate of growth, reaching 4 million tons of biodiesel production in 2020. This would save 13 $MtCO_2$ per annum, also at High cost.*

Box 2: Integrated Urban Planning

If current trends continue, it is estimated China's urban population will increase from 572 million in 2005 to 1 billion by 2030[99]. Inefficient design of urban areas can become deeply embedded, as capital stock turnover is estimated to range between 40 to 120 years for building stock, and 40 to 200 years with respect to the pattern of transport links and urban development[100]. Whilst our analysis has focused on the question of the achievability of short-term 2020 targets, CO_2 mitigation in urban areas beyond this date may depend on planning decisions taken in the coming decade. There is thus a strong case for integrated urban planning, which aims to align people's needs for energy efficient access to services by considering them in light of their impact on one another (and not individually as is often the case with expanding cities). Many energy service companies use such an approach in evaluating the best savings for buildings. Similarly, this approach can achieve reductions in long-term energy demand and emissions in urban energy systems, arising from:

- Better transport links, for instance dispensing with central road arteries or improving last-mile connectivity in freight and passenger transport.
- More efficient provision of heating services (through the integrated planning of district heating/cooling networks and combined heat and power systems);
- Energy-efficient residences and commercial buildings.

'Eco-towns', such as Tianjin Eco-City[101] and Rackheath in the U.K[102], have incorporated integrated design fully into their urban planning. Furthermore, recent developments in China, India and Europe herald a large potential for ensuring the efficient design of buildings, heating/cooling and transport systems through collaborative ventures between these countries and established international consultants.

Longer Term

The IEA's longer term scenarios ACT and BLUE Map[103] suggest that electric vehicle technologies will progress significantly in the period to 2050, with China looking to 'leap-frog' hybrid vehicles and progress directly to electric vehicles. China will need to develop its infrastructure for the charging of electric vehicle batteries and further research, in China and elsewhere, is needed to improve battery energy density and to reduce cost. Continuing efficiency improvements will also be essential, but as China becomes wealthier the desire for larger and more powerful vehicles may be a countervailing tendency.

In the longer term urban design and planning methodologies may have as great an impact on carbon emissions as vehicle technology (Box 2).

Summary of Savings Potential

Figure 2 and Table 1 give the overall impact of the carbon saving options that have been identified. Figure 2 shows that on the basis of existing policies (baseline case) the absolute level of China's CO_2 emissions is set to increase from just over 5 billion tonnes per annum in 2005 to more than 10 billion tonnes in 2020. The "Green" savings options could reduce this by 1.4 billion tonnes to 8.6 billion tonnes. The "Stretch" options, going to closer to the theoretical maximum, would achieve a further reduction of 1.1 billion tonnes, reducing the total to 7.5 billion tonnes. Most of the savings, in both "Green" and "Stretch" cases, come from the power sector, with more than half of the savings, with significant contributions coming from buildings, industry, and transport.

The line across Figure 2 shows how the savings match up to the carbon intensity targets. In the baseline case, although the absolute level of carbon emissions nearly doubles to 2020, carbon intensity declines by 38%, almost sufficient to reach the target range.

Table 1 shows the savings available in the Green and Stretch options in different cost ranges. It shows that adopting just the Green options with negative costs is sufficient to reach the lower (40%) end of the target range, while adopting all the Green options is sufficient to exceed the top (45%) end of the range. By adopting all the Stretch options, China could reduce its carbon intensity by 54%, far exceeding the top of the target range. However that means achieving something close to the theoretical potential in all areas, and could be very difficult in practice.

Our study suggests, therefore, that China's carbon intensity targets to 2020 are achievable with a range of policies with low, and in many cases negative costs. The critical areas are reform and modernisation of the power, iron and steel, and cement industries, switching from coal to natural gas, and biomass, and efficiency gains in buildings, industry, and transport. Ambitious plans in most of these areas are already set out in the 12th Five Year Plan. But there are barriers to be overcome. Reform of the power and heavy industry sectors involves the closure of older less efficient plant which may be resisted locally for economic and social reasons. Ensuring that new plant is "state of the art" requires heavy investment and, in some cases, industrial restructuring which may also face local resistance. Large programmes of new plant construction may face bottlenecks of skilled staff and in the supply chains. In order to improve energy efficiency, particularly in the buildings sector, China needs to strengthen its institutional capabilities to draft, enforce, and monitor the necessary regulations, and to provide sound statistics. It is also necessary to win the support of Provincial authorities for whom economic growth may be an overriding concern. China can reach the top end of the target range with these low cost policies, but only if they are applied in a very thorough way and the barriers described above are successfully addressed.

The main medium and higher cost carbon saving options available to China include switching to natural gas, nuclear power, and renewables, especially (in this timescale) wind power. Rapid deployment of these technologies make it easier for China to reach the target range and, if combined with comprehensive deployment of low and negative cost options, could enable China to significantly exceed the target range, coming closer to the levels of carbon saving envisaged in the IEA's 450 Scenario[104].

Conclusions

China can meet its national 2020 targets for carbon intensity reductions at low or negative cost and, generally speaking, with technologies already available in China. The most important measures are to increase the energy efficiency of power stations, industry, buildings and transport, and to diversify into nuclear power, renewables, and to some extent gas, for electricity generation. To a large degree these amount to extensions of policies that China already has in place, and which are to be intensified in the 12th Five Year Plan.

China will, however, face significant challenges in implementing these policies. The capability for much tighter and more comprehensive enforcement of energy efficiency standards will need to be acquired. This is an area where international collaboration could be helpful. International collaboration could also help China to improve the quality and comprehensiveness of energy statistics. This is needed to underpin and evaluate a wide range of energy policies.

Ambitious construction programmes of advanced power and industrial plant may run into bottlenecks of skilled people and in their supply chains. China will also have to manage the social implications of plant closures and restructuring of heavy industries.

In order to meet the agreed global objective of containing the increase in temperature to 2°C, China's emissions will eventually need to peak and then decline steadily to very low levels. This will require either the comprehensive adoption of CCS for coal and gas stations or a wholesale switch to nuclear power and renewables. It will also require low carbon transport options and a more integrated approach to urban planning. Some of the technologies and policy options that will be most important in 2030 and 2050 will have little impact on the level of CO_2 emissions in 2020. But the progress that is made between now and 2020 in researching and developing them, and creating the conditions for future large scale deployment, will be of crucial importance.

It is important to recognise that China's progress in reducing carbon emissions will have important implications not just for China but also for the rest of the world including the OECD as well as other developing countries. Increasingly, China is a world leader in the mass deployment of low carbon technologies and in driving down their costs. Technologies developed and deployed in China will be available in other parts of the world, sometimes at very competitive prices. Performance standards set for products developed in China will increasingly have international influence. And of course China is likely to become a leading export market for low carbon technologies. China's contribution to climate change mitigation will not, therefore, be limited to the mitigation of China's own emissions.

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Annex 1: Methodology: A Bottom-Up Analysis

Trend extrapolation can provide insights into whether a country is on course to meet its carbon intensity targets. However, such a simple approach provides no insight into the technology and policy options which are required in order to sustain, steer or accelerate the underlying trends. By comparison, the published scenario literature, whilst technologically and policy rich, lacks transparency regarding the many assumptions which determine the specific scenarios. Abstracting detail from the published scenario literature (e.g. why a particular level of technology uptake is observed), and thus novel policy insights, is often not feasible. We therefore had recourse to providing a detailed bottom-up analysis of CO_2 mitigation potential within each of the 4 principal emitting sectors of the respective economies. These include (1) power generation, (2) energy intensive industry, (3) buildings, and (4) transport. We analyse a range of technologies and policies within each of these sectors and attempt to quantify the potential CO_2 emissions reductions that could be achieved with varying levels of technology uptake or policy success.

Projections of activity in each sector to 2020 (e.g. TWh of power generated, or tonnes of steel produced) are derived from literature sources, or else generated from bespoke bottom-up models (particularly in the buildings and transport sectors where published statistics are poor). These bottom-up models take into account key drivers, such as population growth, GDP growth, urbanisation and electrification rates, and existing individual sub-sectoral policy targets. The resulting demand is assumed to be met either by incumbent (e.g. current) or mitigating technologies which are not currently employed owing to excessive (additional) costs, or an array of non-technical barriers.

The level of technology uptake is differentiated into three levels (scenarios): (1) Baseline; (2) Green; and (3) Stretch. Unless otherwise stated, our baseline case (e.g. business-as- usual scenario) accounts for current trends in technology uptake and supporting policies as of March 2010 (both already implemented and planned). These include targets which can be sectoral in scope (e.g. Small Power Plant closure scheme in China), technology-specific (e.g. Solar Mission in India) or economy-wide (Chinese Energy Efficiency target), and are incorporated into our scenarios after a thorough appraisal of their achievability. It is only against this baseline that positive mitigation potential is measured. Our Green and Stretch scenarios do not represent low and high cost cases respectively, or varying levels of uptake along a technology specific (abatement) cost curve. Instead, the Green scenario potential forms what we consider to be a feasibly attainable portfolio of technology implementation, aligned with mid-range literature potential. The Stretch scenario pushes implementation closer to the absolute/theoretical technical potentials identified in the literature.

In order to support our Green versus Stretch potentials, we also take into consideration the marginal abatement cost[105] of each technology. Owing to a lack of consistent cost data across all sectors in both countries we soften our cost analysis to consider 4 cost categories, representative of: Negative (<\$0.tCO_2), Low (<\$10.tCO_2); Medium (\$10-50.tCO_2); or High (>\$50.tCO_2) cost options. We also take into account a range of additional, non-cost, barriers to uptake. These barriers include (for example) high up-front capital costs, rates of incumbent technology retirement, infrastructural constraints (e.g. lack of grid connectivity), weaknesses in regulatory frameworks, and issues surrounding public perception.

Having completed separate sector specific analyses of baseline 2020 emissions and mitigation potential, whole system carbon intensity can be estimated by summing the sector specific emissions and dividing by the projected GDP in 2020 (consistent with those GDP assumptions stated in Section 3). Mitigation from our baseline is calculated by summing all mitigation potential identified in each sector, including low-carbon technologies for power generation and demand side savings, which are allocated directly to the sectors in which they are implemented (costed at an average grid emissions factor). Feedbacks from demand reduction which could potentially reduce the potential to mitigate from the baseline in the power sector are not accounted for (e.g. when reduced demand substitutes for a marginal unit of otherwise mitigating non-fossil power generation). In theory if all demand reductions led to equivalent reductions in new nuclear and renewable generation this could eliminate a large part of the CO_2 reductions from the buildings and industry sectors. In practice, given the commitment of the Chinese and Indian Governments to the diversifications of power supplies, we judge this to be unlikely and that the impact of this second-order effect will be fairly modest.

Annex 2: Abbreviations

AC	Air conditioning
BAT	Best available technology
BPT	Best Practice Technology
BRT	Bus rapid transport
CCS	Carbon capture and storage
CDM	Clean development mechanism
CFL	Compact-fluorescent light-bulb
CHP	Combined heat and power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CRC	Carbon Reduction Commitment (UK policy)
CSP	Concentrating solar power
CTL	Coal-to-liquids
DC	District cooling
DECC	Department of Energy and Climate Change, UK
DH	District heating
DRI	Direct Reduced Iron
DSM	Demand-side management
EIA	Energy Information Administration, US
ESCO	Energy service company
EU ETS	European Union Emission Trading Scheme
EV	Electric vehicle
FCV	Fuel cell vehicle
FES	Fuel economy standards
GDP	Gross Domestic Product
GEN III and	Generation III and IV nuclear reactors
GJ	Gigajoule
$GtCO_2$	Gigatonne CO_2
GW	Gigawatt
HDV	Heavy Duty Vehicle
IEA	International Energy Agency
IGCC	Integrated gasification combined cycle
IMF	International Monetary Fund
IT	Information technology
LCC	Life cycle cost
LED	Light emitting diode
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MEPS	Minimum energy performance standards
$MtCO_2$	Megatonne CO_2
NDRC	National Development and Reform Commission, China
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing power parity
PV	Photovoltaics
R&D	Research and development
RD & D	Research, development and demonstration
RPS	Renewables portfolio standards
SC	Supercritical
UNFCCC	United Nations Framework Convention on Climate Change
USC	Ultra-supercritical
WEO	World Energy Outlook

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About the Authors

Neil Hirst is the Senior Fellow for Energy and Mitigation at the Grantham Institute, Imperial College. Before that he was the Director for Energy Technology and then Director for Global Dialogue at the International Energy Agency and was a senior energy official of the UK government.

Alex Dunnett received an MEng in Chemical Engineering in 2005 and PhD in Energy-Systems Engineering in 2010, both from Imperial College London. Following a period as a policy fellow at Grantham Institute for Climate Change, he now works as an analyst at the Ministry of Justice, specialising in Operational Research. Alex was the Lead Author and Co-ordinator of the analysis, carried out for the UK Government as part of the AVIOD O programme, on which this Report is based.

Mark Faist is currently finishing his PhD on Organic Solar Cells in a project collaborating with Chinese universities. He studied Physics at the University of Heidelberg, Germany. In this report, he worked mainly on the Industry and Buildings sector.

Sam Foster is currently a PhD student in the Department of Physics and Centre for Plastic Electronics at Imperial, researching and developing the technology of organic photovoltaics. His contribution to the report was focused on the areas of power generation and industry.

Mark Jennings is currently a Ph.D. candidate in the Department of Civil and Environmental Engineering in Imperial College London, having previously completed a M.Sc. in Atmosphere/Energy in Stanford University. His Ph.D. research project seeks to ascertain what role mathematical models could play in the logistics of large scale refurbishment of urban energy systems. During this project he largely contributed to assessing the major barriers and policy levers in each sector.

Luis Munuera is a Ph.D. student at the Grantham Institute studying decarbonisation pathways for the buildings sector. He holds degrees in Natural Sciences from the Universidad Autonoma de Madrid and the University of Cambridge, and an M.Sc. in Environmental Technology and Energy Policy from Imperial College. His work in this report focused on the buildings and transport sections.

Danlu Tong is currently a PhD candidate on the development of advanced amine based carbon capture system in the Department of Chemical Engineering. She studied Chemistry at Shanghai Jiao Tong University, China. Her contribution to this report is largely on the power and transport sectors.

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