NRDC WHITE PAPER

Putting it into Perspective: China's Carbon Intensity Target

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Executive Summary

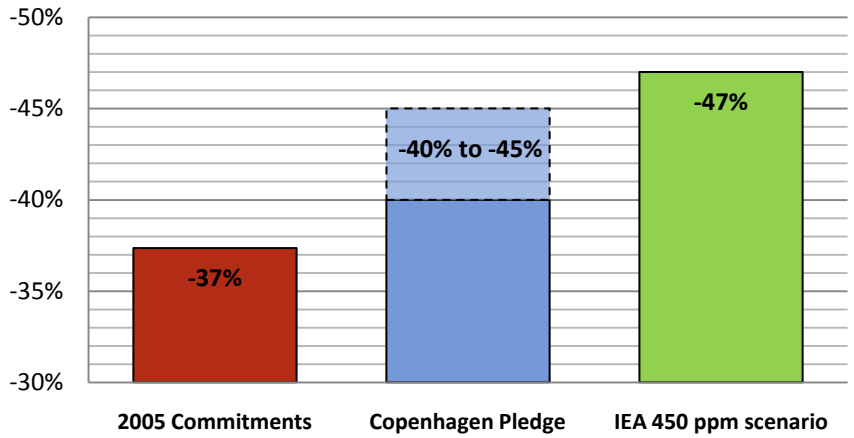
As the world's largest emitter of heat-trapping greenhouse gases (GHGs), China has a crucial role to play in the global fight against climate change. In December 2009, as a participant in the Copenhagen Accord, China pledged to carry out a domestically binding target to reduce its economy's carbon intensity by 40 to 45 percent by 2020 compared to 2005 levels.

International observers continue to debate the significance of China's carbon intensity target. The Natural Resources Defense Council (NRDC) has created this white paper to present our analysis of China's proposed carbon intensity target and the actions that will be required to achieve it. The paper considers three emissions growth scenarios to help clarify the implications of China's carbon intensity target:

- **Scenario #1: Previous Domestic Commitments** finds that if China fulfills only the commitments that were in place prior to its carbon intensity announcement, without extending its energy intensity policies beyond 2010, it would only reduce its carbon intensity by **37 percent** from 2005 levels by 2020.
- **Scenario #2: Extended Efforts** suggests that China may be able to surpass its official target given sufficient efforts, which include further reductions in energy intensity through 2020, leading to a reduction in carbon intensity of **48 percent** by 2020 compared to 2005 levels.
- **Scenario #3: Economic Restructuring** considers the steps China could take to reduce its carbon intensity by as much as **57 percent** by 2020.

On the basis of the above scenarios analysis and reviewing analyses performed in other studies, NRDC concludes that China's 40-45 percent carbon intensity reduction target is a serious new commitment that extends the country' existing efforts to improve energy efficiency and the structure of its energy system. China will only be able to limit the growth of its emissions in accordance with this target through proactive policymaking and substantial new investments similar to those undertaken between 2006 and 2010. However, while China's efforts over the last five years have successfully slowed the growth of its CO_2 emissions, the country will fall short of its 40-45 percent reduction target without undertaking new efforts.

Figure 1: China's Possible Carbon Intensity Reduction by 2020, Compared to 2005 Levels



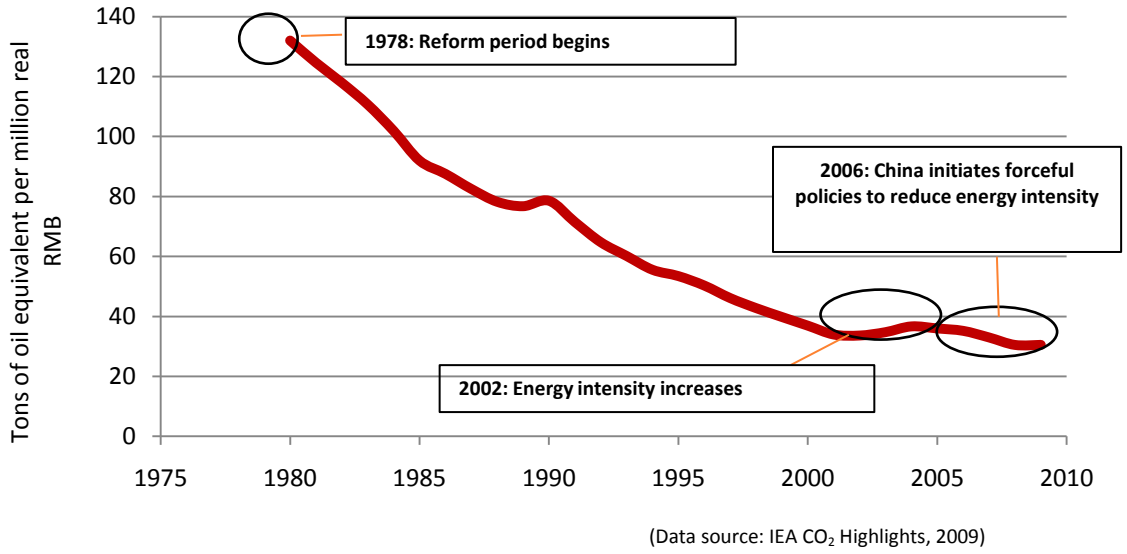
Source: NRDC analysis, International Energy Agency

While it leaves room for even more ambitious action, this carbon intensity target demonstrates China's engagement in and will reinforce its role as a key player in addressing climate change through energy efficiency, structural changes, the deployment of alternative energies, and cleaner fossil fuel generation. It will be essential for China to achieve or even surpass this pledge to the international community in order to avert the worse threats of global climate change.

A Chronology of China's Energy Demand and Carbon Emissions

It is important to get a historical perspective on how China's energy consumption has evolved in the last three decades in order to truly understand the implications of China's current climate policy. In recent years China's large population and tremendous economic growth have projected it ahead of the United States as the world's largest emitter of GHGs,[1] but when compared with industrialized Western countries, China has contributed relatively little to climate change since the industrial revolution. This may be attributed to the fact that China's energy demand has not typically grown at the same rate as its economy. For example, even after the country's economic liberalization in 1978, China's energy demand remained relatively stable between 1980 and 2000. When compared with the country's soaring overall economic growth, the energy demand grew only half as fast.[2]

Figure 2: Energy Intensity of China's Economy between 1980 and 2009



(Data source: IEA CO_2 Highlights, 2009)

Therefore, China's energy intensity—the amount of primary energy consumed per unit of economic output—decreased dramatically during the first two decades of reform and opening. This achievement was attributed to the improvement of China's inefficient capital stock, and the wide-ranging economic reforms, investments in energy efficiency, and a structural adjustment towards less energy-intensive sectors of the economy.[3] During that time, China's energy intensity actually decreased by 5 percent each year.

Between 2002 and 2004, however, China's energy intensity reversed its downward trend and began to rise at a rate of 2 percent per year, as a result of the rapid growth of energy-intensive, heavy industry and intensified competition among provinces for gross domestic product (GDP) growth.[4,5] In addition, policymakers had unfounded beliefs that intervention was not needed, and that the country's economy would continue to naturally shift away from heavy industry. Ultimately, the opposite happened and China's energy intensity spiked.

In an effort to address the rapid growth in energy intensity, in 2006 China enacted aggressive policies to curb the growth of its energy use. In its 11th Five Year Plan (2006-10), the country set a target of reducing its energy intensity by 20 percent by 2010 compared to 2005 levels. To achieve this ambitious target, China took significant measures to improve its energy efficiency including:

- Closing at least 54 gigawatts (GW) of inefficient coal-fired power plants and replacing them with more efficient facilities,
- closing down a substantial amount of outdated heavy manufacturing capacity, and
- establishing a program to improve the efficiency of its top 1,000 most energy-consuming enterprises.[6,7]

In addition, China embarked on an effort to expand its renewable resources, with the Medium- and Long-Term Development Plan for Renewable Energy (2007) mandating that 10 percent of China's energy be produced from renewable sources such as hydropower, wind power, and biomass by 2010, and 15 percent by 2020.[8,9]

Through substantial investments and policy measures implemented by the central government beginning in 2006, China succeeded in reversing the energy intensity trends that began in 2002.[10] Despite resistance from local officials who regarded efforts to reduce energy demand and carbon emissions as obstacles to local economic development, by the end of 2009 the central government reported a 15.61 percent reduction in energy intensity from 2005 levels (although energy intensity worsened in the first quarter of 2010).[11]

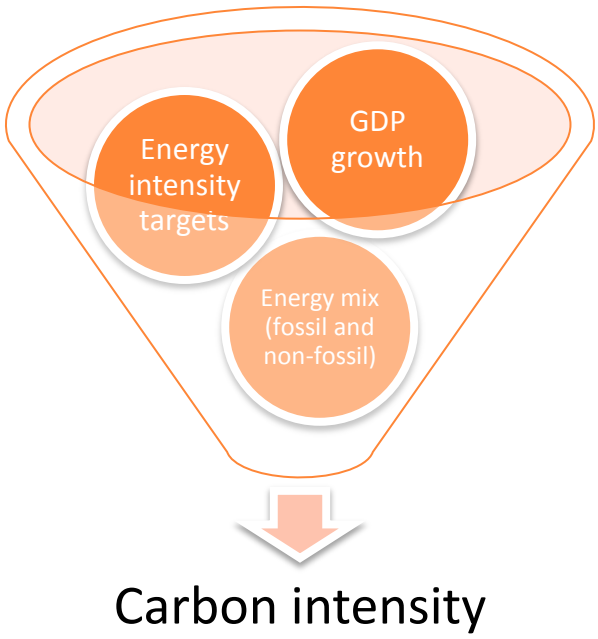
Evaluating China's Carbon Intensity Target: NRDC analysis of China's Previous Commitments and Future Policy Scenarios

In the weeks preceding the Copenhagen negotiations, China's State Council announced a new target that would essentially supplement its previous commitments undertaken in 2005: to unilaterally reduce its domestic carbon intensity from 2005 levels by 40 to 45 percent by 2020. Although not legally binding at the international level, Chinese officials have affirmed that the target will be binding at the domestic level and unconditional on any funding from developed countries.

In order to addresses how the world's most populous country can achieve this ambitious new target and examine the implications, NRDC has created three hypothetical scenarios to present and analyze the range of potential paths that China could take regarding emissions and energy use in coming years.

The carbon intensity target covers CO_2 emissions from fossil-fuel consumption and industrial activity, but will not cover emissions from land use and forestry.[12] In the interest of simplicity, our analysis focuses on energy-related CO_2 emissions—*i.e.*, emissions from fossil fuel combustion—which constitute more than 90 percent of China's non-land-use-related CO_2 emissions, and does not calculate emissions from industrial processes such as cement or chemical production.[13]

Figure 3: Structure of the model used for this study. The inputs are energy intensity targets and long-term energy consumption trends, GDP growth estimates, forecasts for the share of non-fossil energy and the fossil fuel mix, as well as the penetration rate of CCS.



Dissecting Carbon Intensity

The carbon intensity of a country can be divided into three major components:

- **Energy intensity**: The total primary energy consumed per unit of GDP, which is determined by the *energy efficiency* of its industry, buildings, vehicles, equipment, and the share of energy intensive industry, light industry, and services in its *economic structure*.
- **Non-fossil share of energy**: The share of China's primary energy consumption provided by non-fossil energy sources, such as hydro, wind, solar, and nuclear energy, which emit practically no CO_2.
- **Fossil-fuel mix**: China's carbon emissions are also strongly determined by the relative share of its fossil energy sources. For example, natural gas emits about half the amount of CO_2 per unit of energy of coal. Together with the share of renewables and nuclear energy, the fossil fuel mix determines the 'carbon factor' of China's energy mix, or the amount of CO_2 emitted from consuming every Btu of energy.

The exact relationship between these three factors is explained in further detail in the Appendix.

Because China's carbon intensity target does not include land use change, we do not consider emissions of other greenhouse gases such as methane, nor of emissions or sinks from agriculture, land use, and forestry. While these sources play an important role in China's overall GHG emissions, other Chinese policies are designed to address them.[14]

On the basis of China's energy intensity projections, and its share of non-fossil energy and fossil-fuel mix, NRDC has estimated the carbon intensity reductions that China could achieve under three possible policy scenarios:[15]

- Previous Commitments—presents what might happen if China takes no further actions beyond its existing commitments under the 11th Five Year Plan (2006-10).
- Extended Efforts—considers the situation if China strengthens its previous targets by carrying out sustained efforts to mitigate climate change through 2020 and beyond.
- Economic Restructuring—examines the possibilities if China were to embark on a full-scale restructuring of its economy.

Defining Domestically Binding: In a Chinese context, a 'domestically binding' target effectively becomes the law of the land. In particular, sub-targets are allocated to provincial governments and enterprises, with potential penalties for non-compliance. National targets also become incorporated into China's medium- and long-term social and economic development plans.

It has been argued that when a target is embedded in a plan, such as China's Five-Year Plan, it gains the same legal force as a Supreme Court decision in the United States.[16] It should also be recognized that China will develop corresponding statistics, monitoring and evaluation systems, and regulations to measure progress—similar to the systems put in place to measure progress in meeting China's 20 percent energy-intensity reduction goal.[17]

The evolution of China's carbon intensity depends heavily on the evolution of its GDP and the structure of its economy, with carbon intensity reductions becoming increasingly difficult for lower GDP growth, and GDP earned from heavy industry output requiring more energy (and carbon emissions) than GDP generated from services or trade.

In order to evaluate different levels of ambition on an equal basis, NRDC assumes the same level of economic growth in all three scenarios. We use the Energy Research Institute's (ERI) middle-of-the-road forecast as the baseline for China's future economic growth, which is projected at 8.8 percent in inflation-adjusted terms until 2020. This moderate estimate lies between the low estimate provided by Renmin University and the high estimate provided by McKinsey & Company.[18]

PREVIOUS COMMITMENTS SCENARIO

Under the *Previous Commitments* scenario, we assume that China carries out its 2005 national goals for energy intensity reduction and renewable energy, but does not continue its proactive energy policies and activities once the existing goals are achieved.[19] For example, China does not enact any new energy intensity targets for the 2011-2015 and 2016-2020 periods, and that only evolves to natural trends in the economy and policies unrelated to energy and climate change. In short, this scenario estimates a lower bound for what China was poised to achieve under its previous national goals and before the climate pledges leading-up to Copenhagen (A more detailed description of the assumptions underlying this scenario is included in the Appendix).

NRDC's analysis finds that completion of China's previous commitments would result in a 37 percent reduction in carbon intensity from 2005 levels by 2020 (see Table 1).

In the absence of extended efforts to reduce energy intensity past 2010, China's energy consumption grows substantially. Its energy intensity continues to decrease to a certain extent as the economy naturally evolves towards more efficient production and service-oriented output, but progress is minimal compared to what was achieved in the 2005-2010 period.

Overall, this scenario sees China emitting 11 billion tons of CO_2 per year in 2020 and heading towards almost 15 billion tons per year in 2030. This estimate is very close to the Netherlands Environmental Assessment Agency's business-as-usual forecast (10.8 Gt) for 2020. Although China has already made aggressive steps to curb the growth of its emissions since 2005, additional and renewed efforts will be needed to move away from an unsustainable growth path. The *Renewed Efforts* scenario outlined below sets out to examine precisely this possibility.

Table 1: Carbon intensity reduction from 2005-2020 under Previous Commitments, Extended Efforts, and Economic Restructuring scenarios

	Scenario Assumptions			
	Energy Intensity Reduction	***Fossil Mix Improvements***	***Non-Fossil Fuel Share of Primary Energy***	**Reduction in Carbon Intensity 2005-20**
1. Previous Commitments	2006-2010: 20%, followed by the world historical energy/GDP elasticity of 0.8.	Coal: 66% of energy mix Natural gas: 2% Oil: 18% No CCS deployment.	10% renewables by 2010 and 15% by 2020	37%
2. Extended Efforts	2006-2010: 20% 2011-2015: 16% 2016-2020: 14%	Coal: 62% of energy mix Natural gas: 5% Oil: 18% 6 MT of CCS by 2030.	10% non-fossil by 2010 and 15% by 2020	48%
3. Economic Restructuring	2006-2010: 20% 2011-2015: 20% 2016-2020: 20%	Coal: 57% of energy mix Natural gas: 10% Oil: 13% 6 MT of CCS by 2020.	10% non-fossil by 2010 and 18% by 2020	57%

EXTENDED EFFORTS SCENARIO

In the *Extended Efforts* scenario, China follows the ambitious recommendations made by its policy experts and enacts new policies to reduce energy intensity by 16 percent over the 12th Five-Year Plan (2011-2015), and 14 percent in the 13th Five-Year Plan (2016-2020).[20] We also assume that China can increase its share of non-fossil energy to 15 percent in 2020, and that these non-fossil energy sources offset fossil fuels, lowering the share of coal from 70 to 63 percent in 2020, which is consistent with the '450 ppm' scenario developed by the International Energy Agency (IEA). With these changes, China emits 11 percent less CO_2 per Btu of energy consumed than in 2005. Finally, it is assumed that carbon capture and sequestration (CCS) technology is deployed on a small scale (3 Mt) by 2020.[21]

Our analysis suggests that under the *Extended Efforts* scenario, China would achieve a 48 percent reduction in carbon intensity reduction from 2005 to 2020. At the end of the period, China's CO_2 emissions would reach 9.2 billion tons per year, which is a 17 percent improvement over the *Previous Commitments* scenario, and headed towards 11 billion tons in 2030. This improvement is roughly in line with the upper tier of China's official 40 to 45 percent carbon- intensity target range, suggesting that achieving the top of this carbon-intensity target will require extended and renewed policy efforts.

Moreover, we find that the *Extended Efforts* scenario is in line with the reduction called for in the IEA's '450 ppm' scenario in its *World Energy Outlook 2009*, in which each country contributes to

stabilizing atmospheric GHG levels at 450 ppm of CO_2-equivalent. Although IEA's projections only represent one of several proposed pathways to 450 ppm, the *Extended Efforts* scenario suggests that a 47 to 48 percent reduction in carbon intensity would be an important contribution from China in the global effort to prevent temperatures from rising by more than 2 degrees Celsius over pre-industrial levels.

A Note about *Reference Case* Scenarios: Several organizations have examined China's future energy and emissions paths in terms of a *Reference Case* scenario, which, by definition is a carbon mitigation situation in which a country continues its existing policies and trends, juxtaposed with a more ambitious scenario in order to examine the future of energy use under a variety of conditions.[22]

In many *Reference Case* scenarios, agencies estimate that China would achieve a reduction in carbon intensity anywhere between 33 to 46 percent from 2005 levels by 2020 (see Table 2). A word of caution is necessary, however, to clarify the purpose of Reference Scenarios in relation to China's carbon reduction target.

Because China's existing energy policies are relatively proactive, the country's Reference Case forecast generally reflects a situation where China continues to pursue its existing efforts to address energy use and GHG emissions. But several commentators, observing that the range of these Reference Scenario reductions corresponds roughly to China's official carbon intensity target, have mistakenly concluded that China's target will require "no additional effort" and "no leadership to fight climate change."[23] To make such claims is to misunderstand the purpose of Reference Scenarios, failing to recognize the significance of China's actions, which represent a sharp deviation from the country's energy intensity trends from 2002-05 and have required substantial resources and investment.

RESTRUCTURED ECONOMY SCENARIO

Finally, this white paper considers a *Restructured Economy* scenario, designed to sketch out an upper bound on what China could reasonably achieve to reduce its carbon intensity, not only beyond its past efforts but beyond its new official 40 to 45 percent reduction target. For this purpose, China would need to rely heavily on structural adjustment of the economy as well as achieving strong energy efficiency gains. With these efforts, we assume that the country is able to reduce its energy intensity by 20 percent during each of the 12th (2011-15) and 13th Five-Year Plan periods (2016-20). Although an in-depth sectoral analysis would be beyond the scope of this study, structural adjustment would involve a gradual shift away from energy-intensive primary industries such as cement or steel production, and towards a greater share of services and light industry. By comparison with the 20 percent reductions assumed here, the IEA projects in its 450 ppm scenario that China's energy intensity reduction in each of these successive plans would be approximately 15 percent. In other words, the *Restructured Economy* scenario is deliberately designed to be significantly more ambitious than most options currently under consideration.[24]

In this scenario, we also assume that China surpasses its existing non-fossil fuel target—increasing the share of non-fossil energy to 18 percent by 2020—and succeeds in reducing the share of coal to 57 percent by 2020. CCS deployment is assumed to reach a capacity of 6 Mt in 2020, or double the capacity assumed in IEA's 450 ppm scenario. Even in this scenario, however, CCS still accounts for a very small fraction of China's overall CO_2 emissions.

Under the *Restructured Economy* scenario, China would reduce its carbon intensity, based on 2005 levels, by 58 percent by 2020**.** At the end of the period, China's CO_2 emissions would reach 7.7 billion tons per year, which is a 31 percent improvement over the *Previous Commitments* scenario examined above. A noteworthy fact is that even in this scenario—by far the most ambitious of the three considered here—China's emissions would still rise above present levels in 2020. But even more noteworthy is that this *Restructured Economy* scenario would be extremely challenging for China to achieve. Many Chinese provinces have encountered substantial difficulties in reaching their energy intensity targets under the 11th Five-Year Plan, and it is difficult to imagine how they might be able to achieve these reduction targets again—not once but twice over—by 2020.

Making Sense of China's Carbon Intensity Target

Based on NRDC's analysis, China's 40 to 45 percent carbon intensity target represents a concrete new commitment when compared with the 37 percent reduction that might be achieved by the country fulfilling only its previous commitments. In particular, achieving the upper range of China's target will require significant new efforts and be largely in line with the 48 percent reduction under the *Extended Efforts* scenario and the 47 percent reduction called for by the IEA in its 450 ppm scenario.

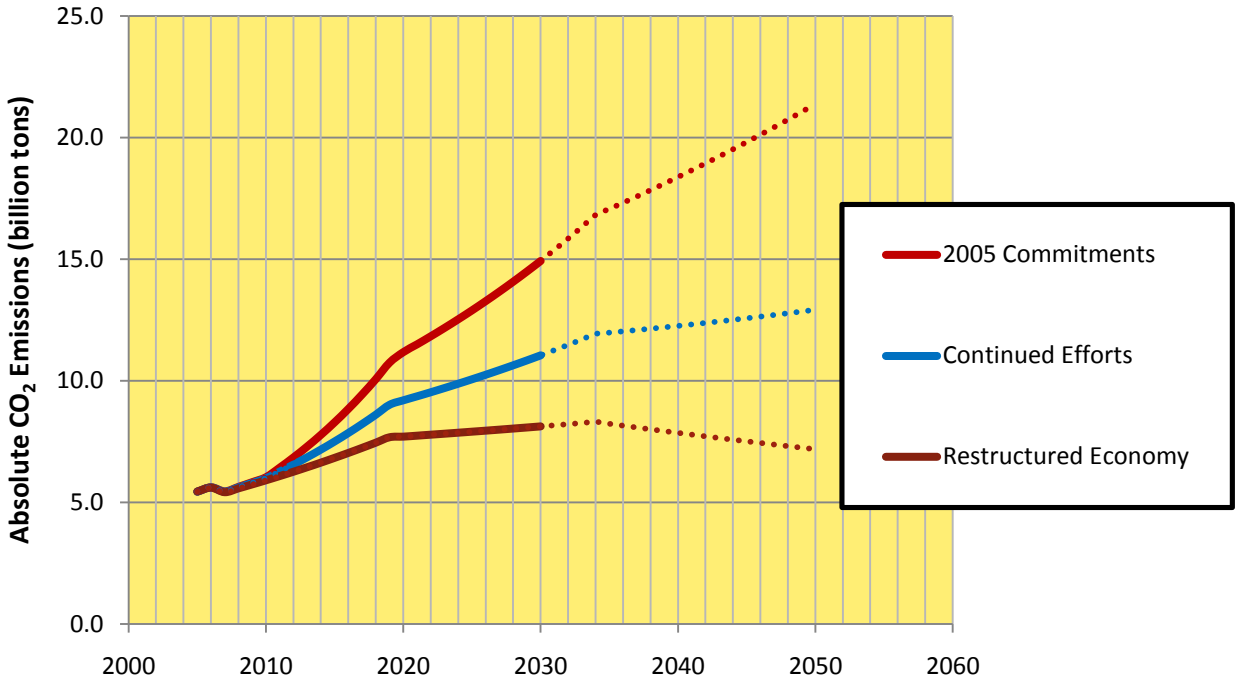
However, a few observations are worth noting:

- **Low-hanging fruit will become increasingly scarce within each economic sector.** Reductions in China's energy and carbon intensity will become increasingly difficult as the "low-hanging fruit," the cheapest options for increasing energy efficiency, such as shutting down outdated and inefficient power plants and manufacturing capacity, are harvested. Structural adjustments to the overall economy will be absolutely necessary in order to achieve stronger reductions.

- **If growth is low because of an economic slowdown, reducing carbon intensity will be more difficult.** This is attributed in part to reduced capital turnover and lower investment in efficient equipment, and also because China will need to achieve lower absolute emissions for a given intensity target. If China's economy grows by an average 7.3 percent per year, instead of 8.8 percent, China will need to keep CO_2 emissions below 8.2 billion tons by 2020, instead of 9.7 billion tons, in order to achieve a 45 percent reduction in carbon intensity. Moreover, these measures will be even more expensive relative to China's GDP if growth is low, that is, unless the slowdown comes from a deliberate central policy to curb the growth of heavy industry. Overall, China's carbon intensity target is a significant commitment in part because Chinese policymakers have committed to achieving it irrespective of how quickly China's GDP grows.

- **Absolute emissions will continue to increase past 2020, but reducing carbon intensity substantially can reduce growth of emissions and hasten the peaking of China's emissions.** The fact that China's absolute emissions will continue to increase does not mean China's target is not ambitious; merely, it underlines that reaching this target is critical. Achieving the carbon intensity reduction implied in the *Extended Efforts* scenario instead of the *Previous Commitments* scenario would avoid more than 2 billion tons of CO_2 emissions per year in 2020, and more than 5 billion tons per year in 2030, even though absolute emissions continue to grow until at least 2030 in both scenarios. On the basis of the long-term emissions paths modeled in this study, it is clear that further commitments past 2020, and even more aggressive mitigation actions, will be needed past 2020 in order to keep atmospheric GHG concentrations below 450 ppm scenario by 2050.

Figure 4: Absolute CO_2 Emission Scenarios for China. The future emissions past 2020 are extrapolated from long-term energy trends projected by Renmin University.



Conclusion

The analysis in this white paper has attempted to place China's carbon-intensity target commitment in its broader context. By laying out possible paths for China's energy intensity and energy mix, and surveying third-party forecasts for China's future energy and carbon trends, this paper has compared China's carbon-intensity target with existing policies and draws implications for future ones.

China's carbon intensity target will complement its existing, substantial policies established since 2006, which focus on reducing energy intensity by 20 percent from between 2006 and 2010, and increasing the share of non-fossil energy to 10 percent by 2010, and 15 percent by 2020. Moreover, our analysis indicates that the 40 to 45 percent carbon-intensity target represents a concrete new commitment by China, since its previous targets and commitments would only have yielded a 37 percent reduction. The upper range of China's target is largely in line with our *Extended Efforts* scenario, which yields a 48 percent reduction by 2020, and with the 47 percent reduction called for by the International Energy Agency to keep global warming below 2 degrees Celsius.

Key to our finding is the understanding that China's existing policies for energy intensity and non-fossil energies represent a sharp deviation from previous energy trends and they have required substantial resources and investment. To simply assume that China would extend these measures until 2020 as a matter of *status quo* would be to fail to recognize the significance of these policies and to penalize China for taking early action. Nonetheless, China's carbon intensity target still leaves room for even more ambitious action. Under a more substantial restructuring of its economy, our analysis finds that China could reduce CO_2 intensity levels by as much as 57 percent by 2020.

Finally, China's CO_2 intensity target is a big step in the right direction and it provides the right incentives for future improvements in reducing emissions. While some in the international community may be frustrated that China's target is not ambitious enough, the fact remains that China's engagement on climate change has been reliable to date and its commitment to a carbon intensity target reinforces this point. Overall, China's commitment to reducing CO_2 intensity levels by 40 to 45 percent is a valuable contribution to the international effort to avert the worst threats of climate change.

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ENDNOTES

[1] Netherlands Environmental Assessment Agency, *Chinese CO_2 emissions in perspective*, available at: http://www.pbl.nl/en/news/newsitems/2007/20070622ChineseCO2emissionsinperspective.html (June 2007).

[2] See William Chandler, *Memo to Copenhagen: Commentary is Misinformed—China's Commitment is Significant,* Carnegie Endowment for International Peace (December 2009), which notes that China's energy-GDP elasticity from 1980-2000 ranged from 0.2 to 0.6, equivalent to a 1.7 to 5 percent increase in GDP for every 1 percent increase in energy use.

[3] See Daniel Rosen and Trevor Houser, *China Energy: A Guide for the Perplexed*, Peterson Institute for International Economics. (May 2007); See also William Chandler, *Memo to Copenhagen: Commentary is Misinformed—China's Commitment is Significant,* Carnegie Endowment for International Peace (December 2009).

[4] See Mark D. Levine and Lynn Price, presentation on "*Assessment of China's Energy-Saving and Emission-Reduction Accomplishments and Opportunities During the 11th Five Year Plan*," LBNL, December 2, 2009, available at: http://bit.ly/aW8cEG.

[5] Jiang LIN, Nan ZHOU, Mark D. Levine, and David Fridley, *Achieving China's Target for Energy Intensity Reduction in 2010: An Exploration of Recent Trends and Possible Future Scenarios*, LBNL-61800 (December 2006).

[6] National Development and Reform Commission, *China's Policies and Actions for Addressing Climate Change—The Progress Report 2009* (November 2009).

[7] See NRDC Fact Sheet, *From Crisis to Opportunity*, available at www.china.nrdc.org; See also Lynn Price, Xuejun Wang, and Jiang Yun, *The Challenge of Reducing Energy Consumption of the Top-1000 Largest Industrial Enterprises in China*, Proceedings of the European Council for an Energy-Efficiency Economy, 2009 Summer Study.

[8] National Development and Reform Commission, *Medium- and Long-Term Development Plan for Renewable Energy in China* (September 2007).

[9] China's renewable energy plan of 2007 technically mandated targets for renewables, whereas 'non-fossil' energy also includes nuclear. In this sense, the 2007 plan initially stretched further than the new official target of 15% non-fossil energy by 2020. The scenario analysis described below accounts for this discrepancy, but the impact on emissions is minimal.

[10] Chandler, Memo to Copenhagen.

[11] Li Jing, *Fight Hard and Long to Save Environment, Wen Tells Nation*, China Daily. (March 6, 2010). A discussion is also ongoing among international experts to reconcile China's announced energy intensity achievements with the GDP and primary energy consumption statistics reported by National Communiqués and the National Bureau of Statistics. Because this discussion is yet unresolved, we have only cited official Chinese government numbers for energy intensity in this section.

[12] See "China says carbon 'sinks' not covered by target", Reuters, 11/26/09, available at: http://www.reuters.com/article/idUSTRE5AP2WR20091126.

[13] Excluding emissions and sinks from land use and forestry, fossil fuel combustion in 2005 constituted 90.5 percent of China's CO_2 emissions versus 9.5 percent for industrial processes. World Resources Institute, Climate Analysis Indicators Tool, 2009, available at: http://cait.wri.org/.

[14] Several studies include these sources in their forecasts for China's emissions (see for example Elzen et al., 'Evaluation of the Copenhagen Accord', Netherlands Environmental Assessment Agency, May 2010). Because of differences in scope, the projections of such studies cannot be compared with directly those in the

present white paper. The Netherlands Environmental Assessment Agency estimates that China's carbon intensity from energy and industry would have decreased by about 18% by 2020 in a business as usual situation.

[15] As a small disclaimer, it should be understood that these scenarios are primarily meant to stimulate policy discussion and should not be interpreted as precise predictions of the future trends in China's emissions.

[16] See Wong, Julian. *Has a U.S-China agreement on transparency been reached?* Climate Progress. (December 2009). Available at: http://climateprogress.org/2009/12/18/has-a-u-s-china-agreement-on-transparency-been-reached/

[17] See State Council Office Announcement, *State Council Standing Committee Investigation and Decision on National Greenhouse Gas Emissions Reduction Control Target* (in Chinese) (国务院常务会研究决定我国控制温室气体排放目标), 11/26/09, available at: www.gov.cn/ldhd/2009-11/26/content_1474016.htm, and "*China announces targets on carbon emission cuts,"* Xinhua, 11/26/09, available at: http://english.gov.cn/2009-11/26/content_1474008.htm.

[18] Energy Research Institute. 2050 China Energy and Carbon Emissions Report. Beijing: NDRC, 2009; Zou, Ji. *"Economy, Energy, Technologies, and GHG Emission in China: a Scenario Study*. Beijing: Renmin University, 2009; McKinsey & Company. "China's Green Revolution." New York, 2009.

[19] China's existing policies and actions are not continued in the *Previous Commitments* scenario because they require sustained effort; without this political and economic effort, many of them would simply be phased out. For instance, the Top 1000 Enterprises Program requires the government to set yearly targets for the top energy-consuming enterprises, to provide sustained funding to help these enterprises achieve the mandated reductions, and to continually monitor their progress. This program is thus carried out with the specific intent of meeting China's existing energy intensity target. Since China has not yet set any national energy intensity targets for the 2011-2015 or 2016-2020 periods, the *Previous Commitments* scenario does not assume that existing programs are sustained. The detailed list of policies and actions included in this scenario can be found in Table 1 and in the Appendix.

[20] See Lin Erda's recommendations to reduce energy intensity by 16% and 14% respectively in the next two Five-Year Plans in *Strategies and Policies for Facing Climate Change Post-Copenhagen,* China Development Gateway. (February 2010). Available at: http://cn.chinagate.cn/webcast/2010-02/24/content_19467401.htm.

[21] This is consistent with the rate of CCS installation estimated by the IEA's *World Energy Outlook 2009*.

[22] The U.S. Energy Information Administration (EIA), IEA, and Chinese think-tanks such as Energy Research Institute (ERI) and the Renmin University group, headed by Zou Ji.

[23] See Carraro and Tavoni, *Looking ahead from Copenhagen: How Challenging is the Chinese Carbon Intensity Target?* Climate Science & Policy. December 2009. Available at: http://www.climatescienceandpolicy.eu/2009/12/looking-ahead-from-copenhagen-how-challenging-is-the-chinese-carbon-intensity-target/.

[24] It could also be argued that China's energy intensity could decrease even further, in the event of a stronger economic shift towards services. Although this is certainly the case, such an extreme restructuring is unlikely, and the *Restructured Economy* scenario aims to describe a far more realizable goal – albeit a challenging one.

Technical Appendix

METHODOLOGY

Overview (Structure)

The analysis provided in this white paper is supported by an analytical model of China's aggregate economic situation and of its energy and emissions trends. The model begins with key inputs such as GDP growth, achievable energy intensity reductions in upcoming five-year plans, forecasts for China's fossil fuel mix, and the share of non-fossil energy sources—all of which are informed by published analyses. Since the model accepts energy intensity reductions directly as an input, it need not make any explicit assumptions about the future structure of the Chinese economy. Given these inputs, the model computes a forecast for carbon intensity in a relatively straightforward matter according to the formulas described below.

As noted above, the scope of this analysis is limited to energy-related CO_2 emissions. These represent the largest factor in China's carbon intensity (91 percent), while the remaining 9 percent comes from industrial processes such as cement manufacturing and chemical processing.[1] It can be assumed that emissions from industrial processes will evolve at the same rate as energy-related emissions. This assumption allows for a direct comparison between China's carbon intensity target (which includes industrial processes) and existing energy and CO_2 emission forecasts (which typically do not).

It should also be noted again that China's carbon intensity target does not include agricultural emissions, land-use change, carbon sinks or other potent greenhouse gases such as methane of hydrofluorocarbons (HFCs). These sources play an important role in overall GHG emissions and other Chinese policies are designed to address them—but since these sources are not contained in the carbon intensity target, this white paper does not address them directly.

Input sources

GDP: In order to estimate China's future economic growth, we have reviewed and compared the GDP growth forecasts from three reports by McKinsey, ERI, and Zou Ji of Renmin University respectively.[2]

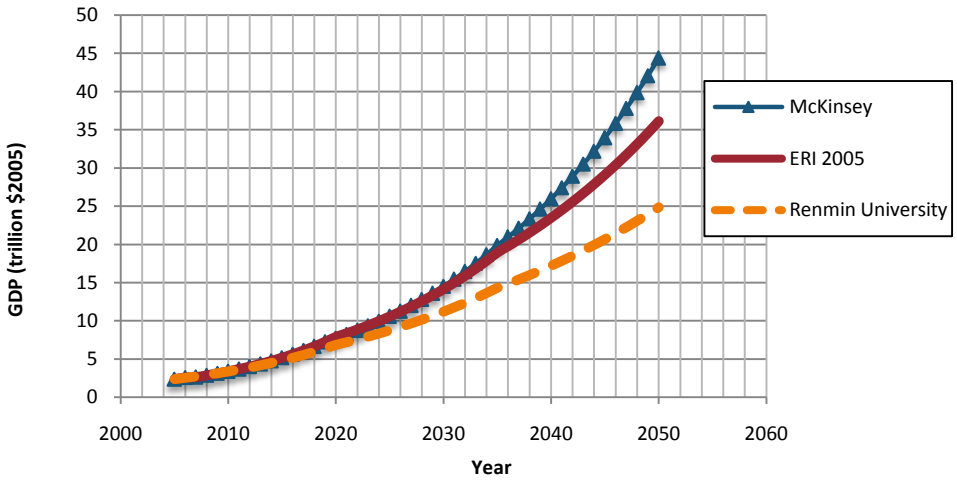

Figure 5: Gross Domestic Product (GDP) scenarios for China

As illustrated in Figure 5, all three forecasts predict that China's real GDP will have tripled by 2020 and continue its momentous increase until 2050.[3] Renmin University has the most conservative estimate, predicting that China's GDP will have increased 10-fold by 2050. At the other extreme, McKinsey predicts a 19-fold increase by 2050. The ERI report offers an estimate in between these two extremes, and for this reason we use this middle-of-the-road forecast as the baseline for China's future economic growth in this study. The ERI forecast for GDP is based on an 8.8 percent growth until 2020, followed by a 6 percent growth until 2035, and a 4.4 percent increase until 2050.

China has consistently exceeded GDP forecasts for the past three decades. This begs the question: what if China's economy grows significantly faster or slower than predicted? Given China's current trends, it appears that faster-than-expected growth would make it easier for China to achieve its carbon intensity target, for reasons described above, but the country's absolute emissions would nonetheless still grow more than anticipated. Conversely, a lower-than-expected economic growth situation would likely make it even more challenging to achieve deep carbon intensity cuts, while paradoxically allowing for lower absolute emissions. At any rate, government officials have made it clear that China will remain formally committed to its carbon intensity regardless of how the country's GDP evolves.

Calculations

CO_2 Emissions: In this white paper, a nation's carbon emissions are analyzed as follows:

$$(CO2 \quad emitted) = \left(\frac{CO_2}{primary\ energy\ consumed}\right) \times \left(\frac{primary\ energy\ consumed}{GDP}\right) \times GDP$$

The first term corresponds to the *carbon factor*, or the average amount of CO_2 emitted from consuming one Btu of primary energy. The second term is the *energy intensity*, which describes the amount of primary energy needed to produce one unit of real GDP. The final term is the nation's total GDP, expressed in inflation-adjusted RMB. Using these definitions, the equation can be re-expressed as:

$$(CO_2\ emitted) = (energy\ intensity) \times (carbon\ factor) \times GDP$$

The three terms which together comprise China's carbon emissions are described in the subsections below.

Energy Intensity: For consistency, the influence on CO_2 emissions of various fossil-fuel burning technologies is been included here as a factor in *energy intensity* and not in the carbon factor. This is because energy intensity is defined in terms of total primary energy consumed, not in terms of end-use power:

$$energy\ intensity = \left(\frac{primary\ energy\ consumed}{GDP}\right)$$

For example, switching from subcritical to ultra-supercritical power plants will reduce the amount of coal needed to deliver a certain amount of end-use power, which reduces China's overall energy intensity but not its carbon factor. This explains why China has been able to reduce its national energy intensity since 2006 by replacing old, inefficient coal plants with newer, ultra-supercritical plants.

Carbon Factor: The nationwide carbon factor is a measure of how carbon-reliant China's overall energy system is. It is denoted here by the symbol Φ and defined as the amount of CO_2 emitted from consuming one Btu of primary energy. The carbon factor is determined by the share of each source in the overall energy mix and by the carbon emissions associated with each source:

$$\Phi_{\text{total}} = \Phi_{fossil} + \Phi_{non-fossil}$$
$$= (\text{share of coal}) \times \Phi_{\text{coal}} + (\text{share of natural gas}) \times \Phi_{\text{gas}} + (\text{share of oil}) \times \Phi_{\text{oil}}$$

For instance, coal emits approximately 9.4 tons of CO_2 for every 100 million Btu of primary energy consumed, while natural gas and oil emit 5.3 and 7.3 tons of CO_2 for every 100 million Btu.[4] Meanwhile, non-fossil sources such as hydro, nuclear, solar PV and wind are nearly carbon-free, so we neglect the emissions associated with these sources for simplicity.[5] China met 69 percent of its primary energy demand from coal, 3 percent from natural gas, 21 percent from oil and 7 percent from non-fossil sources in 2005, so its overall carbon factor in 2005 was 8.2 tons of CO_2 per 100 million Btu.[6]

CHINA'S ENERGY PATH ASSUMING EXISTING POLICIES ARE CONTINUED

Several other studies attempt to use *Reference Case* scenarios to answer how China's energy demand and emissions will evolve if it uses only existing policies. As we have argued above, these *Reference Case* scenarios should not be regarded as a 'do nothing' situation, although they have been misinterpreted as so in a numerous reports.

Rather, these scenarios should serve as useful points of comparison, provided they are interpreted correctly. Table 1 shows the Reference Case scenarios of several leading energy forecasting groups. The table indicates that if China continued its existing policies and trends, it would achieve a reduction in carbon intensity of 33 to 46 percent from 2005 levels by 2020. Since "reference" is an inherently variable notion, the studies cited above make different assumptions about GDP growth, future worldwide energy prices, technological availability, and for the evolution of China's economic structure. Therefore, there exists a great deal of variability in the range of forecasts for China's "Reference" path.

Table 1: Reference Case Forecasts from a selection of other analyses of China's Carbon intensity reduction from 2005-2020

	Summary of 'Reference Case' Forecasts from Other Analyses			
	Energy Intensity Reduction from 2005 to 2020	***GDP growth, 2005-2020***	***Non-Fossil Fuel Share of Primary Energy***	**Reduction in Carbon Intensity 2005-20**
Renmin University (2009) [7]	31% reduction (equivalent to a 7% reduction in each of the 12th and 13th Five- Year Periods).	7.3% per year in inflation-adjusted RMB	Around 9% by 2020	33%
International Energy Agency, (World Energy Outlook, 2009) [8]	41% reduction (equivalent to a 14% reduction in each of the 12th and 13th Five- Year Periods).	5.1% per year in PPP terms	11.9% by 2020	40%
Energy Research Institute, affiliated with National Development and Reform Commission (2009) [9]	38% reduction (equivalent to a 12% reduction in each of the 12th and 13th Five- Year Periods).	8.8% per year in inflation-adjusted RMB	9.5% by 2020	47%
U.S. Energy Information Administration (International Energy Outlook, 2009) [10]	42% reduction (equivalent to a 15% reduction in each of the 12th and 13th Five- Year Periods).	7.2% per year in PPP terms	11.8% by 2020	46%
The World Bank (2010)	43% reduction	6.8% per year in PPP terms (2010-2030)	15% by 2020	46%
EU Commission (POLES model, 2010) [11]	-	-	-	35%

Contrary to conventional wisdom, continuing to pursue existing policies is very different from "doing nothing" for a country like China. The idea that China would continue its existing energy policies represents a departure from the *status quo*, as Chandler and Wang have convincingly argued.[12] In this sense, China's recent Carbon intensity commitment represents the first time that a domestically binding target is in place for energy intensity or carbon intensity all the way to 2020.[13]

CHINA'S ENERGY PATH ASSUMING EXISTING POLICIES ARE *NOT* CONTINUED

Very few studies to date have address what might China's energy path look like if no more efforts are made. Without answering this question, it is impossible to estimate how China's carbon intensity will evolve in the absence of the new climate target, and equally impossible to judge the level of ambition of this target.

There is an overall consensus that China's carbon intensity will decrease to a certain extent regardless of what actions are taken to combat climate change. In general, as countries develop the trend has been that their industrial production becomes more energy-efficient and their economic structure gradually shifts away from heavy, energy-intensive industry towards secondary and tertiary industries.

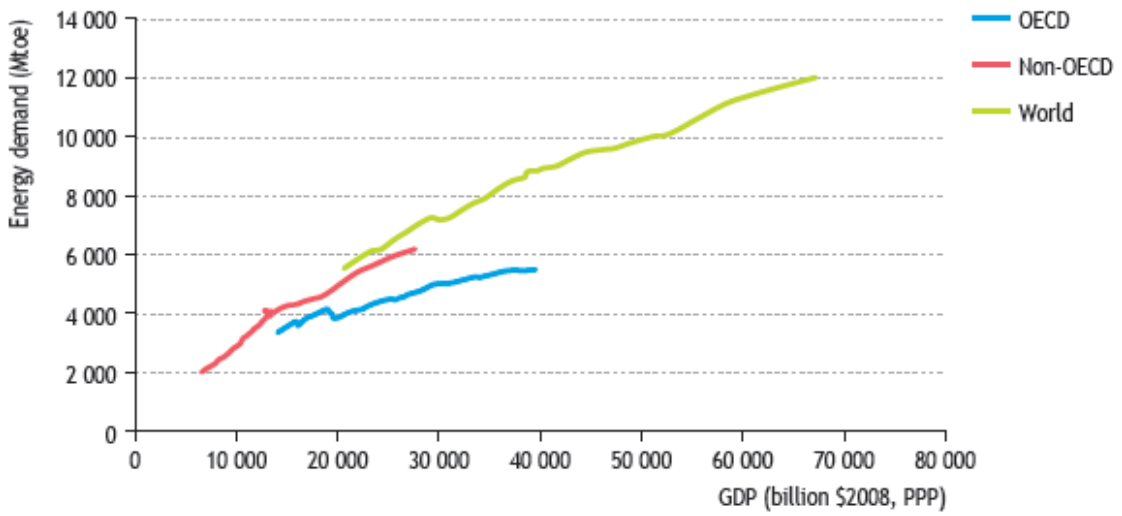

Figure 6: Primary energy demand and GDP (Source: (International Energy Agency, 2009))

Figure 6 shows the evolution of energy demand for several world regions as a function of their historical GDP level. The OECD group included in the graph reached a high GDP well before global warming became a political priority. Yet as the figure indicates, their energy demand partially curbed as their economy grew.[14]

In order to gain an estimate for how China's energy consumption might evolve after 2010 in the absence of any proactive energy policies for the 'Previous Commitments' scenario, we rely on the following sources:

Past energy-GDP elasticity: Since China's CO_2 emissions depend primarily on its energy consumption, it is useful to look at the historical relationship between economic growth and increases in energy use. The *energy-GDP elasticity*–i.e. the ratio of the percent growth in primary energy consumption in a given year to the percent growth in GDP–is a measurement of this relationship. The world average historical energy-GDP elasticity has been about 0.8, which suggests that if China's GDP grows at 8.80 percent per year, energy intensity would drop by about 16 percent from 2010 to 2020. [15, 16] Assuming China comes to close to reaching its existing energy intensity goal, this would add up to a 33 percent reduction in energy intensity between 2005 and 2020. This is the central estimate for energy intensity used in the present study's *Previous Commitments* scenario.

Australian National University study: Stern and Jotzo of Australian National University have performed an in-depth of analysis of the emissions intensity reductions that would have occurred in China under a BaU situation. The study proposes three different BaU scenarios – with increasing degrees of optimism – and finds that China's emissions intensity would have naturally dropped by 24, 33. or 38 percent respectively between 2005 and 2020 in business-as- usual.[17] The first two estimates are more pessimistic than the reduction found in the present study (i.e. 37 percent), which would suggest that China's carbon intensity target may be even more ambitious than argued here.

This analysis suggests that thanks to spontaneous trends in its economy and to its achievements in the 11th Five-Year Plan, China could undertake no new efforts on global warming and still achieve a on the order of 33 percent in energy intensity between 2005 and 2020.

LONG-TERM PROJECTIONS TO 2030 AND BEYOND

As one forecasts China's energy demand and economic growth past 2020 and towards a more distant time horizon, the uncertainty associated with the projections becomes greater. For this reason, this study has focused its discussion on evolutions in the upcoming decade. But it is also possible to forecast into the more distant future, so long as the associated level of uncertainty is understood. In order to extrapolate the trends of China's emissions all the way to 2050 for the data in Figure 4, we have relied on the estimates provided by Zou Ji in the Renmin University study.[18] The Renmin University study also examines three policy scenarios of increasing ambition, and through a detailed analysis of the structure of China's economy, energy markets and other factors, finds that the energy intensity of China's economy would decrease by 56, 65, and 72 percent respectively between 2020 and 2050 in these three scenarios.

For long-term estimates of China's carbon factor, we assume a continuous exponential decrease at a pace determined by the overall trend of each scenario. By 2030, China's energy system emits 9, 15, and 23 percent less CO_2 per unit of primary energy than in 2005 in each of our three scenarios, respectively. In the long term past 2040 and beyond, the carbon factor of China's energy consumption is difficult to determine. As in the rest of the world, it will depend on the technological breakthroughs that will determine the affordability of renewable energy, the progress made towards large-scale vehicle electrification, and status of current concerns over nuclear energy, including economic viability.

TECHNICAL APPENDIX ENDNOTES

[1] Climate Analysis Indicators Tool (CAIT). Version 6.0. Washington, DC: World Resources Institute, 2009.

[2] McKinsey & Company. "China's Green Revolution." New York, 2009; Zou, Ji. *"Economy, Energy, Technologies, and GHG Emission in China: a Scenario Study."* Beijing: Renmin University, 2009; Energy Research Institute. *2050 China Energy and Carbon Emissions Report.* Beijing: NDRC, 2009.

[3] The evaluation of China's carbon intensity target depends heavily on the currency used in China's GDP growth predictions. China's carbon intensity target is defined in terms of inflation-adjusted local currency (RMB). In contrast, many agencies such as EIA and IEA express their predictions for China's GDP growth in US dollars converted from RMB using Purchasing Power Parity (PPP). Although PPP-based forecasts for China's carbon intensity would translate into marginally stronger reductions in local currency terms, the difference is expected to be minimal compared with the magnitude of the changes envisioned here.

[4] Massachusetts Institute of Technology, *The Future of Coal*, 2007, and US Environmental Protection Agency, *2010 U.S. Greenhouse Gas Inventory Report*, available at:
http://epa.gov/climatechange/emissions/usinventoryreport.html.

[5] Hondo, Hiroki. "Life cycle GHG emission analysis of power generation systems." The Energy Journal, 2005: 2042–2056.

[6] *China Statistical Yearbook,* China National Bureau of Statistics. (2008).

7 Zou, Ji. "Economy, Energy, Technologies, and GHG Emission in China: a Scenario Study". Beijing: Renmin University, 2009.

8 International Energy Agency (IEA). (2009). World Energy Outlook. Paris.

9 Energy Research Institute (ERI). (2009). 2050 China Energy and Carbon Emissions Report. Beijing: National Development and Reform Commission.

10 U.S. Energy Information Administration (EIA). International Energy Outlook 2009. Washington DC: U.S. Government.

[11] The EU Commission report also draws conclusions from three other models (TIMER/IMAGE, GEM E3 and E3MG), but only the explicit results of the POLES model are available for China in the report.

[12] Chandler, Memo to Copenhagen.

[13] Although China's Medium and Long Term Plan for renewable energy and energy conservation – released in 2004 – did include a long-term goal of reducing energy intensity by 31 percent from 2010 to 2020, its goals were not domestically binding for local governments and ministries.

[14] The theoretical roots of energy demand as it relates to economic development have been laid out by Medlock et al. from the perspective of economic sectors (Medlock & Soligo). From the perspective of energy supply and demand, it has also been shown that even in the absence of climate considerations, energy intensity tends to spontaneously decrease.

[15] May, Michael, *Energy and Security in East Asia*, Stanford University (January 1998)

[16] Kahrl, Frederic, China's Carbon Challenge: Insights from the Power Sector, U.C. Berkeley (November 2006).

[17] Stern, David and Jotzo, Frank. *How Ambitious are China and India's Emissions Intensity Targets?* Environmental Economics Research Hub, Australian National University (March 2010).

[18]Zou, Ji. "Economy, Energy, Technologies, and GHG Emission in China: a Scenario Study. Beijing: Renmin University, 2009.