An Analytical Comparison of Various Influential Models of China's Future Greenhouse Gas Emissions and Global Role

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Projections regarding future energy consumption and carbon emissions are crucial when the aim is to design policy for global emissions control. What is the different models' take on the projections for global emissions and, in particular, China's role in the global picture? Do they anticipate similar results? If not, why are the results different? What key parameters do they use, and how do they affect the final findings? This Article attempts to answer these questions and, starting from there, to further analyze what it means for the challenge of China's future emissions reduction potential and for the overall goal of global emissions reduction.

Introduction

Over the last ten years, China has experienced rapid economic growth, with levels of industrialization and urbanization at their highest in its history. Per capita GDP grew from less than $1000 to $4400, which has made China now the second economic global power. Meanwhile, China has also become the top consumer and manufacturer of the world's energy and raw materials. While GDP grew fourfold, energy consumption in the same period increased by 120%. In 2010, China consumed twenty-five percent of the world's energy, which ranks first in the world. Clearly, global climate action requires China's participation. In the Durban negotiations in December 2011, at the end of the debate over historical responsibility and future responsibility, a mandate was concluded towards a post-2020 agreement that carries with it a level of

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legal force.[1] The developing countries have been included in this aspirational framework. This outcome means that, from 2012 to 2020, the world will undergo a transition period, with the European Union and some developed countries under a legally binding agreement, while other countries carry out their commitments through a "pledge and review" model. Afterwards, if the mandate is carried forward, all the countries will commit under a common legal agreement. China is no exception.

While the legal format appears possibly to have been resolved, the mitigation numbers are still pending for future negotiations to settle. This will almost certainly be a much harder task, as the burden-sharing approach will be much more difficult to pursue than it was in Kyoto in 1997. Specifically, two major challenges loom. One is the mitigation gap. The current commitment made by countries is far from sufficient to ensure that the world stays below a 2°C increase above pre-industrial levels, even with the developing countries made the emission reduction pledges between 2013 to 2020. The International Energy Agency has calculated that the new policy scenario (which refers to the current level of 2020 pledges put forward by countries after the Copenhagen climate negotiations[2]) would lead to a warming of 3.5°C.[3]

The second issue is equity. According to the Intergovernmental Panel on Climate Change (IPCC)'s fifth Assessment Report, developed countries should commit to a twenty-five to forty percent reduction target for 2020 in relation to 1990 levels.[4] However, the current average level of Annex-B countries put forward is only fifteen percent, which is far below the requirements for maintaining some sense of climate stability. For the developing countries, with the larger share of future emissions, the old concept of equity should also be reconsidered regarding future commitments.

In order to better define China's role and significance in the future regime, we need to obtain more knowledge about China's future emission scenarios. In Sections I.A. to I.D., we first collect several case scenarios on energy and/or carbon projections in different time scales, both globally and in China. To complement them, corporate studies like BP's are included for their energy demand and consumption forecasts. When we compare the results from different

1 Report of the Conference of the Parties on Its Seventeenth Session, Addendum, Part Two: Action Taken by the Conference of the Parties at Its Seventeenth Session, *Decision 1/CP.17: Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action*, U.N. Doc. FCCC/CP/2011/9/Add.1 (Mar. 15, 2011).

2 INT'L ENERGY AGENCY (IEA), WORLD ENERGY OUTLOOK 2011 (2012(.

3 *Id.*

4 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), THE 5TH ASSESSMENT REPORT (forthcoming 2013).

models, such as total energy consumption, energy mix, energy consumption by sector and total carbon emissions, indicators like methodology, scenario settings, macro parameters (population, GDP, urbanization rate) should also be compared, in order to better understand the source and context of those results. Since not all studies cover exactly the same topics in the same timescale, the comparison is only feasible between or among similar segments from selected studies. Section I.E. of the Article is more focused on the energy consumption and carbon emissions projections for China, including the impact of the economic growth rate and proportional change in energy sources on energy consumption and carbon emissions, as suggested by these scenarios. Part II concludes.

I. China's Future Emissions Growth Projection

A. Study Overview

Firstly, studies from the International Energy Agency (IEA), U.S. Energy Information Agency (EIA), Laurence Berkeley National Labotory (LBNL), Energy Research Insititute of Chinese Development and Reform Commission (ERI) and BP were selected based on criteria of influence, namely how broadly quoted or updated the report is, and whether it projects both global and China's future emissions.

B. Comparison of Methodologies

Here we compared the settings of various selected models, including methodology, the choice of model, the global emissions reductions and various baseline years adopted. We note that one important element of the model is that most of the scenarios are run either bottom-up or top-down. Top-down and bottom-up are both strategies of information-processing and knowledge-ordering in policy scenario analysis. The top-down approach starts with the big picture, breaking it down from there into smaller segments. Under a top-down approach, an overview of the policy (e.g., reduction target) is formulated, specifying but not detailing any first-level subsystems. Each subsystem is then refined in greater detail. Under a bottom-up approach, the individual base elements of the system (policy in sectors, capability, and others) are first specified in great detail. These elements are then linked together to form larger subsystems, which in turn are linked until a complete top-level system (reduction target and associated policies) is formed. For climate policy, both bottom-up and top-down are used; only ERI's research features a combination of both methods. By comparing these settings, we were able to better understand the level comparison. Results from top-down and bottom-up analysis may be different, but reflect aspects of possibilities, therefore overview and comparison of those results could provide a firmer foundation for further discussion.

Table 1: Study Settings

Study	Methodology	Model	Global emission reduction target	Baseline year	Target year
IEA	Bottom-up	IEA-WEM (World Energy Model)	New policy scenario: 3.5°C 450 scenario: 2°C	2009	2035
EIA	Top-down	EIA-WEPS+ (World Energy Projections Plus) model	None	2008	2035
LBNL	Bottom-up	LBNL China End-Use Energy Model	None	2000	2050
Renmin University	Bottom-up	N/A	None	2010	2050
ERI	Both bottom-up and top-down	IPA-CGE, IPAC-AIM/Technology, IPAC-Emission	None	2005	2035
BP	Bottom-up	N/A	None	2010	2030

C. Comparison of Scenario Settings

Data inputs, including assumptions on society, economics, technology and other important factors, determine the final energy consumptions we are looking for. There are generally two types of scenarios: the scenario under the current policy framework, or the scenario under a new policy framework. In the selected studies, scenarios with more detailed assumptions were examined as a foundation for further energy and/or carbon projections.

In all the studies, a baseline scenario and comparative scenario were examined. In the IEA study, the baseline scenario is the "current policy scenario," which assumes no new policies are added to those in place as of mid-2011, meanwhile illustrating the value of these commitments and plans.[5] In the study, two comparison scenarios — "new policy scenario" and "450 scenario" — were examined. The new policy scenario assumes recent government policy commitments will be implemented in a cautious manner, even if they are not yet backed up by firm measures.[6] And the 450 scenario — unlike the rest of the scenarios, which are forecasts — is a backward-looking scenario to assess what needs to be done to limit the long-term increase of the global temperature to 2°C above pre-industrial levels.[7]

In the EIA study, the baseline scenario served as the "reference case," which did not incorporate prospective legislation or policies that might affect energy markets.[8] It is a more market-oriented study, therefore the low oil-price case and high oil-price case were examined as comparative scenarios. High and low oil-price scenarios typically examine the impacts of changes in liquids supplies relative to the reference case, based on different assumptions about the Organization of Petroleum Exporting Countries (OPEC)'s decision-making and access to non-OPEC resources and their impacts on world liquids supply.[9]

In the LBNL study, the baseline scenario was a "continued improvement scenario" (CIS) in which (1) current technologies will not remain frozen in place; (2) the Chinese economy will continue on a path of lowering its energy intensity as a function of GDP; and (3) efficiency improvements are consistent with trends in "market-based" improvement, achieving levels that are common in industrialized countries.[10] The comparative scenario was an "accelerated improvement scenario" (AIS), which assumes (1) a much more aggressive trajectory towards current best practice and implementation of important alternative energy technologies; and (2) consideration of efficiency targets at the level of end-use technologies, with Chinese subsector intensities being lowered by implementation of the best currently available products and processes in the short to medium term, taking into account that time is needed for these technologies to penetrate the stock of energy-consuming equipment.[11] To emphasize the potential contribution from carbon capture and storage (CCS), the LBNL study adds a "continued improvement with CCS scenario," which assumes (1) the same generation capacity as the CIS scenario; (2) sufficient CCS-enabled coal capacity to capture and sequester

5 IEA, *supra* note 2, at 54.

6 *Id.* at 55.

7 *Id.*

8 U.S. Energy Info. Admin., International Energy Outlook 2011, at 1 (2012).

9 *Id.* at 27.

10 Nan Zhou et al., *China's Energy and Carbon Emission Outlook to 2050*, at 2 (Lawrence Berkeley Nat'l Laboratory, Working Paper, 2011), *available at* http://escholarship.org/uc/item/4sz7t1tf#page-1.

11 *Id.* at 3.

500 million tons of CO_2 in 2050 — a level calculated following trend lines in the 2009 World Energy Outlook 450 ppm scenario; and (3) ninety percent capture of carbon emissions for pre- and post-combustion technologies, with additional energy requirements of CCS for carbon separation, pumping and long-term storage.[12]

In the ERI study for China's future energy and carbon emission, the reference scenario took domestic development needs into full consideration. The study made the assumption that per capita energy consumption would be ten percent lower than current highly energy-efficient countries by 2050, while China became a medium developed country, under a business as usual (BAU) scenario.[13] In this study, the comparative scenario was more comprehensive than the others because three scenarios were examined. The energy conservation scenario[14] is a model that takes into full consideration the current energy conservation measures, although without a specific policy to tackle climate change. Under this scenario, changes would occur in the economic development model. Energy-intensive production will maintain a relatively high level. City transport will improve in efficiency and convenience, while the public transport system would not to be expected to advance. Energy-efficient equipment, nuclear and renewable energy manufacturing would develop. The key mitigation technologies would not make a breakthrough. CCS would still be lacking economic feasibility. The public will not yet have adopted a resource-stringent way of life and consumption.[15]

The low-carbon scenario[16] takes into consideration China's sustainable development, energy security and economic competitiveness, the capacity for emissions reduction, as well as the conditions of the changing economic development model, production and consumption patterns, and enhanced technical development. It is an ambitious domestic action model, which is unilateral. Also, energy-efficient equipment, nuclear and renewable energy manufacturing development would accelerate and scale up. CCS has been reasonably disseminated, especially in the power sector. Under the circumstances the overall economy has developed well, the investment in a low-carbon

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12 *Id.*

13 Energy Res. Inst. (ERI), China 2050 Low Carbon Development Pathway — Energy Needs and Carbon Scenario Projection (2010).

14 Further in this Article, when we present ERI's reference scenario, it actually refers to its energy conservation scenario, because it assumes that the current energy conservation policies will continue as it committed early on, and therefore could be seen as a reference model.

15 ERI, *supra* note 13.

16 *Id.*

economy has made substantial progress, and a resource-conserving production and consumption model would emerge.

The enhanced low-carbon scenario[17] is under the condition of international cooperation and a global aspirational mitigation goal to control the temperature increase, in which a joint effort will be made by both the developed and developing countries. Major technologies would be developed further than BAU, amongst which key technologies will make a breakthrough. The cost for the main mitigation technologies would be significantly lower, and their application much wider. Under this scenario, there would also be a better external environment for Chinese low-carbon energy, to improve the Chinese energy portfolio and international research and development (R&D) and investment. Meanwhile, the Chinese government could further increase the public investment in low-carbon technologies and make a remarkable breakthrough in clean coal and CCS, especially CCS, which would be broadly applied.

In the BP study, the baseline scenario assumes policy efforts to curb emissions via carbon prices, mandates and low-carbon technologies. The precise policy details will determine the fuel mix — particularly the role of gas.[18] And the policy case was the comparative scenario, which assumed that a wide range of policy tools will have been deployed, including putting a price on carbon. Richer countries achieve significant cuts in carbon emissions, while developing countries focus on reducing the carbon intensity of their economies.[19]

D. Comparison of Macro Parameters

In the greenhouse gas (GHG) emissions and energy consumption scenario models, GDP, population, and urbanization rate are the most frequently used macro parameters. This is partly because energy consumption is closely linked to economic development, which is largely shaped by these three basic parameters. Also, these are the easiest ones to forecast with least errors which contribute to the accuracy of final energy projections. Table 2 presents projections of GDP annual growth rate.

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17 *Id.*

18 BP, BP Energy Outlook 2030, at 53 (2011), *available at* http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2012.pdf.

19 *Id.* at 6.

Table 2: GDP Annual Growth Rate Comparison (%)

			Period		
			2005-2020	2020-2035	2035-2050
IEA	Global	In all scenarios	3.6[20] (2009-2035)		N/A
	China	In all scenarios	8.1[21] (2009-2020)	4.3[22] (2020-2035)	N/A
EIA	Global	Reference case	3.4 (2008-2035)[23]		N/A
		High oil case	4 (2008-2035)		N/A
		Low oil case	1.3 (2008-2035)		N/A
	China	Reference case	3.0 (2008-2035)		N/A
		High oil case	3.7 (2008-2035)		N/A
		Low oil case	2.4 (2008-2035)		N/A
LBNL	Global	N/A	N/A	N/A	N/A
	China	In all scenarios	9.4 (2000-2010)[24] 7.7 (2010-2020)[25]	5.9 (2020-2030)[26]	3.4 (2030-2050)[27]
ERI	Global	N/A	N/A	N/A	N/A
	China	In all scenarios	8.8[28]	6[29]	4[30]
BP	Global	In all scenarios	3.7 (2011-2030)	N/A	N/A
	China	N/A	N/A	N/A	N/A

The IEA, EIA and BP studies have a similar assumption regarding the global GDP growth rate, from 3.6% to four percent, but different projections for China. IEA makes the lowest assumption of 8.1% during the period 2009-2020, then sharply decreasing to 4.3% from 2020 to 2035. The assumption of the local research institute, ERI, which is also the major think tank for China's policymakers, is higher than IEA's, at 8.8% during the period 2005-2020, then six percent in 2020-2035, and four percent in 2035-2050. LBNL's assumption is similar to ERI's, although not in exactly the same timescale.

As the second parameter, population is projected. Like the projections of GDP annual growth, projections of the global population growth presented

20 IEA, *supra* note 2, at 57.
21 *Id.*
22 *Id.*
23 IEA, *supra* note 2, at 9.
24 Zhou et al., *supra* note 10, at 6.
25 *Id.*
26 *Id.*
27 *Id.*
28 ERI, *supra* note 13, at 11.
29 *Id.*
30 *Id.*

in all the scenarios are almost the same, at an average growth rate of 0.9%. In reference to China, the annual growth is projected to be 0.1% by IEA and ERI; however, EIA expects a growth rate three times higher at 0.3%.

Table 3: Population Comparison of China (Billions)

			Period					Average growth rate (%)
			2005-2010	2010-2020	2020-2030	2030-2040	2040-2050	
IEA	Global	In all scenarios	6.8[31] (2009)	N/A	N/A	8.6[32] (2035)	N/A	0.9
	China	In all scenarios	1.34[33] (2009)	N/A	N/A	1.39[34] (2035)	N/A	0.1
EIA	Global	In all scenarios[35]	6.73 (2008)	7.26 (2015)	7.61 (2020)	8.45 (2035)	N/A	0.9
	China	In all scenarios[36]	1.33 (2008)	1.39 (2015)	1.42 (2020)	1.45 (2035)	N/A	0.3
LBNL	Global	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	China	In all scenarios	1.31[37] (2005)	N/A	N/A	N/A	1.41[38] (2050)	N/A
ERI	Global	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	China	In all scenarios	1.37[39] (2010)	N/A	N/A	Peak during 2020-2030 at 1.47 bn[40]	2050 — 1.46 bn[41]	N/A
BP	Global	In all scenarios	N/A	N/A	N/A	N/A	N/A	0.9
	China	N/A	N/A	N/A	N/A	N/A	N/A	N/A

31 IEA, *supra* note 2, at 58.
32 *Id.*
33 *Id.*
34 *Id.*
35 *World Total Primary Energy Consumption by Region, Reference Case*, U.S. ENERGY INFO. ADMIN., http://205.254.135.7/oiaf/aeo/tablebrowser/#release=IEO2011&subject=0-IEO2011&table=1-IEO2011&region=0-0&cases=Reference-0504a_1630 (last visited Feb. 22, 2012).
36 *Id.*
37 Zhou et al., *supra* note 10, at 6.
38 *Id.*
39 ERI, *supra* note 13.
40 *Id.*
41 *Id.*

Thirdly, although urbanization is one of the key factors influencing infrastructure construction, commercial and residential energy consumption and transportation development, only the studies focused on China — by the LBNL and ERI — made specific projections of China's urbanization rate and took consideration of urbanization as one parameter. This may be because these two organizations valued impacts of urbanization on carbon emissions. Both organizations assumed that the urbanization rate would reach seventy-nine percent by 2050.[42]

E. Comparison of Results

After all the macro parameters are set, the results of the various models can be compared. The conclusions regarding energy demand, energy mix, energy consumption from the sectors, as well as carbon emissions were respectively drawn.

1. Total Primary Energy Demand

Table 4 below summarizes the projections of total primary energy demand from the various studies we selected for this comparison. In order to make the figures comparable and consistent, we chose to use million tons oil equivalent (Mtoe) and million tons coal equivalent (Mtce) as the statistical units.

The results show that the various models share both similarities and differences in regard to global emissions growth. In the IEA study, under the new policy scenario, the global energy consumption will keep growing, albeit at a slower pace than under the current policy scenario, but still far beyond what the 450 ppm scenario requires, which is for global energy consumption to peak between 2015 and 2020. EIA's reference case yields a similar result to IEA's current policy scenario, in this comparison. However, its energy price-oriented consumption projection has a lower figure under a low energy price scenario. The BP scenario, on the other hand, is rather closer to IEA's new policy scenario in its conclusion.

Within their global scenarios, IEA, EIA, and BP have calculated China's future energy consumption. Among these three scenarios, IEA's is the most optimistic. EIA's reference scenario and BP's, which drew its conclusions mainly from energy demand, yield similar findings. Especially for the period 2020-2030, EIA and BP have assumed that China would still undergo rapid development. Under high oil price conditions, China's energy consumption would soar.

42 Zhou et al., *supra* note 10, at 5.

Table 4: Total Primary Energy Demand Comparison (Mtce)

			Period						Average growth rate (%)
			2009	2015	2020	2030	2035	2050	
IEA	Global	New policy scenario[43]	12150	13913	14769	16206	16961	N/A	1.3 (2009-2035)
		Current policy scenario[44]	12150	N/A	15124	18302	N/A	N/A	N/A
		450 scenario[45]	12150	N/A	14185	14870	N/A	N/A	N/A
	China	China — New policy scenario	2271	3002	3345	3678	3835	N/A	2.0 (2009-2035)
		China — Current policy scenario	2271	N/A	3465	4068	4361	N/A	2.1(2009-2035)
		China — 450 scenario	2271	N/A	3186	3148	3152	N/A	–1.3 (2009-2035)
EIA	Global[46]	Reference case	12702.82	14463.11	15623.18	18195.52	19413.6	N/A	1.6 (2008-2035)
		High oil price case	12702.82	14228.57	15764.41	19514.8	21419.65	N/A	2.0 (2008-2035)
		Low oil price case	12702.82	14758.17	15766.93	17438.95	18008.9	N/A	1.3
	China[47]	Reference case	2243.7	3132.202	3545.794	4486.464	4826.921	N/A	3.0 (2008-2035)
		High oil price case	2243.7	3099.418	3709.718	5172.42	5823.072	N/A	3.7 (2008-2035)
		Low oil price case	2243.7	3190.206	3520.575	4065.306	4148.529	N/A	2.4

43 IEA, *supra* note 2, at 544.
44 *Id.* at 545.
45 *Id.*
46 U.S. ENERGY INFO. ADMIN., *supra* note 35.
47 *Id.*

			Period						Average growth rate (%)
			2009	2015	2020	2030	2035	2050	
LBNL	Global	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	China[48]	CIS	1533.4 (2005, estimate from figure)	N/A	N/A	3633.461	N/A	3820.257	3.4 (2005-2050) 0.3 (2030-250)
		AIS	N/A	N/A	N/A	3119.075	N/A	3176.926	N/A
		CIS-CCS	N/A	N/A	N/A	3666.917	N/A	3845.349	N/A
	China[49]	Energy conservation scenario	1525.4542 (2005)	N/A	3357.45	3943.28	N/A	4640.14	N/A
		Low carbon scenario	1525.4542 (2005)	N/A	2785.14	3118.31	N/A	3659.25	N/A
		Enhanced low carbon scenario	1525.4542 (2005)	N/A	2732.94	2979.4	N/A	3500.33	N/A
BP[50]	Global	In all scenarios	10800.9 (2005)	13360.4	14627.1	16631.6	N/A	N/A	N/A
	China	N/A	1691.5 (2005)	3117.6	3688	4431.2	N/A	N/A	N/A

1 Quadrillion Btu = 10^9 MMBtu; 1 MMBtu = $2.52*10^{-8}$ Mtoe; 1 Mtce = 0.697 Mtoe

48 Zhou et al., *supra* note 10, at 30.
49 Jiang Kejun et al., *China's Low-Carbon Scenarios and Roadmap for 2050: Energy Needs and Carbon Scenario Projection*, 14 SINO-GLOBAL ENERGY 1 (2009).
50 BP, *supra* note 18, at 40.

The rest of the projections are mainly modeled to forecast China's future energy consumption. The timeline has been respectively set in 2015, 2020, 2030, 2035 and 2050. We will specifically analyze the 2015 projection, because it is closely linked with China's twelfth five-year plan (2011-2015), currently under implementation.[51]

Regarding the 2020 projection for China, IEA, EIA, ERI, and BP have provided the result. IEA's new policy scenario is the lowest. EIA's three scenarios — reference, high oil price, and low oil price — are in the midrange, the difference between them being 200 Mtoe. BP has a similar result in the high oil price case before 2020, then falling in-between the high oil price case and reference case. ERI's energy conservation scenario is only twelve Mtoe higher than the IEA scenario. On the other hand, the ERI's enhanced low-carbon scenario, which should be the most ambitious, with global cooperation as the condition, is 613 Mtoe lower than IEA's new policy scenario, and ERI's more practical low-carbon scenario is 560 Mtoe higher than IEA's, which indicates that China would have to invest considerable effort to achieve it.

According to IEA, from 2010 to 2035, non-OECD countries will account for ninety percent of global population growth, seventy percent of the increase in economic output, and ninety percent of energy demand growth. Amongst them, China will account for half of the new energy demand growth. This projection attests to the crucial role of developing countries in the future global climate deal, and China's significance in particular.

By comparison, the LBNL and ERI studies set the figure at about twenty percent lower, say 3943 and 3633 Mtoe in the reference scenarios. If we look at ERI's projection for 2020, all three scenarios — including the most ambitious, the enhanced low-carbon scenario — are lower than any other model's studies, but somewhat approach the LBNL results. That is interesting, because if we look back at all the major macro parameters being input into the modeling, we'll find that ERI's projection — which was produced by Chinese researchers — sets annual GDP growth from 2010 to 2020 at 8.8%, which is the highest among all the other cases. This means that more low-carbon development efforts are needed under a higher GDP growth assumption. It may also indicate that structural adjustment and technology innovation would greatly contribute to decreasing energy consumption; as ERI has mentioned in their scenario description, a low-carbon pathway requires radically change of the economic development model, as well as the breakthrough and penetration of

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51 APCO Worldwide, China's 12th Five-Year Plan: How It Actually Works and What's in Store for the Next Five Years 6 (2010), *available at* http://apcoworldwide.com/content/PDFs/Chinas_12th_Five-Year_Plan.pdf.

Figure 1: The Total Global Primary Energy Demand (Mtoe)

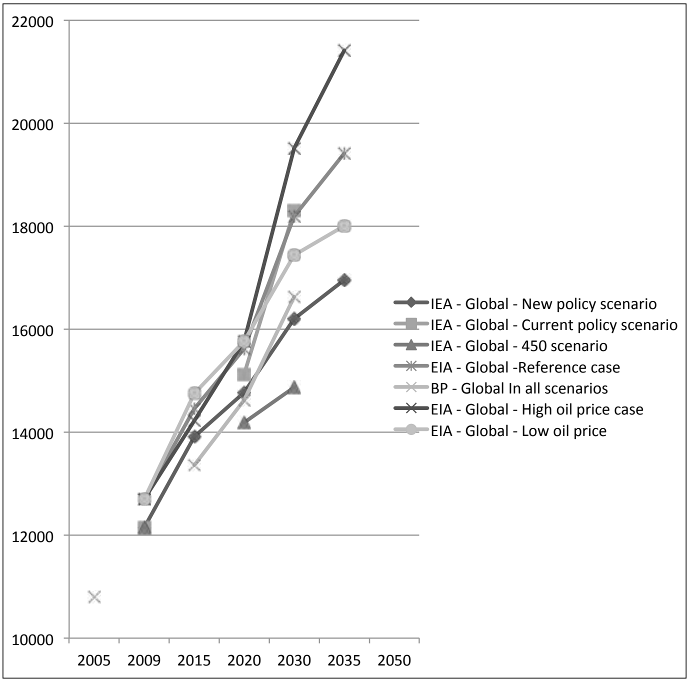
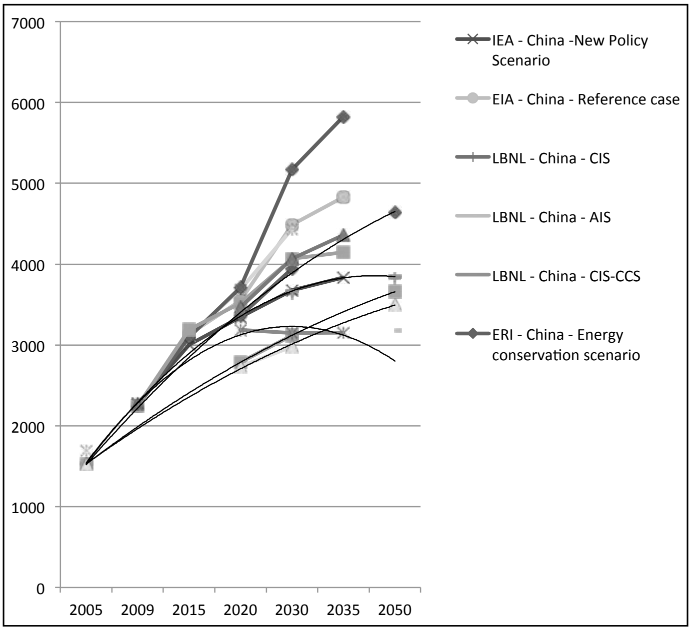


Figure 2: The Total Primary Energy Demand of China (Mtoe)



low-carbon technologies. This also indicates that China's energy consumption is unlikely to peak in the short term.

As seen in Figure 2, both LBNL's CIS and AIS are close to IEA's 2020 results for its reference scenario and its alternative, low-carbon, 450 ppm scenario. Furthermore, the CIS, AIS, ERI, and IEA studies are all close to each other in their results for before 2035. This means that the assumption regarding economic growth is the major determinant of projected energy consumption. The reason EIA's projection is higher is because of its higher assumption regarding future GDP growth.

However, projecting China's future GDP is difficult, as researchers know. Reviewing the previous record, many domestic researchers, including ERI, have severely underestimated that growth. In order to understand which projection is closer to the reality of development in China, we should trace back the trend in China's energy consumption and its relation with GDP growth.

Until 2003, China's energy consumption had not grown so rapidly. Between 1995 and 2000 total energy consumption grew from 1300 Mtce to 1386 Mtce. However, since 2005, the figure had increased to 2220 Mtce in five-years period. The changing trend was very powerful. Even in the eleventh five-year plan (2006-2010), the growth rate was slower than the previous five years, yet the controlling target for internal energy consumption was not met. Table 5 shows the swelling of energy consumption in the mid-2000s and the visible trajectory change since 2006.

As the table also shows, by the end of 2010 China's energy consumption had already reached 3250 Mtce, higher than any institute's projection for 2015, including that of China's leading energy policy research institute — ERI. Its energy conservation scenario, which is the relatively conservative projection for 2015 energy consumption, is 3100 Mtce. The figure of 3250 Mtce also overshot the official government target by twenty percent.

Table 5: China's Total Energy Consumption and Annual Growth Rate[52]

Year	Energy consumption totality (Mtce)	National planning period	Annual growth (%)
1995	1300		
2000	1386	9th 5-year plan	1.3
2005	2220	10th 5-year plan	9.9
2010	3250	11th 5-year plan	7.9

Not only was the academic estimation of GDP growth low, but the GDP growth target set by the government was low as well. Table 6 shows the

52 State Statistical Bureau, Annual Statistic Book 1995-2010.

original target setting and the final implementation result during the eleventh five-year plan. Despite the global financial crisis, actual GDP growth still features a large leap. From the energy data, we see that the government's four trillion CNY stimulus package had a big impact, because the country had almost reached the twenty percent intensity target at the end of 2009, but the trend suddenly changed after the big infusion of finance arrived. Ultimately, an energy intensity improvement of only 19.1% was achieved a year later.

Table 6: Eleventh Five-Year Plan Target and Result[53]

	Eleventh five-year plan official target	Result of implementation
Annual GDP growth	7.5%	11.2%
Energy consumption reduction per unit GDP (energy intensity)	20%	19.1%
Total energy consumption	2700 Mtce	3250 Mtce
Forest coverage	20%	20.36% by Nov 2009
Forest volume	N/A	N/A

Therefore, the projection figures for 2010 in Table 6 have all been invalidated. It is time to look at the new government's twelfth five-year plan and its possible impact on the different implementation scenarios. Table 7 shows the new targets up to 2015, including intensity targets and a nonbinding energy consumption cap. As the Chinese government has announced, the country has adopted a carbon intensity target with the aim of reducing forty to fifty percent of carbon emissions per GDP unit by 2020 relative to the 2005 baseline. Therefore, the success of the 2011-2015 targets will be critical for the final fulfillment of the 2020 target.

GDP again is crucial for the final result for energy consumption, which in large extent indicates the level of carbon emissions. We will compare the projections of carbon emissions below. As estimated, if the GDP annual growth rate reaches eight percent, and if a sixteen percent intensity target is achieved as well, total energy consumption will stand at 4000 Mtce. Basically, 8.5% is the line where sixteen percent could be achieved with an energy consumption of 4100 Mtce. If GDP reaches ten percent annual growth during the five-year plan, energy intensity then needs to exceed twenty percent in order to meet the 4100 Mtce energy consumption target.

53 CHINESE CENTRAL GOVERNMENT, NATIONAL DEVELOPMENT PLAN AND REPORT ON GOVERNMENT WORK (2012).

Table 7: Twelfth Five-Year Plan Official Target and Its Legal Character[54]

	Eleventh five-year plan official target	Legal character of the target
Annual GDP growth	7%	Perception
Energy consumption reduction per unit GDP (energy intensity)	16%	Binding
Carbon reduction of per unit GDP (carbon intensity)	17%	Binding
Clean energy, including renewable energy proportion in primary energy consumption	11.4%	Binding
Total energy consumption	4100 Mtce	Nonbinding
Forest coverage	21.66%	20.36% by Nov 2009

Therefore, according to various domestic and international institutes, it will be more difficult to achieve the twelfth five-year plan's intensity goal than that of the eleventh five-year plan. That is because the low-hanging fruits have been harvested early on: Remaining mitigation opportunities are more costly, and further institutional barriers may need to be overcome, especially since China is still undergoing rapid urbanization and industrialization, while the energy demand from building and transport is booming and will severely challenge the implementation of the above targets.

2. Energy Mix

Beyond contributing to our understanding of the total energy consumption, the energy sources in the future portfolio are also crucial to forecasting the GHG emissions from energy consumption, which would directly affect climate. In this case, the average growth rates of various energy sources are important to illustrate the energy landscape. If the low-carbon technologies, such as nuclear, hydro and renewable, claim a bigger share of the country's energy portfolio, it would be carbon-benificial. Otherwise, the energy strcuture will be more carbon-intensive, especially due to coal combustion power generation.

54 Nat'l People's Cong., 2011 Government Work Report (2012) (except for total energy consumption).

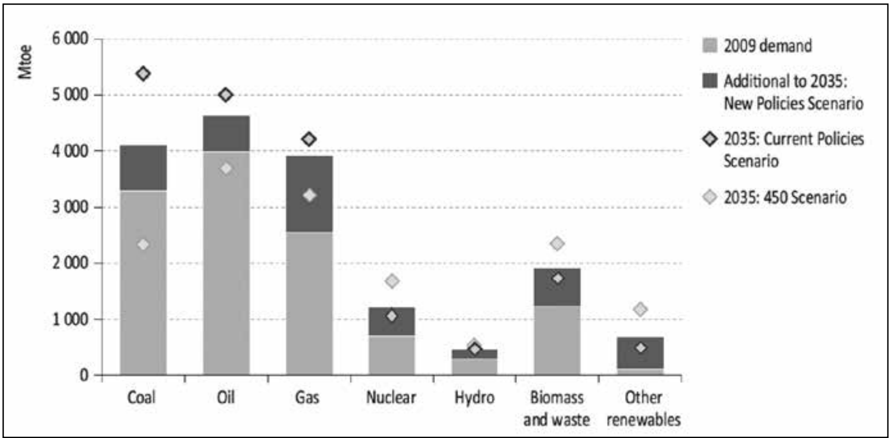
Table 8: Comparison of IEA and EIA World Energy Consumption Growth by Energy Mix, 2020-2035 (Average Annual Growth %)[55]

Energy	IEA	EIA
Coal	1.4	1.6
Liquid	0.9	0.9
Natural gas	1.4	1.6
Nuclear	1.1	1.9
Renewable/others	1.5	1.9
Total	1.3	1.5

Table 8 shows that IEA's and EIA's projections are quite similar, with the most noticeable differences for nuclear and renewable.

IEA's projection can give us a better idea of the total amount of each energy source, in their scenarios. Figure 3 show that the intensity and vigor with which energy and environmental policies are implemented in the different scenarios has a particularly strong impact on the outlook for coal and renewables, but in opposite directions. In the Current Policies Scenario, coal represents nearly thirty percent of the energy mix in 2035, renewables fourteen percent. In the 450 Scenario, the share of coal in total energy demand declines to less than sixteen percent in 2035, while that of renewable increases to twenty-seven percent.

Figure 3: World Primary Energy Demand by Fuel and Scenario, 2009 and 2035 (Mtoe)[56]



55 U.S. Energy Info. Admin., *supra* note 8, at 287.
56 IEA, *supra* note 2, at 72.

There are also some other findings in regard to the energy mix. The share of fossil fuels in world primary energy will fall, but very slowly. IEA forecasts it to be eighty-one percent in 2010 and seventy-five percent in 2035. The shares of oil and coal both will fall as well, but according to EIA's research, coal would still be dominant until 2035. At the same time, improvement in power generation efficiency (five percent higher) and an accelerated move away from the least efficient combustion technologies would lower CO_2 emissions from the power sector by eight percent. Natural gas is the only fossil fuel which will increase its share in the global mix over the period to 2035 in the global scenarios. The above scenarios recognize that natural gas is an increasingly important energy source to help meet rising electricity demand, as well as needs for a variety of other applications.

In addition, renewable energy technologies, led by hydropower and wind, account for half of the new capacity installed to meet growing global demand. China is expected to rapidly increase its utilization of hydro, wind, and nuclear. For example, in China, wind generation accounted for only two percent of total renewable generation in 2008, but would increase to twenty-two percent of the 2035 total according to the EIA reference case.

Globally, renewables are growing fast because of subsidies. For example, IEA forecasts that the share of non-hydro renewables in power generation will increase from three percent in 2009 to fifteen percent in 2035, underpinned by annual subsidies to renewables that will rise almost fivefold to $180,000,000,000 during that period. With that amount of subsidies to renewables, by 2035 increased use of renewables would reduce energy-related CO_2 emissions by 3.4 Gt in the New Policies Scenario, compared to the fuel mix in 2009.

Unconventional gas and liquids are very much emphasized by both IEA and EIA, including oil sand, shale gas, tight gas, deep-water, and coal-bed methane. Their share of output rises from thirteen percent in 2009 to above twenty percent in 2035, on the assumption that the industry is successful in dealing with environmental challenges (IEA). Shell, however, comments that "[h]ow unconventional oil from oil sands, shale, and coal is developed provides a typical Scramble example of solutions being introduced with immediate benefits to energy security but some later negative consequences."[57]

Energy security is a crucial issue for China as well. Net import dependency of oil is projected to increase from thirty-eight percent in 2005 to seventy-two percent in 2030, as the Asia Pacific Economic Corporation (APEC) predicted, which makes China's relationships with resource-exporting countries like

57 Shell Int'l BV, Shell Energy Scenarios to 2050, at 20 (2008), *available at* http://www.manicore.com/fichiers/Shell_scenarii_to_2050.pdf.

Russia crucial. In both scenarios of LBNL's study, China remains a net importer of oil and natural gas and becomes highly dependent on imports: up to ninety-seven percent by 2050, based on its remaining proven oil and gas reserve base.[58] Even with substantial expansion of proven reserves, China's import dependency would remain at over seventy-five percent in 2050.

What's worse, although China is well-known for its coal reserves, ranking right behind the United States and Russia,[59] the remaining extractable coal reserves can accommodate extraction levels of up to over 4,000,000,000 tons per year, meeting the CIS demand for only a relatively short period. Unless China's reserves turn out to be larger than current estimates, China will be increasingly dependent on coal imports in the long run, especially by 2050. At the lowest level of extraction such as under the AIS, domestic reserves may be sufficient and will last considerably longer, according to LBNL.

ERI in its three scenarios — reference, low-carbon, and enhanced low-carbon — has projected the share changes in the energy sources portfolio. The 2005 pie chart in Figure 4 shows the actual numbers as the base year for comparison. From ERI's 2010, 2020, 2030, 2040, 2050 projections, we have chosen to similarly present only those for 2020 and 2030, the two timelines more relevant to short- and medium-term policies, under the reference, low-carbon and enhanced low-carbon scenarios, respectively.

The first chart in Figure 4 presents the 2005 energy source portfolio for China. This set of data is the actual figures from official statistics of that year, provided in this case as reference for the projections. The share of coal, oil and gas in primitive energy consumption is almost ninety-three percent, hydro accounts for 6.01%, and nuclear and wind energy nearly one percent. Coal, which is the main energy source of power production, accounts for 70.2%.

ERI's projections in the three scenarios for 2020 show quite significant changes in the portfolio. In ERI's 2020 reference scenario, due to the contribution of technology development and the goal of improving environmental quality, coal's share in primitive energy consumption would decline to 62.08%. Meanwhile, oil, natural gas, nuclear, wind and other new energy will have taken over the lost share. Furthermore, in ERI's 2020 low-carbon scenario, the share of coal would decline to 54.93%, oil would increase a bit, and the share of natural gas, hydro and nuclear instead would significantly contribute to decarbonizing energy consumption. Interestingly, the enhanced low-carbon scenario seems to place its hopes for further mitigation in three factors, global cooperation on climate change, a change of the economic development model,

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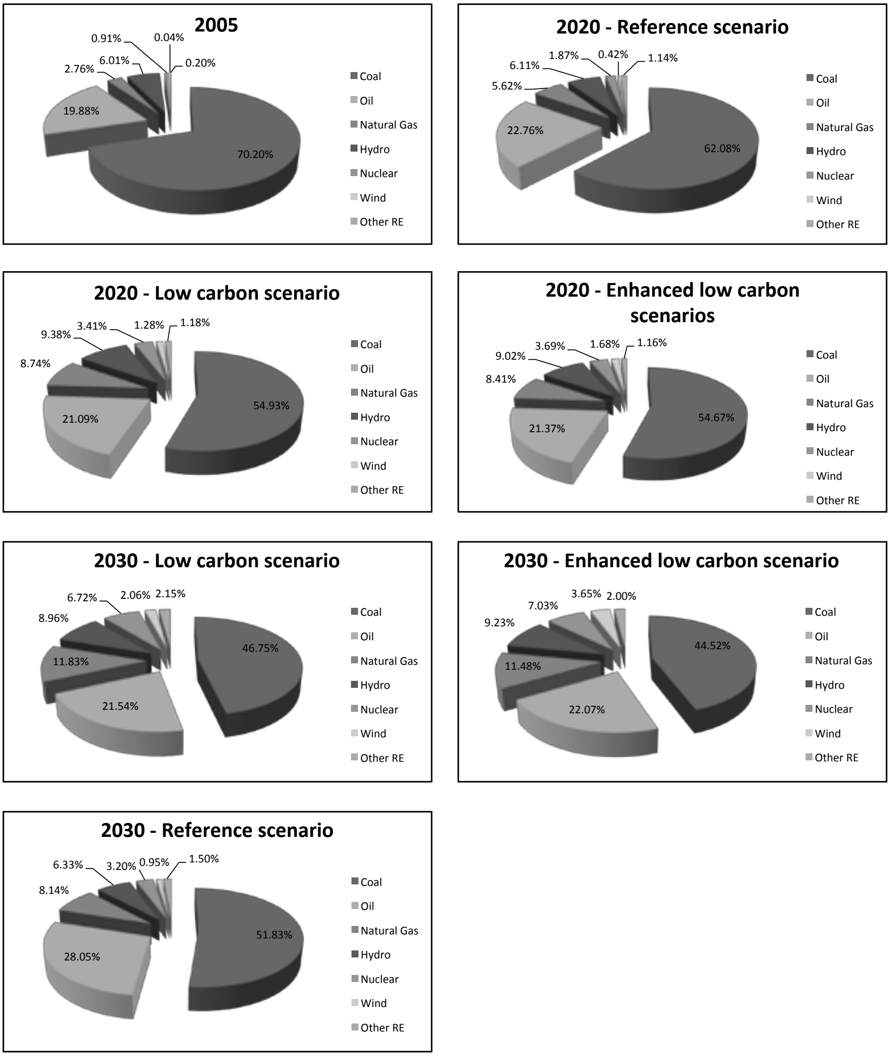
58 Zhou et al., *supra* note 10, at 62.

59 Peter Fairley, *China's Coal Future*, 110 Tech. Rev. 36 (2007).

and the growing application of climate technologies, rather than further improvement in the energy source portfolio.

Figure 4: ERI's Energy Portfolio Projections for 2020 and 2030[60]



The 2030 scenarios are similar, although the trend is slightly different for various technologies. Compared to the 2020 reference scenario, coal's share is down to fifty-one percent in 2030 from 62.08%; oil grows to twenty-eight

60 ERI, *supra* note 13.

percent from 22.76%; natural gas would also increase by about 2.5%; and the growth rate of nuclear and wind energy would be much higher than hydro. In the 2020 low-carbon scenario, the shares of coal and oil would obviously drop, leaving more room for the growth of natural gas and nuclear, as well as wind and other technologies. And, in the enhanced low-carbon scenario, the similar portfolio change would be further reinforced under the same conditions as mentioned above in regard to the 2020 scenario.[61]

Since ERI's scenarios were modeled with a combination of both the top-down and bottom-up approaches, the results included the economic growth and technology development forecasts, which derive from the bottom-up approach, and emissions controls, which stand for the top-down approach.

As one of the major contributors to a low-carbon future, the energy mix very much depends on how various technologies are incentivized or de-incentivized by the different policies. There is obvious potential to bridge the gap between the reference scenario and the low-carbon scenario. However, when it comes to the enhanced low-carbon scenario, the potential becomes much smaller, due to the cost and the technical bottleneck of these technologies. This means that the energy mix's significance is quite limited when it comes to implementing a global peak and emissions reduction pathway under a 450 ppm scenario. Therefore, the reduction efforts from the demand side would also be critical.

3. Total Carbon Emissions Comparison

We have compared China's future energy consumption and energy mix above. However, the overall purpose of this Article is to see what exactly are the projections for China's carbon emissions and the reduction potential in them, which would impact upon the country's position at international climate negotiations. Therefore, it is necessary to review the available carbon emissions projections.

As we've seen, in IEA's New Policies Scenario, which would result in a global average temperature increase of 3.5°C, non-OECD countries account for ninety-three percent of the projected increase in world primary energy demand. China — which IEA preliminary data suggests overtook the United States in 2009 to become the world's largest energy user despite its low per capita energy use — contributes thirty-six percent to the projected growth in global energy use.[62]

By comparison, IEA's projection is lower than EIA's, but not by much as regards the global projection. The difference in the projections for China is

61 In this Article, we only present up to 2030, while leaving 2040 and 2050 out, because the this have less indication for policy at this moment.

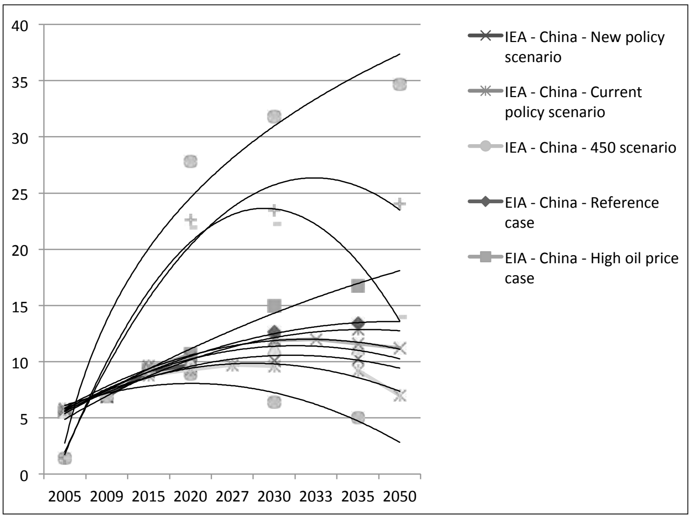
62 IEA, *supra* note 2, at 551-616.

relatively more significant, and is directly caused by their different assumptions regarding GDP growth. However, ERI's projection is almost twice as high as both EIA's and IEA's. That would appear to stem from different assumptions regarding energy efficiency, the prospect of renewables development, and the urbanization rate in China.

As Figure 5 shows, almost all the projections follow a similar trend; only two scenarios show a trajectory of sharp decrease, namely ERI's enhanced low-carbon scenario and IEA's 450 scenario. What these two scenarios have in common is that they both set the condition of progressive global cooperation, although the 450 scenario requires a much earlier peak time and the two scenarios do not meet at the 2050 point. That is because the IEA's 450 ppm scenario refers to the containment of temperature rise to 2°C, while ERI's enhanced low-carbon scenario is still run from China's perspective; it posits global demand for radical emissions reduction. So even if its steep reductions after peak year are very radical from an economic and technical point of view, the emissions pathway is still beyond what the global emissions reduction vision has set to protect the climate.

Upon review of the above scenarios, there is an evident gap between China's projected emissions under global emissions reduction assumptions and China's voluntary efforts. The means to minimize the gap is still not very clear, since economic growth and the energy mix under Chinese circumstances could vary largely in the future.

Figure 5: Carbon Emissions Comparisons (Million Tons)



II. Conclusion: China's Role in Future Global Emissions Reduction

Besides emissions on a country basis, there is another, more just basis for assessing a country's responsiblity for emissions reduction in climate negotiations: per capita emissions. Currently, per capita emissions in China stand at 6.2 tons, which is above the world average of 4.9 tons per capita. According to IEA's projection, China's per capita emissions would reach the European Union level by 2015. In fact, China's per capita emissions have already exceeded the United Kingdom's and Spain's in past years, although specifically at a time of accelerated development. In light of the above presentation and comparison of projections of China's future role in global energy and carbon emissions growth, the pressure is likely to grow on China to cut its emissions as the scientific alarm bells get louder and louder.

The Chinese leadership has argued that two factors should be taken into consideration when comparing per capita emissions. One is China's current developmental stage, which entails a huge amount of emissions from infrastructure construction. A second factor is the embedded emissions in China's exported commodities. At present, China's emissions stem mainly from the manufacturing sector, rather than the consumption sector. However, the emissions from the building and transport sector have been growing fast. Forty-one percent growth was observed in the last five years, with the emissions from these two sectors reaching thirty percent in 2010.[63]

The critical question is what the world's future emissions control trajectory and China's role in it will be. According to IPCC, in reference to the 450 ppm scenario, global emissions would have to peak at latest in 2020 with 30.7 Gt of CO_2 emissions, then drop to twenty-four to twenty-six Gt of CO_2 by 2030, aiming at further reduction to about ten Gt of CO_2. If, by that time, the world population reaches 10,000,000,000, the world average per capita carbon budget under the 2°C scenario would be 1.1 tons CO_2 per capita, which is almost one sixth of China current per capita emission level. This is already an enormous challenge, not only for climate, but also for domestic governance.

According to the results run by China's leading modeling group ERI in 2009, China's total primary energy demand would have reached 3437.9 Mtce at its highest, and dropped to a low of 2971.3 Mtce by 2050. In fact, only a year after these results were published, national energy consumption had already reached 3250 Mtce, which is between the BAU and low-carbon scenarios. At the same time, the energy consumption cap set by the central authority for 2015 was 4200 Mtce, which already exceeds this 2020 low-

63 Tsinghua Univ., China Low Carbon Development Report (2011-2012).

carbon scenario's projection. Furthermore, it has been reported that the numbers added up from local governments' requirements have already gone up to 4700 Mtce for 2015 emissions.

The above analysis has shown that the GDP growth rate is the most critical among all the impact factors when considering mitigation measures. It heavily affects the growth rate of total energy consumption and carbon emissions. However, under China's circumstances, like those of many other countries, current technology still cannot significantly sever the linear relationship between economic growth and carbon emissions. The fact is that for both current GDP and energy growth projection, the figures which have been adopted are much below the reality. The substantial intervention, which may divert these scenarios, will mostly be determined by today's development model for China. The four trillion CNY stimulus package and large scale of energy-intensive industry moving from the east to the west have locked in a high-economics structure in the latter regions. Regarding the stimulus package especially, eighty-one percent of the resource was invested in new housing and infrastructure construction, which strongly stimulated demand for cement and steel, resulting in a surge in energy consumption in late 2009 to 2010.

In Durban, Xu Hua Qing, who is now the deputy director of the State Climate Strategy and International Cooperation Center, said that China could accept an absolute emissions cap beginning in 2020.[64] However, with GDP at a $4000 per capita level, China's economic growth still has decades to go. With respect to the enhanced low-carbon scenario shown above, at least three tons per capita is required for a very optimistic future emissions projection. How to balance economic development with carbon reduction and climate change — transforming the economic development model, while maintaining jobs for the sake of social stability — remains a big question. It renders China's mitigation future more obscure.

To conclude, upon analysis of the different scenarios produced by the various energy research institutes, the carbon emissions reduction commitment that China could make would mainly be based on its own development needs, co-benefits with energy security, and low-carbon industry development opportunities. And its success would be determined largely by how it develops, and whether major institutional factors could be resolved. In future climate negotiations, the dynamics would highly depend on whether major developed countries and groups are willing to be constrained by the common goal, but even so the potential for China to make an additional commitment would still be limited due to its domestic conditions.

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64 Li Jing & Lan Lan, *China May Adopt Emission Limit*, China Daily, Dec. 2, 2011, http://www.chinadaily.com.cn/bizchina/2011-12/02/content_14203056.htm.