Paper 2

A Preliminary Analysis of Modelling Results Relevant to China from the International Emission Scenarios Database

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The BASIC Project is a capacity strengthening project – funded by the European Commission – that supports the institutional capacity of Brazil, India, China and South Africa to undertake analytical work to determine what kind of climate change actions best fit within their current and future national circumstances, interests and priorities. Additional funding for BASIC has also been kindly provided by the UK, Department for Environment, Food and Rural Affairs and Australian Greenhouse Office. For further information about BASIC go to http://www.basic-project.net/

About BASIC

The BASIC Project supports the institutional capacity of Brazil, India, China and South Africa to undertake analytical work to determine what kind of national and international climate change actions best fit within their current and future circumstances, interests and priorities. BASIC has created a multi-national project team linking over 40 individuals from 25 research and policy institutions, the majority based in BASIC countries. Project activities comprise a mix of policy analysis, briefings, workshops, conferences, mentoring and training clustered around five tasks lead by teams as follows:

- Task 1 – Mitigation and sustainable development (China Team);
- Task 2 – Adaptation, vulnerability and finance (India Team);
- Task 3 – Carbon markets, policy coherence and institutional coordination (South Africa Team);
- Task 4 – Designing international climate change policy and enhancing negotiations skills (Brazil Team); and
- Task 5 – Creation of developing country expert group/mechanism on a long term basis (All Teams).

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About this Paper

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Other papers produced by BASIC Task Team 1 include:

- Energy Models in China: a Literature Survey, Fei Teng, Alun Gu and Maosheng Duan, Tsinghua University
- Energy Requirements for Satisfying Basic Needs: China as a case for illustration' Jiahua Pan and Xianli Zhu, Chinese Academy of Social Sciences, China
- The Role of Policies and Measures for Climate Mitigation in China; Rob Bradley and Hilary McMahon, World Resources Institute, USA
- Technology Transfer by CDM Projects; Erik Haites, Margaree Consultants Inc., Canada, Maosheng Duan, Tsinghua University, China, Stephen Seres, Climate Change Analyst/Economist, Canada

- Climate Change Impacts, Vulnerability and Adaptation in China, Li Yue, Xiong Wei and Wu Yanjuan, Institute of Environment and Sustainable Development for Agriculture, Chinese Academy of Agricultural Sciences

Abstract

China’s place in the global energy economy makes its emissions trends vital for understanding the overall climate change challenge faced by the world. Yet at the moment China’s emission trends are poorly understood and hard to predict. This paper makes a significant contribution to understanding the limits of our ability to forecast China’s emissions. The paper explains why all the international models consistently overestimated China’s emissions growth in the period 1990-2000. Improvements might help rectify such discrepant results for the future but improving modelling capabilities will require significant resources. Two significant policy relevant insights emerge from this paper: (1) for the time being it will not be possible to set emissions targets in China with any degree of confidence and (2) in an economy undergoing such rapid and large scale transitions as those in China, it may simply not be possible to project future emissions reliably on a national scale. Accordingly, work to improve modelling capacity and to better understand emissions from specific sectors and on underlying factors influencing energy intensity warrants further investigation.

Table of Contents

Figures

Tables

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Task 1 under BASIC Project focuses on “Energy, Mitigation, and Sustainable Development: Linking Modeling and Policies” described in more detailed in the BASIC Final Report. As part of Task 1, this paper reviews new modelling results for China since the Special Report on Emissions Scenarios (SRES), including those in the Japanese scenario database and the new Chinese modelling results. This work was first presented at the BASIC South Africa workshop held on 15-20 Oct 2005 in Johannesburg and then presented at the BASIC Beijing workshop for further discussion. This revised version is updated to March 2006 based on comments from the BASIC international support team.

I. Introduction

There is something powerful about being number one. As China’s emissions grow along with its fast-expanding economy there has been an increasing interest internationally in Chinese emission trends. The International Energy Agency now estimates that China’s GHG emissions will surpass those of the United States in 2009. True, on a per capita basis Chinese emissions will remain well below American ones. But the world faces the very likely scenario that the second commitment period of the Kyoto Protocol, just like the first, will leave the world’s largest emitter without a cap. This problem has not gone unnoticed elsewhere. In the United States lawmakers are greatly preoccupied with the role played by China, and seek to understand under what conditions China might be persuaded to cap its emissions.

Given the generally obstructive role the United States has played in international negotiations to date, this concern has raised political hackles. Chinese policy makers articulate with some justice their strong political objections to taking a quantitative commitment to limit emissions. They point to China’s relatively low per capita emissions (still only one quarter of those in the U.S.), and lesser historical contribution to today’s greenhouse gas concentrations. They argue that much lower levels of economic development, with correspondingly small usage of modern conveniences such as cars, electronics and air conditioning, mean that China has a right to emit more if that is necessary to ensure economic growth and to reduce poverty. Finally, despite rapid growth and adoption of more sophisticated technologies China still lacks the financial and technical resources that more developed countries enjoy, and which will be vital in reducing emissions without hampering growth.

All of these factors are moral or political arguments against China setting a binding cap on its emissions. While they disagree on whether China should adopt a cap, both China’s policy makers and their international counterparts routinely assume that the question is essentially a political one. This has led to a range of proposals which seek to address the political problem by adjusting the incentives for absolute emission limits. “No Regrets” caps that reward emission reductions without penalizing growth, or caps set at an arbitrarily high level to as to constitute a financial transfer (as was offered to entice Russia into the Kyoto Protocol), are examples of these.

While these political questions are undoubtedly important, however, they do not address an even more fundamental issue: even if the political will existed, is it possible to set a plausible cap on Chinese emissions? The concept of adjusting fast-growing emissions against some "business as usual" (BAU) scenario presupposes that such a BAU can be identified.

Finding a plausible range for projecting emissions growth is essential. Any target which appears to threaten China's economic development at this stage will not be accepted. On the other hand, setting an extravagant growth target could allocate to China enough "hot air" allowances to wreck any international emission trading system. If China could be relatively sure of its projected emissions then it would be able to propose a cap which avoids both these two risks. Can this be done?

This paper explores the state of the art in emission scenario modeling for China. It draws on a database of scenarios compiled by National Institute for Environmental Studies (NIES)1 in Japan, as well as drawing on some more recent literature. Including the SRES database3, the latest version of the NIES database (updated May 12 2005) consists of 734 scenarios from 251 sources. Section II introduces the structure of the database and identifies 13 sources with a region that approximates to China. The comparisons and analyses focus on reference scenarios and then shift to stabilization scenarios. In the last section, conclusions are drawn and areas of future research to build better links between modeling and policies for China and other developing countries are discussed.

II. Overview of the Database and Modeling Exercise relevant to China

The structure of the database

The NIES emissions scenarios database includes five elements:

- **Sources:** i.e. the organization and modeling exercise that generated the scenario. Currently, there are 251 sources in the database.
- **Scenarios:** Often two or more scenarios are developed with the same model as part of a modeling exercise. Currently, there are 734 scenarios in the database, including non-intervention or reference scenarios (business-as-usual emission projections based on a set of socio-economic growth assumptions), and intervention or policy scenarios (with a constraint on emissions/concentrations to model different climate change mitigation or energy policy).
- **Regions:** Among the 734 scenarios in the database, some are national, such as those in National Communications, but most are global scenarios covering different regions of the world. The EDS guide recommends that the modeller submitting scenario results use

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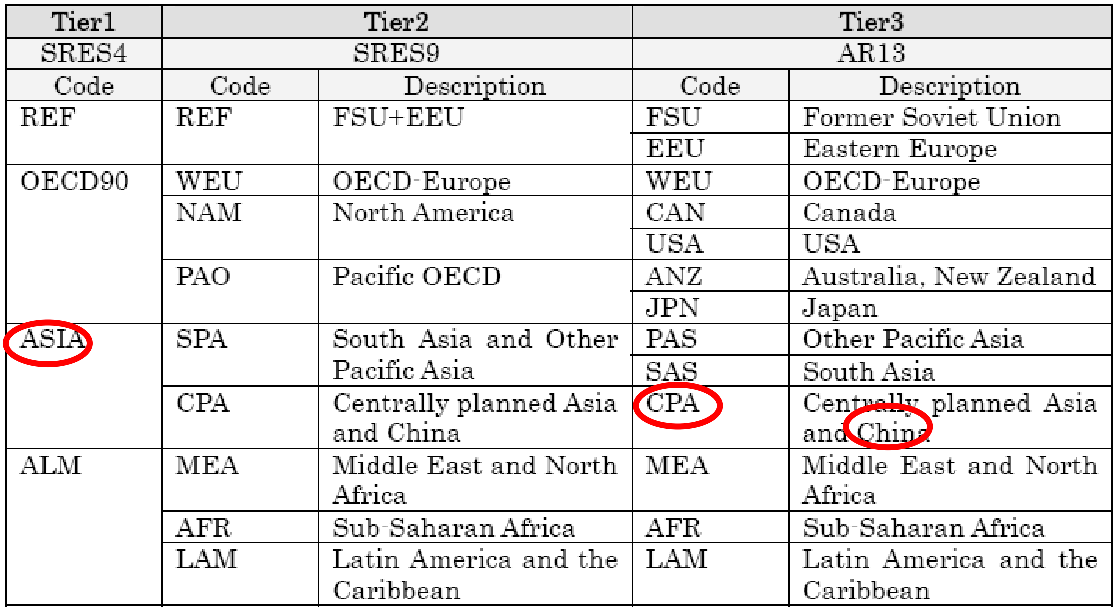
[1] NIES database can be downloaded at http://www-cger.nies.go.jp/cger-e/db/enterprise/scenario/scenario_index_e.html.

[3] SRES data can be downloaded separately at http://sres.ciesin.columbia.edu/final_data.html.

one of three levels of regional aggregation known as SRES4, SRES9 and AR13. The details of this aggregation are presented in table 1. However, some models have their own regional classification. The objective of this paper is to look closely at the results for China, which is sometimes handled as a separate country and sometimes included in a broader region, depending on the model.

Table1. An example of correspondence among SRES4, SRES9 and AR13



Tier1	Tier2		Tier3	
SRES4	SRES9		AR13	
Code	Code	Description	Code	Description
REF	REF	FSU+EEU	FSU	Former Soviet Union
			EEU	Eastern Europe
OECD90	WEU	OECD-Europe	WEU	OECD-Europe
	NAM	North America	CAN	Canada
			USA	USA
	PAO	Pacific OECD	ANZ	Australia, New Zealand
			JPN	Japan
ASIA	SPA	South Asia and Other Pacific Asia	PAS	Other Pacific Asia
			SAS	South Asia
	CPA	Centrally planned Asia and China	CPA	Centrally planned Asia and China
ALM	MEA	Middle East and North Africa	MEA	Middle East and North Africa
	AFR	Sub-Saharan Africa	AFR	Sub-Saharan Africa
	LAM	Latin America and the Caribbean	LAM	Latin America and the Caribbean

- **Variables**: The database contains values for a series of variables that describe the status of population, economic activities, energy and environmental impacts for each region. This paper will not only look at emissions but also the main driving forces, such as population, GDP and energy consumption, etc.
- **Results**: The results of emissions scenarios represent different development paths expressed with multiple variables. A variable that changes with time is called a record. Different models have different temporal coverage. Most of long-term emissions scenarios offer results from 1990 to 2100 with 10 year intervals. The latest version of NIES database consists of 93,668 records in total.

Models related to China and their fundamental characteristics

China, as the second largest emitter in the world, receives detailed attention in almost all global emissions scenarios. Some models treat China as a separate country, but others include China in a broader region, such as CPA (Central Planned Asia and China)[4] and ASIA (Asian Pacific developing countries)[5]. China accounts for 90%-95% emissions of CPA and dominates the region in terms of population, economic and energy indicators. Thus it is not surprising that model results for China and CPA are generally comparable. However, ASIA encompasses many more countries, including large countries such as Bangladesh, India,

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[4] CPA known as Centrally planned Asia and China covers Cambodia, Hong Kong, Korea (DPR), Laos (PDR), Mongolia, Viet Nam and China.

[5] IPCC SRES define Asia as a region covering CPA(Centrally planned Asia and China), SAS (South Asia) and PAS (other Pacific Asia). SAS includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. PAS includes American Samoa, Brunei Darussalam, Fiji, French Polynesia, Gilbert-Kiribati, Indonesia, Malaysia, Myanmar, New Caledonia, Papua New Guinea, Philippines, Republic of Korea, Singapore, Solomon Islands, Taiwan China, Thailand, Tonga, Vanuatu and Western Samoa.

Indonesia, Korea and Pakistan, in addition to China. As a result China only accounts for about 50%-60% of the ASIA emissions, population, GDP and energy consumption. The model results for ASIA often differ from those for China or CPA.

To analyze emission scenarios modeling results relevant to China, 13 sources (global emissions scenarios since 1998) are identified in the current database that report results for China or CPA or ASIA. Table 2 presents the regional classifications for these 13 sources.

Table 2 Models and Region Classification related to China

	Sources	Region Classification
China	AIM/EMF16	Annex I, CANZ, **China,** EEC, EFSU, India, Japan, Mexico&OPEC, non Annex1, OECD, OECD, ROW, USA, WORLD
	RICE99	Annex1, **China,** EEC, EFSU, India, non Annex1, non OECD, non OECD Annex1, OECD, Other High Income, ROW,USA, WORLD)
	SGM99	Annex I, CANZ, **China,** EEC, EFSU, Japan, Mexico&OPEC, non Annex1, non OECD, OECD, ROW, USA, WORLD
CPA	DNE21/98	Annex1, **CPAsia,** EFSU, Japan, LatinAmerica, MEastNAfrica, nonAnnex1, nonOECD, NorthAmerica, Oceania, OECD, OECDEurope, SEAsia, SubSAfrica, WORLD
	IIASA/WEC98	Africa, Annex1, **CPAsia,** EastEurope, EFSU, FSU, LatinAmerica, MEastNAfrica, nonAnnex1, nonOECD, NorthAmerica, OECD, OECDPacific, Opacific, SouthAsia, TRD, Westeurope, WORLD
ASIA	AIM	**ASIA**, REF, OECD90, ALM, WORLD(**)
	ASF	
	IMAGE	
	MARIA	
	MESSAGE	
	MiniCAM	
	LDNE	
	WorldSCAN	

** Definition of SRES World Regions, see IPCC SRES Appendices III. REF=countries undergoing economic reform, including EEU (Central and Eastern Europe) and NIS (Newly independent states) of FSU (the former Soviet Union); ALM= Africa and Latin America, including MEA (Middle East and North Africa), LAM (Latin America and the Caribbean) and AFR (Sub-Saharan Africa); OECD90 includes NAM (North America), WEU (Western Europe) and PAO (Pacific OECD).

It should be noted that the above regional aggregation is only for the purpose of summarizing results in the database; often it is not the regional structure used by the model. For instance, the emissions module of AIM model has 17 regions. Probably many of the models for which ASIA results are reported also have results for China as a separate region. Replacing the results for a scenario aggregates to the ASIA region with the corresponding results for China improves the analysis. But at present, only the aggregate data are in the database.

Models used to generate emissions scenarios are often classified as bottom-up or top-down models. Energy optimization models such as DNE21/98, LDNE and MESSAGE are typical bottom-up models. CGE (Computable General Equilibrium) models such as RICE99, SGM99 and WorldSCAN are top-down models. Some models, such as AIM/EMF16 and

MiniCAM, try to combine strengths of these two approaches. The fundamental characteristics of some China-related models are described in Appendix I of this paper. Further details can be found in related literature.

III. Reference Scenarios Analysis

Overview of Reference Scenarios Related to China in the Database

There are totally 85 reference scenarios from 13 sources related to China in current database. See Table 3 for details.

Table 3 Reference Scenarios Related to China

No.		Sources	Reference Scenarios	Num.
7	China	AIM/EMF16	Ref	3
221		RICE99	Ref	
225		SGM99	Ref	
42	CPA	DNE21/98	Ref	5
98		IIASA/WEC98	A1, A2, A3, B	
11	ASIAP	AIM	SRES- A1, A1C, A1G, A1T, A2, B1, B2	77
10			pSRES-A1B,A1G,A2,B1,B2	
20		ASF	SRES-A1, A2, B1, B2	
19			pSRES-A2	
102		IMAGE	SRES-A1, A2G, B1, B2	
101			pSRES-A1,B1	
125		MARIA	SRES-A1, A1T, B1, B2, B2C	
124			pSRES-A1B, A1T, B1, B2	
136		MESSAGE	SRES-A1, A1C, A1G, A1T, A2, B1, B1High, B1T, B2	
135			pSRES-A1B, A1C, A1G, A1T, A2, B1, B1High, B1T, B2	
143		MiniCAM	SRES-A1, A1C, A1G, A1V1, A1V2, A2, A2-A1, B1, B1High, B2, B2High	
142			pSRES-A1C, A1FI, A2, B1Ha, B2H, B2L	
117		LDNE	pSRES-A1,A1G,A1T, A2,B1,B2	
244		WorldSCAN	pSRES-A1, A2, B1, B2	
Total				85

77 of the 85 reference scenarios were developed by IPCC, including 40 SRES and 37 pSRES scenarios. They only provide results for the ASIA region instead of China as a separate region. The 40 SRES reference scenarios are from four storyline families (A1, A2, B1 and B2) developed by 6 different modeling approaches[6] for the preparation of third assessment report (TAR):

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The three A1 groups

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[6] Two more modeling teams LDNE and WorldSCAN joined for development of pSRES scenarios.

are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.
- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

It is noteworthy that there exist some differences in the 1990 base year data across the models. To eliminate the influence of base year data differences on the ultimate results, all 40 reference scenarios were standardized to ensure all 1990 and 2000 data are completely consistent. The detailed standardization methods are described in the SRES report (see Page 243, Box 5-1). The pSRES series of baseline scenarios are the original group of reference scenarios without standardization. Standardization revealed that the base year data differences resulted in such small differences in the scenarios that they could be ignored.

Four reference scenarios named A1, A2, A3 and B, were developed by IIASA/WEC98 with different sets of social-economic assumptions. They are totally different from the SRES Scenarios.

Comparisons of Reference Scenarios and Their Driving Forces

As we know, the projections of reference scenarios often vary widely. The model structure provides only part of the explanation. Different assumptions for the main driving forces are more important in terms of their impact on the scenario projections.

- **Models with China as a separate region**

Figure 1 shows three reference scenarios where China is reported as a separate region. The temporal coverage of both AIM/EMF16 and RICE99 is the year 2100 and the simulation results are very similar. But SGM99 shows a quite different trend to 2050.

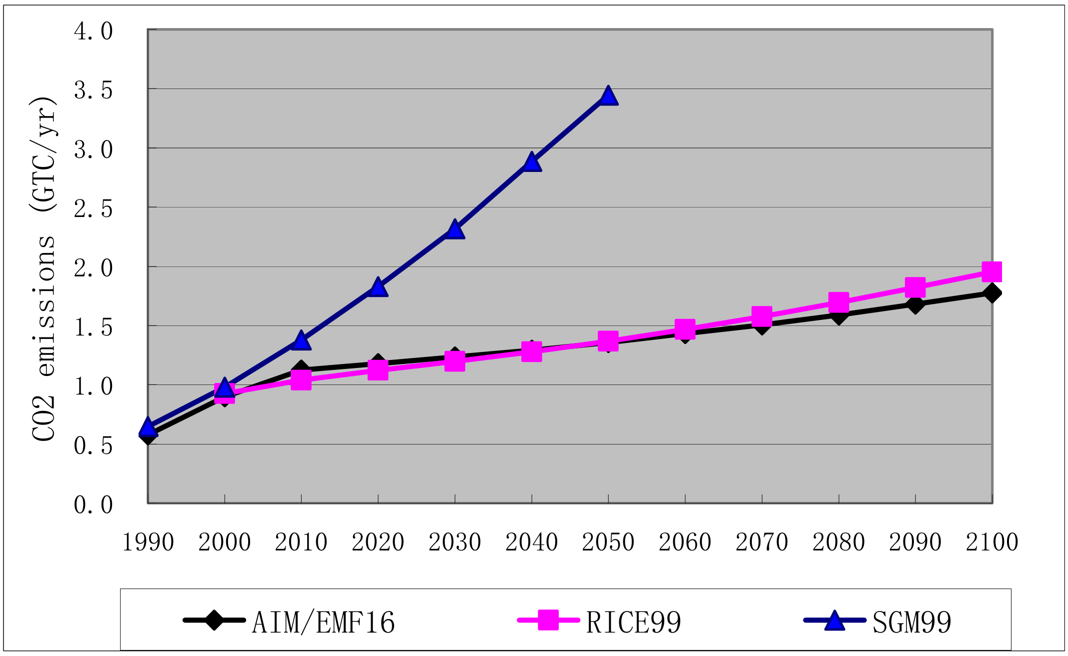

Fig. 1 **Reference Scenarios where China is Reported as a Separate Region**

Why are the results similar or different? Are they similar because their projected population, GDP and energy use are similar or are there offsetting differences? If their projected population and/or GDP and/or energy use are different, which is responsible for the main differences? Besides CO$_2$ emissions, a set of 5 indicators, population, GDP, primary energy (PE), CO$_2$/PE, GDP growth rate, PE/GDP are identified as main driving forces for comparison to give some insights.

Table 4 **Comparison of the Driving Forces**

	RICE99	AIM/EMF98	SGM99
CO$_2$ emissions (GtC)			
1990	0.92	0.58	0.65
2020	1.12	1.18	1.83
2050	1.37	1.36	3.44
2100	1.95	1.77	-
GDP (billion 1990$)			
1990	749 (2000)	355	1824
2020	1520	1813	14769
2050	3242	3414	54266
2100	8266	9245	-
Primary energy (PE) (EJ)			
1990	-	28.47	30.57
2020		55.15	85.86
2050		65.32	150.49
2100		86.29	-
CO$_2$/PE (tC/TJ)			
1990	-	2.04	21.3
2020		2.14	21.3
2050		2.08	22.9

2100		2.05	-
GDP growth rate (%)			
1990-2020	3.6	5.6	7.2
2020-2050	2.6	2.1	4.4
2050-2100	1.9	2.0	-
PE/GDP (MJ/1990$)			
1990	-	80.2	16.8
2020		30.4	5.8
2050		19.1	2.8
2100		9.3	-

As shown in Table 4, the trends of CO_2 emissions and GDP growth are similar for RICE99 and AIM/EMF98 although the other variables are not available in the data for RICE99. Comparing the driving forces of SGM99 and AIM/EMF98, things are quite different. SGM99 has a much higher base year GDP and a much higher GDP growth rate over the whole time period. The SGM99 projections for primary energy and energy mix (CO_2/PE) show that China is assumed to use coal as its main energy source to meet the rapidly increasing energy demand, leading to CO_2/PE about ten times higher than that of AIM/EMF98.

- **Models with CPA**

Figure 2 shows a group of four reference scenarios (A1, A2, A3 and B) developed by IIASA/WEC98 and one developed by DNE21/98 for the CPA region. Since China dominates the CPA region and to compare these scenarios with the three reference scenarios in Figure 1, the CPA values are multiplied by 0.95 to provide an approximation for China. The reference scenarios in Figure 2 cover a wide range. A2 gives the highest CO_2 emissions projection at 5.2GtC/yr in 2100 while A3 gives the lowest at 0.6GtC/yr among the IIASA/WEC98 group, although the trends are relatively similar for the four scenarios before 2040.The DNE21/98 reference scenario does not provide details for the 2050-2100 period, but it appears to be a relatively high emissions scenario. The SGM99 scenario is very similar to A2. The RICE99 and AIM/EMF16 scenarios are similar to A1 by 2100, but the shapes of their curves are different. The A1 scenario rises to a peak around 2050 and then declines, while the RICE99 and AIM/EMF16 emissions scenarios keep growing almost linearly with no peak.

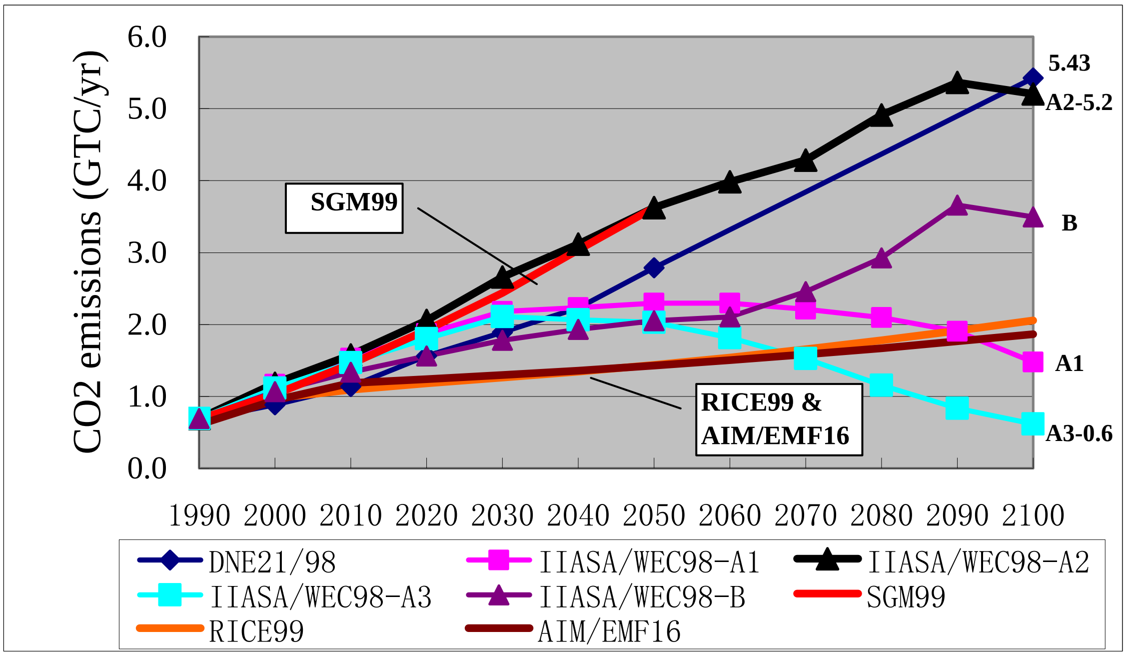

Figure 2 Reference Scenarios where Results are Reported for the CPA Region Adjusted to Approximate Emissions for China

Table 5 explains the differences among the reference scenarios in terms of their driving forces. All four scenarios developed by DNE21/98 have the same population assumption. Three of them, A1, A2 and A3 share the same assumption of high economic growth, while B assumes a medium growth rate. Primary energy consumption is quite similar for A1, A2 and A3. The main difference is in the carbon intensity of the energy mix. Carbon intensity remains high throughout 2100 for A2, but declines for A1 and A3. Most of the changes to the energy mix occur after 2040 so all four scenarios have similar emission trends until 2040.

The CO_2 emissions curve of DNE21/98 goes up linearly, which differs from the four IIASA/WEC98 scenarios. The emissions in 2050 and 2100 are 2.79 and 5.43 GtC/yr, approximately equal to those of the A2 scenario. Primary energy in DNE21/98 is about half that of the IIASA/WEC98 A2 scenario, but the emission intensity of primary energy is roughly double that of the A2 scenario. Like the A2 scenario, the emission intensity of primary energy remains virtually constant through 2100 in DNE21/98.

Table 5 Comparison of Driving Forces for the CPA Region

	IIASA/WEC98					DNE21/98	
	1990	A1	A2	A3	B	1990	Ref
CO_2 emissions (GtC)	0.69					0.68	
2020		1.87	2.06	1.80	1.56		1.56
2050		2.29	3.63	2.03	2.05		2.79
2100		1.48	5.21	0.62	3.50		5.43
Population (million)	1242					—	
2020		1714	1714	1714	1714		—
2050		1984	1984	1984	1984		
2100		2099	2099	2099	2099		
GDP (billion US$)	474					—	
2020		3852	3852	3852	2038		—

2050		13871	13871	13871	6660		
2100		44593	44593	44593	26933		
Primary energy (PE)(EJ)	40					23	
2020		106	106	105	88		56
2050		188	188	181	149		102
2100		301	304	297	249		175
CO_2/PE (tC/TJ)	17.3					29.6	
2020		17.6	19.4	17.1	17.7		27.9
2050		12.2	19.3	11.2	13.8		27.4
2100		5.0	17.1	2.1	14.1		31.0
GDP growth rate (%)	-					-	
1990-2020		7.2	7.2	7.2	5.0		-
2020-2050		4.4	4.4	4.4	4.0		
2050-2100		2.4	2.4	2.4	2.8		
PE/GDP (MJ/1990$)	84.4					-	
2020		27.5	27.5	27.3	43.2		-
2050		13.6	13.6	13.0	22.4		
2100		6.7	6.8	6.7	9.2		

- **SRES scenarios**

As described above, the 40 SRES scenarios are from four storyline families (A1, A2, B1 and B2) developed with 6 different modeling approaches. The annual CO_2 emissions for the ASIA region, which includes China, range from 0.65 (B1T-MESSAGE) to 14.06GtC (A1C-AIM) by 2100.

The SRES authors selected a marker scenario for each family, i.e. AIM for A1B, ASF for A2, IMAGE for B1, and MESSAGE for B2; and for the two additional illustrative scenarios, i.e. MESSAGE for A1T and MiniCAM for A1FI. These six marker scenarios are the most frequently used although it has been emphasized that they are not more realistic or more likely than the other 34 reference scenarios.

Figure 4 compares six marker scenarios for the ASIA region. They vary widely, CO_2 emissions in 2100 range from a low of 0.93 GtC for the B1 scenario to a high of 10.74 GtC for the A2 scenario. Although the range is wide it is similar to that for the scenarios for the CPA region. Multiplying the values for ASIA by 0.6 gives an approximation for the CPA region of 0.56 to 6.44 GtC compared with a range 0.6 to 5.43 for the CPA reference scenarios. Among the six SRES marker scenarios, only A2 and B2 increase monotonically; the others peak at different times prior to 2100. Generally, the lower the CO_2 emissions by 2100; the earlier emission reduction actions are required. For example, A1F1 peaks in 2080, A1 in 2060 and A1T and B1 around 2040. As mentioned above, the SRES scenarios were standardized so the 1990 and 2000 data under all scenarios are the same. The data for 2000 are the average values predicted by the participating modeling groups.

Similarly, Table 6 shows the driving forces for the six marker scenarios. As mentioned above, they are from different families, which represent different storylines. A2, the highest emissions scenario among the six results from high population growth, low economic growth,

A2 10.74

high carbon intensity of the energy mix

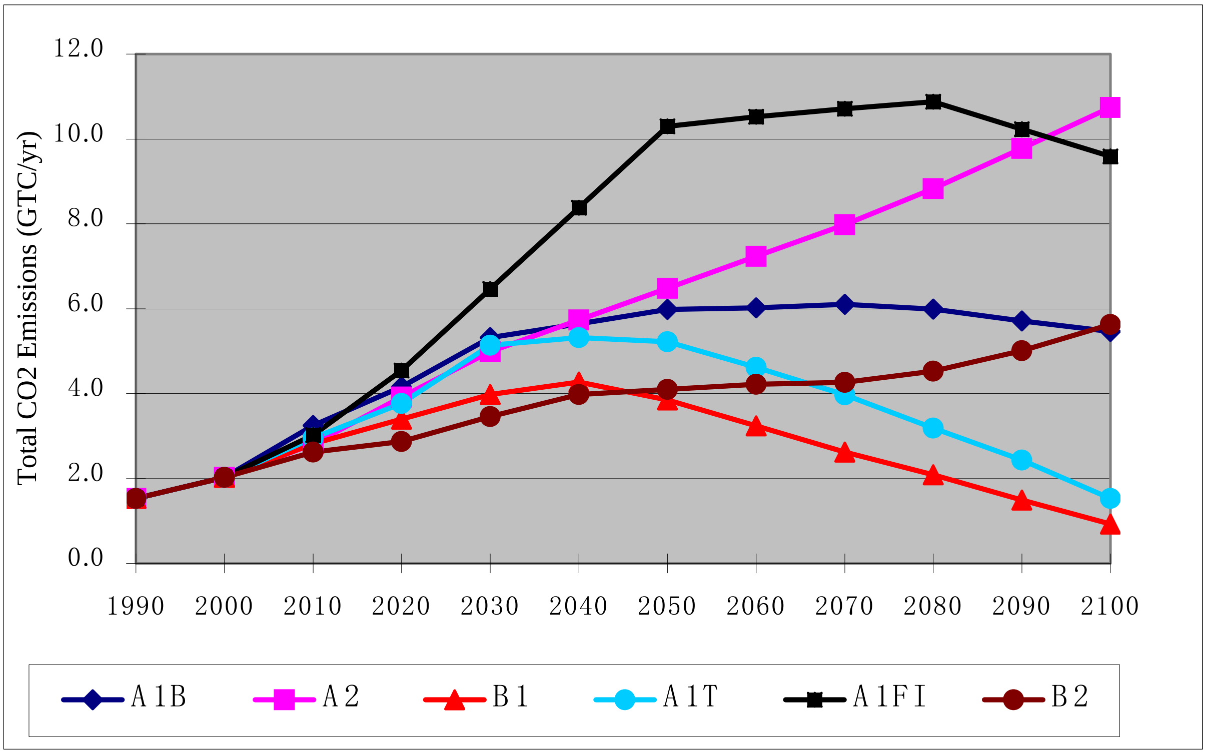

Figure 3 The Six Marker Scenarios of SRES for the ASIA Region

and high energy intensity (low energy efficiency). B1, the lowest emissions scenario benefits from medium economic growth, low energy intensity (high efficiency) leading to low primary energy consumption, and medium carbon intensity.

Table 6 Comparison of Driving Forces for SRES Marker Scenarios (ASIA Region)

Marker Scenario	A1FI	A1B	A1T	A2	B1	B2
Total CO_2 emissions (GtC)						
1990	1.53	1.53	1.53	1.53	1.53	1.53
2020	4.54	4.16	3.77	3.92	3.40	2.87
2050	10.3	5.64	5.22	6.48	3.85	4.10
2100	9.59	5.46	1.53	10.74	0.93	5.63
Population (million)						
1990	2790	2798	2798	2791	2781	2798
2020	3937	3851	3937	4308	3929	4008
2050	4219	4220	4220	5764	4220	4696
2100	2919	2882	2882	7340	2886	4968
GDP (Trillion US$)						
1990	1.4	1.5	1.5	1.4	1.4	1.5
2020	11.7	12.3	13.5	5.3	8.7	13.2
2050	61.0	62.7	65.3	15.0	37.9	41.8
2100	192.6	207.3	218.2	57.1	103.1	97.1
Primary energy (PE) (EJ)						
1990	49	80	74	53	79	74
2020	228	214	231	174	195	185
2050	611	440	467	335	272	319

2100	758	838	736	581	154	521
CO_2/PE (tC/TJ)						
1990	31.2	19.1	20.7	28.9	19.4	20.7
2020	19.9	19.4	16.3	22.5	17.4	15.5
2050	16.9	12.8	11.2	19.3	14.2	12.9
2100	12.7	6.5	2.1	18.5	6.0	10.8
GDP growth rate (%)						
1990-2020	7.3	7.3	7.6	4.5	6.3	7.5
2020-2050	5.7	5.6	5.4	3.5	5.0	3.9
2050-2100	2.3	2.4	2.4	2.7	2.0	1.7
PE/GDP (MJ/1990$)						
1990	35.0	53.3	49.3	37.9	56.4	49.3
2020	19.5	17.4	17.1	32.8	22.4	14.0
2050	10.0	7.0	7.2	22.3	7.18	7.6
2100	3.9	4.0	3.4	10.2	1.49	5.4

1. Comparison of Modeling Results to Actual Data

As many of the reference scenarios were developed in 1990s, most of them take 1990 as the base year and data of 2000 and thereafter are modeling results. Today, it is possible to compare actual data with the modeling results for 2000. Such a comparison can provide a better understanding of what assumptions and driving forces led to the most realistic emissions projections for 2000. However, consistency for the first decade does not mean that the scenario is more likely or provides a better prediction of long-term emissions. Table 7 lists several possible sources for the actual data.

Table 7 Possible Sources for Actual Data

Resources	Issued by		GHGs	Time
World Development Indicators (WDI)	World Bank	2004 version	CO_2	most countries are till 2000
CAIT tools	World Resource Institute (WRI)	launched in 2003	CO_2 from energy, cement production, land use changes (some available but highly uncertain) Non-CO_2	1960-2000, CO_2 till 2002
IEA statistics of	IEA		CO_2 emissions from fossil fuel combustion	1971-2001
Energy Information Agency (EIA)	US	updated on July 11, 2005	CO_2 from energy activities	1980-2003

Generally, these sources do not directly offer aggregation the data into such country groups as CPA and ASIA, rather the totals for such regions must be computed from the data for the constituent countries. Since "actual" data for the CO_2 emissions from land use change are highly uncertain and most of the reference scenarios are limited to energy-related CO_2 emissions, the comparison will concentrate on CO_2 emissions from energy activities. Given this focus, the EIA provides the latest and most comprehensive country data on energy-related CO2 emissions and the driving forces so its data are used for the comparison.

- **Models with China as a separate region**

Figure 5 compares modeling results and the actual data for China as a separate region. It shows that SGM99 as a high emission scenario has been higher than the actual emissions for the first decade. The AIM/EMF16 prediction is generally consistent with the trend to date, although a model that operates in ten year time steps can not hope to represent the annual fluctuations in the actual data. The year 2000 emissions for RICE99 are higher than the actual data because energy consumption happened to go down at that point; for 2003 the actual emissions are virtually identical to the RICE99 trend.[7]

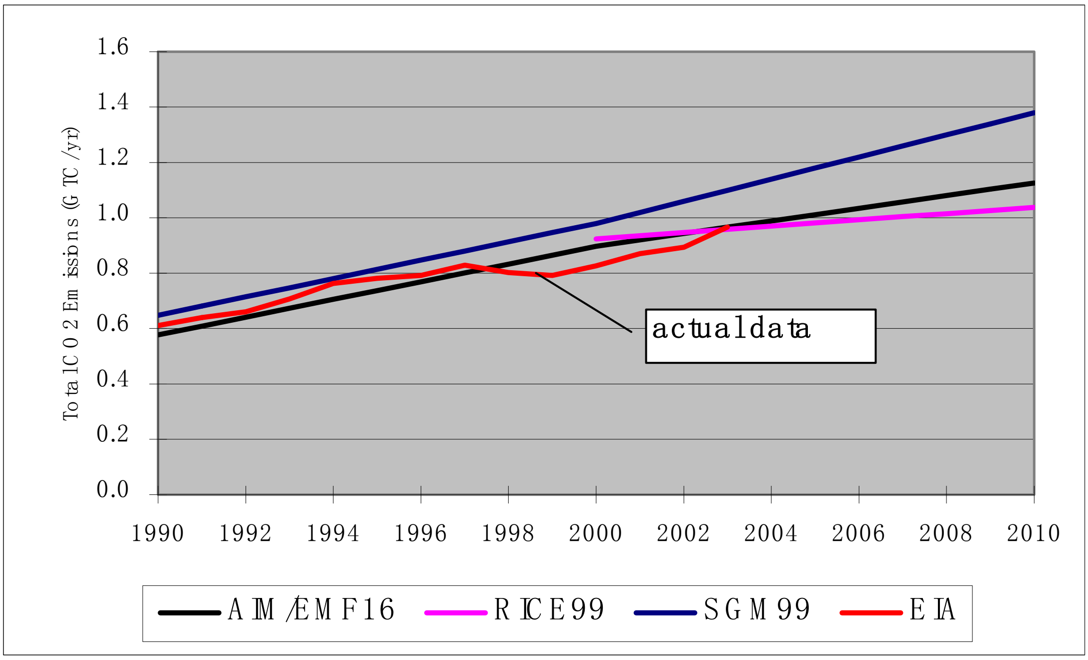

Figure 4 **Comparison of the Modeling Results and Actual Emissions for China**

- **Models with results for the CPA Region**

Figure 6 compares the actual data and the model results for the CPA including results from SGM99 and AIM/EMF16 divided by 0.95 to shift them to the CPA region. DNE21/98 and AIM/EMF16 are relatively consistent with the actual data but all four of the scenarios from the IIASA/WEC98 model are higher than the actual emissions.

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[7] Some papers discuss the reliability of China's historical statistics, particularly around 2000.

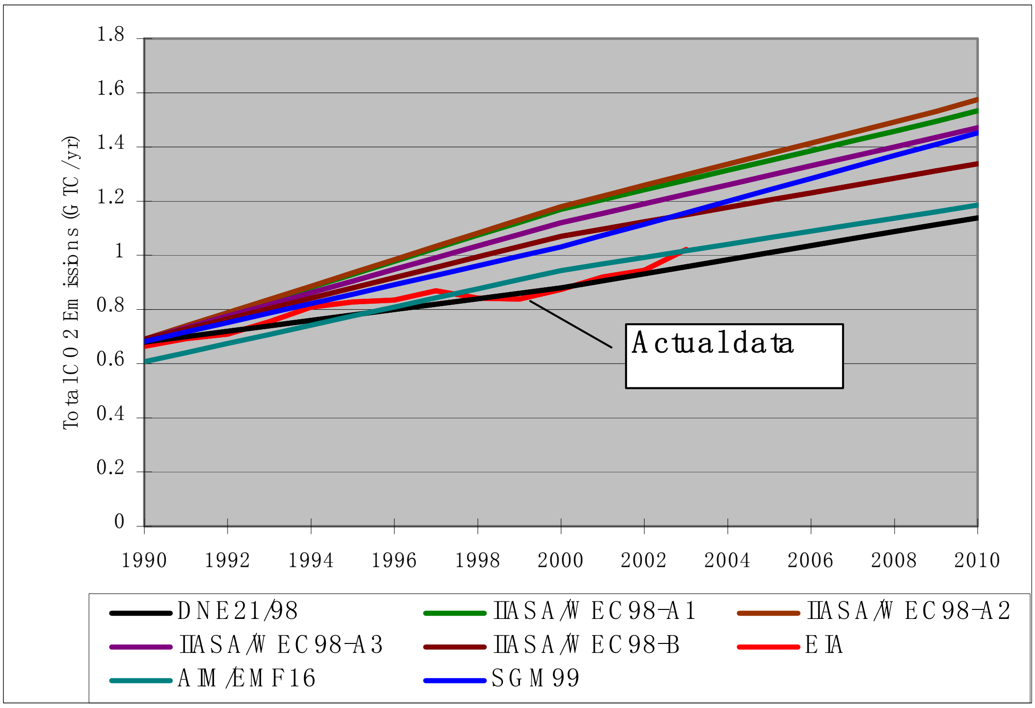

Figure 5 Comparison of Model Results and Actual Data for the CPA Region

Why do most of the modeling results overestimate the emissions for the first decade? Table 8 compares the index of the driving forces. It can be seen that population projections are accurate for all models. The problem comes from GDP and energy use. For the IIASA/WEC98 A1, A2 and A3 scenarios the projected GDP exceeds the actual GDP and the energy intensity is higher so that the projected primary energy also exceeds the actual primary energy. The carbon intensity also is higher so that the higher primary energy leads to higher energy-related CO_2 emissions. For the IIASA/WEC98 B1and SGM99 the projected GDP is lower than the actual GDP, but the energy intensity is much higher so the projected primary energy exceeds actual value. The carbon intensity is correct for SGM99 and higher for IIASA/WEC98 B1 so that the higher primary energy leads to higher energy-related CO_2 emissions.

Table 8 Comparison of Driving Forces to the Actual Data for CPA (2000）

CPA	CO_2 （1990）	CO_2 (GtC) (2000)	Population (1990＝100)	GDP (1990＝100)	Primary Energy (1990＝100)
Actual data	0.66	0.87	112	238	129
IIASA/WEC98-A1	0.69	1.17	115	248	153
A2	0.69	1.18	115	248	153
A3	0.69	1.12	115	248	147
B1	0.69	1.07	115	187	144
DNE21/98-Ref	0.68	0.88	-	-	132
AIM/EMF16/0.95	0.61	0.95	-	234	141
SGM99/0.95	0.68	1.03	-	223	153

- **SRES scenarios**

The above pattern appears to apply to the SRES marker scenarios for the ASIA region as well. Figure 7 compares the actual data and the modeling results for the ASIA region. Recall that the SRES scenarios were standardized for 1990 and for 2000 at the average value of the model projections for that year. From Figure 7 it is obvious that these standardized values are higher than the actual emissions. Table 9 shows that the model results tend to overestimate the emissions of developing countries, but are precisely accurate for OECD countries.

Table 10 compares the projected and actual values for the driving forces. Again, population is accurately projected, perhaps because it changes relatively slowly, but it appears to be difficult to accurately model the economic development models and energy use in developing countries. The projected energy intensity is too high for three marker scenarios (A1T, A1F and A2) and too low for the others (B1, A1B and B2). The carbon intensity of primary energy is too high for four of the market scenarios (A1T, B2, B1 and A1B), correct for scenario A2, and too low for A1F, which is ironic since it is the fossil fuel intensive scenario.

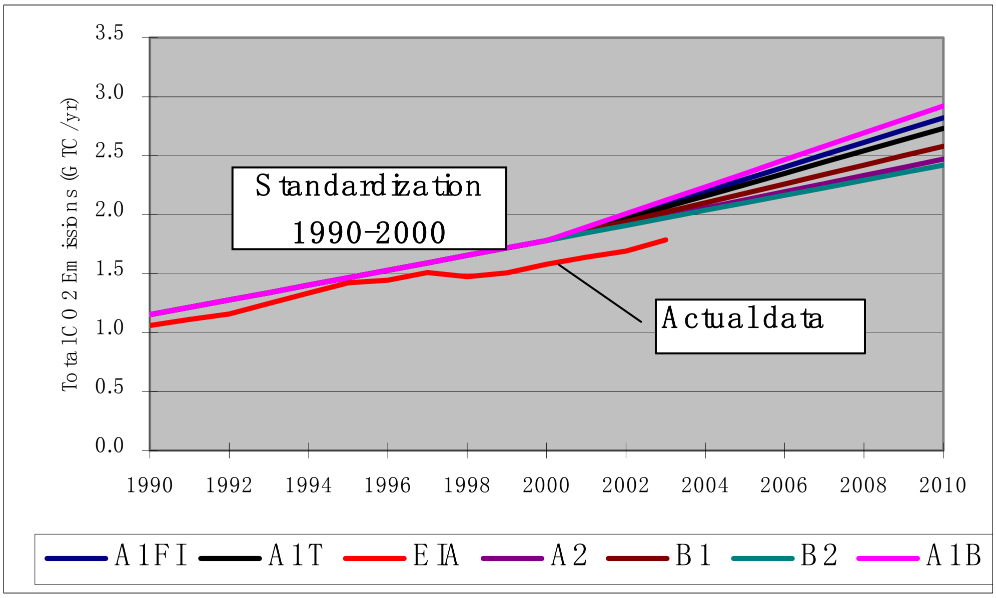

Fig. 6 Comparison of Modeling Results and the Actual Data for the ASIA Region

Table 9 CO_2 Emissions of the World and Regions for SRES Marker Scenarios (GtC/yr)

	1990	Actual data	2000	Actual data
World total CO_2 emissions	7.10	-	7.79	-
World CO_2 from energy	5.99	5.84	6.90	6.5
ASIAP	1.15	1.06	1.78	1.58
OECD90	2.83	2.85	3.20	3.20
REF	1.30	1.40	0.91	1.00
ALM	0.72	0.53	1.01	0.74

Table 10 Comparison of Driving Forces to the Actual Data for the ASIA Region (2000)

ASIAP	CO_2 （1990）	CO_2 (GtC)	Population (1990＝100)	GDP (1990＝100)	Primary Energy (1990＝100)
Actual data	1.06	1.58	116	191	142
AIM/SRES, A1=A1B,	1.15	1.78	117	180	125

ASF/SRES, A2			118	159	155
IMAGE/SRES, B1			117	194	135
MESSAGE/SRES, A1T			117	180	142
MESSAGE/SRE, B2			116	233	139
MiniCAM/SRES, A1FI			116	218	173

Several factors could help explain why it is not easy to project economic growth and energy use in China and other developing countries. First, China is experiencing rapid economic growth and energy consumption and related CO2 emissions are increasing rapidly as well. However, the models tend to overestimate primary energy and emissions. They generally underestimate the change in the energy intensity due to the shifts in the structure of the economy as it grows and to improvements in energy efficiency. The models also tend to underestimate the reduction in the carbon intensity achieved as primary energy production expands.

These discrepancies illustrate important limitations in what emissions models developed primarily by and for developed countries can tell us about developing country trends. Emissions growth in a rapidly developing country such as China is variable and unpredictable. A wide range of domestic and international influences, including technology shifts, global commodity prices, capital cycles and trade patterns, combine in unpredictable ways. Figure 8 shows the much greater range between upper and lower emission projections through 2025 in developing countries than in their richer counterparts. The linear growth assumptions of in the models therefore look to be a very inadequate ways of treating trends in developing economies.

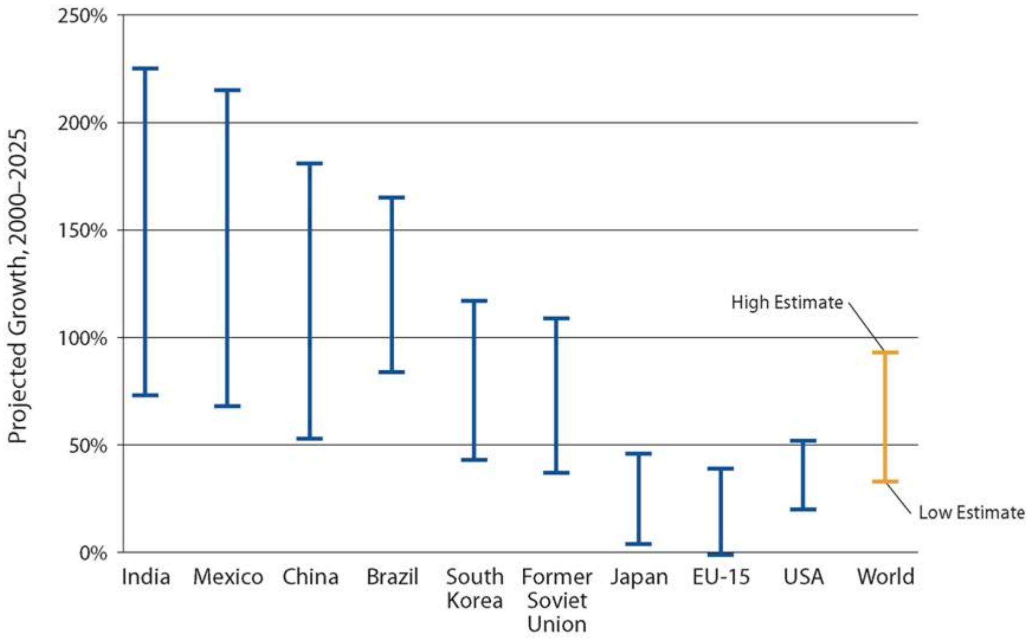

Fig. 7 Uncertainty in projecting emissions growth (Source: EIA, 2004)

To improve the models and projections, modellers need to better account for the national circumstances in developing countries, such as informal sectors, regulation and/or government management of the energy sector, the macro economic policies of the government, barriers to achievement of efficiency in energy production and consumption, shifts in the pattern of energy consumption from basic needs to luxuries as per capita incomes rise, etc. to get a better understanding of economic development in China and other developing countries.

IV. Stabilization Scenarios Analysis

Overview of Stabilization Scenarios in the Database

Policy scenarios are developed by a model from a particular reference scenario based on a specific policy target. Table 11 lists the 111 policy scenarios in the database that have a region that includes China. Most of policy scenarios adopt a stabilization target, such as 450ppmv or 550ppmv, and hence are called stabilization scenarios. They include, 77 pSRES scenarios, the largest group of stabilization scenarios that provide results for the ASIA region. Some stabilization scenarios incorporate other features that affect the cost of achieving the stabilization target, such as emission trading (no trade, partial trading or global trading), the emissions pathway (WGI, WRE or MID) and technology innovation (for example, carbon capture and storage technology).

Table 11 China Related Policy Scenarios in the NIES Database

China (20)	AIM/EMF16 (6)		Annex I + India China, Annex I Trading, Double Trading, Global Trading, No Trading, Supply Curves for Sinks
	RICE99 (1)		550-sta
	SGM99 (13)		WGI450 (trade), WRE450 (trade) MID550 (no trade), MID550 (partial trading), MID550(trade), WGI550 (no trade), WGI550 (trade), WRE550(no trade), WRE550(trade) WGI650 (no trade), WGI650(trade), WRE650 (no trade), WRE650(trade)
CPA (3)	DNE21/98 (1)		550-sta
	IIASA/WEC98 (2)		C1,C2
ASIA (88) pSRES (72) pSRES2001 (16)	AIM (10)	pSRES (7)	A1B-450, A1B-550, A1B-650 A1G-550, A2-550, B1-550,B2-550
		pSRES2001 (3)	A1B-450, A1B-550, A1B-650
	ASF (4)	pSRES (2)	A2-550,A2-750
		pSRES2001 (2)	A2-550,A2-750
	IMAGE (3)	pSRES (2)	A1-550, B1-450
		pSRES2001 (1)	B1-450

	MARIA (13)	pSRES (12)	A1B-450, A1B-550, A1B-650, A1T-450, A1T-550, A1T-650, B1-450, B1-550, B1-650, B2-450, B2-550, B2-650,
		pSRES2001 (1)	B2-450
	MESSAGE (17)	pSRES (14)	A1B-550, A1C-450,A1C-550,A1C-650,A1C-750, A1G-450,A1G-550,A1G-650,A1G-750, A1T-450,A1T-550, A2-550,A2-750, B2-550
		pSRES2001 (3)	A1T-450,A1T-550 B2-550
	MiniCAM (19)	pSRES (15)	A1C-550, A1FI-WRE450, A1FI-WRE550, A1FI-WRE550aei, A1FI-WRE550all, A1FI-WRE550alu, A1FI-WRE550FCM, A1FI-WRE550seq, A1FI-WRE550sol, A1FI-WREe650, A1FI-WRE750, A2-550, B1Ha-550, B2H-550, B2L-550
		pSRES2001 (4)	A1F-450,A1F-550,A1F-650,A1F-750,
	LDNE (7)	pSRES (6)	A1-550,A1G-550,A1T-550,A2-550,B1-550,B2-550
		pSRES2001 (1)	B1-550
	WorldSCAN (15)	pSRES (14)	A1-450DR, A1-450EA, A1-550DR, A1-550EA, A2-450EA, A2-550DR, A2-550EA, B1-450DR, B1-450EA, B1-550DR, B1-550EA, B2-450DR, B2-450EA, B2-550EA
		pSRES2001 (1)	B1-550

The same reference scenarios but different stabilization targets

Figure 8 shows the reference scenario of pSRES-A1B and a group of stabilization scenarios (450, 550 and 650 ppmv) based on that reference scenario developed using the AIM model. Obviously, compared to a specific reference scenario, the lower the stabilization target, the larger the emission reductions required and the earlier reduction actions must be implemented.

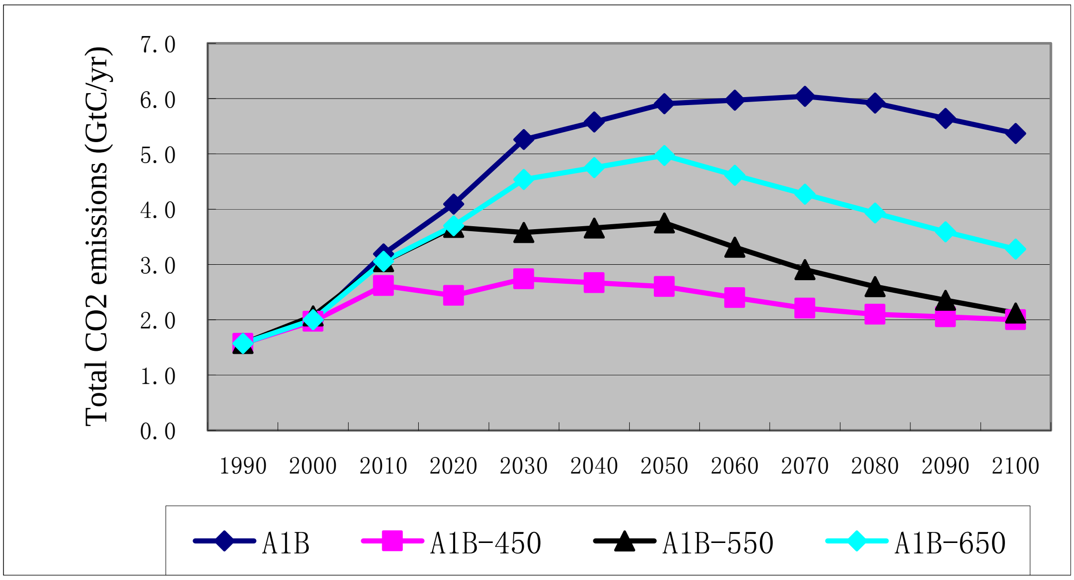

Fig. 8 The reference and A group of stabilization scenarios (AIM/pSRES-A1B) for ASIA

Different reference scenarios but the same stabilization target

Figure 13 shows two groups of reference and stabilization scenarios developed by different models (RICE99 and DNE21/98). The reference scenario from DNE21/98 (shifting CPA to China by multiplying by 0.95) is much higher than that of RICE99, but the pathways of two 550 ppm stabilization scenarios after 2050 are virtually identical.

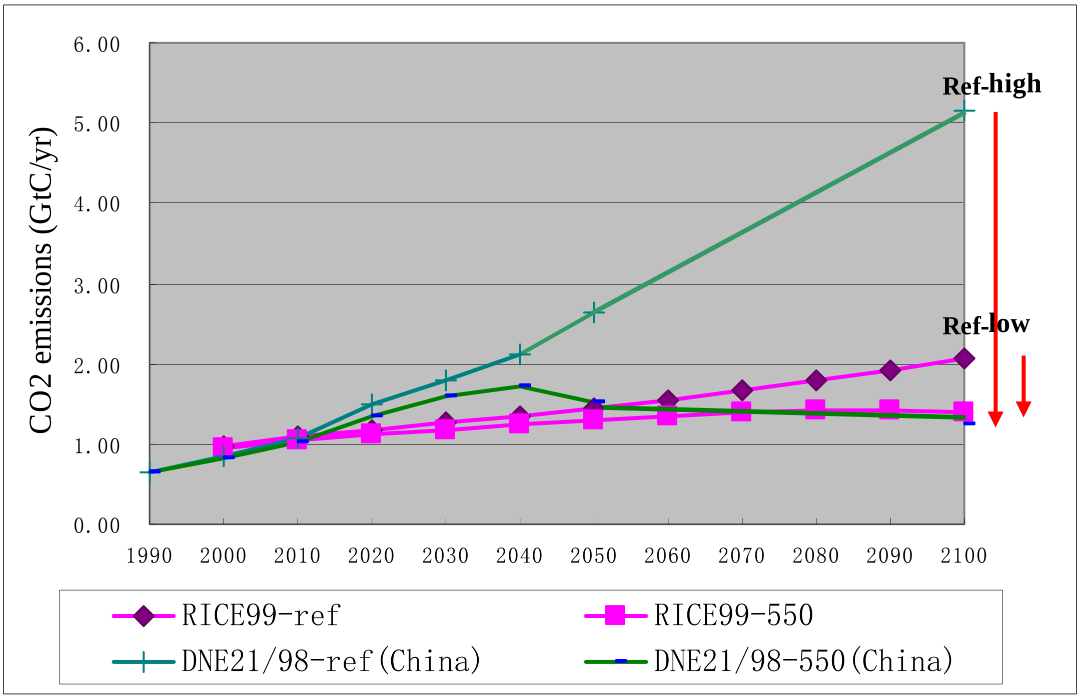

Fig. 9 Comparison of two groups of reference and stabilization scenarios for China

It is obvious that to achieve the same global stabilization target of 550ppmv, much larger emission reductions would be needed from the higher reference scenario (DNE21/98) than from the lower reference scenario (RICE99). Although the reference scenarios include no specific climate policies, this difference highlights that the development path has clear implications for climate change mitigation. Making development more sustainable in developing countries is a very effective way to fight global climate change.

4 The same stabilization target with different emission paths

Figure 14 shows that the six SRES marker scenarios achieve the same stabilization target, 550 ppmv, via different emissions paths. Scenarios A1F and A2 have similar emissions in 2100, but those for A1F are higher during most of the century. Thus, to achieve stabilization the emissions path for A1F peaks earlier (2040 vs. 2050) and is lower thereafter. The reference scenarios for A1B and B2 are similar and the stabilization paths are also similar; the B2 path is a little lower until 2040 and a little higher thereafter. The reference scenario for A1T produces emissions a little higher than that for B1 throughout the period to 2100. The stabilization scenario for A1T similarly produces higher emissions over the entire period, but consistent with the rapid technological change storyline for A1T the emissions decline rapidly after 2040.

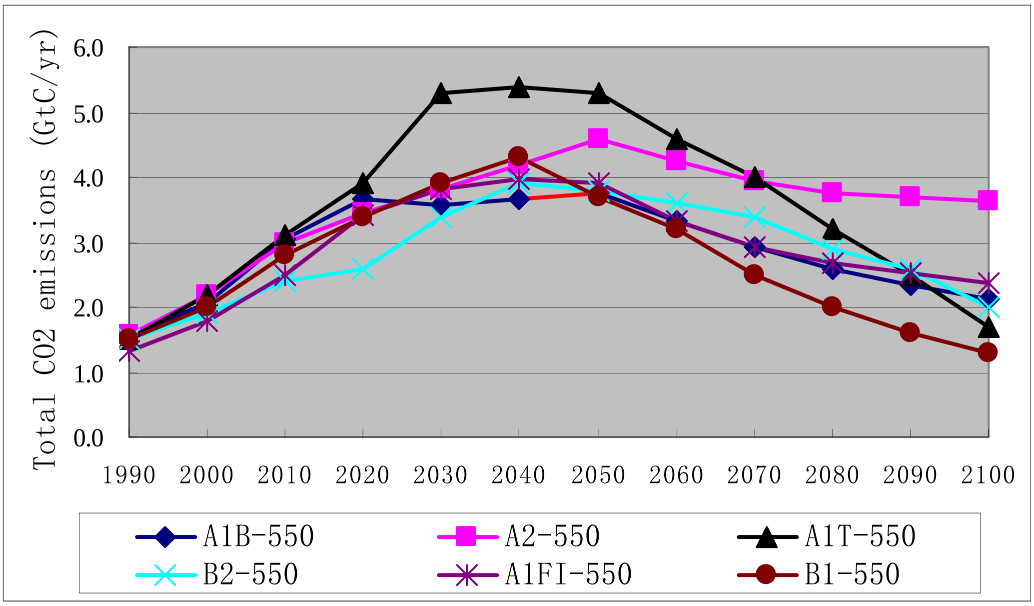

Fig 10 pSRES stabilization scenarios of 550ppmv based on the six markers

The impacts of the stabilization target on the main driving forces

Table 12 compares the impact of different stabilization targets – 450, 550 and 650 ppmv – on the main driving forces for a given marker scenario – A1B.

Table 12 The impacts of the stabilization target on main driving forces (AIM/pSRES-A1B)

	A1B	A1B-450	A1B-550	A1B-650
Total CO2 emissions	100			
2020 2050 2100		59.7 44.0 37.2	89.7 63.5 39.5	90.4 84.1 61.1
GDP	100			
2020 2050 2100		95.1 95.1 92.0	98.4 98.3 97.3	100.0 99.0 98.6
Primary Energy (PE) (EJ)	100			
2020 2050		82.0 66.3	101.0 77.4	96.9 85.2

2100		58.3	59.2	77.1
Energy Intensity (PE/GDP)	100			
2020		86.2	102.6	96.9
2050		69.7	78.7	86.1
2100		63.4	60.8	78.2
Carbon Intensity (CO2/PE)	100			
2020		72.8	88.8	93.3
2050		66.4	82.0	98.7
2100		63.8	66.7	79.2

Except for the A1B-450 target, the impact of the stabilization target on GDP is relatively small, less than 2% for both 550 and 650 ppmv throughout most of the century. The more stringent the concentration target, the bigger and earlier the reduction in the energy intensity. The improvement in energy intensity is due to changes in the structure of the economy and increases in energy efficiency. As a result primary energy consumption declines more for a more stringent stabilization target. Changes to the energy mix also contribute to meeting the stabilization target. Again the reduction in the carbon intensity of primary energy is larger the more stringent the stabilization target.

Shifting to low carbon fuels and promoting renewable energy development is not as easy as adjusting the parameters in model scenarios. In practice such developments are restricted by many factors, such as shortages of renewable energy resources, availability of suitable technologies, limited investment capital, public support, and other barriers. In the A1B reference scenario the share of coal in primary energy consumption (including traditional energy like biomass) for ASIA falls from 37.2% in 1990 to 23% by 2050 and to only 5.7% by 2100. The stabilization scenarios assume earlier and larger shifts away from coal so that it supplies only 14.8% of (a lower amount of) primary energy by 2050 and 2.4% by 2100.

Traditional energy like biomass is used unsustainably in many places of China. With economic development and urbanization, a large amount of traditional energy used in rural areas will be replaced by commercial energy a substantial portion of which is supplied by coal. To minimize the impact of this shift to commercial energy on CO2 emissions requires a sustained improvement in energy efficiency for buildings, appliances and equipment as well as wide use of renewable primary energy, steady increasing before 2020 and finally beyond 50% by 2100. Technological innovation is critical to realization of a stabilization target.

Although these stabilization scenarios seem to offer a win-win solution of protecting the global environment without sacrificing social and economic development, the model results unfortunately do not provide sufficient details on the pathways that achieve these stabilization scenarios. Even in developed countries, emissions reduction is not easy. For developing countries in the process of industrialization and urbanization, lacking technology and capital, the feasibility of achieving stabilization scenarios without sacrificing social and economic development is still unclear for policymakers.

Different regions' share in world emission reductions under the same stabilization target

Although emissions scenarios are not designed for purpose of answering questions about burden-sharing, it is interesting to see the distribution of emission reductions in different regions implied by a stabilization scenario with no trade. The share of the global emission reductions over the period 1990-2100 that occur in the ASIA region is shown in Table 13 for the B1-550, A1B-550 and A1FI-550 market scenarios. The B1, A1B and A1F reference scenarios have the lowest to highest emissions among the six marker scenarios.

Table 13 Regions' share in world emission reductions

2100	B1-550	A1B-550	A1FI-550
Cumulative world emissions reductions (GtC)	1.3	6.3	12.77
ASIA	0.3	2.2	6.21
EFS	0.2	0.47	1.62
OECD90	0.2	1.48	2.31
ALM	0.5	2.15	2.63
AISA's share in World reductions (%)	23%	35%	49%

As expected the higher the emissions of the reference scenario, the larger the world emission reductions need to achieve the 550 ppmv stabilization target. The higher the emissions of the reference scenario, the larger the emissions growth in the ASIA region. And to achieve the stabilization target, the models assume larger emission reductions the higher the emissions of the reference scenario. Of course, in developing these stabilization scenarios modellers take no consideration of equity and other important factors, such as the basic needs of developing countries in the AISA region, or who should pay for these reductions.

Conclusions and future research

The importance of China in the global energy economy make its emission trends important in understanding the overall climate challenge. Furthermore, there is strong interest both within and outside China in finding ways to tame its rapidly growing emissions, in ways that are effective but fair, in line with China's state of economic development. Yet at the moment China's emission trends are poorly understood and hard to predict. A better understanding of these trends starts with a review of the "state of the art" among international climate models. This paper reviews the modeling results relevant to China in international emissions scenarios. In some of these models China is modelled on its own, and in others the published versions incorporate China into a larger regional grouping. It is probable that with these models the China-specific data can be separated out, and this may be a useful further enquiry.

A comparison between the models and observed emission trends in China is salutary. During the period covered by the models in this analysis, 1990-2000, all the models consistently overestimate China's emissions growth. In particular they underplay improvements in energy intensity as the economy grows. This suggests at a minimum that considerable improvements will be needed if these models are to provide an adequate basis for understanding and

projecting emission trends in China. A stronger conclusion is that for the time being it will not be possible to set emissions targets in China with any degree of confidence. If, as discussed in the introduction, targets would notionally be set relative to some projected “business as usual” trend, the fact that today’s models seem not to be capable of identifying such a trend will likely make policy makers hesitate before picking any particular emission level.
Much further work will be needed to improve modeling capability, but this will not be a simple task. During the period studied, as we have already noted, real emissions growth has been lower than all the models predicted. However, in the period since 2000 early indications are that emissions intensity has jumped dramatically, which means that recalibrating the models will not be a straightforward matter. A broader lesson may be that in an economy undergoing such rapid transitions as those being seen in China it may simply not be possible to project emissions reliably.

Further work could explore the underlying drivers of energy-related emissions in more detail, including the economic and sector-level shifts influencing energy intensity. It may be possible to model emission trends more accurately in specific sectors, and this is an area worthy of further investigation.

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Appendix I:

Characteristics of China-related Models

AIM (Asian Pacific Integrated Model)
Developed by National Institute of Environment Studies (NIES) in Japan, it is a large-scale computer simulation model for Asia Pacific emission scenarios and climate change impact analysis, so far it has been expanded to global coverage. It contains 3 modules: emissions, climate, and impacts. The latest version combines the top-down parts with two bottom-up modules (energy economy and land balance). The energy economy module includes 9 regions and the land balance and top-down module contains 17 regions. The temporal dimension is from 1990 to 2100 and multiple greenhouse gases are covered.
RICE (Regional Integrated Climate and Economic model), i.e. Regional DICE (Dynamic Integrated Model of Climate and the Economy)
Developed by William Nordhaus, it is a regional dynamic general equilibrium model, mainly considering the optimum growth models of individual sectors and appropriate expansion leads to the integration of economic activities and climate. The model consists of 8 regions with temporal dimension from 2000-2100.
SGM (Second Generation Model)
Developed by Jay Edmonds and Ronald D Sands, it is multi-sector regional CGE model specifically designed for analysis of energy, economy, and greenhouse gas emissions. It adopts dynamic-recursive approach covering 14 sectors with a time frame from 1990 to 2050 in five-year time steps.
DNE21 (Dynamic New Earth 21)
Developed by Y.Fujii and K.Yamaji from Tokyo University, Japan, it is a bottom-up global energy optimization model including detailed energy technology data and is especially well suited to model supply side changes for analysis of technological options in the global energy system for limiting the atmospheric CO2 concentration. The model consists of 14 regions with time frame from 1990 to 2050, which can be extended to 2100.
IIASA/WEC
Developed by International Institute of Applied Systems Analysis (IIASA) and World Energy Council (WEC), it is a model for research of long-term development of economic and energy systems at regional and global scales, including scenarios of infrastructure financing, trade in energy carriers, and environmental impacts. The model consists of 17 regions with time frame from 1990 to 2100.
ASF (Atmospheric Stabilization Framework)
Developed by ICF Consulting in the USA, it is a bottom-up model including energy, agricultural, and deforestation models to provide emissions and atmospheric estimates for 9 world regions.
IMAGE (Integrated Model to Assess the Greenhouse Effect)
Developed by National Institute for Public Health and Environmental Hygiene (RIVM) the Netherlands, used in connection with the Dutch Bureau for Economic Policy Analysis (CPB) WorlScan model, it is an integrated assessment model consisting of three fully linked systems of models: the Energy-Industry System (EIS), the Terrestrial Environment System (TES), and the Atmosphere-Ocean System (AOS). The model divides the world into 13 regions with time frame from 1990 to 2100.

MARIA (The Multiregional Approach for Resource and Industry Allocation Model)
Developed by Science University of Tokyo in Japan, it is a compact integrated assessment model to assess the interrelationships among the economy, energy, resources, land use, and global climate change. The core of the model is an inter-temporal non-linear optimization model that deals with international trading among 9 regions with time frame from 1990 to 2100. The origin of MARIA is the Dynamic Integrated Model of Climate and the Economy (DICE) model.
MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact)
Developed by International Institute of Applied Systems Analysis (IIASA), it is a bottom-up dynamic linear programming model for analysis of energy supply for cost minimization. The latest version consisting 10 regions with time frame from 1990 to 2100, has been combined with the MACRO macro economic model.
MiniCAM (The Mini Climate Assessment Model)
Developed by Global Change Group at Pacific Northwest Laboratory, it is a small rapidly running Integrated Assessment Model that estimates global GHG emissions with the ERB (Edmonds-Reilly-Barns), a partial equilibrium model and the agriculture, forestry and land-use model. The latest version consists of 14 regions with time frame from 1990 to 2100.
LDNE (Long Dynamic New Earth)
Developed by Tokyo University, Japan, it is a long-term, worldwide energy/ environment model, linear-version of DNE for analysis on contributions of various energy supply and environmental technologies/options by minimizing total energy system cost under carbon emission constraint scenarios. The model divides the world into 10 regions with time frame from 1990 to 2100.
WorldSCAN
Developed by Dutch Bureau for Economic Policy Analysis (CPB), the Netherlands it is a dynamic general equilibrium model for long-term scenarios and policy analysis with time frame from 1990 to 2100.