

Making more progress in modeling in China

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Making Progress in Modeling for China

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Abstract

Since 1990, studies of climate change by Integrated Assessment Models (IAMs) have made notable progress by many research groups around the world. Some groups in China have worked on IAMs and had collaboration with experts in other countries. In reviewing the results from different IAMs, we notice that the results differ from each other, especially for the analysis of China. Different modeling mechanisms and different parameter assumptions are the major reasons for these difference. This paper will focus on some of the assumptions incorporated in emission models, based on the modeling work underway in China.

1. Macroeconomy and Energy in China

-Economy development

In China, the annual average GDP growth rate was 8.9% in the 1980s, following the country's economic reforms and opening (Figure 1). From 1991 to 1995 the average growth rate increased to 11.7%, giving China one of the highest economic growth rates in the world. Rapid economic development stimulated large social changes in China. Secondary industry has increased its share of overall economic activity. This trend is a common characteristic of countries in the early phase of industrial development.

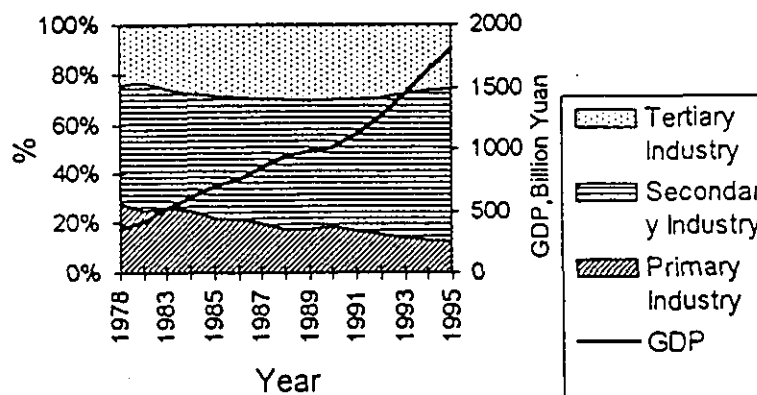


Figure 1: GDP of China

-Population

The natural annual growth rate of the population was 2.06% from 1952 to 1970, 1.61% from 1970 to 1990, and 1.16% from 1990 to 1995 (Figure 2). The rate has decreased with rapid economic development and the execution of government population policy. However population is still a serious problem for future development in China. It has been decided that long term population controlling policies will be adopted.

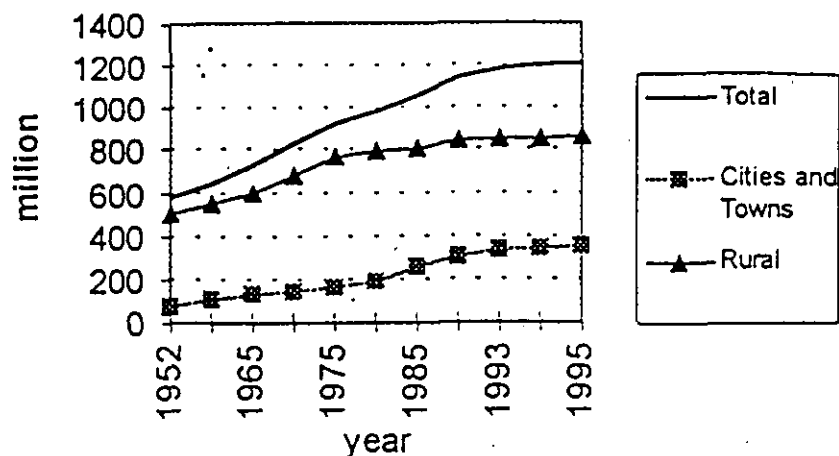


Figure 2: Population in China

-Energy production and consumption

Along with rapid economic development, energy production and consumption increased very quickly. In 1995, they are 901 million toe and 903 million toe respectively, with annual growth rates of 5.2% and 4.8% from 1980 to 1995 (Figure 3).

Based on domestic resources and the stage of economic development, energy production and consumption can be summarized as follows:

- Mainly rely on domestic energy supplies.
- Coal is the major fuel consumed in China.
- Industrial sector consumes more than 60% of total energy.
- Noncommercial energy accounts for a large share of rural energy consumption.
- Small average energy consumption per capita, but high energy use per unit of output.
- Energy prices are not rational.

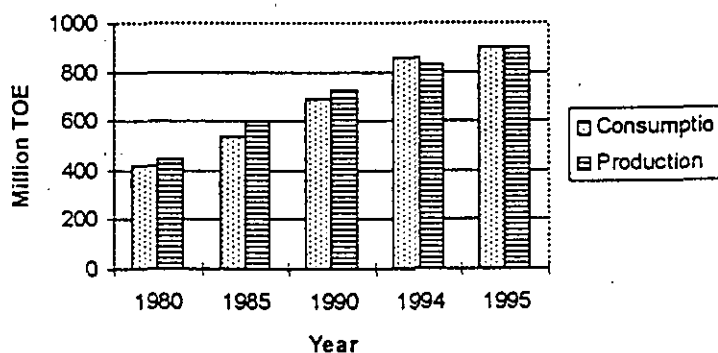


Figure 3 : Energy Production and Consumption in China

-Energy consumption structure

Coal plays a larger role in China's energy production and consumption (Figure 4 and Figure 5) than in most countries. This kind of energy production and consumption pattern creates serious environment problems and low energy efficiency. It is difficult to change this situation in China in the near future.

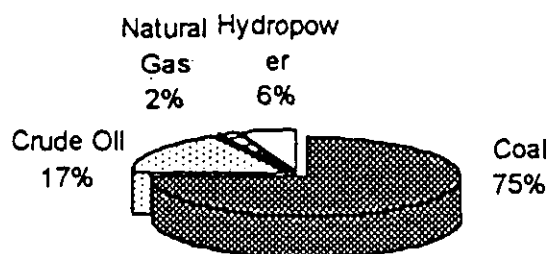


Figure 4: Energy production structure, 1995

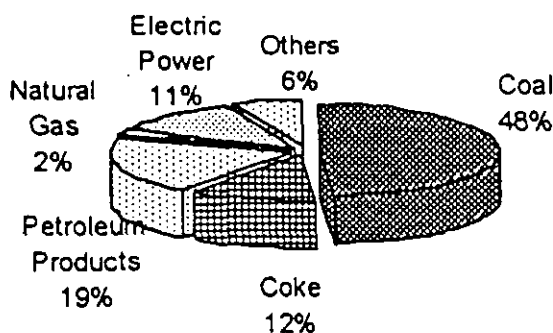


Figure 5: Mix of Final Energy consumption, 1994

-Energy imports

Historically, China exported energy to earn foreign exchange. More recently, the situation has changed. Because of rapid economic development, domestic energy supplies are insufficient. More and more high rank energy will be demanded. As a result China is expected to import increasing amounts of energy from international sources. These energy imports are unavoidable. By the middle 1990s, China became a net importer of energy (Figure 3 and Table 1).

Table 1: Energy export in China

	Net Export			
	Crude Oil million tones	Oil Products million tones	Coal million tones	Total Energy million toe
1980	12.94	3.74	4.33	27.97
1985	30.03	5.31	5.46	54.34
1990	21.07	2.39	15.29	45.65
1993	3.78	-12.98	17.81	-1.51
1994	6.20	-9.10	23.08	14.30

2. Key factors of future development to setup the scenario for China

By comparing input assumptions and the results from selected scenarios, several key factors for the future development pattern of the economy, energy and environment are discussed. These factors provide a framework for China scenarios, and improve our understanding of model assumptions applications in China. In recent years, the Energy Research Institute (ERI) collaborated with NIES, Japan, on AIM/China, and with PNL on ERI-SGM. Viewpoints of experts in ERI were used for the China scenario development in those two models. They are selected here for comparison.

2.1 CO₂ emission forecast

Many research groups have analyzed scenarios for China and other regions and derived results for GHG emissions. Several CO₂ emission forecasts from those studies are presented (Figure 6 & Figure 7).

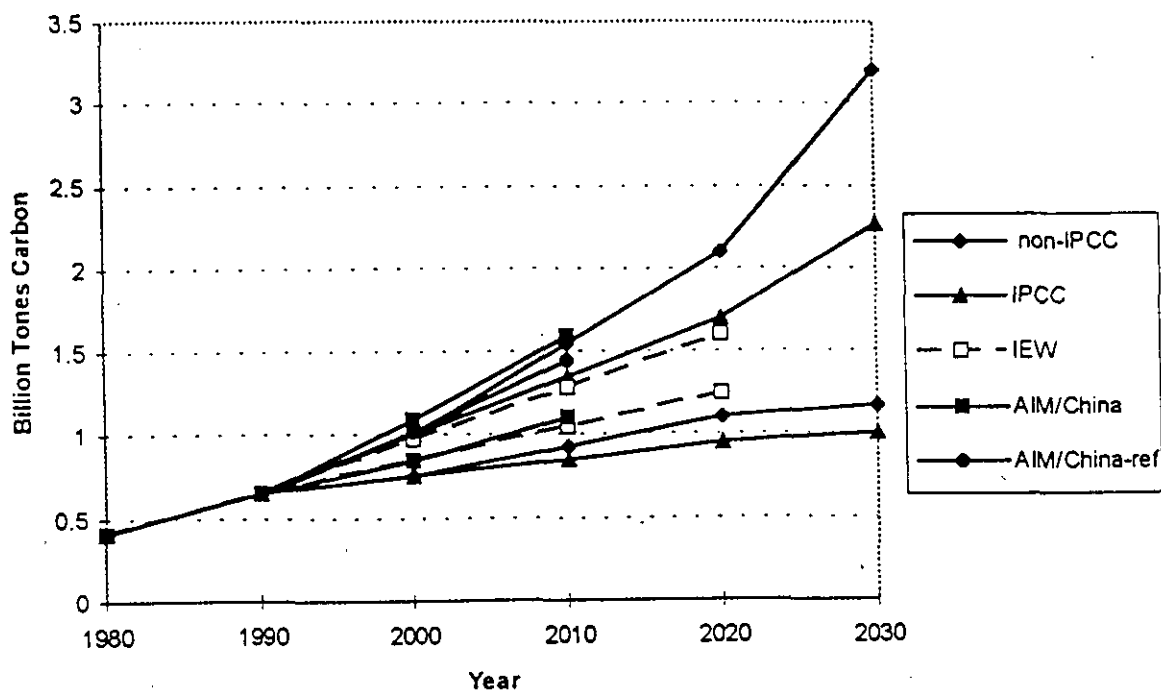


Figure 6: Carbon emission scenarios for China

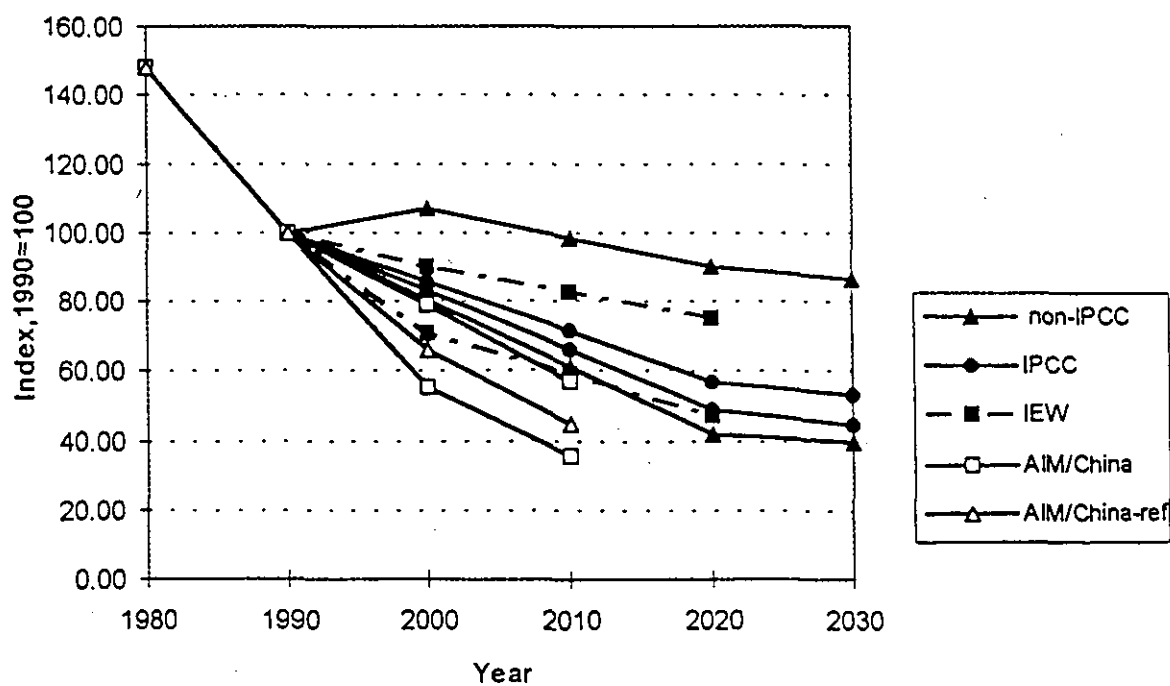


Figure 7: Energy intensity scenarios for China

It can be seen from these figures that the range among scenarios is large, which means variety exists to make this kind of forecast. This variety is much stronger for China. Rapid economic development occurred in China after 1980. This economic development has many of the characteristics of early phase of industrialization as found in other countries. However there is also a very big difference between China's development experience and that of with other developed countries. If a forecast for China was only based on the developed countries experience, some unreliable results will be generated. Some the key factors will be examined in the following discussion.

Among those scenarios, the Energy Research Institute (ERI) of China is collaborating with National Institute for Environment Studies on the AIM project, and an 'AIM/Emission for China' model was constructed for CO₂ emission forecast in China. The result from AIM is a little different from other results.

2.2 Some key variables for selected non-intervention scenarios

Some variables used by selected non-intervention (reference) scenarios for China are listed in Table 2. For comparison, high growth scenarios were selected. There are some differences in the study area and period between the AIM scenario and other scenarios: for example, the end of the study period for AIM is 2010, while for the others is 2020; and the AIM/China scenario only refers to China while other scenarios are for China and centrally planned Asia (Cambodia, Laos, Mongolia, North Korea and Vietnam). Even allowing for these differences, there is still a remarkable contrast between those assumed values in the AIM/China and other scenarios.

Table 2: China and centrally planned Asia average growth rate for selected non-intervention (reference)scenarios

Non-intervention scenarios	POP	GDP Capita	GDP	Energy GDP	Carbon Energy	Carbon Emissions
IS92a	1.03	3.91	4.98	-1.73	-0.32	2.84
IS92c	0.69	2.98	3.7	-1.61	-0.51	1.51
IS92e	1.03	4.83	5.91	-2	-0.21	3.57
WEC B	0.94	4.08	5.06	-2.40	-0.03	2.51
GREEN			4.4	-0.27	0.25	4.38
AIM/China	0.97	7.21	8.25	-3.23	0.33	4.09

Note: 1. Variables from AIM/China are for 1990 to 2010, while others are from 1990 to 2020.

2. The AIM/China scenario is only for China, others scenarios are for China and centrally Planned Asia.

Results from AIM/China show CO₂ emissions at the top of the range in Figure 6, but energy intensity at the bottom of the range in Figure 7. The major differences in variable consideration include: 1)economic growth rate; 2)potential for energy conservation; 3)population growth; 4)electricity demand increases; and 5)non-commercial energy demand decreases. By comparing China and other developed countries, social/economic/environment differences can be observed. This difference is the main reason to introduce the variable assumption difference. More detailed discussions are given as follows.

2.3 Key factors to be considered for future energy development

Social and economic development in China has some patterns the same as other countries during their developing period, and also has some special characteristics. Some key factors are summarized here to describe a framework for modeling the development of China, with a focus on energy and environment activities.

-Economic development

After 1990, the economy in China developed at a very high growth rate which exceeded that of earlier forecasts. This kind of development gave encouragement to China. It is commonly viewed that China can continue to develop very quickly if there is no social turbulence. Table 3 presents one economic development forecast for China in the next century.

The pattern of economic development will change during the next one or two decades. This change will affect energy use and environment protection. Current economic development in China can be regarded as being small scale and involving low technology development. This

kind of development pattern has the following characteristics: mainly relying on new projects with high investment to support the high growth rate; slow technology progress; wasted resources and environment problems; and unrational structure, low product quality and low value added. It was an unavoidable period as the country began its economy development. When the economy develops to a certain point, the type of economic development will become better: scaled and qualified economic development. China is at the stage to make this kind of change during the next one or two decades.

Table 3: Forecast of economy of China in 21 century

Year	Period	Annual average GDP growth rate(%)	
		growth rate	scope
1995—2000	5	8.5	8.5—9.5
2000—2010	10	8.0	8.0—8.8
2010—2020	10	7.0	7.0—7.8
2020—2030	10	6.3	6.3—7.1
2030—2040	10	5.4	5.4—6.2
2040—2050	10	4.6	4.6—5.4
1990—2020	30	8.4	8.4—9.0

(Source: Chen,Xikang: Economic development in China, 1996)

Scaled and qualified economic development will focus on the improvement of existing enterprises, raise the quality and efficiency of production factors, raise the contribution of synthesized productivity to economic development, rely on technology progress, high level management and qualified labor to reduce material use, upgrade the economic structure, increase the scale of production and facilitate the rational location of industry.

China is making efforts to make this change within 15 or 20 years. This change in development pattern will be the main mechanism for China to achieve energy saving measures. Saving resources, including energy, became a major objective of development. Enterprises will improve efficiency, adopt advanced technology, increase product quality and raise productivity.

-Population

Population remains an important factor for future development in China. The following elements will affect future population growth: Planned population increase; Fertility reduced with an increase in income; Family working patterns-both husband and wife typically have jobs; Educated people have few children; One survey shows that many people in cities think 1 or 2 children are best; Life-span increases; Death rate decreases.

Based on these elements, a forecast of the population in China was made (Table 4).

Table 4: Population forecast in China

		1995	2000	2010	2020	2030	2050
Middle Scenario	Growth rate(%)		1.140	0.88	0.69	0.39	0.13
	Population(Million)	1211.21	1282	1400	1500	1560	1600
High Scenario	Growth rate(%)		1.380	0.91	0.75	0.42	0.17
	Population(Million)	1211.21	1297	1420	1530	1595	1650
Low Scenario	Growth rate(%)		1.055	0.79	0.63	0.34	0.10
	Population(Million)	1211.21	1276	1380	1470	1520	1550

(Source: Chen,Xikang: Economic development in China, 1996)

-Energy Supply and Consumption

Energy supply is another factor to restrict future energy consumption in China. With the quick economic development, energy consumption will also increase very quickly, (especially high quality energy). The relative scarcity of domestic energy resources in the future can not support large energy demands. Importing energy requires large amounts of foreign exchange. This constraint forces development in China to adopt an energy saving pattern.

Importing energy from the international market is an option to improve energy supplies in China. It is certain that China will become an energy importing country, the uncertainty is how much energy will be imported. Crude oil and natural gas will be the major energy supplies imported to improve the energy consumption pattern. The 1990s demonstrate this trend (Table 1).

Reviewing development over the last ten years, energy consumption elasticity has been low compared with developed countries and recently advanced developing countries. If China can complete its economic development pattern and get sufficient investment, it is possible for China to keep a low energy consumption elasticity as well as a high economic growth rate.

-Limitation of Transportation

The development of transportation lags behind economic development. Insufficient transport capacity has become a critical factor restricting energy development in the short term. Because of the long distance between energy production sites and energy consumption sites, energy transportation accounts for almost half the national railway freight transport traffic.

Reliance on domestic energy supplies will last for a long time, and new energy production sites will be located in remote regions. Long distance transport strongly effects energy prices. Transport cost accounts for more than half of the price of coal in the eastern coast region.

-Technology Progress

Small sized enterprises form the bulk of the economy in China (Table 5). Small sized enterprise typically have low productivity, low levels of technology and increased material use. In China, increasing the size of enterprises is a major method for saving energy.

Table 5: Numbers of Industrial Enterprises and Gross Output Values at the Township and Above Level, 1995

	Large	Medium	Small
Number	6416	16591	569069
Gross output value, Billion Yuan	2536.3	1075.1	3027.6

Technologies in major industries are 15 to 30 years behind the level of developed countries. It is a major need, and opportunity, to improve technology in China.

-Savings and Investment

Personal savings increased quickly with the growth of income. After 1990, the savings rate is above 30% which is one of the highest in the world. These large amount savings contributed to economic development. In China, the investment rate was also very high during last 10 years. Total investment in 1995 was 2001.9 billion yuan, which accounted for 34% of GDP. Large investments are the major force to support quick economic development in China.

Foreign investment accounted for 11% of total investment in fixed assets in 1995, with a growth rate 30% over 1994. Foreign investment has become an important part of investment

in China. Advanced technology and new enterprise management techniques are introduced along with foreign investment.

-Income and Consumption

Family income is a very important factor for future energy requirements by the residential sector in China. Following economic reforms, personal incomes have increased quickly (Table 6). With rising income, residential consumption will change markedly. Compared with developed countries, consumption quality in China is still very low. Commercial energy consumption per capita for living is 0.13 toe, which is much smaller than that for developed countries. Energy consumption will increase for living with the raising of income, and this raising will introduce total quantity increase of energy consumption in the residential sector, and also quickly change its composition.

Table 6: Annual per Capita Income and Index of Urban and Rural Household

	Annual per Capita Net Income of Rural Household.		Annual per Capita Income Available for Living of Urban Household.	
	Yuan	Index, 1978=100	Yuan	Index, 1978=100
1978	133.6	100	316	100
1980	191.3	138.1	439.4	127
1985	397.6	261.2	685.3	161.6
1990	686.3	300.7	1387.3	197.8
1994	1221	355.5	3179.2	273.7
1995	1577.7	375.4	3892.9	287.2

-Labor Supply

Labor supply is incorporated as an assumption in some IAMs, and it is also very special in the case of China. China has abundant labor resources. The available work force was 755 million in 1994, which is 490 million higher than in 1952, or 63% of the total population compared to 46.5% in 1952.

Table 7 presents the shifting of labor among sectors between 1952 and 1994. The general trend is labor shifting from primary industry to second industry and tertiary industrial, from crop planting to fishery, animal husbandry, forestation and orchard. There is a large amount of rural surplus labor which is available for employment generated by economic development. The biggest problem for labor supply is to improve the quality of labor.

Table 7: Employment in China

Year	Total	(million)			Mix(%)		
		Primary Industry	Secondary Industry	Tertiary Industry	Primary Industry	Secondary Industry	Tertiary Industry
1952	20729	17316	1528	1885	83.5%	7.4%	9.1%
1962	25901	21259	2033	2618	82.1%	7.8%	10.1%
1970	34432	27786	3479	3167	80.7%	10.1%	9.2%
1980	42361	29117	7736	5508	68.7%	18.3%	13.0%
1990	56740	34049	12158	10533	60.0%	21.4%	18.6%
1994	61470	33386	13961	14123	54.3%	22.7%	23.0%

-Urbanization

Population growth in cities and towns is much higher than that in rural area in recent years (Figure 2), and this trend is expected to continue for the medium term. This changes energy demand forecasts based on the different level of energy use for people living in cities compared to those in rural areas. In contemporary China, urbanization is beneficial for social development. Education and health service in cities and towns are much better than those in rural areas. Urban areas are also the center of environment pollution and the centers for pollution control.

-Private transport development versus public transport development.

Because of the large population in China, and rising of family income, it is unavoidable that the number of private car will increase quickly, especially in cities. The rapid increase of private cars will lead to serious traffic jams and air pollution. The Government must make suitable policies for private car development. Public transport is put as the first rank development priority in China. Many public transport development plans were made in metropolitan areas, to meet the future demand.

The annual growth rate for private transport is assumed to be 32% from 1990 to 2010 in AIM/China.

3. What is the future of energy in China?: Energy Efficiency Improvement

Reviewing the energy consumption intensity over last 15 years, the index is 0.5 in 1995 compared with 1 in 1985. The average annual energy conservation rate is 4.5%, which is a very high rate compared with the development history of other countries. Analysis on energy conservation in China showed that 2/3 of this energy conservation came from indirect energy conservation (economic structural change), and only around 1/3 of energy conservation came from direct energy conservation (technology progress). Several key factors are discussed for future energy efficiency improvement, as follows.

-Economic structure

Economic structural change includes industrial structural change and products structure change within each sector.

- **Industrial structure**

Table 8 shows the economy change in China from 1978 to 1995. Secondary industry had the highest share of 65.9% in 1995. This economy structure represents the typical development pattern when a country is in the early phase of industrialization.

Table 8: Economy structure in China

	Primary Industry	Secondary Industry	Tertiary Industry
1978	28.1	48.2	23.7
1985	22.6	49.4	28.5
1990	19.0	52.0	30.5
1993	15.1	61.1	29.0
1995	13.2	65.9	27.8

This kind of economy structural change increases energy consumption, because energy consumption intensity in the secondary industry is much higher than that in others (Table 9). According to the experience of developed countries, the share of secondary industry will get smaller and the share of tertiary industry will increase in subsequent phase of industrialization. It is believed that China will also follow this path of structural change.

Table 9: Energy consumption intensity, toe/million 1978 Yuan

	Primary Industry	Secondary Industry	Tertiary Industry
1980	229.404	1369.615	374.0018
1985	178.9152	1061.426	243.7635
1990	174.8839	907.3358	208.1117
1993	153.5623	654.0262	216.2097
1994	157.6341	602.1498	200.9385

- **Products structure**

The pattern of changing product types with each sector made the biggest contribution to energy saving in China over the past 10 years. The share of heavy industry products was reduced while light industry products increased and high value added products were developed quickly. Along with the change in economic development pattern, products will shift from poor quality to high quality, from low value added to high value added and from low technical level to high technical level.

-Technology Progress

The state of technology in major sectors is 15-30 years behind that in developed countries because of the stage of economic development. According to some estimates, the contribution rate of technical progress to economy development is below 30%, which is much lower than that in developed countries, and also lower than the average level in developing countries. There is a very big requirement and opportunity for China to improve technology conditions.

To raise the level of technology, the following measures will be taken:

- New demand will rely on existing enterprises thereby enlarging production capacity and raising productivity.
- Reforms to enterprises and reorganization of capital will be speeded up to get better benefit.
- Strengthen technology innovation, make full use of advanced technology from domestic and foreign countries, to raise the technology level of enterprises.
- Organize large sized enterprise groups which cross regions and sectors.

The main problems to improve technology in China are: 1) Necessity of deeper reforms to enterprises: enterprises should leave the old economic framework, assume sole responsibility for their benefit and losses, and recognize that technology is the life of the enterprise. 2) Lack of investment: there are many projects which would benefit from energy conservation, but can not put available technologies into use because of the lack of investment.

-Performance of Government

China has a centrally planned economic base. The economy was developed according to the government plan by administrative orders. Now China is shifting its planned economic framework to a socialism market economy framework. Multilevel economic reform has progressed since 1980. Government will quit the direct operation of enterprise by constructing market mechanisms, to give management of enterprises to the market. The country remains the capital owner of state owned enterprises. It will be an advantage for economic development if the government can use this power suitably.

Sustainable economic development is adopted by government and corresponding actions and plans are made out to achieve this target. Environmental protection is an important issue to be examined along with development. China should take a different development path than other developed countries. Government policies should prompt the improvement of energy use.

-Performance of Enterprise

Because of the pattern of long term economic planning, enterprise did not concern itself about the sale of products and enterprise quality was not the major concern. The result was low efficiency, low productivity and low product quality. Once enterprise enters the market, it will lose market share if it does not take care of its quality and efficiency. From the long term view, technology conditions will be improved with enterprise keeping its competitive ability in the market.

-Market

Market mechanisms are the key objectives of economic reforms. After more than 15 years of reform, a primary market system has built up in China. But this market is still very weak compared with the market in developed countries. Fostering and amplifying market mechanisms are the targets of government in the near future.

-Energy price

Energy price in China has been controlled by government for a long time and the price differed sharply from the international market. After 1990, energy prices began to be market oriented, but it is still not a completely market price system. The price of energy still does not reflect its production cost. Energy prices are the principal foundation to energy use patterns in the future and increased market reforms are expected.

-Life style change

With rising income, people want a better living environment. This kind of change will strongly change the energy consumption pattern in the residential sector as demand for hot water, lighting and space heating and cooling will increase quickly. This pattern can be observed in recent years. Because energy consumption for living per capita is much smaller than in developed countries and the size of population in China is large, a small change in energy demand in the residential sector will greatly influence future energy needs.

-Laws and regulations

The government is trying to improve China's law and regulation system. The 'Energy Conservation Law' and 'Electricity Law' are being prepared. Some sectoral and regional regulations and laws also will be adopted. New energy standards were adopted and will be implemented by each sector. A more complete framework of law and regulation related to energy use will thus be constructed, based on China's current energy situation.

-Energy use management

It is well known that the management of energy use is very weak in enterprises in China. Because of the historic economic development pattern, reducing product costs was not treated seriously. The inefficiency and irrational use of energy can be seen in many enterprises. Good energy use management would greatly reduce energy consumption. According to a study on energy conservation in China, improving energy use management will contribute 1/10 of total energy conservation.

-Education

In China, education is very important for energy conservation and environment protection. Public involvement is an important factor to improve environmental management. However,

because of the backward economic conditions in China, public education is still at very basic level. More effort should be made to improve education and public information system.

4. Case Study: SO₂ emission in China

4.1 SO₂ emission forecast

Several scenarios for SO₂ emission forecasts are presented here to consider important factors for this analysis. In China, there have not been many analyses made, of SO₂ emission, by IAMs. Some analyses were made for temperature with the affect of sulphate aerosols. Just like CO₂ emissions, SO₂ emission has a very close relationship with energy consumption. All of the above discussion on energy consumption is pertinent to SO₂ emission forecasts. However SO₂ emissions in China also have some special factors that differ from CO₂ emission and make it more complex to analyze.

Several forecasts of SO₂ emission in China are given in Figure 8 (on the following page). Because the base year for the forecasts are different by scenarios, the figure shows 1995 as a common base year for comparison. The range of results is wide, with some scenarios assuming that policies are introduced to reduce emissions.

4.2 Major consideration

-SO₂ emissions are a serious problem in China.

In 1995, SO₂ emissions were 18.9 million tons and produced serious acid rain impacts on economic development and public living in some area. Every year there will be losses valued at more than 50 billion Yuan because of acid rain. The government will increase efforts to reduce SO₂ emission in China.

-Source of SO₂ emission in China.

In China, anthropogenic SO₂ emissions come mainly from coal combustion and metal ore smelting. Coal is the major source of energy in China, and the average sulfur content is high for coal and fuel oil in some regions. The result is increases in SO₂ emission proportional to increases in energy consumption.

-Measures for reducing SO₂ emission in China.

- Administrative measure
 - Policy for controlling environmental quality
 - Strengthen environment management
 - Improve energy consumption patterns
 - Energy supply management
- Charges for SO₂ emission
- Clean coal technology
- Desulfurization technology
- Energy conservation
- Energy sunstitution

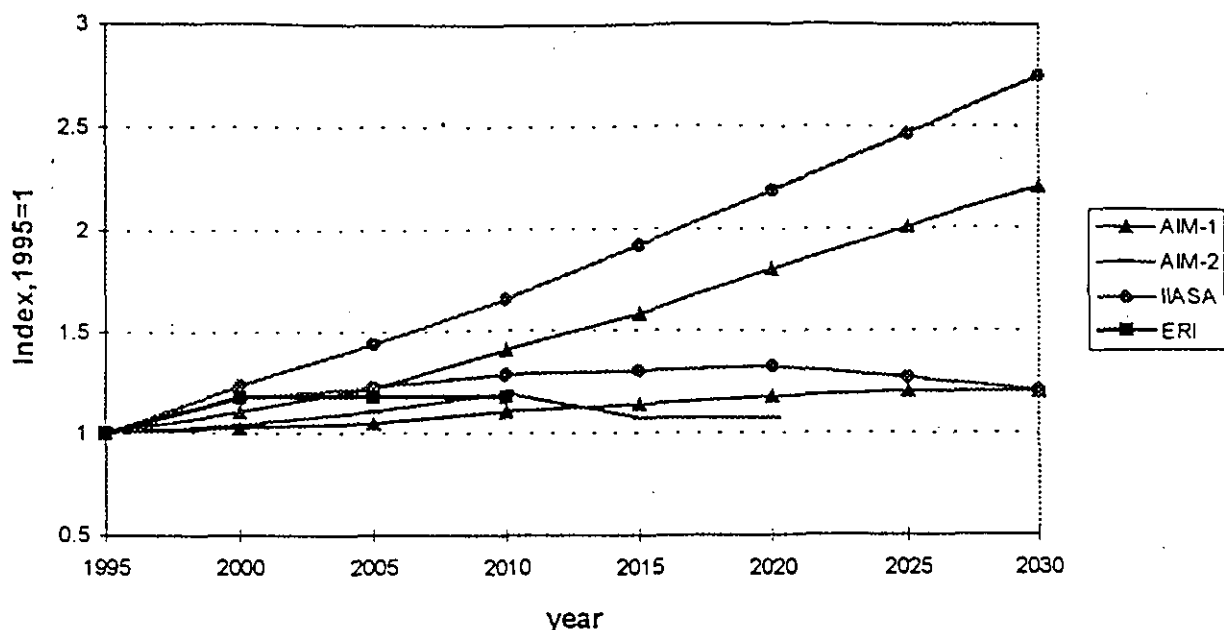


Figure 8: SO₂ emission forecast for China by selected scenarios

-Desulfurization technology.

Possible desulfurization technologies in China include:

Desulfurization before combustion

- Sulfur separated by magnetism technology
- Microwave sulfur separation technology
- Sulfur separated by bacterium

Desulfurization during combustion

- Recycle fluid bed combustion technology
- Calcium injection in furnace
- Sulfur fixed in briquette

Desulfurization after combustion

- Rotating injection in dry flue gas
- Ammonium phosphate fertilizer desulfurization technology
- Wet dust removing desulfurization technology
- Electric beam radiation technology

5. Targets of Future Modeling for China

Most models are designed by research groups in developed countries, based on the situation in those countries and western development patterns. When those models are used to forecast SO₂ emissions in China, there are some difficulties with their application. More efforts should be made to improve the models to recognize Chinese factors.

-Stress Data availability

According to the modeling experience in China, data availability is a major obstacle to using models from other countries. There are many differences between data systems in China and other countries. Different economic accounting system, restrictions/variability in the level of available data, differences in the meaning of indicators, and the different framework used in energy balance sheets are some examples. Data availability and quality should be stressed for modeling.

-Improve model mechanisms to reflect regional situations

Many economic structural differences exist between developing countries and developed countries. IAMs should consider the special situation in developing countries. Even though developing countries may follow the development pattern of developed countries after the economy reaches a certain stage, current notable differences should be fully recognized in IAMs. Market mechanisms, price systems, life styles, etc. have important difference in China from those represented in models based on developed country experience.

-Extend the research activities of IAM in China

Because of the complexity of climate change, the importance of IAM can be seen clearly. Much research on IAM has been done by groups from different countries. In China, this kind of research is still very limited. China is a major country in term of GHG emissions. Relative research including IAM applications should be strengthened in China. More research teams in China should be involved in work on IAM.

-Provide better support for policy making

Because of rapid economic development, future energy consumption will face a critical social and environmental situation. Government will make efforts to make suitable policy choices to improve the situation. Experts in China should support this policy making process. Although there are still many difficulties to support policy making by modeling, IAM should be used to assess available policy options. It is a task for experts not only in China, but also for collaborators in other countries.

-Strengthen research on modeling in China and other developing countries

Most IAMs were developed by research groups in developed countries. Because of the special economic development situation in China, it is necessary to collaborate to improve modeling for China. Better understanding between researchers in China and in other countries will be very helpful for future IAM applications. Through collaboration, more suitable development scenarios and policy options can be identified. Another important point is that researchers in China should contribute to the research of design work for IAM along with other countries' researchers, to gain a better understanding of the process incorporated in IAM.

6. Conclusion

IAM provide strong support to the research of climate change. They are a useful means to understand the affects of climate change. Results from some IAMs have been used as the knowledge base for international conventions. How to reduce uncertainties, how to quantify uncertainties, and how to make large scale IAM easily adopted by other experts and government officials to make real response, are the main challenges facing IAMs. In order to get a common viewpoint for framework for further research on IAMs, it is necessary to involve more experts from developing countries at all stages of model construction, data selection, analysis, interpretation, and policy evaluation.

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