Non-CO2 Emission Scenario in China

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1. Introduction

Non-CO2 emission mitigation polices are key component of policy package to response to climate change in many developed countries. Six gases were given in Kyoto Protocol, which demand specified policies making to reach commitment of Annex 1 countries by adoption of both CO2 and non-CO2 emission mitigation policies. More demand to mitigate non-CO2 emission is raised for long-term view point beyond Kyoto Protocol commitment period.

This analysis is part of scenario study for China. This scenario study focus on the possible development pattern by emphasizing various domestic policies to pursued sustainable development. As a developing country, China's economic development will be major target for next several decades. However environment protection is fully recognized by Chinese government. Because of the priority in China, this study hope to understand the relationship between domestic development goal and climate change. This scenario study is supported by several relative research projects, including the project collaborated with National Institute for Environment Studies(NIES) on AIM, Pacific Northwest National Laboratory(PNNL) on SGM, and RIVM on TIMER.

2. Non-CO2 gases emission in China

There are a few studies in China for CH4 emissions. Several studies in emission were summarized in table 1. There is very limited information for other NO-CO2 gas emission in China.

Recently a study by Davids etc. gives estimation of CO2 and CH4 emission for recent years by using IPCC emission factor. It is found that methane emissions in China raised from 30.7 Tg in 1990 to a peak of 34.1 Tg in 1997 and then falls to 33.4 Tg in 2000.

There are quite detailed study for SO2 emission in China and published emission data from industry and energy activities(Environment Year Book of China, 2001). Figure 1 gives the SO2 emission in China.

However the study for national wide CO, NOx, N2O emission is really lacked. In this study, a simple way is used to calculate 1990 emission as giving as following.

Very less information is available for emission of HFC, PFC and SF6. A preliminary study based on expert estimation and production survey said emission of HFCs, PFC and SF6 in 1995 are 2244, 2581 and 215ton respectively.

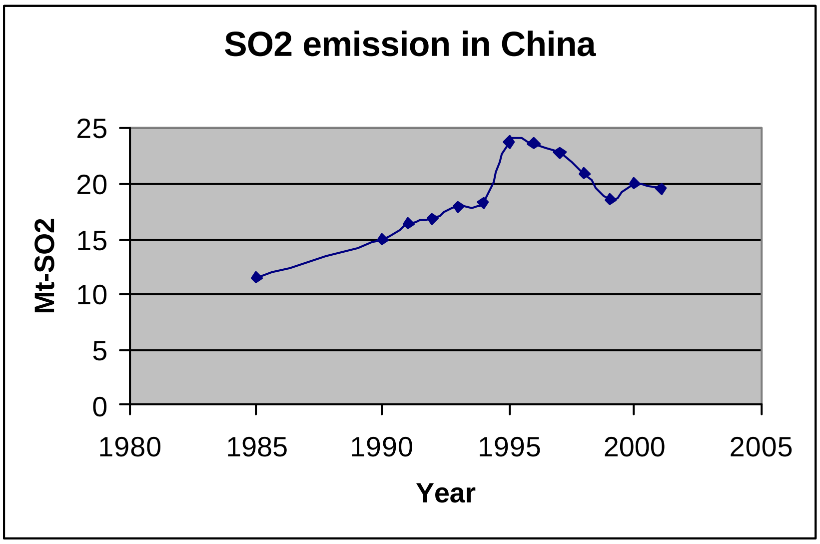


Figure 1 SO2 emission in China

3. Methodology framework

In this study, similar process used in IPCC SRES scenario development was used here. First we made narrative storyline for China, second use model to quantify of future energy consumption, land use change, and industrial production in China, and then make quantification of GHG emission scenarios. The scenarios quantified in this study are based on domestic development trend with emphasizing on sustainable development goal set up by Chinese government. No specific climate policies are considered. However it is difficult to distinguish climate policies and other social and environment policies. Strong policies are considered in low emission scenarios.

In the emission scenario study, nine gases are included, including carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O), nitrogen oxide (Nox), sulfur dioxide (SO_2), HFC, PFC and SF6. Table 2 shows the list of sources that emit non-CO2 gases. These sources include energy combustion, land use change, and industrial production processes.

There is no use of SF6 in aluminum and production process in China, which is different with that in other countries.

For quantifying these gases from various sources, IPAC-emission model was used, and comprehensive storylines of future development paths were formulated. Future GHG emissions were then projections was conducted by the integrated assessment model in energy use, energy production, industrial processes, land use changes, agricultural production, livestock, etc., from 1990 to 2100, according to the storylines.

Table 1. Summary Information on emission study in China

	1	**2**	**3**	**4**
Title of the general project or the name of report or publication	Response Strategy on Global Climate Change in China	China: Issues and Options in Greenhouse Gas Control	China Climate Change Country Study	Asian Least Cost GHGs Abatement Strategy
Title of the inventory	Current Emissions of GHGs	Estimation of GHGs Emissions and Sinks in China, 1990	Preliminary Compilation of GHG Emission Inventories	GHG Inventory by Sectors
Sponsor	ADB	GEF	US DOE	ADB
Performer	Energy Research Institute	Design and Research Institute of Environmental Engineering, Tsinghua University	Energy Research Institute	Energy Research Institute
Year of inventory	1990	1985-1990	1990	1990
GHGs	CO_2, CH_4, N_2O	CO_2, CH_4, N_2O	CO_2, CH_4	CO_2, CH_4, N_2O
Year of completion	1993	1994	1998	1998
Emission estimates:				
All energy				
Fuel combustion	609.2 Mt-C	667.64 Mt-C, 1.8-2.6 Mt-CH_4	559.56 Mt-C, 2.97 Mt-CH_4	559.6 Mt-C, 2.97 Mt- CH_4
Fugitive fuel emission	0.4 Mt- CH_4			0.092 Mt- CH_4
Oil and gas	5.3 Mt- CH_4	0.179 Mt- CH_4	0.092 Mt- CH_4	8.78 Mt- CH_4
Coal mining	25.5 Mt-C	18.45 Mt- CH_4	8.689 Mt- CH_4	25.59 Mt-C
Industrial processes	20.5 Mt- CH_4	28.29 Mt-C	22 Mt-C	12.59-20.09 Mt- CH_4
Agriculture	x	20.841 Mt- CH_4	18.2 Mt- CH_4	-75.93 Mt-C
LUC and forestry	0.6 Mt- CH_4	42.53 Mt-C	-86 Mt-C	0.899 Mt- CH_4
Waste		0.792 Mt- CH_4	2.5 Mt- CH_4	

Table 2 Source of emitted gases

Gas	Sources			
	Fossil fuel use and production	Land use change	Production process	Others
CH4	Fossil fuel combustion	Deforestation		Landfill
	Leakage from extraction	Cultivation		Sewage
		Enteric ferment		
		Agricultural waste burning		
		Biofuel resident		
CO	Fossil fuel combustion	Deforestation		
		Agricultural waste burning		
		Biofuel resident		
N2O	Fossil fuel combustion	Deforestation	Nitric acid & adipic acid production	
		Agricultural waste burning		
		Biofuel resident		
		Manure management		
Nox	Fossil fuel combustion	Deforestation	Steel & cement industry	
		Agricultural waste burning		
		Biofuel resident		
Sox	Fossil fuel combustion	Deforestation		
		Agricultural waste burning		
		Biofuel resident		
NMHCs	Fossil fuel combustion			
HFC			Production of HCFC, refrigerator	Use and disposal of airconditioner, refregerator, solvent, distinguiwsher
PFC			Use of electricity facilities, other equipment	Use and disposal of airconditioner, refregerator, solvent, distinguiwsher
SF6				Use of electricity facilities, other equipment, fire distinguiwher

4. Calculation for future emission

Emission of CH4, N2O, CO from energy combustion is calculated from technology. Emission factor for these gases for each technology is adopted from US EPA, Chinese studies and IPAC. Table 2 gives example of these emission factors.

Table 2 Technology for transport and emission parameters

Technology	Fuel	Life Span	Efficiency	Cost	Emission Factor				
					CO2	CO	CH4	N2O	NOx
Rail	Oil	15	0.33	0	73.5	570	13	5	1640
Jet aircraft	Oil	15	0.33	0	74.2	120	2	1	290
Aviation-gasoline	Oil	15	0.33	0	37.3	23500	60	1	80
Ships	Oil	15	0.33	0	73.9	320	20	2	830
Light duty gasoline vehicle	Oil	15	0.33	0	58.0	10400	36	0.5	400
Heavy duty gasoline vehicle	Oil	15	0.33	0	44.3	19100	60	6	740
Light duty diesel vehicle	Oil	15	0.33	0	73.9	340	2	20	300
Heavy duty gasoline vehicle	Oil	15	0.33	0	73.5	600	8	5	1200
Light duty methanol vehicle	Oil	15	0.33	0	61	8500	15	0	130
Light duty compressed natural gas vehicle	Gas	15	0.33	0	49.9	4	120	7	140
Coal used for transportation	Coal	15	0.33	0	93.4	88	2.3	14	312
Electricity for transport	Ele.	15	1	0	0	0	0	0	0

CH4 emission from leakage in energy exploitation and transport is assumed as scenario. By 2100, recovery of CH4 from coal mining is assumed to be 65%, leakage from oil and gas exploitation and transport is assumed to be 1% of total production.

SO2 and NOx emission is calculated by using Environmental Kuznets curve. The Environmental Kuznets curve is an inverse-U-shaped pattern relation between national environmental quality and national income (Khan, 1995; Klaassen, 1996; Andreoni, *et al.* 1998). Frossman and Krueger (1994) and Selden and Song (1994) present cross-national evidence that as nations grow richer they first degrade their environment. As incomes increase further, air quality increases. They estimated that the turning point for particulate and sulfur dioxide occurs at roughly $6000-$8000 dollars of GNP per-capita.

The Environmental Kuznets curve used here is a simplified form. The SO_2 emissions reduction rate is dependent on GDP per capita, final reduction rate and period to reach the final reduction rate. It can be expressed as the following:

$$Ei = ENEi \quad FEMISi * RRATE \qquad (1)$$

Here Ei is the SO_2 emissions from fuel I, $FEMISi$ is the SO_2 emission factor of fuel i, $RRATE$ is the emission reduction rate.

If $CGDPt < TGDP$

$$RRATE = 0 \tag{2}$$

Here $CGDPt$ is the per capita GDP at year t, $TGDP$ is the per capita GDP of turning point.

If CGDPt >= TGD and t-ts< Pe

$$RRATE = (1 - FRATE)\ \frac{t - t_s}{Pe} \tag{3}$$

t_s is the year when the turning point reached, Pe is the assumed period required to reach final reduction rate $FRATE$

If $t\text{-}t_s > Pe$

$$RRATE=FRATE \tag{4}$$

Fuel i identify coal, crude oil, natural gas and biomass.

Use of the Environmental Kuznets curve means the pollutants will be reduced with the increase of income. In the case of SO_2 emissions, the reduction is caused by many ways that cover not only energy saving by technology progress but also introduction of desulphurization technologies, regulations etc. It is the different point with the assumption in the medium-term emission study.

Emission of HFC, PFC, and SF6 is calculated with relation with relative emission activities. HFC and PFC are calculated by giving elasticity with development of GDP, SF6 is calculated with relationship on power generation by giving elasticity.

5. Scenario story Lines

A set of scenario story lines for China was formulated by defining several key driving factors such as GDP growth, population, energy efficiency improvement, etc. The future development patterns used were mainly taken from different trend of development in China. IPCC SRES B2 scenario was adopted for the global scenario. Only parameters for China will be changed to follow the scenario line for China, while other regions ‘ parameter keeping same. The historical data on energy use and GHG emissions were taken from OECD statistics, FAO statistics, data on China, related special papers on emissions, expert advice, and other sources. This section briefly describes the assumptions that we used for key parameters.

In order to reflect the possible development trend for China, 7 story lines were developed. In order to reflect different voice for economic development in China, three economic development pattern including high GDP growth rate, medium growth rate and low GDP growth rate are covered, while focus was given to medium growth rate which follows the planning from government. There are two development paths for population, one is low population growth and another is high growth scenario, and the high population path is close to government planning. However there is no big difference among the two population paths because there are many study and government planning for population development. By combining these key factors, 7 story lines were formulated. The brief definition of these story line is given in table 3.

Table 3 Description of scenarios

Scenario	Code	Description
Traditional development scenario	S1	Future energy and environment development follows the experience of industraialized country during their initial stage of industrialization. Large space for energy intensive industry because of relying on row material production and low innovation of knowledge which makes slow technology progress and high energy demand.
Conventional scenario	S2	Economy development and energy industry follows the experience of China in last several decades. Industry will continue to keep dominant for next several decades. Energy supply mainly rely on domestic resource.
Energy policy intervention scenario	S3	Energy industry is promoted by government with planning, emphases on clean energy and improvement of energy efficiency. International energy market is regards as one of the important source for clean energy. Energy policies from government could be well implemented.
Environment driven scenario	S4	Base on the understanding on domestic environment problem, much more environment policies will be introduced beside existing energy and environment policies. Energy supply and use will satisfy the requirement of domestic environment. Clean energy and clean production is a mainstream of the society.
Tiger development scenario	S5	A higher economic growth is assumed. Conventional development pattern is same as that in scenario S2, when higher technology progress is assumed because of financial ability for technology R&D.
Gray development scenario	S6	A lower economic growth is assumed. Conventional development pattern is same as that in scenario S2, when lower technology progress is assumed because of financial ability for technology R&D.

IPCC SRES B2 scenario was taken as a global scenario. B2 is a world with good intentions, which it is not always capable of implementing. This storyline is most consistent with current national and international developments. On balance the B2 world is one of central tendencies that can be characterized as neautul progress among SRES scenarios. Human welfare, equality, and environmental protection all have high priority, but the world proves unable to tackle these concerns at a global level and resolves them as best it can regionally or locally. Generally high educational levels promote both development and environmental protection. Education and welfare programs are widely pursued leading to reductions in mortality and to a lesser extent fertility. This results in a central population projection of about 10.4 billion people by 2100, consistent with the United Nations median projection. GWP grows at an intermediate growth rate of 2 percent per year, reaching about US$235 trillion in 2100. The B2 storyline also presents a generally favorable climate for innovation and technological change especially in view of high educational levels compared to today and relatively efficient markets at the regional level. B2 is a world of "regional stewardship" that, in some regions, is particularly frugal with energy and many other natural resources. Consequently, energy system structures differ among the regions. Overall high priority is given to environmental protection, although global policies prove elusive and regional polices vary widely.

In this B2 scenario, the basic consideration in this scenario for the Developing Asia-Pacific is that economic development utilizes resources so as to maintain equity for the future, while maintaining balance among regions as well as between urban and rural areas. Such an approach is introduced based on the recognition of environmental issues and sustainable development. This scenario can be described as regional stewardship from a global perspective, based on a natural evolution of the present institutional policies and structures. It is characterized by limited population growth, medium economic growth, inequality reduction, weak global governance but strong national and regional governance, a strong deurbanization trend, strong pursuit of environmental improvement, and encouragement of renewable energy use. It is a low per capita economic development scenario. In this scenario, the per capita GDP is nearly 1/5 that of the OECD countries by 2100.

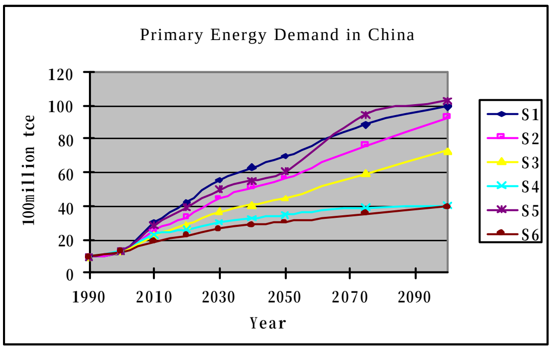
All china's emission scenarios were developed under B2 scenario. In IPAC-emission model, international energy trade was included in the study based on the resource cost effective availability.

Assumption for each scenario is given in appendix.

6. Non-CO2 emission scenario

Similar with CO2 emission trend in China, Non-CO2 GHG gases emission also shows increase trend by following economic activities. SO2 emission has close relationship with energy activities, but countermeasures were included in the analysis by giving environmental Kuznets curve. Significant reduction trend were seen for SO2 and Nox emission in China. Figure 1 to 10 present the results. Put all the non-CO2 GHG gases(CH4,N2O,HFC,PFC and SF6) together by following IPCC data on GWP for these gases(IPCC TAR WGI), by 2050, total Non-CO2 emission could reach a range from

690million t-Ce to 1200 million t-Ce, taking the share of total GHG emission from 16% to 30%. Compared with the share in 1990 as 32%, we see decrease trend of the share.



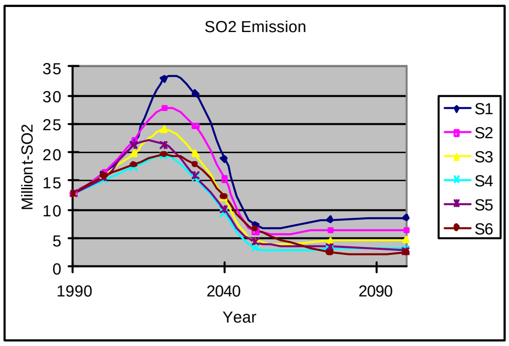
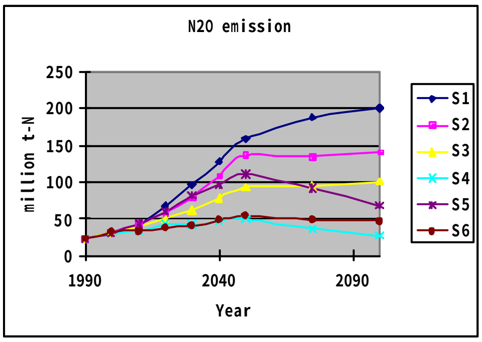


Figure 1 Primary energy use in China

Figure 2 Primary energy mix



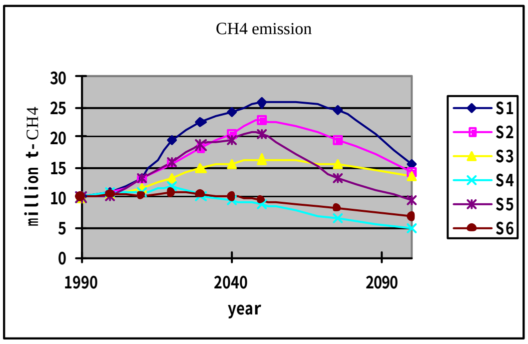
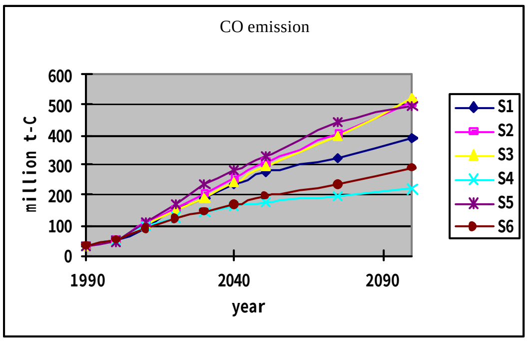


Figure 3 N2O Emission from energy use

Figure 4 CH4 emission from energy



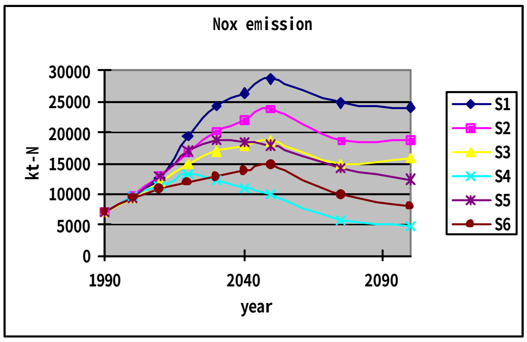


Figure 5 CO Emission from energy

Figure 6 Nox Emission from energy use

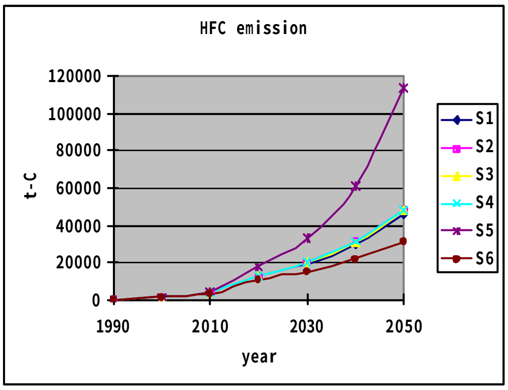


Figure 7 HFC emission in China

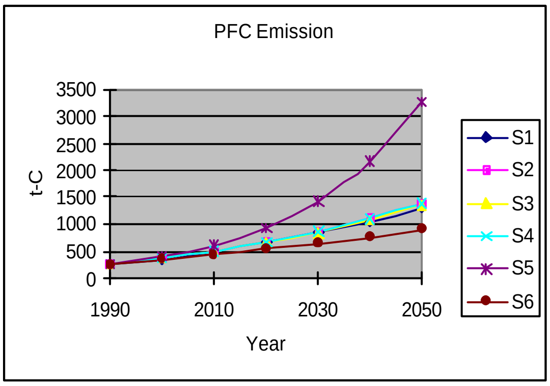


Figure 8 PFC emission in China

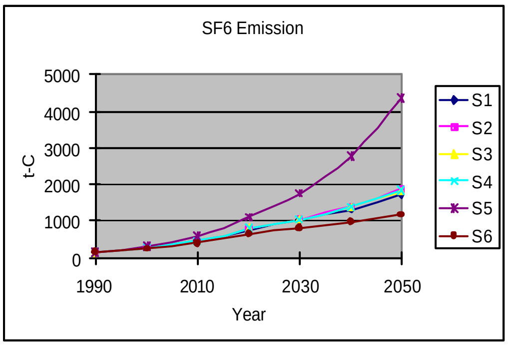


Figure 9 SF6 emission

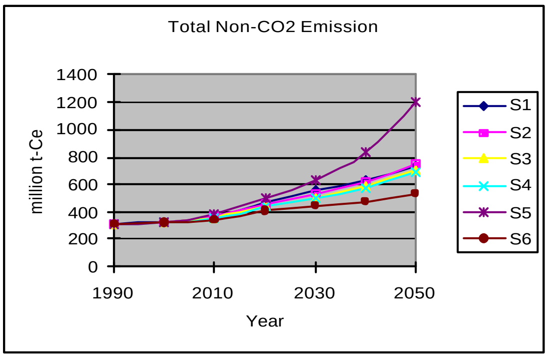


Figure 10 Total non-CO2 emission in China

7. Conclusion

Because of the local environment concerning, SO2 and Nox emission could be reduced as economy development. China will follow the experience from developed countries to control these emissions.

Other non-CO2 gases emission will keep growing with enlargement of economic activities and life level increase. Total effect of gas emission will increase because SO2 and Nox are cooling effects gases.

Policy and technology should be developed to control non-CO2 emission in China. In future policy making process, these non-CO2 emission should be included as a package for national mitigation strategy to response to climate change and support local sustainable development.

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