# GHG Emissions and Climate Change

## - Trends and Mitigation Potentials -


### Summary

It has been acknowledged that climate change is one of the important issues facing humanity in the present century and needs to be studied over a long-term horizon. The effects of climate change are already visible in different parts of the world. Analysis of climate data observed in last century and projected by climate models toward the end of this century have shown that much higher drastic changes in climate change indicators like annual mean temperature and precipitation is expected over the next century than that witnessed in the past century. These changes are likely to adversely impact the ecosystems in the region and have been a major cause of concern for both the developed and the developing countries. This study highlights the likely impacts of climate change on the ecosystems of China, India and Korean Peninsula.

China has been prone to floods frequently and has been a cause of concern for policymakers. Impact studies have shown that farsighted investments in infrastructure for preventing flood disaster from early decades in this century have a potential to mitigate not only additional flood disasters caused by future climate change but also flood disasters which currently occur because of climate variability. The impact analysis also covers the impact of climate change on the vegetation in the Korean Peninsula and on the water resources in India. The Korean country study highlights the extent of vegetation damage caused by climate change while the Indian analysis brings out the acute risk of drought that India would face if the country grows in an unsustainable manner.

However technological development resulting from both market driven investments in research and development and push policies from national governments has resulted in development of technologies with the potential to abate green house gas (GHG) emissions and thus mitigate adverse impacts on the environment. A section of this study using the AIM Global framework analyses the GHG emission trends -both past and future- and the reduction potentials in countries in the Asia Pacific region. The countries studied in detail include China, India, Korea and Thailand.

The dynamic optimization model provides global greenhouse gas emissions paths under different socioeconomic scenarios with various constraints on multiple greenhouse gas emissions, temperature increases, rates of temperature increases and rises in sea levels. It identifies the short-term mitigation targets under different long-term goals. Stabilization of GHG concentrations at 500 ppmv is required in order to limit any temperature increase as close as possible to 2ºC in 2150 relative to the 1990 level. The GHG reductions required to

achieve such a 500 ppmv cap on total GHG concentrations are 7.1 Gt-CO2eq in 2020 and 19.0 Gt-CO2eq in 2030 compared to the BaU case.

The AIM Global modeling results show GHG reduction potentials in different sectors for world regions for the year 2020. The study brings out the potential of mitigating GHG emissions and the costs involved. To achieve this reduction potential it is essential to set up a mechanism that would facilitate transfer of advanced technologies and financial aid to less developed nations of the world.

## Contents

# A. Climate Change and Its Impacts in Asia

## A.1 Climate Change Observed in 20th Century (20c) and Simulated for 21st Century (21c)

### Trends of Annual Mean Temperature and Precipitation

- Temperature increase during 21c is larger in China, Japan and Korea than in India, while it is smaller in Thailand. Difference of temperature increase among models (model uncertainty) is also large where temperature increase is large.
- Temperature change by the end of 21c is the largest in SRES-A2 scenario, followed by A1B, B2, and B1 scenarios.
- While future precipitation is quite uncertain, increase in precipitation seems to be a common future trend in China both among models and among emission scenarios.

Figure A1-1 shows time-series of annual-mean temperature and precipitation observed for the period 1901 to 2002 and simulated for the period 2003 to 2100. Thick-colored lines denote 10-year moving average of annual mean value based on CSIRO-mk2 AO-GCM, while thin-colored lines denote annual mean value. Error-bars at the right-end show the range of decadal mean for the period from 2091 to 2100 among 6 different AO-GCMs (CCSR/NIES, CGCM, CSIRO-mk2, ECHAM4, GFDL-R30, and HADCM3) distribute at IPCC Data Distribution Centre. Black-lines show the observed values based on CRU2.1 time-series dataset distributed at Climate Research Unit in University of East Anglia, UK. Using the difference between observed and simulated values for the period from 1991 to 2000, bias of model simulation from observation is removed.

In India, temperature change from 1990s to 2040s ranges between 1.04 $^oC$ (B2) and 1.75 $^oC$ (A2) and temperature change from 1990s to 2090s ranges from 2.1 $^oC$ (B1) to 4.05 $^oC$ (A2) due to the emission scenario diversity (SRES-A1B, A2, B1, B2) according to CSIRO-mk2's result. However, difference among climate models is quite large, and temperature change from 1990s to 2090s under A2 scenario ranges between 2.83 $^oC$ and 5.31 $^oC$. This uncertainty in range resulting from model diversity is larger than that resulting from emission scenarios used by one model. In China, temperature change from 1990s to 2090s ranges from 3.23 $^oC$ (B1) to 5.48 $^oC$ (A2) according to CSIRO-mk2's result, and it is higher than in India. Difference among climate models is also larger than that of India. On the other hand, temperature change and its difference among models are smaller in Thailand than in India. In all the 5 countries, temperature change by the end of 21c is the largest in A2 scenario, followed by A1B, B2, and B1 scenarios. In the first half of 21c, the largest temperature increase is expected to occur under B2 scenario. Future precipitation is quite uncertain and it is difficult to tell whether it would increase or decrease in each country. However, it can be out of the range experienced in 20c. Only in China, increase in precipitation seems to be a common future trend among emission scenarios. Annual precipitation in China will increase from 611 mm/year in 1990s to 624 – 660 mm/year in 2040s, and it will reach 664 – 715 mm/year in 2090s according to CSIRO-mk2’s result. The error bars at the right-end also tell that most climate models agree with the trend in China. It is a common result among the five countries that the uncertainty range derived from model diversity is larger in A2 scenario than in B2 scenario. It means that behavior of precipitation under the same degree of temperature increase is still quite different among climate models.

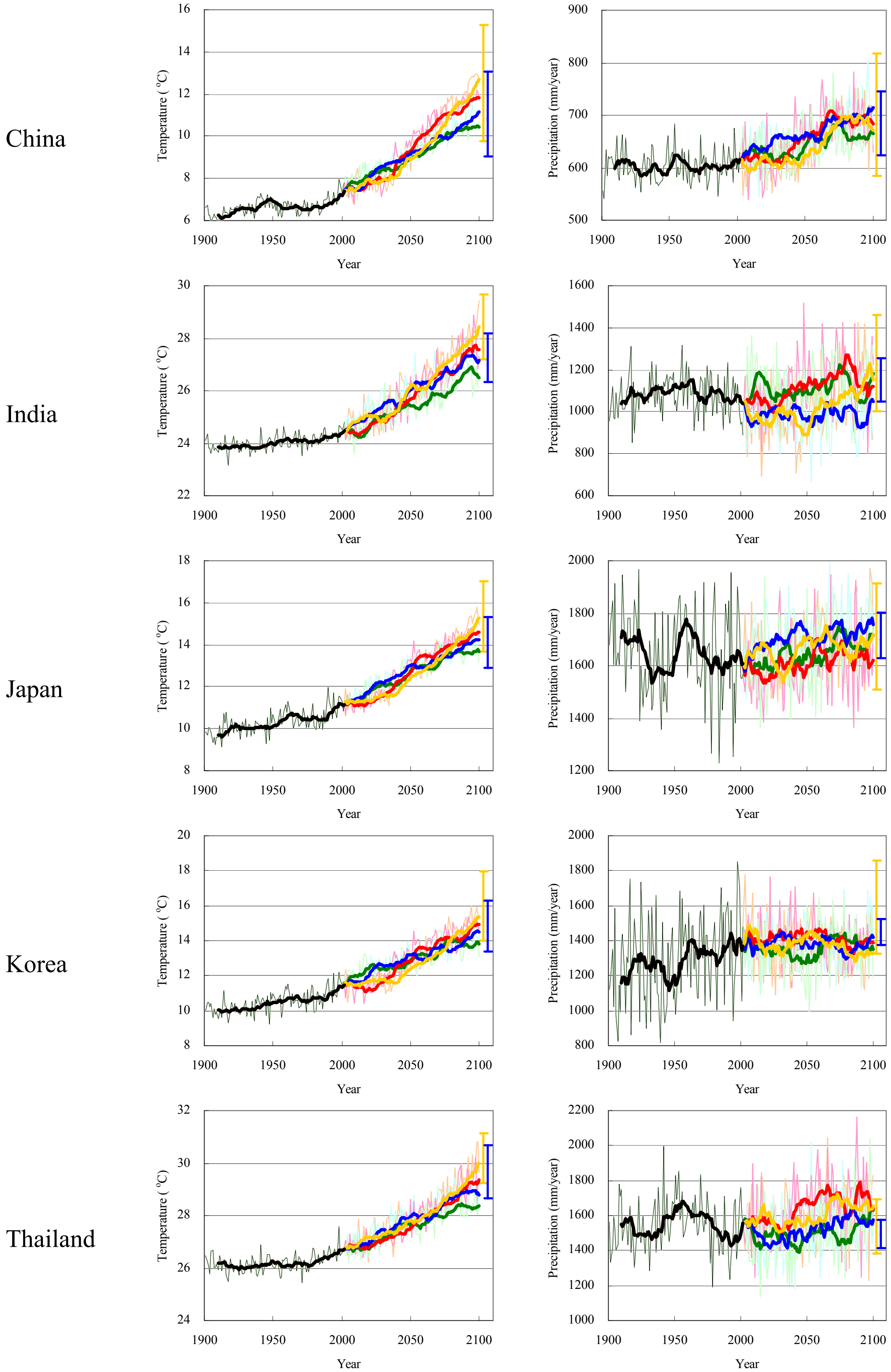



**Figure A1-1**: Time-series of annual-mean temperature and precipitation (Red: SRES-A1B, Yellow: A2, Green: B1, Blue: B2, Black: Observed)

## Rate of Temperature Change

- Drastic GHGs mitigation is required for keeping temperature increase per decade below 0.2°C.

Figure A1-2 shows the rate of temperature change in 5 countries for 2 emission scenarios (SRES-A2 and B2). Plotted data is based on CRU2.1 for 20c and mean of 6 AO-GCMs' results for 21c. High rate of climate change is considered to affect vulnerable sectors such as natural ecosystem significantly, and some studies have defined 0.2°C/decade as the critical limit. It can be found that decadal rate of temperature will continue to increase even in the latter half of 21c in A2 scenario, while it will be rather stable in B2 scenario. Even in B2 scenario, the rate would be more than 0.4 °C/decade in the first several decades of 21c and it may not cross the critical line of 0.2 °C/decade during the century in most countries. In order to fulfill the climate control target of 0.2 °C/decade, more drastic mitigation of GHGs is required.

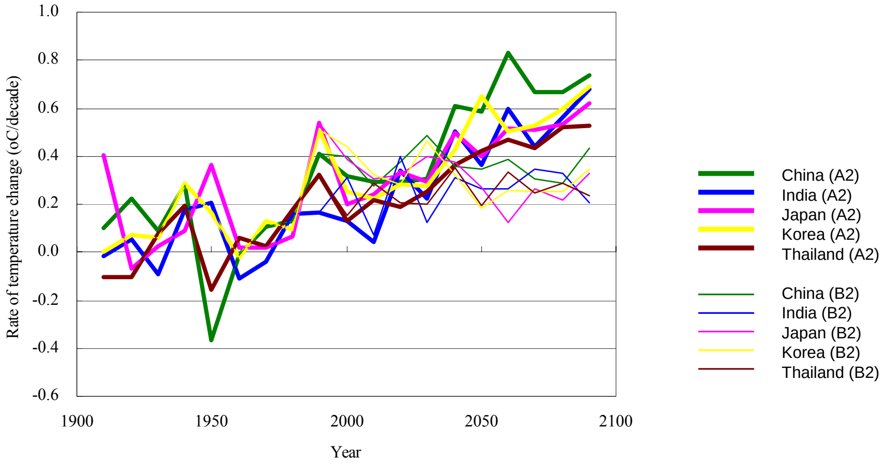



**Figure A1-2**: Rate of temperature change in 5 countries

## Fluctuation of Monthly-Mean Temperature during a Year

- In China and India, fluctuation of monthly temperature during a year has been decreasing.

Figure A1-3 shows decadal-mean of intra-annual temperature fluctuation index for A2 and B2. The index is defined as an annual-mean of absolute values of difference between annual-mean temperature and monthly-mean temperature and it is described in the equation below.

$$\text{Intra-annual temperature fluctuation index} = \sum_{m=1}^{12} \left| temp_m - temp_{ave} \right| / 12$$

Here, $temp_m$ denotes monthly-mean temperature and $temp_{ave}$ denotes annual-mean temperature. Thick-lines show the trend of observation (20c) and mean value of 6 GCMs' simulation results (21c), while dotted thin lines show the range of 6 GCMs' simulations. China (green) and India (blue) show a clear trend of decrease in the index through both the observation and simulation periods. It means that future temperature increase in cold season is larger than that in hot season and fluctuation of monthly temperature during a year decreases. In Korea and Japan, there is a decreasing tendency in 20c but may not continue to decrease in 21c. In Thailand, through both the observation period and the simulation period, the index will not change significantly.

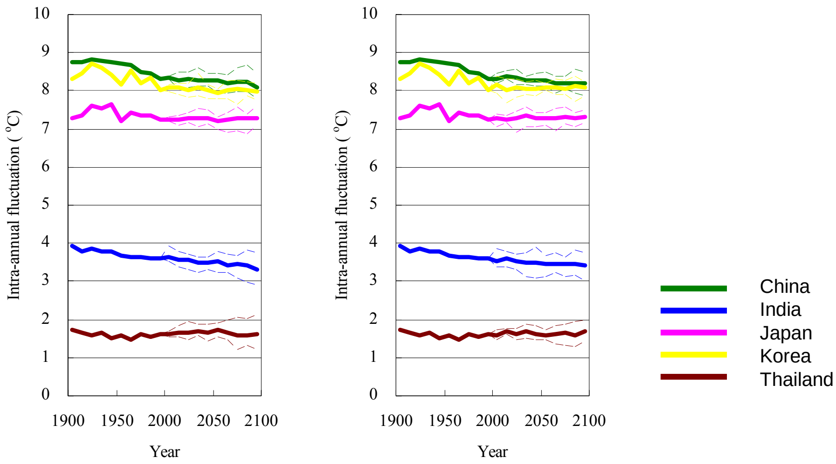



**Figure A1-3**: Intra-annual temperature fluctuation index (Left:A2, Right:B2)

## Fluctuation of Annual-Mean Temperature during a Decade

・In India and China, extreme events may occur more often in future.

Figure A1-4 shows inter-annual temperature fluctuation index of each decade. This index is defined as decadal-mean of absolute values of difference between decadal-mean temperature and annual-mean temperature. The index of 1990s is described in the equation below.

$$\text{Inter annual fluctuation index} = \sum_{y=1991}^{2000} \left| temp_{ave,y} - temp_{dec,1990s} \right| / 10$$

Here, $temp_{ave,y}$ denotes annual-mean temperature in the year $y$ and $temp_{dec,1990s}$ denotes decadal-mean temperature in 1990s. The meaning of line-style is the same as in Fig. A1-3. Although the future trend of inter-annual fluctuation is quite different among GCMs, it may increase significantly in India and China according to the mean of the 6 GCMs' results. Extremely hot summer and its disastrous impact are reported in many regions of the world these days. Increasing tendency of the index implies that such an extreme climate event will occur more often in future.

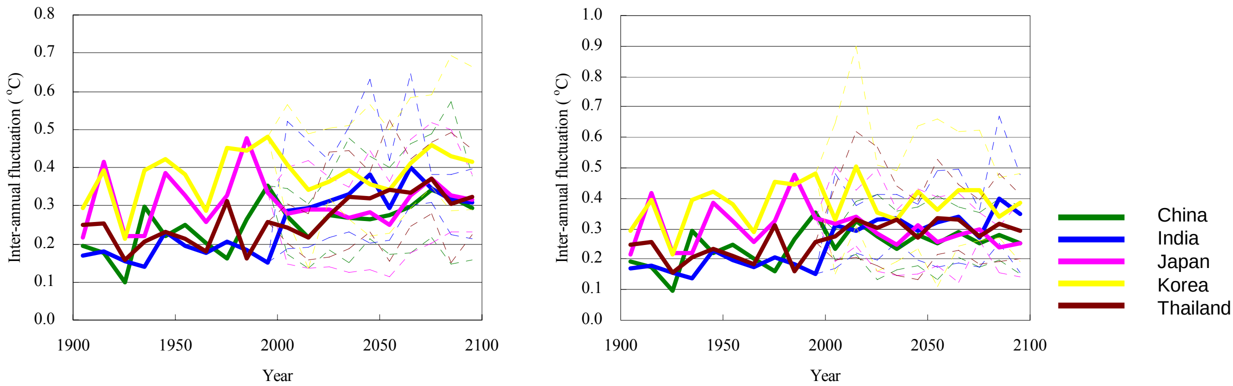


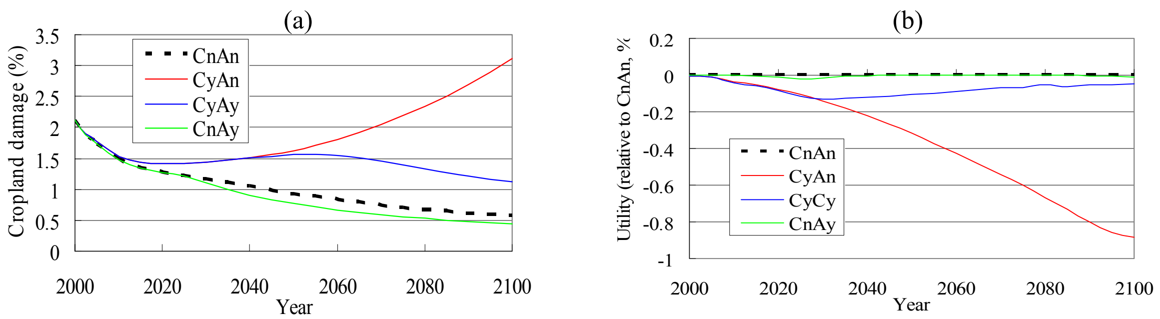

**Figure A1-4**: Inter-annual temperature fluctuation index (Left:A2, Right:B2)

## A.2 Climate Change Impacts in Asian Countries

**In China, we might as well invest in flood prevention infrastructure from early decades in 21st century with supposing future flood damage increase because of climate change.**

Flood, one of the main natural disasters in China, occurs frequently, not only in southern China where a humid monsoon climate prevails but also in arid and semiarid northern China. Changes in flood risk is considered to be one of the potential impacts of climate change, since some studies estimate the increase in frequency/intensity of heavy rain. On the other hand, additional investment in infrastructure for preventing flood disaster from early decades in this century have a potential to mitigate not only additional flood disasters caused by future climate change but also flood disasters which currently occur because of climate variability.

We evaluated the optimal amount of investment in infrastructure for preventing flood disasters by considering the uncertainty of future flood occurrence. Figure A2-1 shows (a) estimated flood damage to cultivated land under four alternative scenarios (CnAn (baseline), CyAn, CyAy and CnAy) and (b) the estimated changes in consumer's utility compared with baseline case. Flood is expected to damage 1.13% of cultivated land in 2100 even if investment takes climate change into consideration and climate changes do occur (CyAy). The damage will gradually increase to 3.11% by the end of the century when there is no investment in flood prevention infrastructure to combat projected climate change and climate change unfortunately occurs (CyAn). Comparing with the consumer's utility per capita in CnAn case, it will decrease by 0.83% when no adaptation investment is implemented while climate change occurs (CyAn). The decrease of utility can be reduced to 0.1% if adaptation investment is implemented (CyAy). Even if investment is larger than the optimal level (CnAy), consumer's utility per capita will not be lost significantly. According to this analysis, it doesn't seem to be a bad strategy to invest in flood prevention infrastructure with supposing flood damage increase because of climate change even if the occurrence and magnitude of climate change is still uncertain. In other words, we can consider this strategy to be fairly robust.

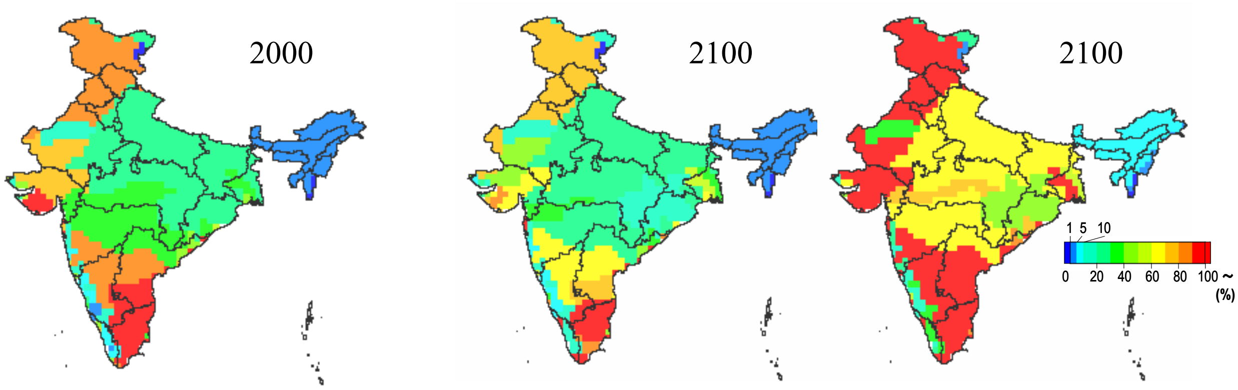



| | |
|---|---|
| [CnAn] Policymakers do not arrange adaptation investment for the projected climate change and climate change does not occur. ( = Baseline case) | [CyAn] Policymakers believe climate change will not occur and thus no adaptation investment is implemented to mitigate flood damage from climate change, but unfortunately climate change occurs. (The amount of adaptation investment is assumed to be same as that in CnAn.) |
| [CnAy] Policymakers believe that climate change will occur and adaptation investment is arranged to mitigate flood damage from climate change, but climate change does not occur. (The amount of adaptation investment is assumed to be same as that in CyAy.) | [CyAy] Policymakers believe climate change will occur and thus adaptation investment is arranged to mitigate flood damage from climate change and actually climate change occurs. |

**Figure A2-1**: (a) Ratio of cultivated land damaged by flood (%) and (b) Consumer's utility per capita relative to the baseline scenario (%).

**In India, drought risk will go up in future if high rate of population increase continues. Climate change may exacerbate the risk in some regions.**

Figure A2-2 depicts the stress on India's water resources resulting from climate change and socio-economic change. The water stress index is the ratio of water withdrawal to renewable water resource in each basin. Under the unsustainable scenario, which reflects high-rate of population growth and low rate of water-use efficiency improvement, water stress index will significantly increase in India, leading to increasing drought risk. On the other hand, under the sustainable scenario, water stress index will decrease slightly in most basins reflecting high rate of water-use efficiency improvement (there are small number of exceptional basins where water stress index increases because of the regional pattern of climate change).

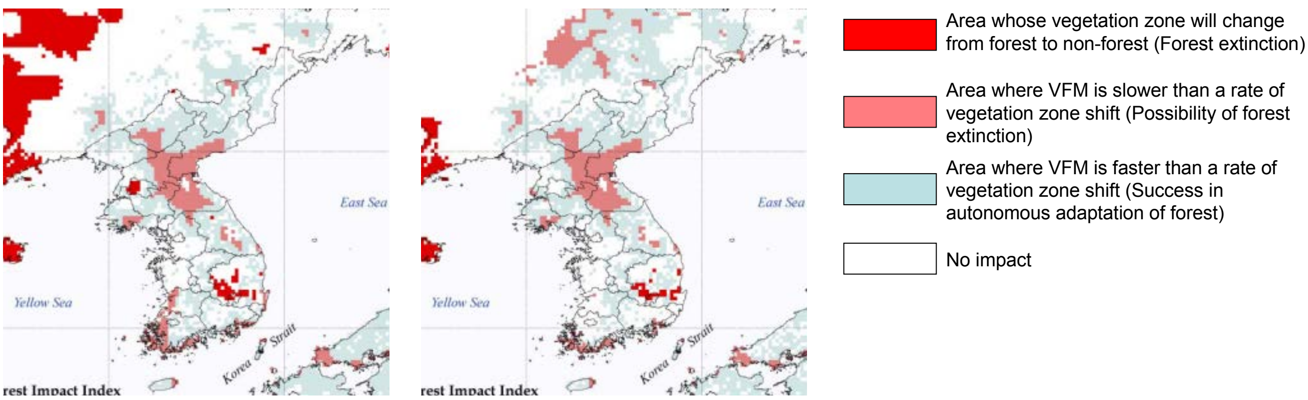



(a) Current (b) Sustainable society scenario (c) Unsustainable society scenario

**Figure A2-2**: Stress on India's water resources in 2100

**Forest loss caused by climate change may reach 2.08% of the area of Korean Peninsula**

Figure A2-3 shows the extent of forest vegetation damage caused by climate change on the Korean Peninsula by 2100. Whether current forest vegetation will be damaged or not is identified by comparing potential velocity of forest moving (VFM) with the velocity of vegetation zone shift that is estimated considering climate change scenario. VFM is assumed to be in the range from 0.25 to 2.0km/year in our assessment. In SRES A2 scenario, whose temperature increase is higher than the other SRES scenarios, the extinction area will be 2.08% of the Korean Peninsula if VFM is assumed to be 0.25km/year.




(a) CCCma SRES-A2 (b) CCCma SRES-B2

**Figure A2-3**: Climate change impact on Korean natural vegetation in 2100

# B. GHG Emissions and Reduction Potentials in Asia

## B.1 China

By 2002, population in China is 1.28 billion, when it is 0.987 billion in 1980, with annual growth rate 1.18. Studies for population growth in China suggested it will be around 1550million by 2030. Urbanization rate could reach 60% by 2030. GDP in 2002 is 10.47 trillion Chinese yuan with annual growth rate 9.5% after 1980. Among industries, first industry account for 15.4%, second industry and tertiary industry account for 51.1% and 33.5%, respectively.

In terms of future development, developing the economy and improving the living standard are the first rank of one short- and long-term targets set out by the Chinese government. At same time sustainable development is recognised as an important issue.

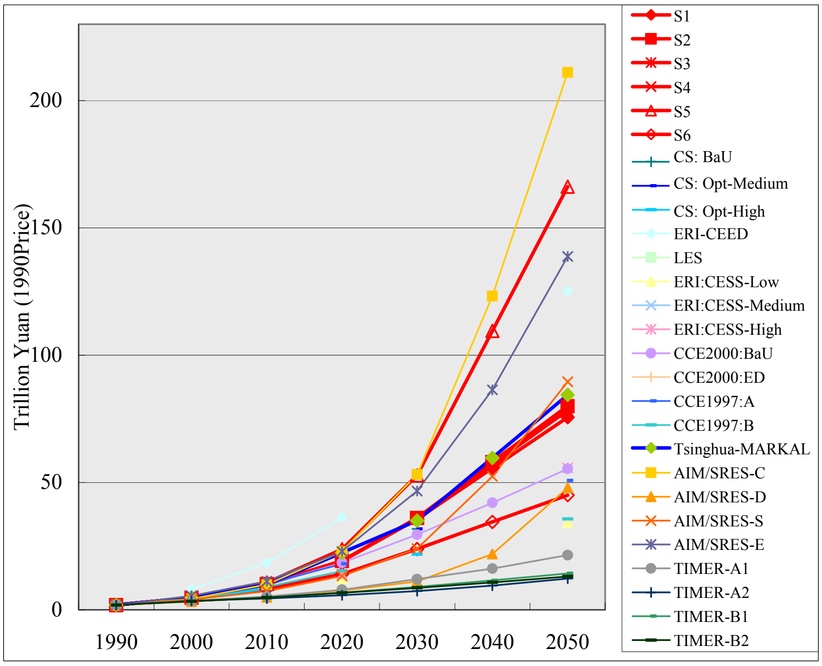



**Figure B1-1**: GDP scenario for China

Figure B1-1 gives GDP development trend presented by various studies. All studies show GDP growth will keep fast for next several decades. Basic trend follows government targets which aim GDP per capita will reach the level of OECD countries at beginning of 1990s by 2050. Recently new economic development target was given by Chinese government. It is planned to be quadrupled of the GDP of the year 2000 by 2020, with a well-off society in an all-round way. That means the average GDP growth rate will be 7.18% for next twenty years, giving China one of the rapidest countries in the world.

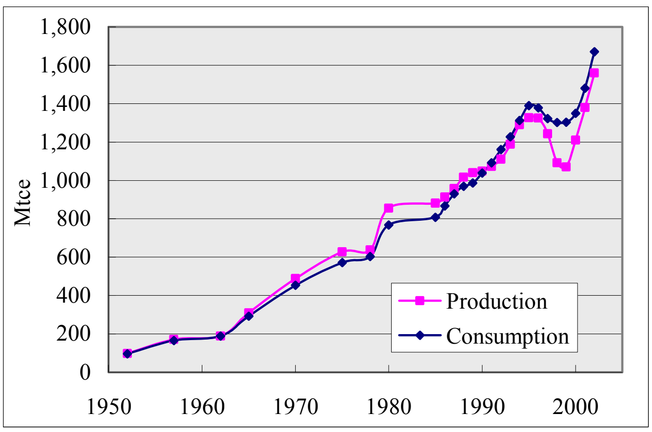



**Figure B1-2**: Energy production and consumption

### Energy and Emission Profile

Because of rapid economy growth, total primary energy consumption increased from 400 Mtoe in 1978 to 1036 Mtoe in 2002, with an annual average rate 4% (see Fig. B1-2).

Coal is the major energy in all energy use, taking share of 70.7 % in 1978 and 66.1% in 2002 in total primary energy use (see Fig. B1-3).

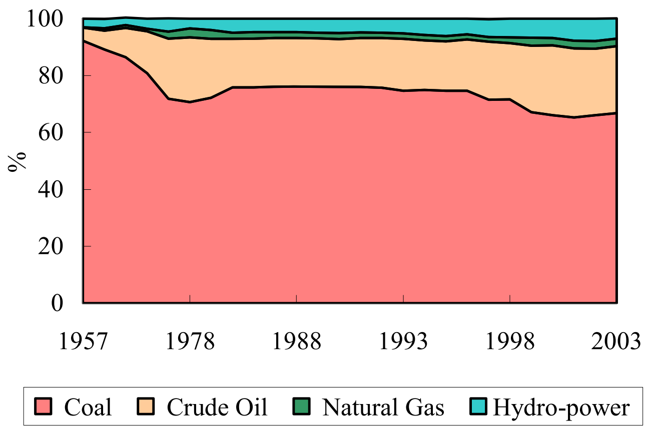



**Figure B1-3**: Energy mix

By using IPAC-AIM/China with considering various GDP, population and technology assumption, the scenario results on energy demand and $CO_2$ emission by different cases for China are presented in Fig. B1-4 and Fig. B1-5. There will be a significant increase of primary energy demand, which ranges from 2.3billion tce to 3.7billion tce in 2020, and 2.7billion tce to 4.4billion tce in 2030. And it also can be seen obviously from Fig. B1-5 that $CO_2$ emission will increase quickly with economic development in China. Compared with base year 1990, $CO_2$ emissions will be 1.7, 2.5 and 3.8 times in 2000, 2010 and 2030 for medium case which can be regarded as a possible development case, 1.6, 2.1 and 3.3 times for policy case which is the lowest growth rate of $CO_2$ emission. Figures B1-6 presents the distribution of $CO_2$ emission in 2010 in China, which show the coast region account for most emissions.

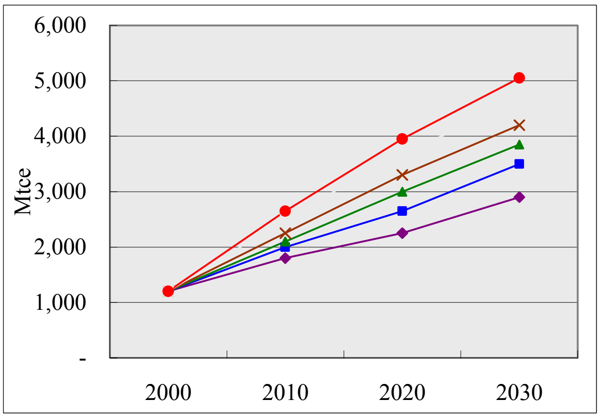



**Figure B1-4**: Primary energy demand scenarios in China

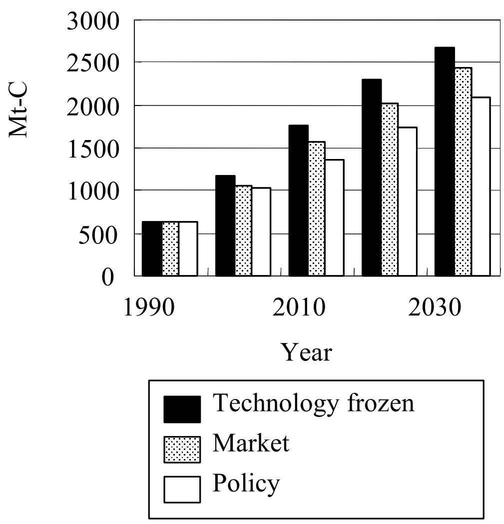



**Figure B1-5**: CO2 emissions in China

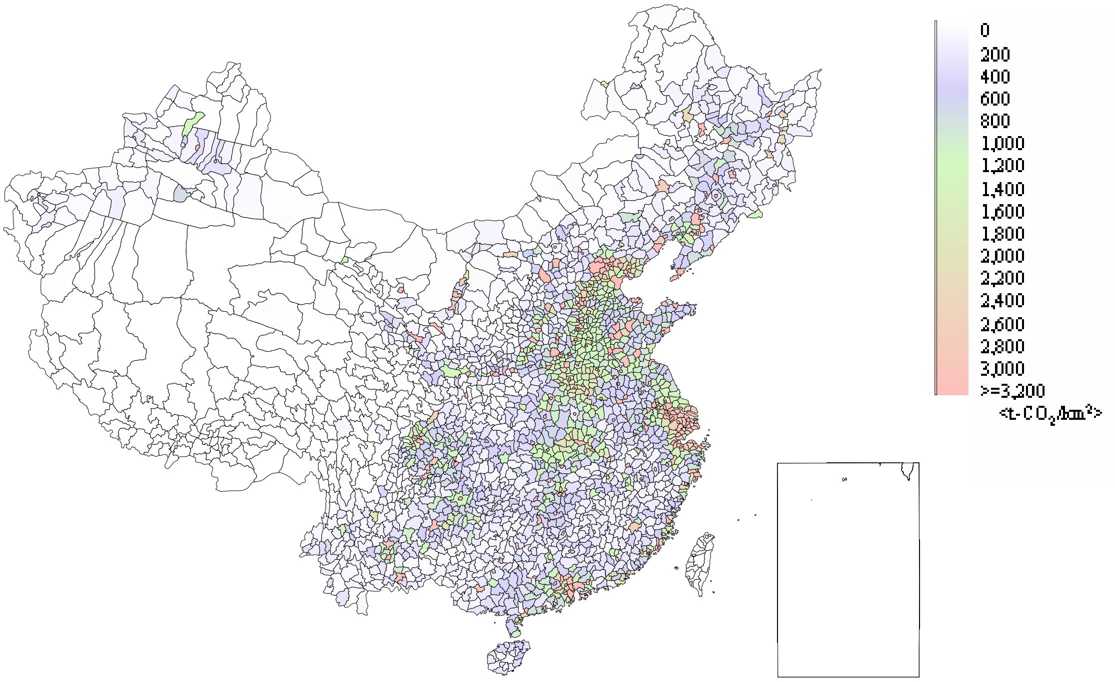



**Figure B1-6**: $CO_2$ emission distribution in 2010

**Emission Reduction Potential**

From Fig. B1-4 and Fig. B1-5 we can see the potential for energy saving and $CO_2$ emission reduction. There could be significant potential, ranged by 8% to 46% in 2030. Figure B1-7 presents the $CO_2$ emission reduction curve by major sectors.

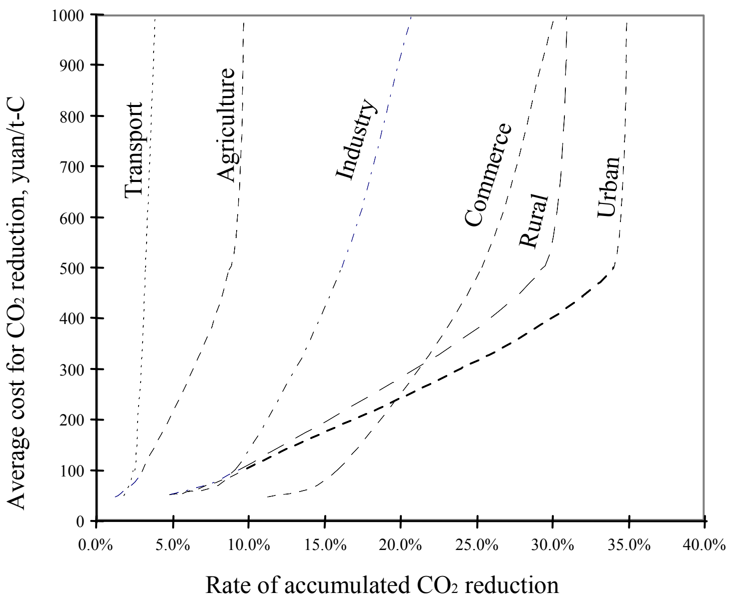



**Figure B1-7**: reduction cost by sectors

The reduction potential by sector was simulated with a wider cost range of up to US$50/tC. Emission reduction potential by these sectors with cost less than US$50/tC is shown in Fig. B1-8. This could be used as basis to identify CDM projects in China.

**Technology and Policy measures**

Technology play key role in climate change mitigation in the scenario studies. As a large country at the stage for economy to take off, technologies is very important in the sake of energy, environment and climate change.

Most of these technologies are also match the demand for energy conservation and environment both in short-term and long-term. Therefore technology strategy could well combined with energy and environment policies.

Climate policies should be combined with domestic sustainable development strategy. Sustainable development is an important factor in national development for both short- and long-term plans. Policy options, such as clean energy utilisation, including natural gas, and nuclear and renewable energy, could well match the targets described in these national plans. Win–win opportunities should be developed. Much of the potential emission reductions discussed above could be achieved through market mechanisms (often even with finding benefits larger than costs). Many energy-saving oriented projects could contribute to $CO_2$ emission reduction. Efficiency improvement discussed above could be well-integrated with energy-saving strategies in China.

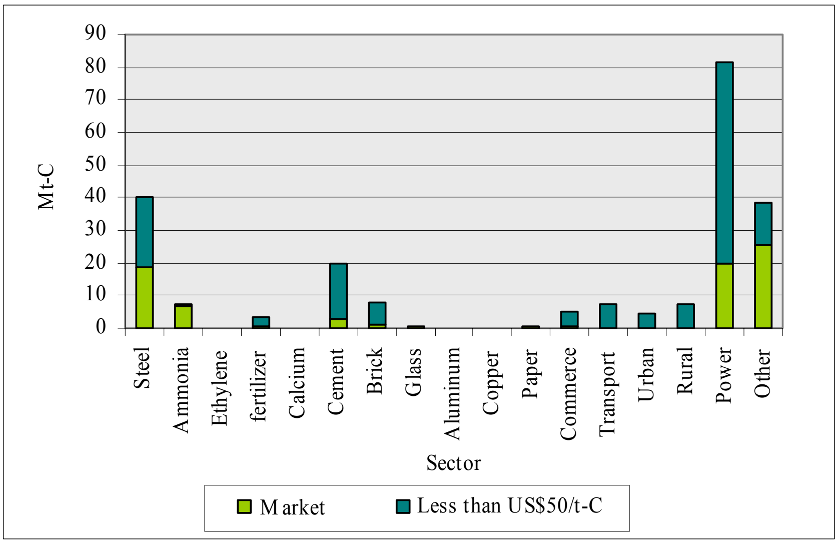



**Figure B1-8**: Emission reduction potentials by sectors

Climate policies should be integrated with the national energy development plan. As shown in some scenarios, it is expected that future energy supply modes will slowly become cleaner, based on imports of natural gas and oil, implementation of clean coal technology and limited introduction of renewables. Such trends build on existing energy policies in China. The climate policy options could be seen as a stronger effort in these directions.

International mechanisms such as CDM should be used as a way for technology transfer. These mechanisms focus on GHG emission reduction and domestic sustainable development and could help reducing some of the political and financial barriers to greenhouse gas mitigation in China.

Climate policies should match domestic economic instruments. Tax reform in China started 10 years ago. So far there is no energy tax. However, energy subsidies have been reduced and a fuel tax for transport will be established soon. A carbon tax may not be possible in the short term, but could be implemented through a mixed energy tax. Such effects could be enhanced through double-dividends, as discussed in the IPCC Third Assessment Report.

## B.2 India

Expanding industrialization, modernizing agriculture, and rising incomes have led to rapidly rising energy use in India. The Indian GDP grew at an average of about 6.5% during the period 1990-2000. Driven by 7.3 % growth in the manufacturing sector and over 9 % in agriculture, economic growth stood at 8.2 per cent in 2003-04. Also with 70% of India's population expected to be in the working age group by 2015, economists are predicting higher levels of savings, capital investments and growth. This growth is expected to be energy intensive resulting in a policy need to push for a sustainable growth path.

### Energy and Emission Profile

Total primary energy consumption for India increased 2.7 times during the period 1970-2000 and is expected to increase by about 2.1 times during the period 2000-2030. The share of the dominant energy resource-coal-increases from 22% in 2000 to 27% in 2030 (Fig. B2-1). Also due to reduced availability and switch to commercial fuels, the consumption of biomass remains almost constant at about 5 Exa Joules, reducing its share in primary energy consumption from about 45 % in 2000 to 24 % in 2030. Figure B2-2 gives the share and growth of different green house gases for the same period.

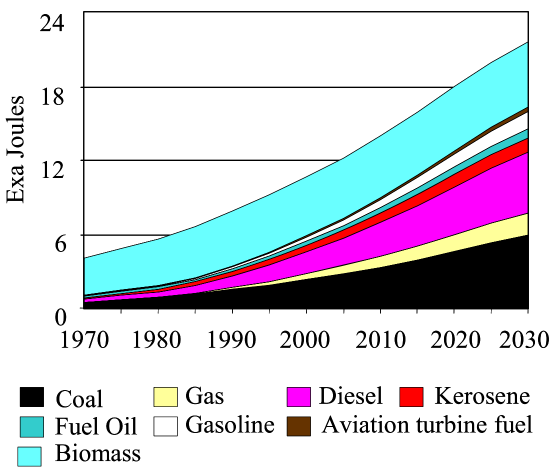



**Figure B2-1**: Primary energy consumption

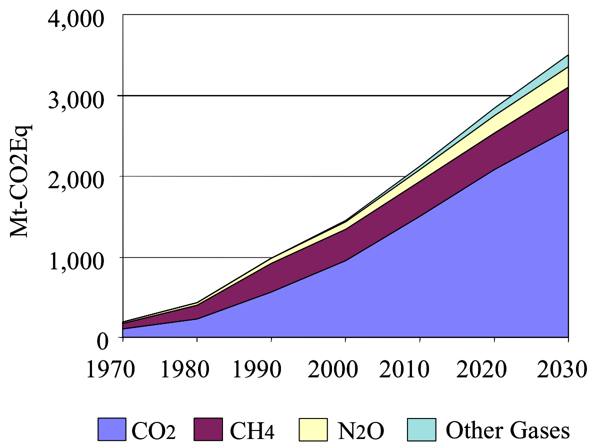



**Figure B2-2**: Share of GHGs emissions

$CO_2$ equivalent GHG emissions grow about 2.6 times from 1454 Tg to about 3507 Tg during 2000-2030 (as compared to about seven times during the period 1970-2030). This is propelled by high growth in $CO_2$ and $N_2O$ emissions. The share of other gases, which include PFC, HFC and $SF_6$, increases to about 4.5% in 2030 from an insignificant 0.77% in 2000 (Fig. B2-2). The major sources of $CO_2$ emissions are the industrial sector followed by the residential and the transport sectors.

Figure B2-3 gives the regional distribution of $CO_2$ emissions in India for 2000 and 2030. $CH_4$ emission sources include Paddy and enteric fermentation from livestock. Agriculture sector also contributes to a majority of $N_2O$ emissions. Also a major local pollutant in India is $SO_2$, which has profound health impacts. These emissions are expected to grow from about 5.5 Tg in 2000 to 8.4 Tg in 2025 and then show a declining trend in line with Kuznets effect.

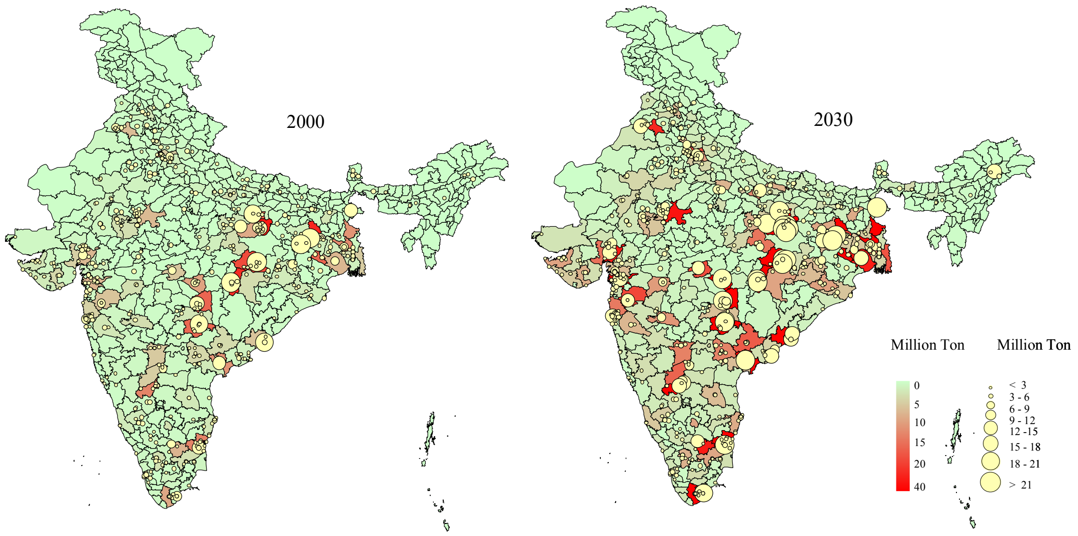



**Figure B2-3**: Regional distribution of $CO_2$ emissions in India

## Potential and Costs for Mitigating Greenhouse Gases

Preceding analysis highlighted the growing trend in green house gases and its impact on the regions natural resource. However technological development resulting from both autonomous investments in research and development and push policies from national governments has resulted in development of technologies with the potential to abate green house gas emissions. Figures B2-4 and B2-5 present abatement potential and marginal costs for green house gas abatement for some important sectors.

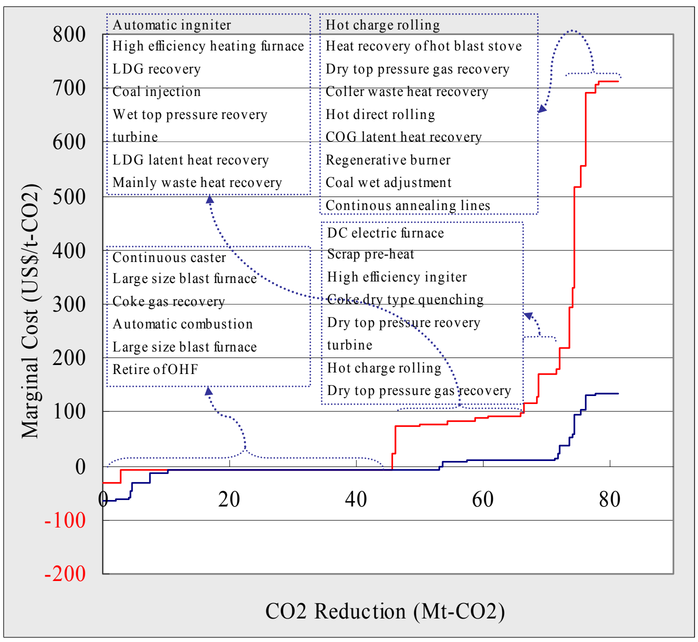



**Figure B2-4**: MAC curve (Steel Sector) in 2020

India produced 27.1 million metric tonnes of finished steel from main and secondary producers in 2000. The Indian steel industry has grown above 7% (compounded) per annum during the 1990s and is poised to grow even faster during the present decade due to thrust on infrastructure development and housing by the Government. The total steel production is projected to reach 52.5 Mt (in 2010), 81 Mt (2020) and 103 Mt (2030).

Presently, the Indian steel industry is about 1.5 times more energy intensive than the average international steel producers, both for the integrated steel plants and the medium and small steel-rolling mills. Therefore it has considerable potential for energy conservation. Figure B2-4 shows the $CO_2$ reduction potential in the steel sector and the associated costs of the technologies for the year 2020. Also, the cumulative carbon emissions from the Indian steel sector for 2000-2030 are projected to be about 1.5 billion tce. Energy conservation and carbon mitigation technologies may mitigate about one-third of these. The main technologies for India are indicated in Table B2-1.

Figure B2-5 depicts the abatement options and the costs involved in mitigating $CH_4$ in 2020. Investigation on coal bed methane for its commercial exploitation is a comparatively recent phenomenon in India. The government announced in October 2003 that 14 bids for eight blocks had been received under the second round of bidding for coal bed methane exploitation. Also, Indian cities are introducing private sector participation in Solid Waste Management. The aim is to attract funding and new technologies for better service delivery. The waste to energy technologies in India include incineration, pelletization and bio-methanation. The other sectors that have also been considered for estimating reduction potential are the paddy and the natural gas production and distribution sectors. The biomass and enteric fermentation sectors were outside the scope of this analysis.

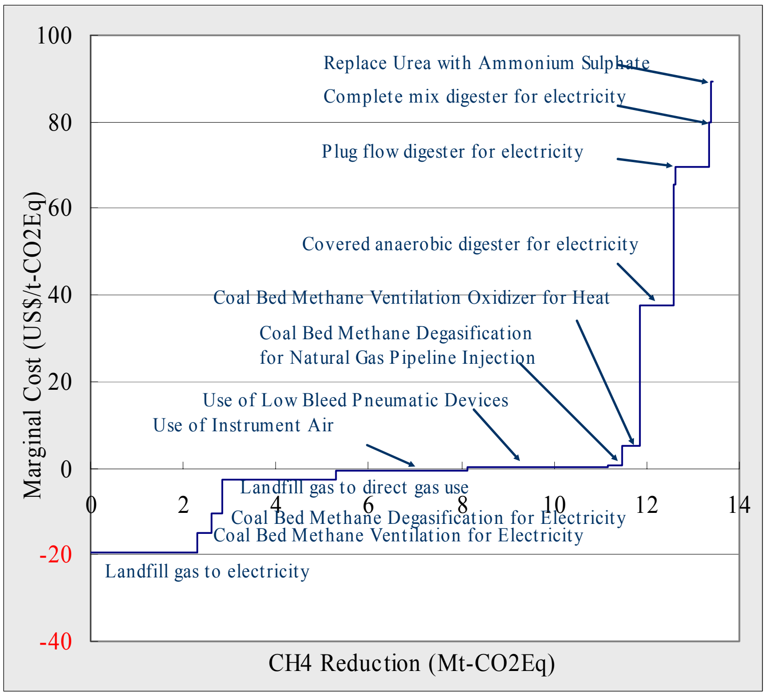



**Figure B2-5**: MAC curve for $CH_4$ in 2020 across sectors

Policymakers have been pushing for cleaner environment through various laws and incentives. The recent policy initiatives to use compressed natural gas for public transport in Delhi, emission limiting performance standards for passenger vehicles, and stricter enforcement of existing environmental laws has helped bring down the related emissions from the transport sector.

Also some examples of innovations at the local level that have helped save energy, water use and reduced emisions include innovative arrangement of sugar cane plants (agriculture), use of improved chulahs(rural households) and introduction of electric cars (by a private company) and design of pollution free motor cycles (through individual initiative).
As an example of state inititaive, the state of Andhra Prades has provided thrust for the developemnt of Eco Tourism in the state. The Andhra Pradesh Tourism Development Corporation (APTDC) and the Andhra Pradesh Forest Development Corporation (APFDC) have both adopted their own strategies in developing this sector. APTDC has decided to

**Table B2-1**: Energy conservation and carbon emission reduction technologies for Indian iron and steel industry

| Procedures | Technology description | Cumulative mitigation (MtCE) for 2000-2030 |
|---|---|---|
| Prior-iron system | Coal grade mixing | 9 |
| | Coal washing and drying | 13 |
| | Coal grinding | 20 |
| | Coal injection | 14 |
| Process control | Better plant management to reduce auxiliary energy consumption | 41 |
| | Excess air control | 32 |
| | Temperature regulation in the furnace | 37 |
| | Computerized controls | 35 |
| | Residual heat recovery from blast furnace | 31 |
| | Residual heat recovery from hot air furnace | 26 |
| | Residual heat recovery from steel dregs | 13 |
| Steel-rolling system | Pre-heating (Steel rolling technologies) | 26 |
| | Variable speed drives for motors | 18 |
| Comprehensive Technology | Electric arc furnace penetration | 14 |
| | Electric arc furnace (existing) energy conservation | 35 |
| | Fuel switching (coal to gas) | 53 |
| Future technology | Deoxidized steel making technologies (new) | 32 |
| | $CO_2$ capture and storage | 6 |
| **Cumulative carbon mitigation (MtCE) over 2000-2030** | | **455** |

develop eco-tourism in three aspects: natural wonders such as caves and waterfalls; wilderness camping and trekking; and wildlife tourism.

Clean Development Mechanism (CDM) has developed a lot of interest from industry in India. During the period 2002-2012 nearly 120 TgC emissions could be reduced at below $25/t-C with domination of efficiency improvements on demand and supply side (see Fig.B2-6).

Technology transfer and financial aid would have importance for the higher cost measures. In case of India, technology penetration is also of significance since some new technologies are available but their penetration is low. Mechanisms to bring in financial aid that is not part of ODA need to be put in place in order to reap the benefits of carbon funding.

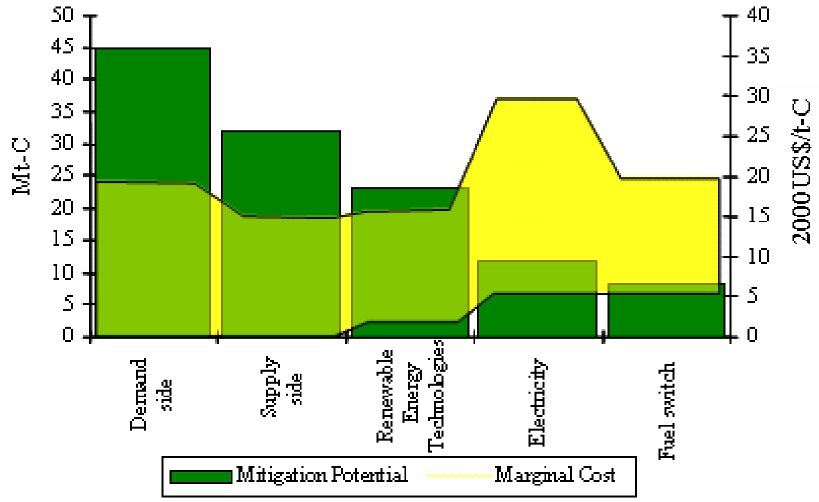



**Figure B2-6**: CDM potential in India for the period 2002-2012

## Discussions

Developing countries like India may also be coupled with competing mitigation options for different green house gases and scarce resources. Policy initiatives to introduce technology options for utilizing gases like methane as an energy source can provide the much-needed flexibility in the mitigation exercise. Also autonomous investments in industries (like steel and power) to improve energy efficiency can help reduce emissions.

## B.3 Korea

Korean economy has been rapidly developed since 1970s with average of about 8.8% GDP growth rate during the period 1986-1995. In 2001, manufacturing sector takes GDP share by 36.0 % and 46.8% was for the service sector. However, in 1998 Korean economy faced severe financial crisis, which inevitably downgraded its sovereign credit rating. After the painful restructuring its economy, Korean economy has been successfully recovered.

**Energy and Emission Profile**

Total primary energy consumption for Korea was 192.9 million toe (tones of oil equivalent) in 2000, which was the tenth largest consumption in the world. More than 97% of total energy consumption was imported. In 2000, Korea was the world sixth largest oil consuming, the third largest oil importing, and the second largest coal and natural gas importing country. The total primary energy consumption will be expected to increase by about two times during the period 2000 – 2030 under BaU scenario. Also due to the high demand for the cleaner energy source, the share of natural gas, which was about 9% in 2000, will be expected to increase by 13% in 2030. In 2030, the share of oil will be still more than 40% of total primary energy source (Fig. B3-1).

$CO_2$ equivalent GHG emissions grow about 1.7 times during 2000-2020. This is mainly due to the high growth in $CO_2$ emissions and relatively stable growth of $N_2O$ emissions. The share of other gases, which include methane and PFC, HFC and $SF_6$, decrease to about 40% in 2020. Therefore in 2020, most of GHG emissions ($CO_2$) related to energy will take the share of 94.9% from 93.5% in 2010. This trend will continue and in 2030, almost all GHG emissions will come from energy. The major sources of $CO_2$ emissions are the industrial sector followed by energy transfprmation sector such as power generation, the transport and residential sectors (Fig. B3-2).

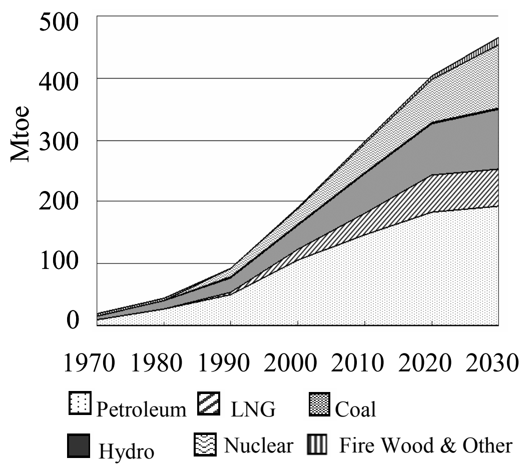



**Figure B3-1**: Primary energy consumption

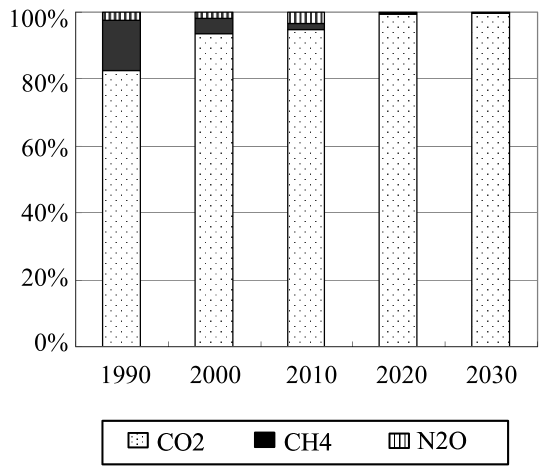



**Figure B3-2**: Share of GHGs emissions

$CH_4$ and $N_2O$ emissions are from agricultural sector, which is affected by land use for rice cultivation, fertilizer, so on. However, in Korea, the area of rice field is to decline gradually. Also, the number of livestock is to decline. Another source of $CH_4$ is waste. However, due to the very tight waste management policies in Korea, the total volume of waste is relatively stable, which contributes the stable emissions of $CH_4$ and $N_2O$.

Figure B3-3 shows the regional distribution of $CO_2$ emissions in Korea for 2000 and 2030. During this period, overall $CO_2$ emissions in all prefectures in Korea will increase with 1.5% - 3.3% growth rates. Especially, the $CO_2$ emissions in Kyunggi-Do (Metropolitan Seoul Area) will increase with highest growth rate. The main reason for the rapid increase in this prefecture is the increase of the population and the expansion of its economic activities.

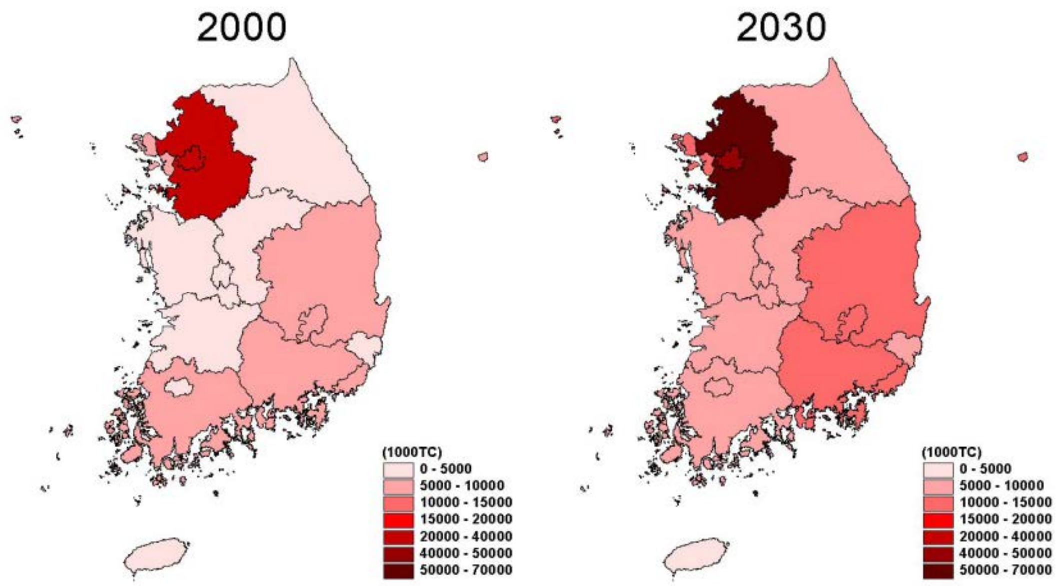



**Figure B3-3**: Regional distribution of $CO_2$ emissions in Korea

**Emission Reduction Potential**

Since energy is the very important component for the sustainable economic development and high living standard, it is somewhat inevitable for one country, whose economy is to grow, to increase GHG emissions. However, the GHG emission reductions can be achieved by energy efficiency improvement, advance technology adaptation and other policy and measures. Figures B3-4 and B3-5 show the results of some options to reduce GHG emissions and their implementation costs.

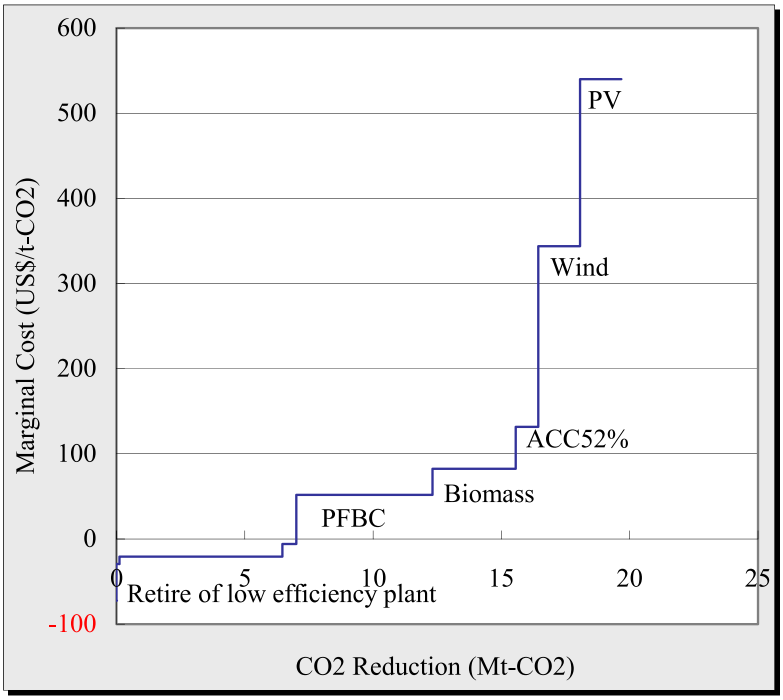



**Figure B3-4**: MAC curve for $CO_2$ reduction in power sector

The introduction of advanced technologies and some policy measures are good enough to reduce GHG emissions at costs shown above. One of important findings is that some options show even negative cost of reducing $CO_2$ emissions. Many options are to introduce advanced technologies in various sectors, while some of them are fuel substitutions and GHG sink options.

**Importance of Financial Aid, technology transfer, R&D and capacity building**

Korea is one of active supporters in the area of global environmental issues. Korea has been a member of Global Environment Facility (GEF) since 1994. Korea has contributed US$5.5million to GEF in every five-year term. During the period of 1998 – 2001, Korea contributed more than US$4 million to multilateral institutions and projects that are related to environment. Furthermore through the Korean International Cooperation Agency (KOICA), total US$455 million grant aids were assisted to individual country and international organization in 2001

As a member of Organization for the Economic Cooperation and Development (OECD), Korea launched many energy efficiency improvement and training programs via KOICA. These programs included energy conservation policies, energy efficiency management systems, voluntary agreements, energy-service companies (ESCO). In 1998, Korea and United States agreed to start a bilateral cooperation in four major technology areas, so called Climate Technology Partnership Korea (CTP-Korea).

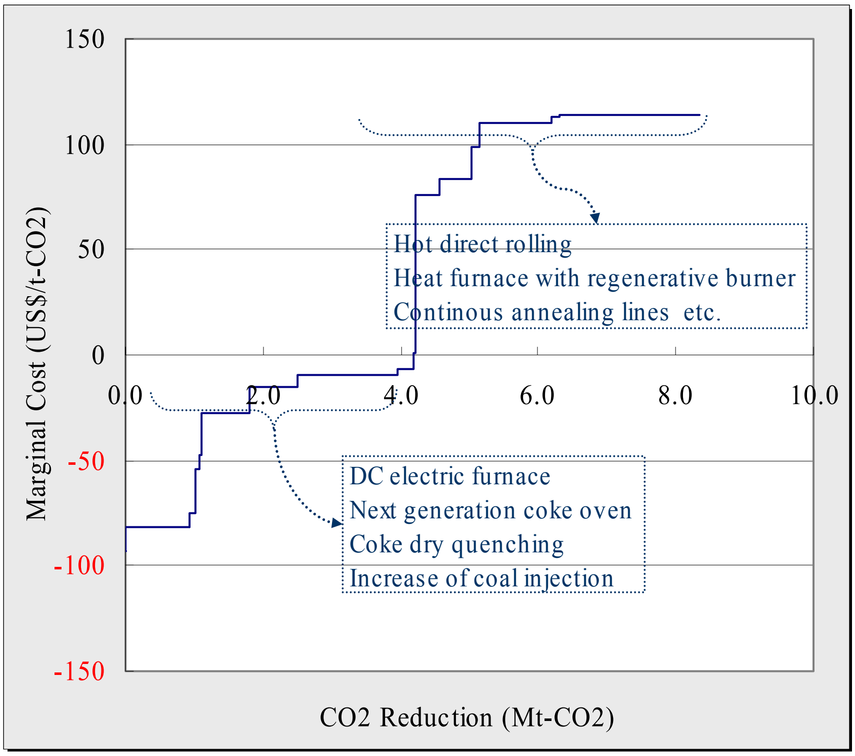



**Figure B3-5**: MAC curve for $CO_2$ reduction in steel sector

**Discussions**

Korea as one of OECD and advanced developing countries supports UNFCCC, developing aggressive energy conservation policy and measures to mitigate GHG emissions. At the same time, Korea also fully recognizes the sustainability of its economic development. It is the most difficult challenge for every country how to harmonize economic development and environmental preservation. More precise policy analysis and emission projections for the future are very necessary process for a country to tackle this climate change issues. For the better understanding the climate related issues, providing proper policy analysis of mitigating GHG emissions, it is crucially important for both developed and developing countries to work together, sharing information and knowledge. As a part of such effort, Korea has actively participated into AIM research network for more than ten years.

Especially in Asia, the heterogeneous situation of each country in this region requires more information sharing and joint effort to tackle global environmental issues such as climate change. In this sense, the AIM research network has contributed a lot in leading the research activity in this region.

## B.4 Thailand

Thailand experienced one of the world's highest economic growth rates starting from mid-eighties until the year 1996 with an average annual growth rate (AAGR) of 9.5 per cent during 1986-1996. Although the financial crisis from 1997 to 1999 reduced the momentum of the economy, it has experienced strong growth over the past few years, mainly due to improved demand for Thai exports and growth in domestic demand. The country's real gross domestic product (GDP) grew by 6.7 per cent in 2003, up from only 2.1 per cent in 2001. The country has the second largest economy among the ASEAN[1] countries with a total GDP of US$ 143 billion and the population of 64 million in 2003. Thailand is also the second largest consumer of energy consumption in the region in 2000.

**Energy and Emission Profile**

Although slowed by the 1997-1998 financial crisis, the total primary energy consumption (TPEC) in Thailand is expected to grow rapidly in the future. As can be seen from Fig. B4-1, the TPEC is estimated to increase from about 6 Mtoe in 1970 to almost 187 Mtoe by 2030 under business-as-usual (BAU) case. In 2000, fossil fuels (coal, oil and natural gas) accounted for 81 per cent of TPEC and they are expected to continue to be the dominant source of energy even in year 2030. About half of the TPEC was from oil in 2000. The share of oil is estimated to decrease to one-thirds of the TPEC by 2030, whereas the share of natural gas will remain unchanged in 2030. The share of coal, however, is estimated to increase to about 30 per cent.

The sectoral anthropogenic emission profiles of $CO_2$ and selected local pollutants ($SO_2$ and $NO_x$) from 1970 to 2030 are presented in Fig. B4-2 to B4-4. $CO_2$ emissions are estimated to increase from 18 million tons in 1970 to about 511 million tons by 2030 at an AAGR of 6.9 per cent. In 2000, the power and the transport sectors, combined together, contributed about 64 per cent of total $CO_2$ emissions. By 2030, the industrial sector are expected to have the largest share (33 per cent) in the total $CO_2$ emissions, whereas the share of the power sector would be declining and that of the transport sector would remain almost the same.

A similar picture arises for emissions of $SO_2$ and $NO_x$ as well. Total $SO_2$ emission is estimated to increase by more than four times the level from 2000 to 2030. The power sector will contribute the most in total $SO_2$ emissions during 2000-2030. It is also estimated that the industrial sector's share will be increasing. Likewise, $NO_x$ emission is estimated to increase by almost three folds during 2000-2030. The transport and power sectors were the two leading contributors to $NO_x$ emissions in 2000. By 2030; however, transport sector alone is expected to contribute most to $NO_x$ emission.

Most of these emissions are concentrated in and around the capital of Thailand, Bangkok, and few other areas (such as Ayutthaya, Lampang, and Rayong provinces), where major power plants and energy intensive industries are located. Figures B4-5 to B4-6 show the regional distributions of $CO_2$ and $SO_2$ in Thailand. The points marked by circles show the spatial distribution of emissions from power plants and major industries (such as steel, cement and paper) based on their emission intensities.

[1] The Association of South East Asian Nations (ASEAN) includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

**Potential and Costs for Mitigating Carbon Dioxide Emissions**

In view of the major environmental problems caused primarily by the use of fossil fuels, it is important to evaluate the effects of possible mitigation options. The graphical representation of $CO_2$ emission abatement cost curve during 2010-2030 is shown in Fig. B4-7. As can be seen from the figure, at the incremental abatement cost (IAC) of 28$/ton of $CO_2$, about 142 million tons of $CO_2$ could be mitigated, while 1 billion tons of $CO_2$ emission could be reduced at the IAC of 111$/ton of $CO_2$ .

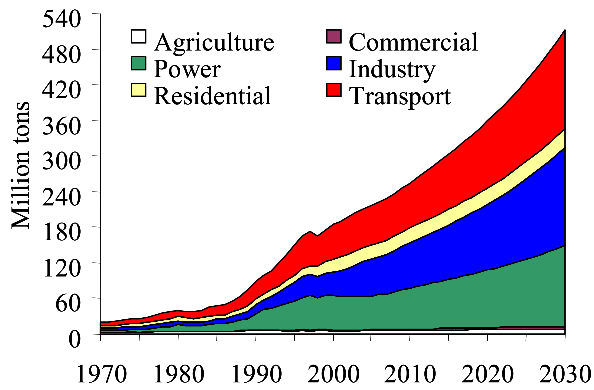



**Figure B4-1**: Primary Energy supply during 1970 – 2030

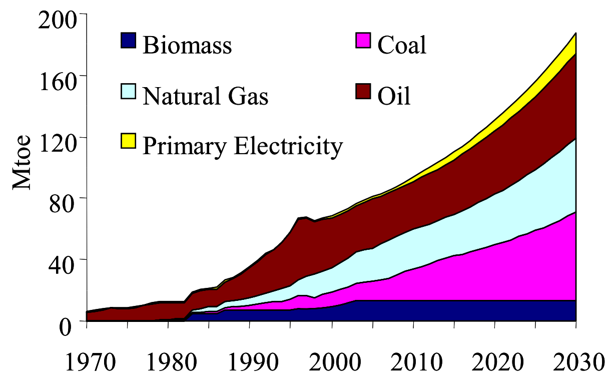



**Figure B4-2**: $CO_2$ emissions during 1970 – 2030

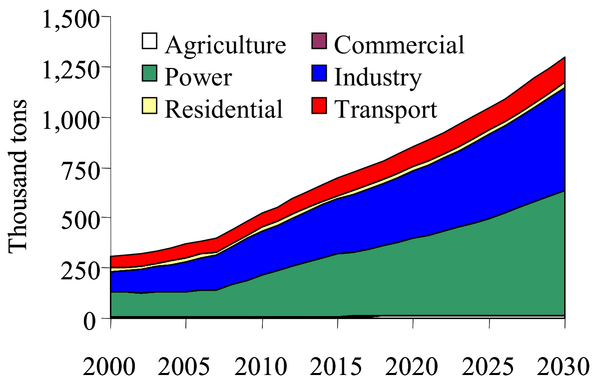



**Figure B4-3**: $SO_2$ emissions during 2000 – 2030

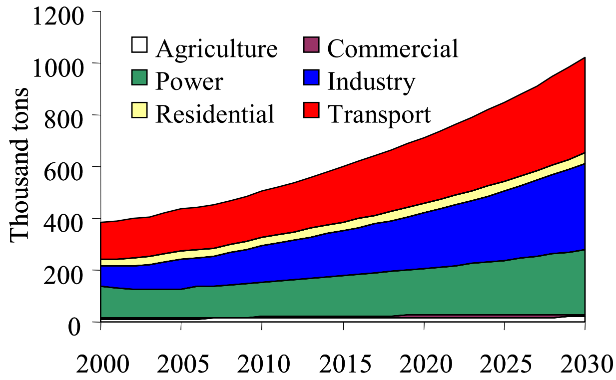



**Figure B4-4**: $NO_X$ emissions during 2000 – 2030

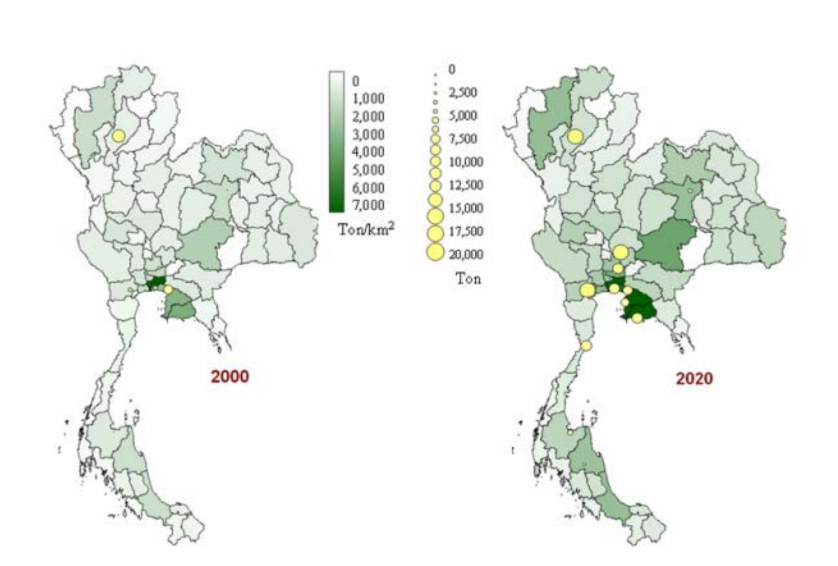



**Figure B4-5**: Regional distribution of $CO_2$ emissions in Thailand

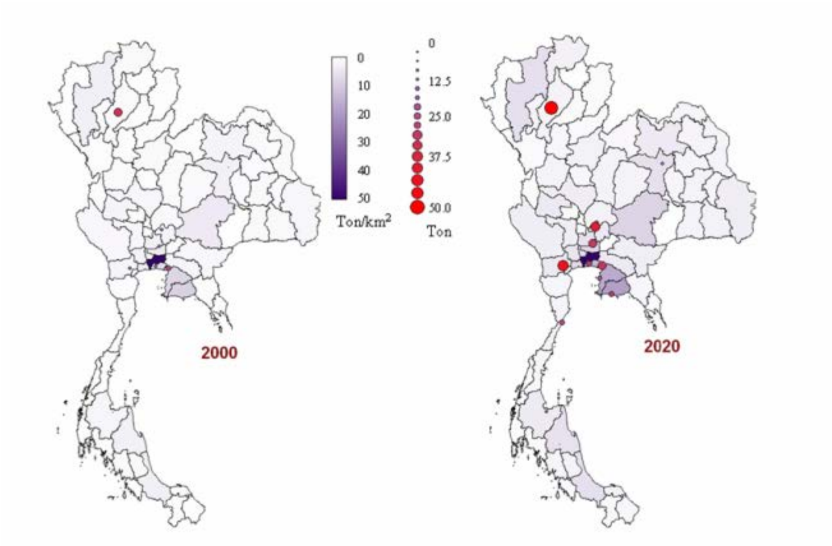



**Figure B4-6**: Regional distribution of SO2 emissions in Thailand

A study by Shrestha analyzed the role of technological options for GHG reductions under Clean Development Mechanism (CDM) in the power sector of three Asian countries, including Thailand. This study shows that cleaner thermal power generation technologies involving fuel switching from coal to gas or oil would be the main source of $CO_2$ reduction not only at the presently prevailing prices of Certified Emission Reduction (CER), i.e., 3 to 6 dollars, but also at significantly higher prices.

**Environmental Innovations and Strategies, and Capacity Building**

Several approaches including environmental innovation and strategy programs for sustainable development are initiated in Thailand to reduce the impact of GHG emissions. Demand Side Management (DSM) and energy efficiency programs in energy sector mandated by Energy Conservation and Promotion Act of 1992, new emission standards and mass transit systems in transport sector, and forest protection programs are some of the examples. Also, most of the proposed CDM activities in Thailand are based primarily on two issues: (i) electricity generation from biomass energy and (ii) waste management project.

As part of the collaborative Integrated Assessment Modeling (IAM) project activities, a workshop in Bangkok, Thailand suggested that the financial support should be explored for research and course development in developing Asian institutes to involve researchers and doctoral students in such activities. It is also important to recognize a need for coordination and cooperation between existing expertise and institutions, as well as national and regional organizations for the assessment of mitigating climate change in developing countries of Asia.

**Discussions**

As with other developing countries in Asia, both Thailand's energy intensity and carbon intensity levels have increased over the past decade and they are expected to increase in the foreseeable future. Deteriorating air quality in the urban areas (such as Bangkok) and concerns of the country's other low-lying coastal areas in the event of rising oceans due to climate change are some of the environmental concerns of Thai government.

One option to reduce GHGs would be to diversify its energy sources from currently heavy dependence on fossil fuels to increasing use of renewable energy sources. Among the renewable energy sources, biomass power generation seems to be one of the attractive cost-effective options in future. In addition, the further development of new innovation strategies and technology transfer seems necessary for mitigating GHGs and to promote sustainable development in the country.

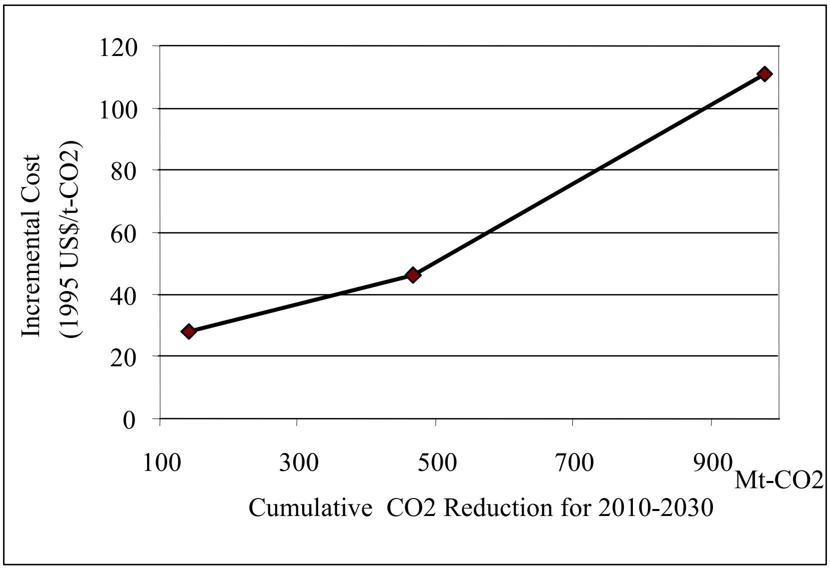



**Figure B4-7**: Incremental cost of $CO_2$ abatement in constant 1995 US$

# C. Long-term Emissions Scenarios and Short-term Targets

## C.1 Global GHG Emissions Paths

The dynamic optimization model included in AIM/Impact[policy] provides global greenhouse gas emissions paths under different socioeconomic scenarios with various constraints on multiple greenhouse gas emissions, temperature increases, rates of temperature increases and rises in sea levels. The model incorporates four sub-models: economic-energy model, simplified climate model, sea level rise model, and GHG emissions model. The world is treated as a single region. The time periods are the decades from 1990 through 2200. In this model, the focus is on several greenhouse gases: $CO_2$, $CH_4$, $N_2O$, $SO_2$, CFCs, PFCs, $SF_6$, BC, and $O_3$. Several future projections of GHG emissions paths under reduction constraint strategies are described in this report.

### Required GHG reductions to achieve a 500 ppmv stabilization of GHG concentrations are 7.1 Gt-$CO_2$eq in 2020 and 19.0 Gt-$CO_2$eq in 2030

This model provides a framework to assist policymakers in their decisions on meeting the UNFCCC's ultimate objective; "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." To discuss the time frame and volume of GHG reductions, this study took six cases into consideration as follows:

- Simulation cases (reference Scenario: SRES B2)
  - ✓ Case 1: Business as usual (BaU)
  - ✓ Case 2: 450 ppmv cap on $CO_2$ concentration
  - ✓ Case 3: 550 ppmv cap on $CO_2$ concentration
  - ✓ Case 4: 650 ppmv cap on $CO_2$ concentration
  - ✓ Case 5: 500 ppmv cap on total GHG concentrations
  - ✓ Case 6: 550 ppmv cap on total GHG concentrations

With respect to Cases 2 to 6, constraint optimization calculations were carried out in which $CO_2$ or total GHG concentrations do not exceed the constraint levels from 1990 to 2200. Total GHG concentrations were calculated based on their global warming potential as reported by the IPCC. Figure C1-1 compares carbon emissions for the six alternatives. Figure C1-2 indicates $CO_2$ concentrations. These concentrations indicate $CO_2$ itself, not converted $CO_2$ concentrations from the total for GHGs. Figure C1-3 shows the results of global mean temperature changes from 1990 for the six alternatives. Under the business as usual case, $CO_2$

emissions continue to rise up to 2050 and in 2150 the $CO_2$ concentration is almost double the 1990 level. The temperature increases by nearly 2°C in 2060 and by 4.2°C in 2150.

The WBGU suggested from a review of the available literature that "above 2°C the risks increase very substantially, involving potentially large extinctions or even ecosystem collapses, major increases in hunger and water shortage risks as well as socioeconomic damage, particularly in the developing countries."

In investigating the temperature increases for Cases 2 to 4, in which the maximum $CO_2$ concentrations are restricted, in each case the increase surpasses 2°C in 2150. This is because there are no constraints on the emissions of other GHGs except for $CO_2$. In Case 2, which represents the most severe constraint, the temperature increases by 3.1°C in 2150.

In the case of constraints on GHG concentrations, Case 5 (500 ppmv stabilization of GHG concentrations) indicates a temperature increase of around 2°C relative to 1990 in 2150 (2.2°C). The GHG reductions required to achieve a 500 ppmv cap on total GHG concentrations are 7.1 Gt-$CO_2$eq ($CO_2$ reduction: 6.1 Gt-$CO_2$) in 2020 and 19.0 Gt-$CO_2$eq ($CO_2$ reduction: 17.0 Gt-$CO_2$) in 2030, compared to the BaU case.

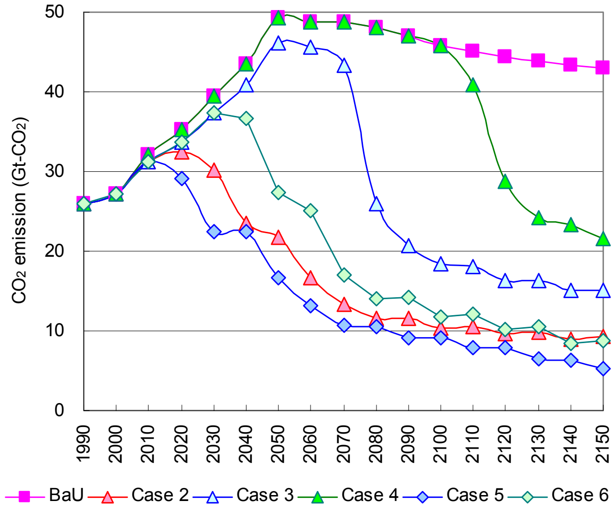



**Figure C1-1**: Global $CO_2$ emissions

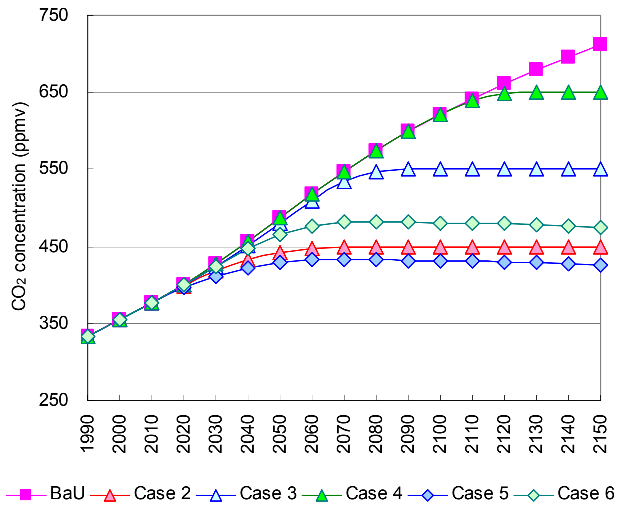



**Figure C1-2**: $CO_2$ concentrations

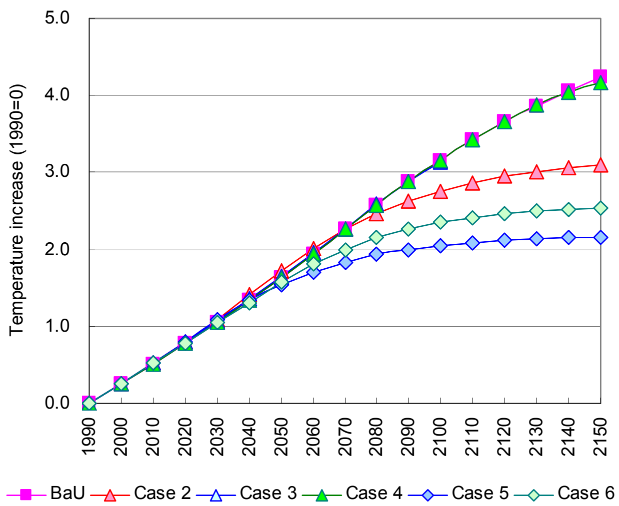



**Figure C1-3**: Global mean temperature changes

## C.2 GHG Emissions Reduction Potentials

The reduction potentials in 2020 in steel and residential sectors are shown in this section. AIM/Enduse is used to measure global and regional reduction potentials and required direct costs. They are estimated for 21 regions (see Table AP-1).

### C.2.1 Steel Sector

#### 800 Mt-$CO_2$ emission increase in 20 years from steel sector

The world steel production in 2000 was about 800 Million tons, contributing to the largest $CO_2$ emissions share in the industry sector. It is expected that world steel production will continue to increase, with high growth in steel production in the developing countries. In this study, steel production is assumed to increase by 40% over the next 20 years. In the absence of technology improvement emissions are projected to reach about 800 Mt-$CO_2$ emission, which is 50% more than the 2000 emission levels .

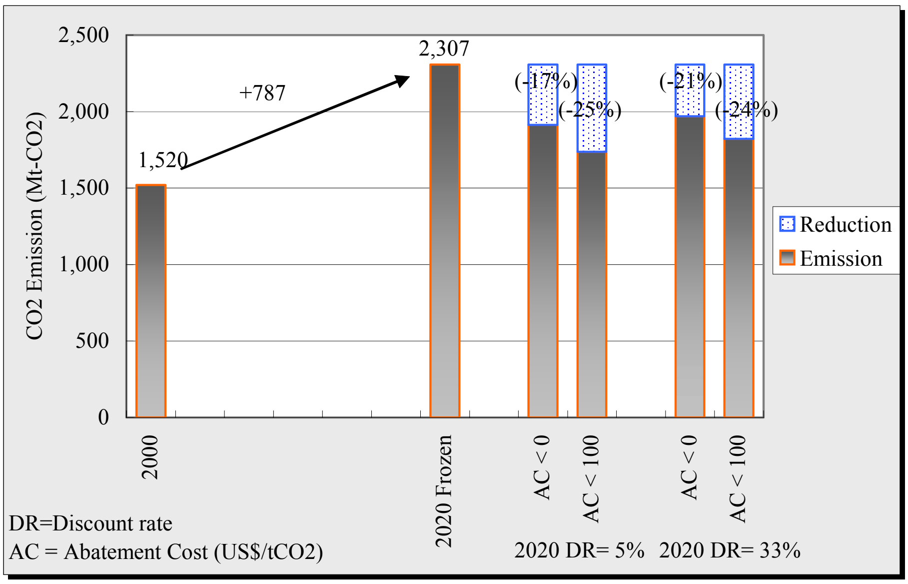



**Figure C2.1-1**: $CO_2$ emission and reduction from steel sector in 2020

#### Reduction potential of abatement technology

The dotted blue areas in Fig. C2.1-1 indicate the reduction potential of $CO_2$ emissions resulting from use of energy efficient technologies in 2020. Two discount rates are assumed; 5% and 33%. With 5% discount rate, market driven investment is expected to reduce 395 Mt-$CO_2$. Also advanced technologies at marginal abatement cost of 100US$/t-$CO_2$ could reduce 571 Mt-$CO_2$ emissions. This reduction corresponds to 17% and 25% of emissions in the frozen case scenario.

As private industries take into account high investment risk for energy conserving technologies, a payback period of 3-years is usually assumed. The discount rate corresponding to 3-years payback is about 33% based on the assumption of 30 years lifetime for steel plants. The reduction potential with 33% discount rate is less than 5% discount rate case. The reduction in emissions (with a 33% discount rate) corresponds to 338 Mt-$CO_2$ in the market-driven case and 486 Mt-$CO_2$ at marginal abatement cost of 100US$/t-$CO_2$.

## Country-wise reduction potential

Figure C2.1-2 shows country-wise reduction potential from steel industry with 33% discount rate (see also Table C2.1-1). The reduction potential is large in countries where the current energy efficiency is low and the expected production in 2020 is large. For example, the reduction potentials for China, Russia and India are 115 Mt-$CO_2$, 58 Mt-$CO_2$ and 46 Mt-$CO_2$ in market case, and 175 Mt-$CO_2$, 74 Mt-$CO_2$ and 67 Mt-$CO_2$ at abatement cost 100US$/t-$CO_2$, respectively. ,

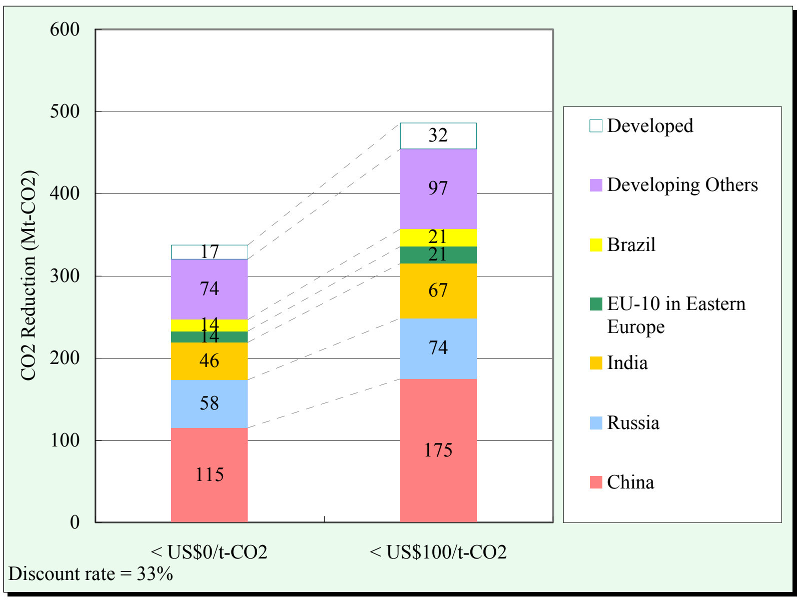



**Figure C2.1-2**: Country-wise reduction potential from steel sector

## Technology-wise reduction potential

Figure C2.1-3 shows technology-wise reduction potential from steel industry with 33% discount rate (see also Table C2.1-2). Examples of market driven technologies include large plant technologies such as furnace gas recovery, blast furnace and coke oven. Most of these technologies are installed in developed countries. Examples of technologies installed at marginal abatement costs of 100US$/t-$CO_2$ are LDG recovery, LDG latent heat recovery and coal injection.

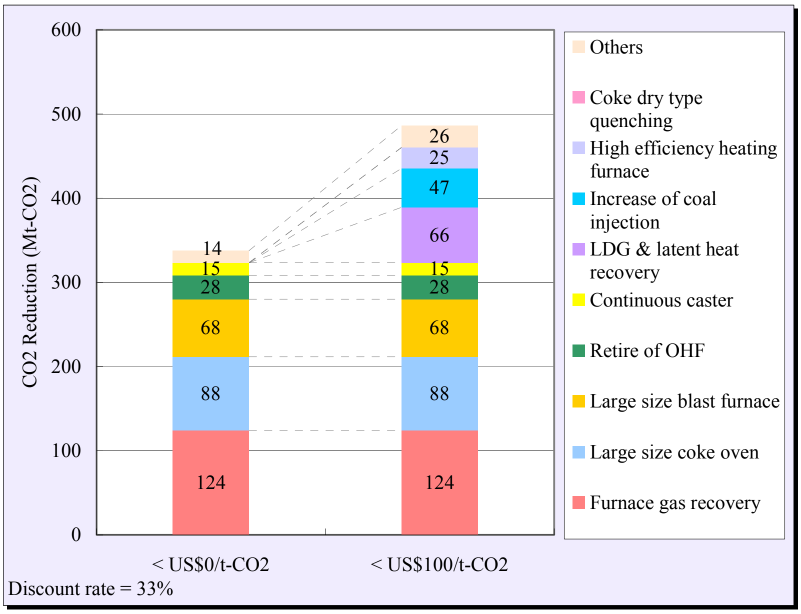



**Figure C2.1-3**: Technology-wise reduction potential from steel sector

**Table C2.1-1**: Country-wise reduction potential of steel sector

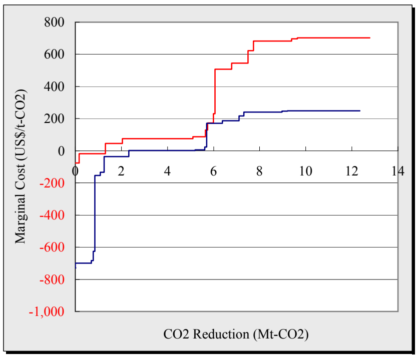
| | Steel Production 2000 | CO2 Emission 2000 | CO2 Emission 2020 Frozen | CO2 Reduction DR=33% < 0US$/t-CO2 | | DR=33% < 100US$/t-CO2 | | DR=5% < 0US$/t-CO2 | | DR=5% < 100US$/t-CO2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mt | Mt-CO2 | Mt-CO2 | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen |
| Japan | 106 | 156 | 147 | 1 | 0.8% | 5 | 3.6% | 2 | 1.6% | 7 | 4.8% |
| China | 127 | 347 | 635 | 115 | 18.2% | 175 | 27.5% | 115 | 18.2% | 205 | 32.2% |
| India | 27 | 73 | 219 | 46 | 20.8% | 67 | 30.4% | 54 | 24.5% | 75 | 34.4% |
| Indonesia | 3 | 2 | 3 | 0 | 4.7% | 0 | 11.7% | 0 | 12.9% | 1 | 22.7% |
| Korea | 43 | 58 | 86 | 1 | 0.9% | 2 | 2.8% | 4 | 4.9% | 5 | 6.0% |
| Thailand | 2 | 1 | 2 | 0 | 0.0% | 0 | 8.4% | 0 | 7.7% | 0 | 20.8% |
| Other South-east Asia | 5 | 3 | 4 | 0 | 0.2% | 0 | 9.0% | 1 | 16.3% | 1 | 21.3% |
| Other South Asia | 1 | 3 | 5 | 1 | 28.8% | 2 | 38.5% | 2 | 33.7% | 2 | 42.2% |
| Middle East | 4 | 2 | 3 | 0 | 0.0% | 0 | 7.9% | 1 | 15.9% | 1 | 20.4% |
| Australia | 7 | 17 | 22 | 2 | 9.5% | 3 | 15.6% | 2 | 10.7% | 4 | 18.8% |
| New Zealand | 1 | 1 | 2 | 0 | 18.2% | 1 | 29.0% | 1 | 29.2% | 1 | 32.6% |
| Canada | 17 | 20 | 24 | 1 | 2.9% | 1 | 5.1% | 1 | 4.8% | 2 | 7.0% |
| USA | 102 | 144 | 181 | 10 | 5.4% | 13 | 7.1% | 15 | 8.4% | 18 | 9.7% |
| EU-15 in Western Europe | 163 | 217 | 240 | 3 | 1.4% | 8 | 3.4% | 14 | 5.9% | 17 | 6.9% |
| EU-10 in Eastern Europe | 20 | 50 | 78 | 13.62 | 17.4% | 20.71 | 26.5% | 14 | 17.7% | 24 | 31.2% |
| Russia | 59 | 156 | 241 | 58 | 24.2% | 74 | 30.7% | 71 | 29.5% | 81 | 33.8% |
| Argentine | 4 | 7 | 10 | 2 | 18.3% | 3 | 28.5% | 3 | 29.5% | 3 | 32.9% |
| Brazil | 28 | 52 | 74 | 14 | 18.9% | 21 | 28.8% | 21 | 28.9% | 24 | 31.9% |
| Other Latin America | 24 | 28 | 41 | 7 | 18.5% | 12 | 29.0% | 8 | 20.7% | 14 | 34.9% |
| Africa | 14 | 27 | 38 | 6 | 16.5% | 10 | 26.2% | 6 | 16.8% | 12 | 31.8% |
| Rest of the World | 79 | 155 | 252 | 56 | 22.1% | 67 | 26.7% | 58 | 23.0% | 74 | 29.3% |
| Total | 836 | 1,520 | 2,307 | 338 | 14.6% | 486 | 21.1% | 395 | 17.1% | 571 | 24.7% |

**Table C2.1-2**: Technology-wise reduction potential of steel sector

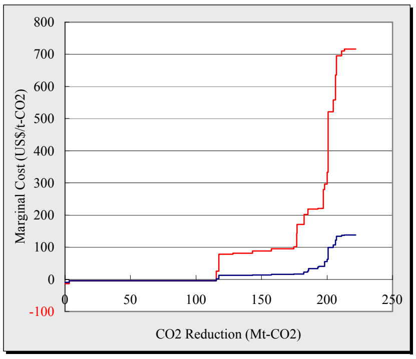
| | CO2 Reduction | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DR=33% | | | | DR=5% | | | |
| | < 0US$/t-CO2 | | < 100US$/t-CO2 | | < 0US$/t-CO2 | | < 100US$/t-CO2 | |
| | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share |
| Large size coke oven | 88 | 25.9% | 88 | 18.0% | 88 | 22.2% | 88 | 15.3% |
| Coke gas recovery | 84 | 24.8% | 84 | 17.3% | 84 | 21.3% | 84 | 14.7% |
| Automatic combustion | 2 | 0.6% | 2 | 0.4% | 2 | 0.5% | 2 | 0.3% |
| Coke dry type quenching | 0 | 0.0% | 0 | 0.0% | 8 | 1.9% | 21 | 3.6% |
| Coal wet adjustment | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| COG latent heat recovery | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Next generation coke oven | 12 | 3.7% | 12 | 2.6% | 12 | 3.1% | 12 | 2.2% |
| Automatic ingniter | 0 | 0.0% | 4 | 0.9% | 2 | 0.5% | 4 | 0.7% |
| Coller waste heat recovery | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 12 | 2.1% |
| Mainly waste heat recovery | 0 | 0.0% | 5 | 0.9% | 1 | 0.3% | 7 | 1.2% |
| High efficiency ingiter | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 0.2% |
| Large size blast furnace | 68 | 20.2% | 68 | 14.0% | 68 | 17.3% | 68 | 12.0% |
| Blast furnace gas recovery | 40 | 11.9% | 40 | 8.3% | 40 | 10.2% | 40 | 7.1% |
| Wet top pressure reovery turbine | 0 | 0.0% | 2 | 0.4% | 4 | 1.0% | 10 | 1.8% |
| Dry top pressure reovery turbine | 0 | 0.0% | 0 | 0.0% | 1 | 0.1% | 2 | 0.4% |
| Heat recovery of hot blast stove | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 4 | 0.7% |
| Coal injection | 0 | 0.0% | 47 | 9.6% | 16 | 4.1% | 47 | 8.1% |
| Dry top pressure gas recovery | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 0.2% |
| Retire of OHF | 28 | 8.3% | 28 | 5.8% | 28 | 7.1% | 28 | 4.9% |
| LDG recovery | 0 | 0.0% | 31 | 6.3% | 6 | 1.4% | 31 | 5.4% |
| LDG latent heat recovery | 0 | 0.0% | 35 | 7.2% | 2 | 0.5% | 35 | 6.1% |
| Continuous caster | 15 | 4.5% | 15 | 3.2% | 15 | 3.9% | 15 | 2.7% |
| Hot charge rolling | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 10 | 1.7% |
| Hot direct rolling | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 6 | 1.1% |
| High efficiency heating furnace | 0 | 0.0% | 25 | 5.1% | 4 | 1.1% | 25 | 4.4% |
| Heat furnace with regenerative burn | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| Continous annealing lines | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| DC electric furnace | 0 | 0.0% | 1 | 0.1% | 12 | 2.9% | 15 | 2.7% |
| Scrap pre-heat | 0 | 0.0% | 0 | 0.0% | 1 | 0.4% | 2 | 0.3% |
| Total | 338 | 100.0% | 486 | 100.0% | 395 | 100.0% | 571 | 100.0% |

## Marginal abatement cost curve of steel sector in 2020 (1/2)

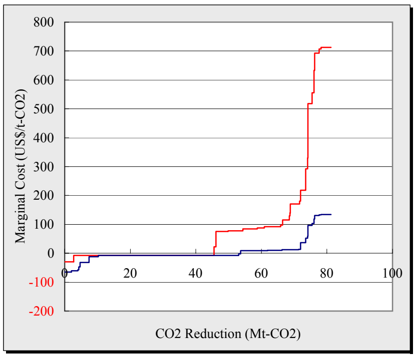
**Japan** 100,000 t 147 Mt-CO2



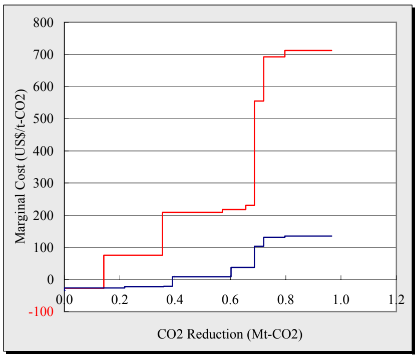

**China** 233,000 t 635 Mt-CO2



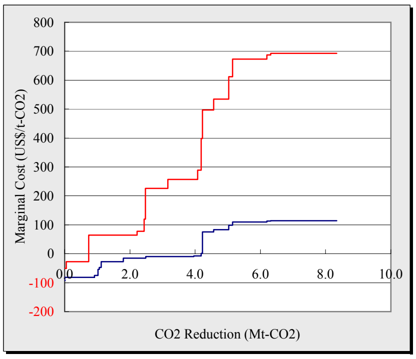

**India** 81,000 t 219 Mt-CO2



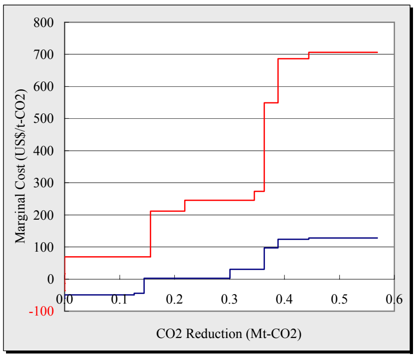

**Indonesia** 4,622 t 3 Mt-CO2



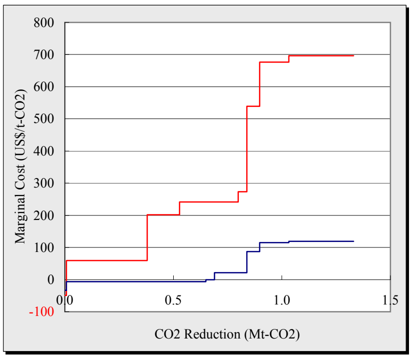

**Korea, Republic Of** 64,000 t 86 Mt-CO2



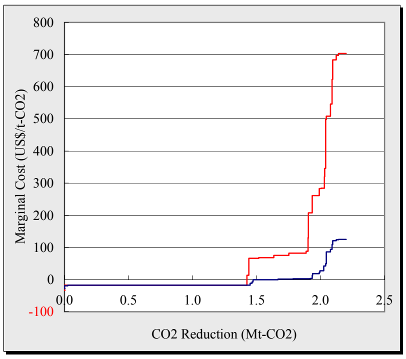

**Thailand** 3,408 t 2 Mt-CO2



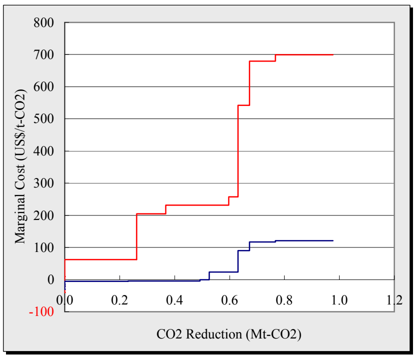

**Other South-east Asia** 8,130 t 4 Mt-CO2



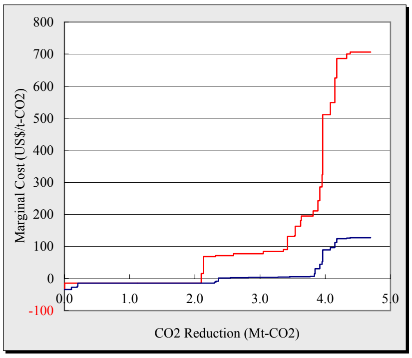

**Other South Asia** 1,671 t 5 Mt-CO2



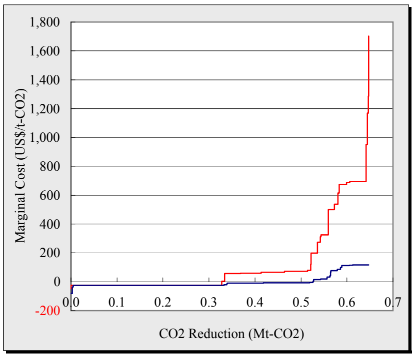

**Middle East** 5,723 t 3 Mt-CO2



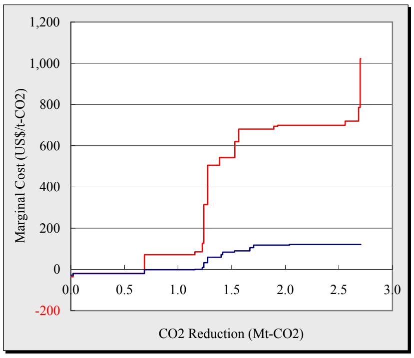

**Australia** 9,296 t 22 Mt-CO2




**New Zealand** 998 t 2 Mt-CO2



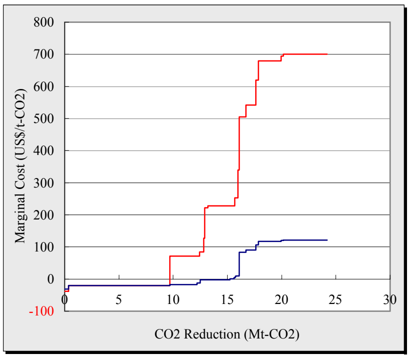

**Canada** 19,911 t 24 Mt-CO2



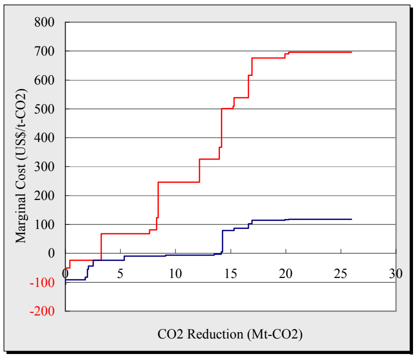

Discount Rate = 33%
Discount Rate = 5%

## Marginal abatement cost curve of steel sector in 2020 (2/2)

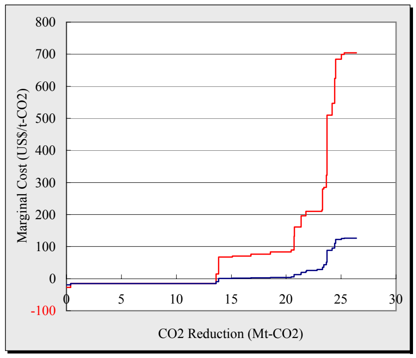
**USA** 127,567 t 181 Mt-CO2



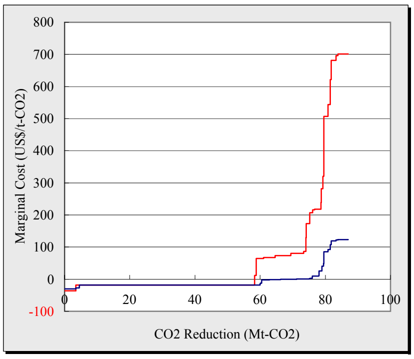

**EU-15 in Western Europe** 180,681 t 240 Mt-CO2



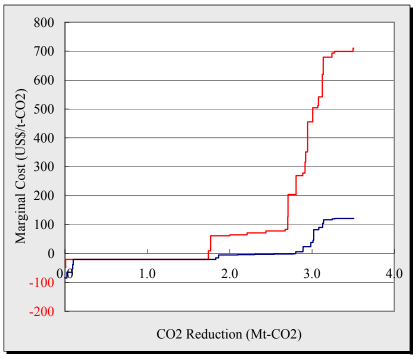

**EU-10 in Eastern Europe** 31,134 t 78 Mt-CO2



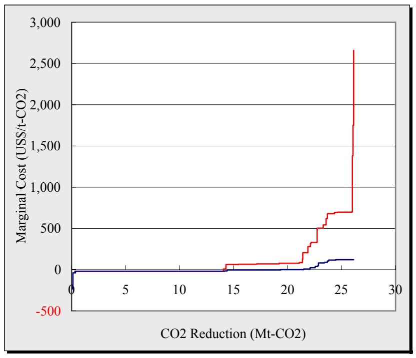

**Russia** 91,185 t 241 Mt-CO2



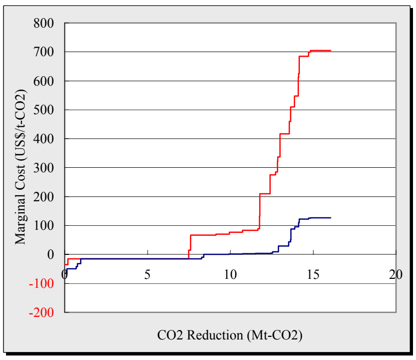

**Argentine** 6,367 t 10 Mt-CO2



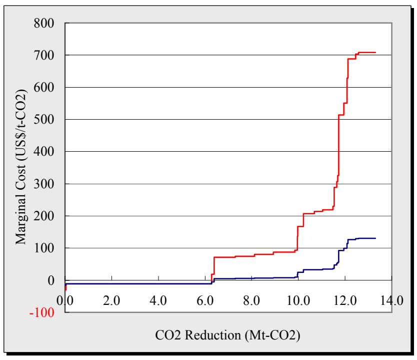

**Brazil** 39,610 t 74 Mt-CO2



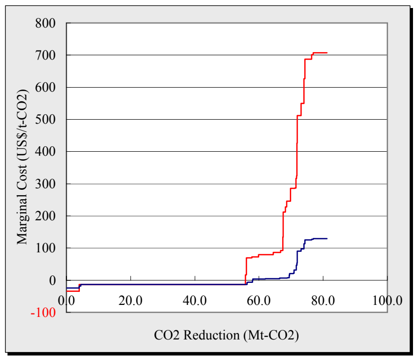

**Other Latin America** 33,489 t 41 Mt-CO2




**Africa** 19,819 t 38 Mt-CO2




**Rest of the World** 128,495 t 252 Mt-CO2




Discount Rate = 33%
Discount Rate = 5%

## C.2.2 Residential Sector

### 1,500 Mt-$CO_2$ emission increase in 20 years from residential sector

World population has been increasing approximately 1.5% per year, and energy consumption and $CO_2$ emission per capita themselves are also expected to increase rapidly based on the economic growth and improvement of the standard of living, especially in developing countries. This study shows that $CO_2$ emission from residential sector increases about 50% to reach 4,500 Mt-$CO_2$ over the next 20 years. However, it also shows that energy efficiency equipments have a potential to reduce $CO_2$ emission approximately 800 Mt-$CO_2$ in 2020.

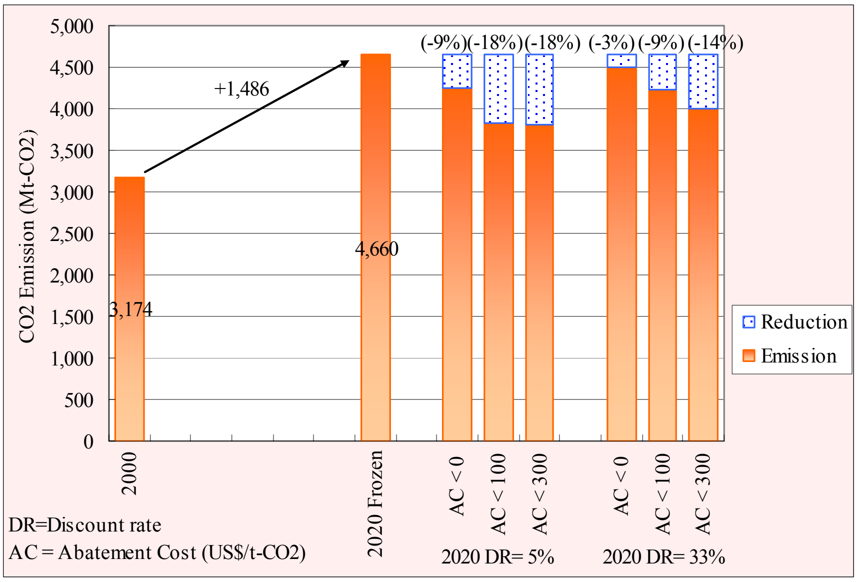



**Figure C2.2-1**: $CO_2$ emission and reduction from residential sector in 2020

### Reduction potential of abatement technology

The dotted blue areas in Fig. C2.2-1 indicate the reduction potential of $CO_2$ emissions by applying energy efficient equipments in 2020. In this study, two discount rates are assumed; 5% and 33%. The higher discount rate is set based on the assumption that high investment risk would be a barrier to the promotion of energy efficient equipments in the residential sector as well.

With 5% discount rate, it's estimated that 412 Mt-$CO_2$ is reduced in market driven case. In addition, advanced equipments at marginal abatement cost of 100US$/t-$CO_2$ and 300US$/t-$CO_2$ could reduce 824Mt-CO2 and 847Mt-CO2 respectively. These reductions correspond to 9%, 18% and 18% of emissions in the frozen case scenario respectively.

The reduction potential with 33% discount rate is less than that of 5% discount rate case. The reduction in emissions (with a 33% discount rate) corresponds to 157 Mt-$CO_2$ in the market driven case, 424 Mt-$CO_2$ at marginal abatement cost of 100US$/t-$CO_2$ and 668 Mt-$CO_2$ at marginal abatement cost of 300US$/t-$CO_2$.

## Country-wise reduction potential

Figure C2.2-2 shows country-wise $CO_2$ reduction potential from residential sector with 33% discount rate (see also Table C2.2-1). As shown in the figure, most of the reduction potentials in market driven case are seen in Russia and in developed countries such as EU or Japan. On the other hand, the reduction potentials in developing countries are very small because of the inexpensive fuel price. While the reduction potentials at marginal abatement cost of 100 or 300US$/t-$CO_2$ are very large in Russia, China and India.

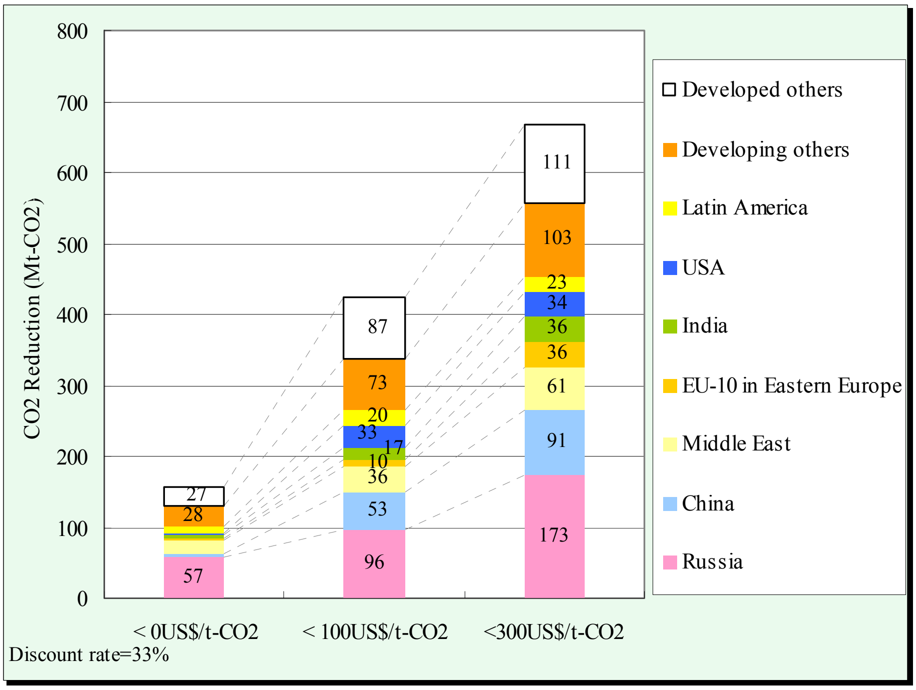



**Figure C2.2-2**: Country-wise reduction potential from residential sector

## Technology-wise reduction potential

Figure C2.2-3 shows technology-wise reduction potential from residential sector with 33% discount rate (see also Table C2.2-2). In market driven case, efficient heaters and water heaters are predominant. In 100 and 300US$/t-$CO_2$ cases, wall insulation, fluorescent of incandescent type and efficient refrigerator have great contribution to the reduction.

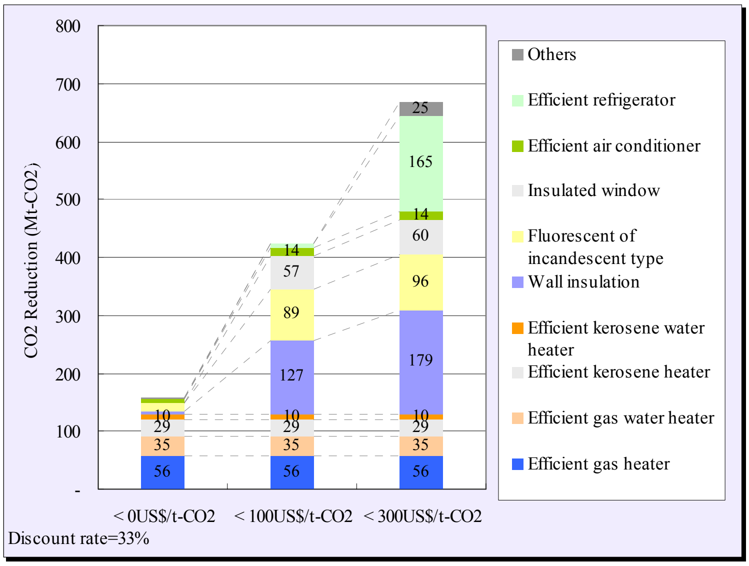



**Figure C2.2-3**: Technology-wise reduction potential from residential sector

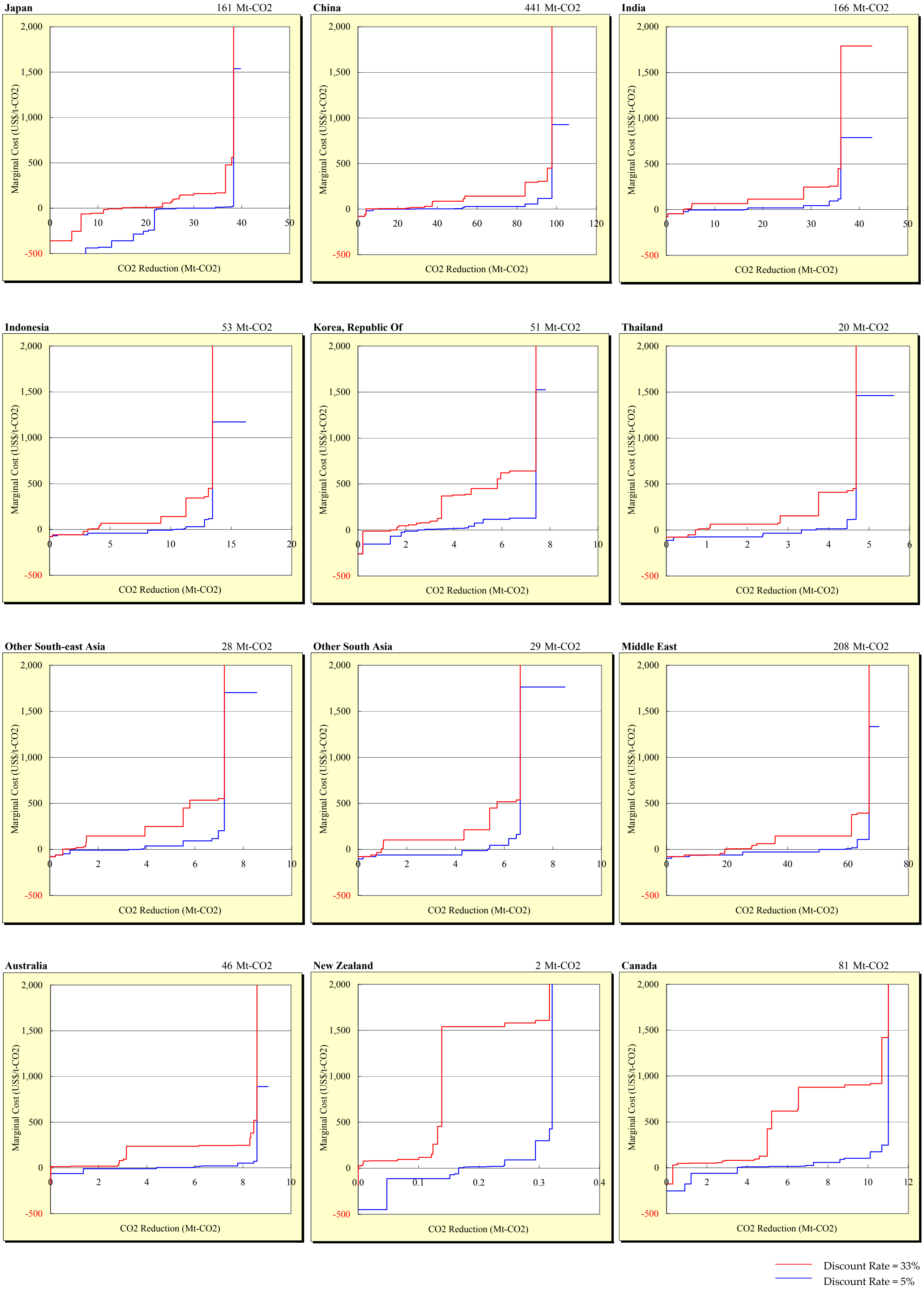
**Table C2.2-1**: Country-wise reduction potential of residential sector

| | CO2 Emission | | CO2 Reduction | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2020 | DR=33% | | | | | | DR=5% | | | | | |
| | | Frozen | < 0US$/tCO2 | | < 100US$/tCO2 | | <300US$/tCO2 | | < 0US$/tCO2 | | < 100US$/tCO2 | | < 300US$/tCO2 | |
| | Mt-CO2 | Mt-CO2 | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen | Mt-CO2 | vs Frozen |
| Japan | 124.6 | 160.6 | 15.1 | 9.4% | 26.0 | 16.2% | 36.6 | 22.8% | 29.1 | 18.1% | 38.3 | 23.8% | 38.3 | 23.8% |
| China | 308.4 | 441.1 | 4.0 | 0.9% | 53.0 | 12.0% | 90.6 | 20.5% | 7.6 | 1.7% | 90.6 | 20.5% | 97.6 | 22.1% |
| India | 97.5 | 165.6 | 3.5 | 2.1% | 16.9 | 10.2% | 35.6 | 21.5% | 16.1 | 9.7% | 35.6 | 21.5% | 36.2 | 21.8% |
| Indonesia | 29.6 | 53.5 | 3.2 | 5.9% | 9.2 | 17.2% | 11.3 | 21.1% | 10.2 | 19.0% | 12.8 | 23.9% | 13.5 | 25.2% |
| Korea | 36.4 | 51.0 | 1.3 | 2.6% | 3.3 | 6.5% | 3.5 | 6.8% | 2.5 | 4.9% | 5.2 | 10.2% | 7.4 | 14.6% |
| Thailand | 8.9 | 19.7 | 0.7 | 3.6% | 2.8 | 14.2% | 3.8 | 19.0% | 3.3 | 16.9% | 4.5 | 22.6% | 4.7 | 23.7% |
| Other South-east Asia | 18.4 | 27.8 | 0.5 | 1.9% | 1.5 | 5.5% | 5.5 | 19.8% | 3.3 | 11.7% | 6.7 | 24.1% | 7.2 | 26.0% |
| Other South Asia | 14.4 | 29.3 | 1.0 | 3.3% | 1.0 | 3.6% | 5.4 | 18.4% | 5.3 | 18.1% | 6.2 | 21.1% | 6.7 | 22.7% |
| Middle East | 133.7 | 207.9 | 19.3 | 9.3% | 35.9 | 17.3% | 61.2 | 29.4% | 50.5 | 24.3% | 63.1 | 30.3% | 67.0 | 32.2% |
| Australia | 35.0 | 45.6 | 0.0 | 0.0% | 3.1 | 6.9% | 8.3 | 18.2% | 4.4 | 9.7% | 8.6 | 18.8% | 8.6 | 18.8% |
| New Zealand | 1.4 | 1.8 | 0.0 | 0.0% | 0.1 | 5.5% | 0.1 | 7.2% | 0.2 | 9.2% | 0.3 | 16.2% | 0.3 | 17.4% |
| Canada | 61.2 | 81.3 | 0.3 | 0.4% | 4.6 | 5.7% | 5.0 | 6.1% | 3.5 | 4.3% | 8.8 | 10.8% | 11.0 | 13.5% |
| USA | 490.6 | 871.8 | 2.1 | 0.2% | 33.1 | 3.8% | 34.2 | 3.9% | 37.8 | 4.3% | 90.9 | 10.4% | 90.9 | 10.4% |
| EU-15 in Western Europe | 547.1 | 755.2 | 10.0 | 1.3% | 49.8 | 6.6% | 57.4 | 7.6% | 44.3 | 5.9% | 91.2 | 12.1% | 91.2 | 12.1% |
| EU-10 in Eastern Europe | 96.0 | 139.1 | 4.2 | 3.0% | 9.9 | 7.1% | 36.0 | 25.8% | 4.5 | 3.2% | 41.6 | 29.9% | 42.6 | 30.6% |
| Russia | 870.8 | 1,163.1 | 57.5 | 4.9% | 95.5 | 8.2% | 173.3 | 14.9% | 99.7 | 8.6% | 204.0 | 17.5% | 204.1 | 17.5% |
| Argentine | 9.0 | 17.5 | 1.5 | 8.4% | 2.0 | 11.4% | 3.4 | 19.3% | 3.3 | 19.1% | 3.5 | 19.9% | 3.8 | 21.5% |
| Brazil | 8.1 | 13.2 | 2.9 | 21.8% | 3.0 | 22.3% | 4.5 | 33.8% | 4.8 | 36.1% | 4.8 | 36.5% | 5.4 | 40.8% |
| Other Latin America | 39.3 | 78.1 | 7.3 | 9.4% | 15.4 | 19.7% | 15.4 | 19.7% | 16.8 | 21.5% | 17.2 | 22.0% | 18.0 | 23.0% |
| Africa | 61.2 | 133.9 | 5.1 | 3.8% | 16.4 | 12.2% | 25.9 | 19.3% | 22.1 | 16.5% | 32.7 | 24.5% | 33.4 | 25.0% |
| Rest of the World | 182.9 | 202.7 | 17.5 | 8.7% | 41.6 | 20.6% | 51.5 | 25.4% | 42.4 | 20.9% | 57.6 | 28.4% | 59.4 | 29.3% |
| Total | 3,174.3 | 4,659.9 | 157.1 | 3.4% | 424.1 | 9.1% | 668.1 | 14.3% | 411.7 | 8.8% | 823.9 | 17.7% | 847.0 | 18.2% |

**Table C2.2-2**: Technology-wise reduction potential of residential sector

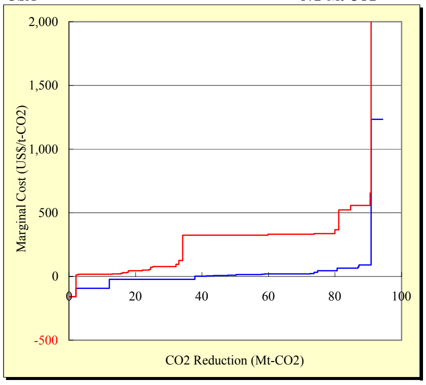
| | CO2 Reduction | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DR=33% | | | | | | DR=5% | | | | | |
| | < 0US$/t-CO2 | | < 100US$/t-CO2 | | < 300US$/t-CO2 | | < 0US$/t-CO2 | | < 100US$/t-CO2 | | < 300US$/t-CO2 | |
| | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share | Mt-CO2 | Share |
| Efficient refrigerator | 0.0 | 0.0% | 7.6 | 1.8% | 165.4 | 24.8% | 107.8 | 26.2% | 189.0 | 22.9% | 189.0 | 22.3% |
| Efficient television | 0.0 | 0.0% | 0.0 | 0.0% | 4.5 | 0.7% | 7.1 | 1.7% | 23.1 | 2.8% | 35.8 | 4.2% |
| Efficient air conditioner | 8.6 | 5.4% | 13.8 | 3.2% | 13.8 | 2.1% | 15.1 | 3.7% | 19.9 | 2.4% | 20.2 | 2.4% |
| Fluorescent of incandescent type | 14.0 | 8.9% | 88.5 | 20.9% | 95.6 | 14.3% | 79.0 | 19.2% | 95.6 | 11.6% | 95.6 | 11.3% |
| Efficient gas cooking stove | 0.9 | 0.5% | 0.9 | 0.2% | 2.6 | 0.4% | 2.6 | 0.6% | 3.9 | 0.5% | 11.6 | 1.4% |
| Efficient kerosene water heater | 9.8 | 6.2% | 9.8 | 2.3% | 9.8 | 1.5% | 10.4 | 2.5% | 11.4 | 1.4% | 11.4 | 1.3% |
| Efficient gas water heater | 34.8 | 22.1% | 34.8 | 8.2% | 34.8 | 5.2% | 40.3 | 9.8% | 46.2 | 5.6% | 48.6 | 5.7% |
| Efficient electricity water heater | 0.0 | 0.0% | 0.0 | 0.0% | 17.5 | 2.6% | 56.9 | 13.8% | 110.7 | 13.4% | 110.7 | 13.1% |
| Efficient kerosene heater | 28.7 | 18.2% | 28.7 | 6.8% | 28.7 | 4.3% | 28.7 | 7.0% | 28.7 | 3.5% | 28.7 | 3.4% |
| Efficient gas heater | 56.5 | 35.9% | 56.5 | 13.3% | 56.5 | 8.5% | 56.5 | 13.7% | 56.5 | 6.9% | 56.5 | 6.7% |
| Wall insulation | 3.9 | 2.5% | 126.8 | 29.9% | 179.1 | 26.8% | 7.6 | 1.8% | 179.1 | 21.7% | 179.1 | 21.1% |
| Insulated window | 0.0 | 0.0% | 56.9 | 13.4% | 59.9 | 9.0% | 0.0 | 0.0% | 59.9 | 7.3% | 59.9 | 7.1% |
| Total | 157.1 | 100.0% | 424.1 | 100.0% | 668.1 | 100.0% | 411.7 | 100.0% | 823.9 | 100.0% | 847.0 | 100.0% |

**Marginal abatement cost curve of residential sector in 2020 (1/2)**

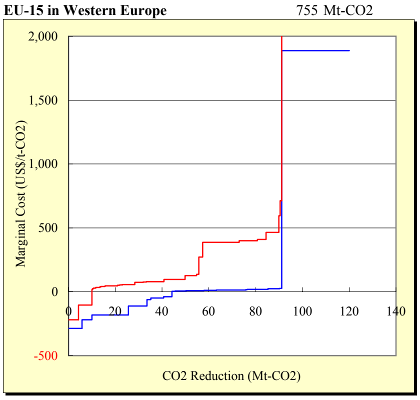


**Marginal abatement cost curve of residential sector in 2020 (2/2)**

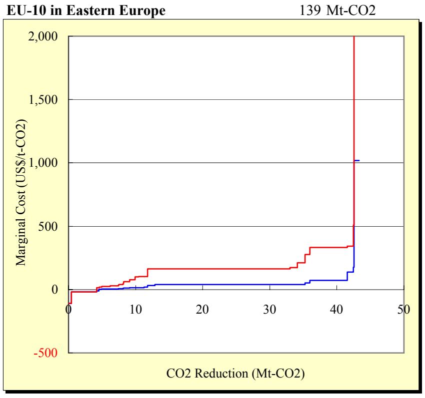
**USA** 872 Mt-CO2



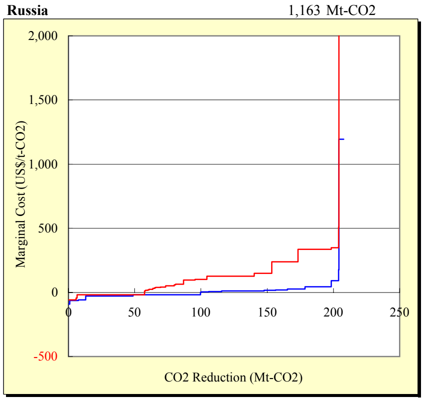

**EU-15 in Western Europe** 755 Mt-CO2



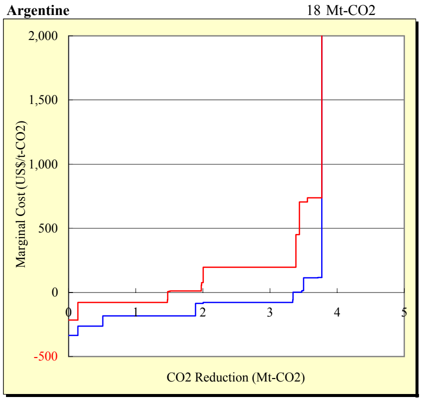

**EU-10 in Eastern Europe** 139 Mt-CO2



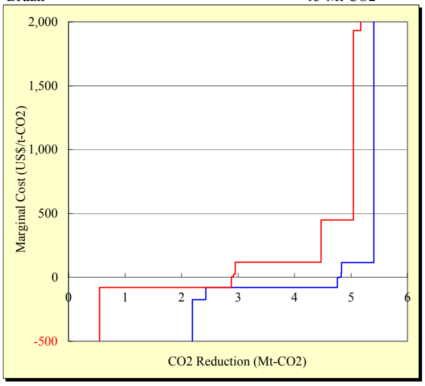

**Russia** 1,163 Mt-CO2



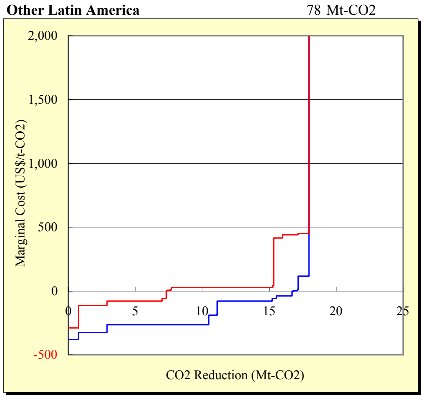

**Argentine** 18 Mt-CO2



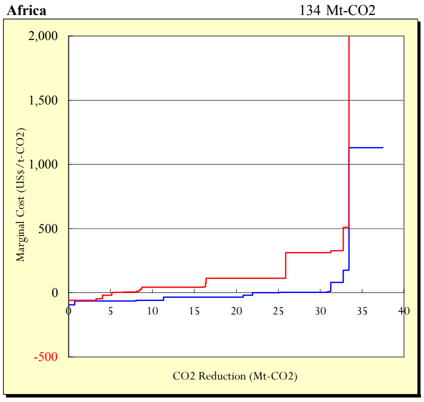

**Brazil** 13 Mt-CO2



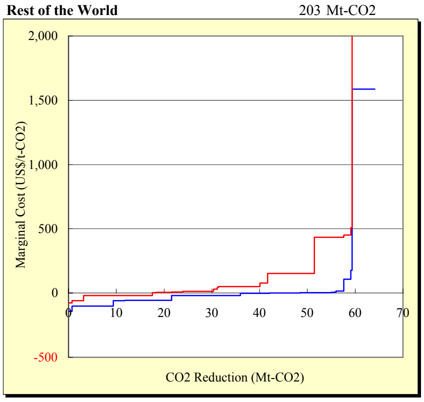

**Other Latin America** 78 Mt-CO2




**Africa** 134 Mt-CO2




**Rest of the World** 203 Mt-CO2




Discount Rate = 33%
Discount Rate = 5%

## Appendix: Outline of Asia-Pacific Integrated Model (AIM)

The Asia-Pacific Integrated Model (AIM) is one of the main tools of developing policy options for the Asia-Pacific region. It is a set of integrated computer simulation models used to assess policy options for sustainable development in this region. It started as a tool to evaluate policy options to mitigate climate change and its impacts, and extended its function to analyze other environmental issues such as air pollution control, water resources management, land use management, and environmental industry encouragement. More than 20 modules have been developed so far, and models to evaluate climate policy options are classified into emission models, climate models and impact models from the viewpoints of climate policy assessment. These models have been used as single models or in combination depending on the policy needs.

### Models Used in This Pamphlet

AIM models used in this pamphlet are AIM/Enduse, AIM/CGE, AIM/Impact and AIM/Impact[policy]. Brief explanations of each model are written in the following pages. They were separately or jointly used to get the outlook of climate change impacts and mitigation potential in the future. AIM/Enduse was used to measure global and regional reduction potential and required direct costs. AIM/CGE was used to estimate economic burdens of emission reduction to comply with the path. AIM/Impact was used to estimate country level climate impacts, and AIM/Impact[Policy] was used to project allowable emission paths from the view point of climate stabilization. These four models are used in this pamphlet following the paths illustrated in Fig. AP-1.

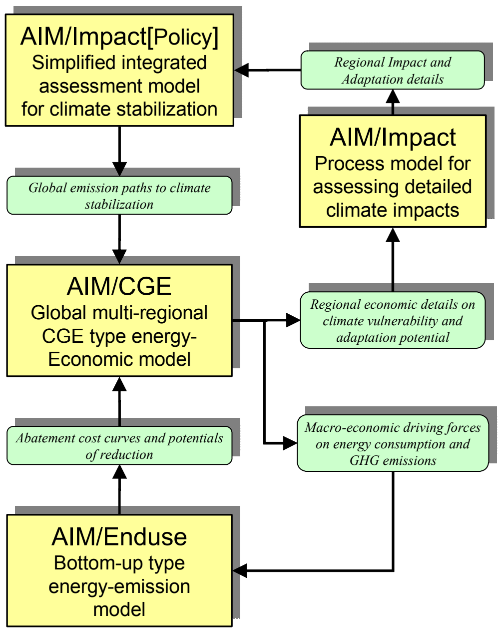



**Figure AP-1**: AIM models used in this pamphlet

### AIM/Enduse Model

AIM/Enduse is a technology selection framework for analysis of greenhouse gas emissions mitigation policies. It simulates flows of energy and materials in an economy, from supply of primary energy and materials, through conversion and supply of secondary energy and materials, to satisfaction of enduse services. AIM/Enduse models these flows of energy and materials through detailed representation of technologies.

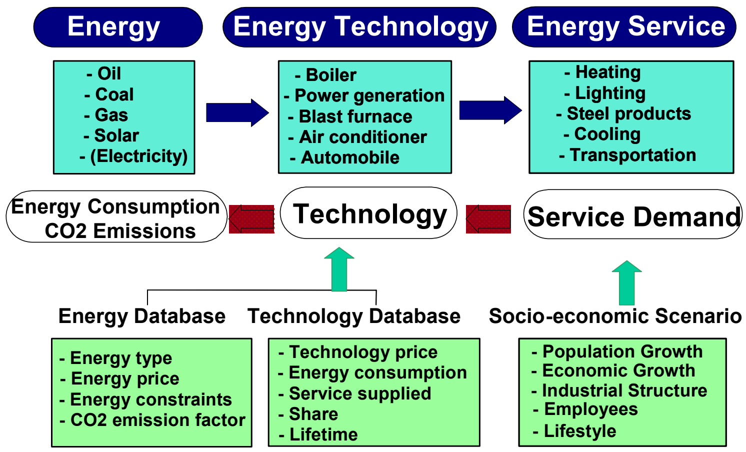



**Figure AP-2**: Structure of AIM/Enduse model

Selection of technologies takes place in a linear optimization framework where system cost is minimized under several constraints like satisfaction of service demands, availability of energy and material supplies, and other system constraints. System cost includes fixed costs and operating costs of technologies, energy costs, and other costs like taxed or subsidies. The model can perform calculations simultaneously for multiple years. Various scenarios including policy countermeasures can be analyzed in AIM/Enduse. Figure AP-2 illustrates AIM/Enduse model.

**Table AP-1**: Regional classification of global model

| | |
|---|---|
| Asia | Japan |
| | China |
| | India |
| | Indonesia |
| | Korea |
| | Thailand |
| | Rest of South East Asia |
| | Rest of South Asia |
| Oceania | Australia |
| | New Zealand |
| North America | USA |
| | Canada |
| South America | Argentine |
| | Brazil |
| Africa | Africa |
| Europe | EU15 |
| | EU10 |
| | Russia |
| | Rest of Europe |
| Middle East | Middle East |
| | Rest of the World |

The first version of AIM/Enduse focused on analysis of country-level policies on $CO_2$ mitigation in Asia region. It extended to analyze co-benefits of $CO_2$ and $SO_2$ mitigation objectives by collecting local information such as large point sources sector-by-sector and revising model structure. Then regions of interest are extended to global level. The regional classification is listed in Table AP-1.

AIM/Enduse model permits analysis of various countermeasures. These are characterized as follows:

- Enduse stage countermeasures like efficiency improvement or better use and management of devices.
- Emission tax on fuels for greenhouse gases and air pollutants.
- Energy tax on a (polluting) fuel to discourage4 its use.
- Regulatory constraint on quantity of emission of a gas in selected group of sectors in an

economy.

- Regulatory constraint on quantity of use of an energy-type in selected group of sectors in an economy.
- Subsidy on capital cost or operating cost of a device to promote its selection.
- Subsidy to promote attachment of an emission removal process to a device.
- Regulatory constraint on use of a lean or efficient device or its combination with an emission removal process.

## AIM/CGE Model

AIM/CGE model is a recursive dynamic equilibrium model of the world economy used to analyze the effects of climate stabilization policies. The model divides the world into 21 geopolitical regions. The structure of AIM/CGE is described in Fig. AP-3. The updated model includes framework for both $CO_2$ and non-$CO_2$ gases.

The model has three sectors- the production, household, and government sectors- in each region. $CO_2$ and non-$CO_2$ gases are emitted by each of these sectors. The production of electricity and non-energy goods involves the production and use of fossil fuels leading to emission of these gases. In addition, the use of automobiles and other direct use of fossil fuels by the household and government sectors lead to emissions. It is assumed that the household sector has multi gas emissions rights and distributes them to other sectors and within the household sector itself. Fossil fuels cannot be used without having such rights. The price of these rights depends on several factors such as emission targets and the method of emissions trading. The household sector also supplies primary factors to the production and government sectors. An agent in the household sector determines consumption and savings.

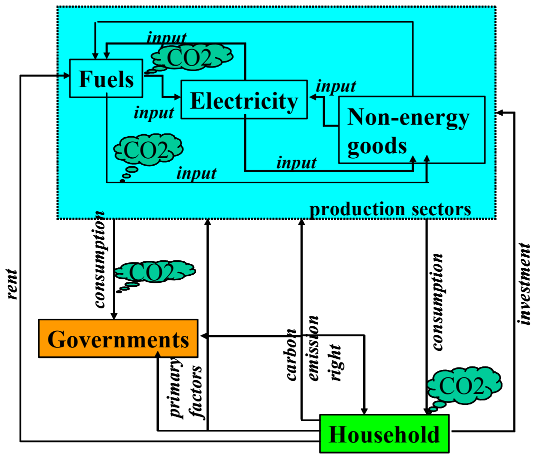



**Figure AP-3**: Structure of AIM/CGE Model

The bottom-up AIM/Enduse and topdown AIM/CGE models are used interactively. The outputs of AIM/CGE such as energy price and service demands can be used by AIM/Enduse and the information on technology efficiencies is an input to AIM/CGE.

## AIM/Impact Model

The AIM/Impact model has been developed in order to evaluate future climate change impacts to support decision making on the Global/Asia scale. The AIM/Impact model consists of sub-models for evaluating impacts on major vulnerable sectors and linkages among them. Figure AP-4 shows the linkages between the sub-models.

The FOOD sub-model consists of a productivity model for 12 major crops and an agricultural trade model. The potential productivity changes caused by climate change are estimated using a 5o x 5o spatial resolution. Next, based on the estimated changes in crop productivity, the agricultural trade model calculates the allocation of the production of, and demand for, crops and other commodities that maximize social welfare. The HEALTH sub-model examines the impact of malaria infection. It evaluates the suitability of climatic factors for the malaria causing mosquito to reproduce, and estimates the extent of malaria infection. The VEG sub-model estimates the impact of climate change on several forest and other vegetation types. The model simulates forest collapse in regions where the rate of climate change is too high for the existing vegetation patterns to continue. Work to modify the model so that it simulates dynamic changes to the vegetation is continuing. The HYDRO sub-model uses information on climate, soil and terrain to simulate surface runoff and river discharges. The WATER sub-model estimates the future water demand at the national level and assigns that demand to each grid block, thereby creating a spatial distribution of water demand. CLIMATE sub-model provides future climate scenarios for the sub-models of AIM/Impact with processing of the spatial GCM projections and observed climatology. Results of AIM/Impact are contained in the impact database in AIM/Impact[Policy] and used for further policy analysis.

Assessment tools for country-scale impact have also been developed by refining AIM/Impact's global-scale modules through the collaboration between Japanese and each country's team members. Results introduced in the pages 6 and 7 are the outputs of those country-scale models.

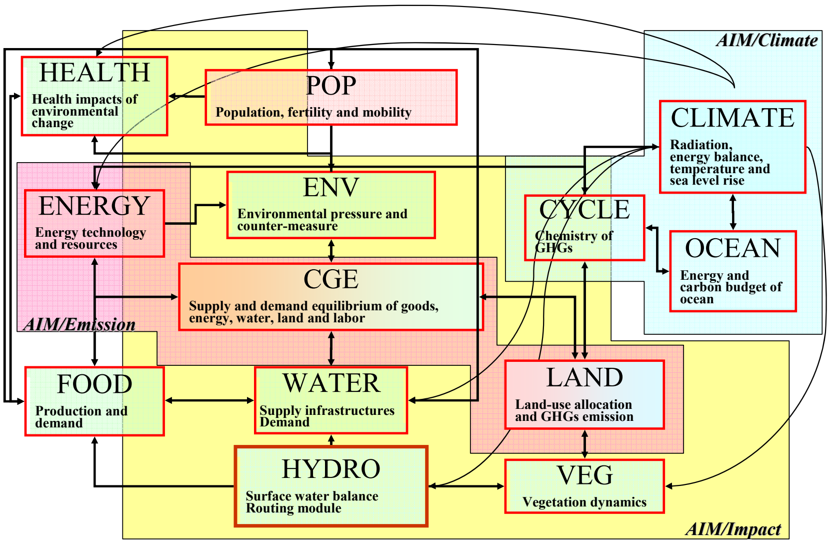



**Figure AP-4**: Framework of AIM/Impact model

**AIM/Impact[Policy]**

AIM/Impact [policy] is an integrated assessment model which provides a framework for evaluating climate change impacts management under stabilization strategies for GHG emission, concentration and temperature. The objectives of model development are (1) to provide a platform to integrate past impacts studies of climate change on several sectors and analyze climate change impacts on dangerous level, economical damage and adaptation strategy comprehensively, (2) to provide a platform to investigate GHG emission reduction strategies for achieving climate stabilization goals and to analyze the effects of burden sharing scheme and flexibility scheme for GHG emission reduction.

This model consists of a series of linked sub models representing the major processes of GHG emission and climate change impacts (Fig. AP-5). The GHG emission part includes four sub models. The dynamic optimizing model is used to analyze global GHG emission path under different socio-economic scenarios and reduction constraint strategies of multi GHGs. In this model, the world is treated as single region and economic and simplified climate modules are incorporated. The burden sharing scheme model provides quantitative information on burden of GHG reduction at country level. Input data of global GHG reduction volume on various scenarios are provided by the dynamic optimizing model. This scheme includes several types of burden sharing approach, e.g. Contraction and Convergence, Brazilian Proposal, Multi-stage, etc. The global CGE model is a recursive dynamic equilibrium model of world economy at regional and country level. This model enables quantitative evaluation of economic damages caused by GHG reduction and climate change impacts. The flexibility scheme model is incorporated in the global CGE model and enables to evaluate range of emission reduction effects utilizing emission trading and carbon tax scheme.

Climate change impacts part include one sub model, impact assessment and adaptation model for global climate change. This is a database type model and composed of pre-simulated results of process type models. In this model, country-averaged climate change derived from GCM and projected quantitative impacts derived from detailed impact studies in sensitivity analysis are linked with the global temperature increase projected by a simple climate module. This module is built as a dynamic optimizing model in order to estimate country-wise impact on several sectors. Results of external impact research group as well as the results of AIM/Impact are contained in the impact database. This model indicates the sector-wise severity of the impacts based on the relationship among socio-economic scenario, adaptation capacity and sector-wise potential impacts.

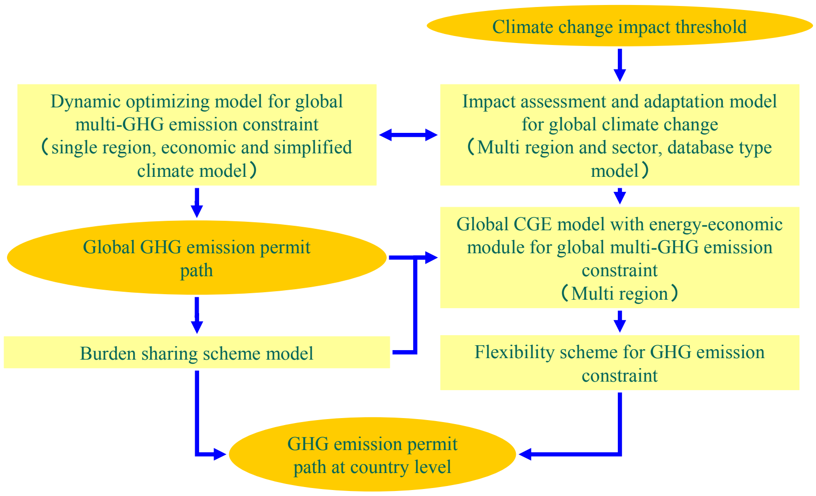



**Figure AP-5**: Framework of AIM/Impact[Policy]

## AIM Network

The research project of AIM started in 1990 and has been specifically developed using a collaborative approach of Asian region, based on international collaboration programs with participation of governments and developing countries to get their own Integrated Assessment tools, and these countries have already applied own Integrated Assessment Models to their actual policy making processes

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