B-15.3 Development of Socio-Economic Scenarios for AIM Simulations

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Abstract:

This project assesses scenarios of socio-economic development, technological improvements and other related scenarios for prediction of GHG emissions and global warming impacts in the Asian-Pacific region. The basic information necessary for developing the Asian-Pacific scenarios has been collected for 18 countries in the region. It has been analyzed to identify the characteristics of each country for energy use, industry, and lifestyle so as to create scenarios for each country's socio-economic growth. Previous global scenarios have been reviewed, and the consistency between population growth and economic growth has been analyzed using a new model in order to prepare an appropriate scenario for population growth and economic growth. Finally, the sensitivities of the uncertainty caused by the above socio-economic scenarios, as well as those from natural factors have been estimated for GHG emissions and climatic changes using the world module of the AIM model.

Key Words Socio-Economic Scenario, Asian-Pacific Region, Population Growth, Economic Growth, Emission Scenarios, Climate Change Scenarios

1. The Necessity for Scenario Analyses

The estimated levels of future GHG emissions and climate change depend significantly on the input assumptions, such as economic growth, population growth and technological innovation. For example, population growth has a direct effect on GNP growth, and GNP growth has an important influence on energy consumption. Technological innovation is a determining factor of energy efficiency improvement, and also determines the CO_2 emission factor per unit of energy consumption.

It is necessary to carefully examine all assumptions when establishing such future socio-economic scenarios. Furthermore, each scenario interacts with others. Historical data shows that an increase in per capita GDP tends to reduce the fertility rate. Also, a high rate of economic growth is believed to increase the speed of technological innovation. The existence of such factors requires that the modeler examines each scenario for consistency. Scenario analyses are thus aninevitable step in the process of predicting global warming impacts.

The role of this project is to conduct such analyses, establish consistent future scenarios and conduct sensitivity analyses of such scenarios on global warming.

2. Fundamental Data Analyses and Scenario Analyses

(1) Fundamental Data Analyses for the Asian-Pacific Scenarios

As the first step in the scenario analysis, a data-base was established to set socio-economic scenarios in the Asian-Pacific region. Basic data, such as that for population, economy, manufacturing, agriculture, transport, infra-structure and labor were investigated, as well as major policy and forecasting studies for 18 countries in the region. The targeted countries were India, Indonesia, Republic of Korea, Democratic People's Republic of Korea, Thailand, Taiwan, China, Japan, Bangladesh, Pakistan, Philippines, Viet Nam, Malaysia, Myanmar, Mongolia, Laos, Australia and New Zealand. The collected data was filed and used to analyze the characteristics of the socio-economic trends. This is important for preparation of forecasts of the impact of policy measures included in various scenarios on a range of socio-economic factors.

For example, Figure 1 shows the relationship between per capita GDP and energy intensity (energy consumption per unit of GDP) based on data from 1970 to 1989. This figure shows that economic growth increases energy efficiency, if traditional energy supplies are included in the calculation. The speed of energy efficiency improvement is high when per capita GDP is below US$1,000 and above US$10,000 (1985 dollars). Between $1,000 and $10,000, the improvement is very slow. Using such analyses of historical trends, future technological improvement scenarios and other socio-economic scenarios were checked for their reliability.

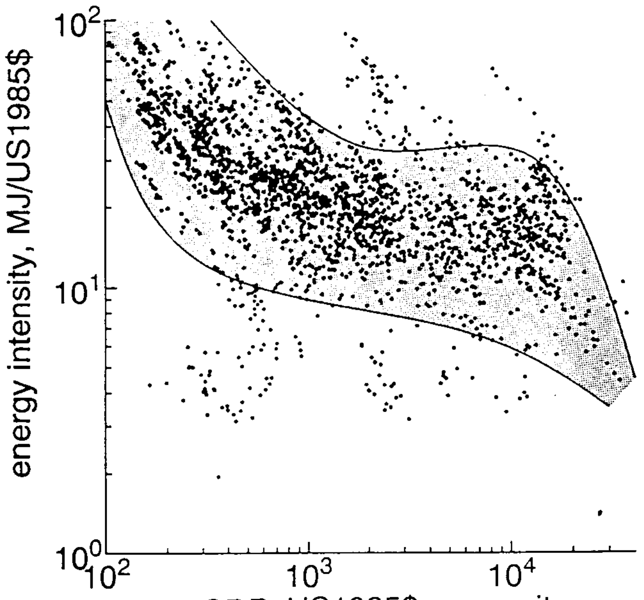

Fig.1 Cross Country Analysis of Energy Intensity

(2) Review of Socio Economic Scenarios

In order to identify the range of the uncertainties in global future socio-economic activities, previous scenarios used in global simulations were reviewed.

Figure 2 presents those estimates of future world population used as assumptions in previous emission scenarios. Beginning at 1990, with the world's population at about 5.3 billion, it can be seen that estimates of world population at 2100 range widely from 3.6 billion (World 3 model; Meadows et al, 1992) to 109.4 billion (UN, 1992).

The United Nations estimates (UN, 1992) which are extraordinary high, were calculated assuming that the total fertility rate (TFR: the average number of children per woman) in the early 21st century would remain as it now. Mesarovic's (1974) high level, which is the second highest estimate, was calculated assuming that the current rate of increase would not change in the future. It is considered that these figures should be regarded merely as calculated values, rather than rationale estimates. The scenario with the population of 3.6 billion at 2100 was calculated by Meadows et al(1992) and assumes that the death rate would increase because of environmental pollution. This scenario is also considered to be extremely unlikely. The most practical and useful range is considered to extend from the 1990 estimates of the World Bank (WB, 1990; Bulatao, 1990), which estimated that the TFR will become 2.1 (population replacement) at a comparatively early stage, to the 1987 estimate of the U.S. Bureau of Census which estimated that this time is reached later.

Figure 3 presents estimates of future economic growth assumptions (per capita GDP) used in various emission scenarios. The total value of economic activities is determined by population size X per capita GNP, so CO_2 emission estimates are very sensitive to assumptions about per capita GNP. In this figure, the upper group of thin lines are the per capita GDP values of OECD nations, while the lower group of thin lines are those for South and East Asian nations excluding Japan. The bold lines are global estimates.

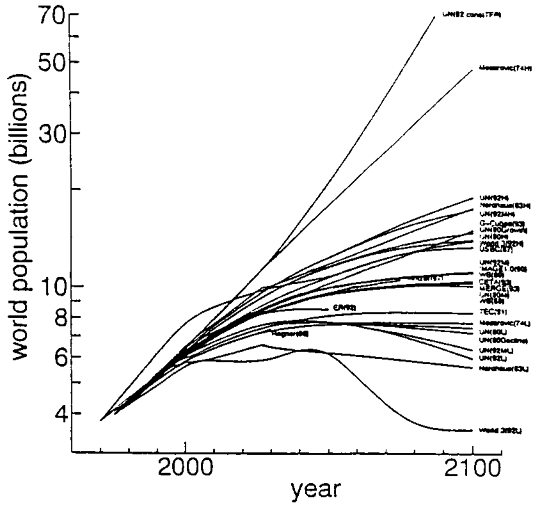

Fig.2 Future World Population Assumptions

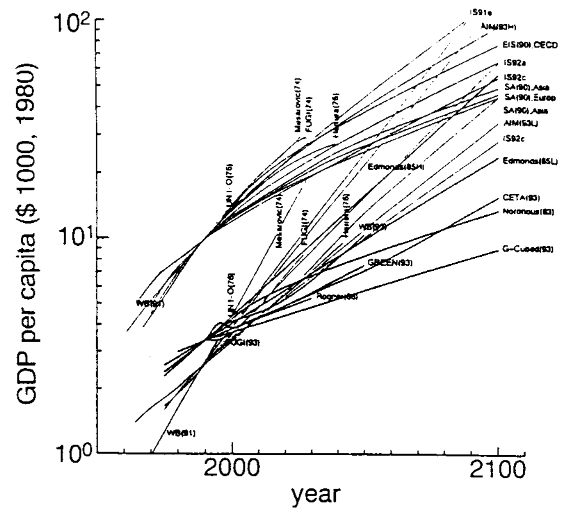

Fig.3 Future Economic Growth Assumptions (The upper lines are OECD countries, while the lower lines are South Eastern countries excluding Japan. The thick lines are global estimates.)

The per capita GDP assumptions for the developed regions increase by between about 4 and 9 times from now to the end of the 21st century. Those for the South and East Asian countries increase from 10 to 40 times, and in some cases reach, or exceed, the assumptions for developed regions at 2100. All but two of these assumptions exceed the OECD countries current per capita GDP by 2050. These two end before 2050, but their extrapolation for just a few years would result in them reaching this level before this time. The global assumptions in particular, are very wide ranging. In general, the more recent ones show a lower level of growth.

Table 1 presents AEEI (Autonomous Energy Efficiency Improvements) values of some typical recent emission models. Where there is no great attention paid to saving energy, the annual improvement rate is between 0 and 0.5%, while if great savings are assumed, it rises to 1.0%.

The implications of some normative energy saving scenarios can be examined. For example, in the scenario of Lovins et al (1981), between 1975 and 2080, per capita consumption of primary energy is reduced to 22% in developed regions, and to 50% in developing regions. The scenario of Goldemberg et al (1988) assumes that between 1980 and 2020, per capita energy consumption in developed regions is reduced to 50%, while in developing regions it is restricted to 110%.

When these values are converted to annual ratesusing energy prices during the forecast periods and per capita GDP growth rates, values of about 1.1 to 2.9% are obtained.

Table 1 AEEI of Major Global GHG Emission Models

MODELERS	AEEI (%/annum)
Global energy models	
Manne and Richels (1994)	0.7
Goulder (1994)	0
Nordhous (1993)	0 - 1.25
Mckibbin and Wilcoxen (1993)	0
Peck and Teisberg (1993)	0.25
Manne et al. (1993)	0.5
Anderson and Bird (1992)	1
Edmonds and Reilly (1991)	0.5 - 1
IEA (1991)	1.1 (OECD)
GREEN (1991)	1
Manne and Richels (1990)	0 - 1
IPCC (1990) (*)	0.16 (low growth) 0.46 (high growth) (USA)
Feasibility studies of energy efficient scenarios	
Lovins (1981) (*)	1.12 (Developed) 1.53 (Developing)
Goldemberg (1988) (*)	2.85 (Developed) 1.40 (Developing)

(*) Estimated

(3) Consistency between Population and Economic Growth

In setting population growth and economic growth assumptions, their correlativity must be considered. A decrease in population growth rates of developing regions, especially fertility rates, increases the potential for saving and promotes the formation of capital. As a result, productivity can increase and economies develop. Presently, countries in the South-Asian region in particular are very interested in the impact of this mechanism in the construction of development strategies, so are directing much effort into creating models and preparing scenarios (Bilsborrow, 1989).

Figure 4 plots the relationship between TFR and per capita GNP. The empty circles show Japan's situation from 1925-1990, while the black points represent all other countries from 1950-1985. The relationship between these two factors is equivalent to the slope of the triangle shown in the figure, which in turn equals the following equation:

$$\Delta \text{TFR} = - \alpha \, \Delta \ln \text{[per capita GNP]}$$

and the parameter α can be statistically calculated as 1.3.

This value can then be used to calculate future estimates of world population, using the cohort population projection model, as has been done in Figure 5. Here, our calculated estimates of future population growth under the different GNP growth rates (the dotted lines), are compared with the UN/WB projections (the solid lines). As can be seen, the median estimate of the UN/WB projections is equivalent to a GNP growth rate of around 3%/year.

The use of such a model in these circumstances can help provide planners and policy makers with more consistent future scenarios.

3. Sensitivity Analysis of Global Warming

(1) Simulation Cases

Based on the above review, range of socio-economic scenarios as well as natural input conditions have been prepared for sensitivity analyses. These assumptions and options were

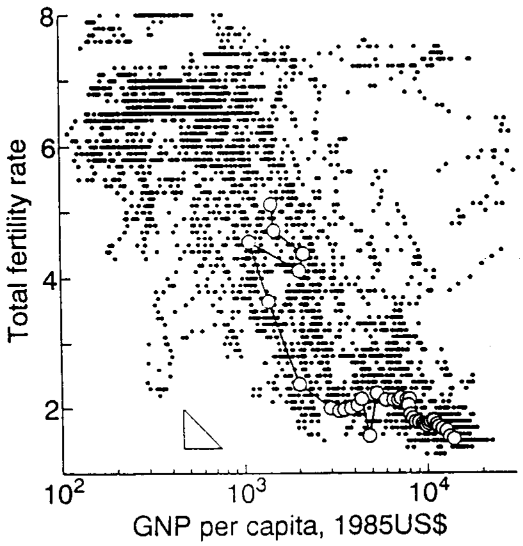

Fig.4 TFR and Per Capita GNP

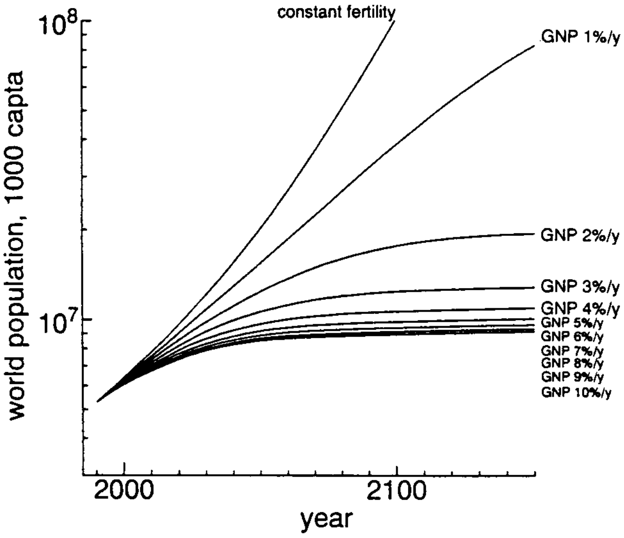

Fig.5 Per Capita GNP and Global Population Changes

integrated and examined to establish our simulation cases. The standard cases were developed by integrating population, economic growth and AEEI. Measures to restrict GHGs were not included. Two standard cases were produced:

(1) High Standard Scenario : High Population Scenario (assumed by U.S.Bureau of Census, 13.5 billion in 2100), plus High Economic Growth (IRS91a, growth rate +20%), plus Low Efficiency Scenario.

(2) Low Standard Scenario : Low Population Scenario (assumed by World Bank in 1990, 11.3 billion in 2100), plus Low Economic Growth (IRS91a, growth rate -20%), plus High Efficiency Scenario.

To incorporate the effect of the missing sink and feedbacks simply, we added the following allowances to the high and low standard cases: First, to the high estimate, we added: (1) a 2% annual decline in the missing sink; (2) positive feedback mechanisms - an increase in the metabolism of terrestrial ecosystems, an increase in methane emissions from wetlands and increased destabilization of methane hydrates: and (3) a change in ocean circulation. To the low estimate, we added: (4) a proportional increase in the missing sink as atmospheric CO_2 concentration increases; and (5) a negative feedback mechanism - the fertilization effect of CO_2.

Assuming the above cases, we estimated GHGs emissions and temperature increases using the global component of AIM model.

(2) Simulation Results

Figure 6 shows estimated CO_2 emissions from fossil fuel consumption using the above assumptions. Under the two standard scenarios, CO_2 emissions are assumed to be 1.4 - 2.4 times as large in 2025 and 2 - 7 times as large in 2100. As a result, emissions in 2100 will reach 39.7 billion tC under the high standard scenario and 11.2 billion tC under the low scenario. A comparison of these values with the previous reported values is presented in Figure 7. As can be seen, they correspond well to the range of these values.

Figure 8 presents changes in GHGs concentrations over time. The dark area is the range caused by uncertainties in economic growth, population growth and technological change. This figure also shows the range caused by uncertainties in the missing sink (labeled MS in the figure), positive and negative feedback mechanisms, and the impact of oceanic CO_2 absorption.

The range of the scenario becomes wider as these mechanisms are added. GHG concentrations, estimated as CO_2 equivalents, would grow from 819 - 1846 ppmv to 690 - 2379 ppmv.

The range of temperature increases changes in the same way and is shown in Figure 9. The interesting feature here is that the great influence of changes in ocean circulation can be seen. Figures 8 and 9 are based on a climate sensitivity of 3℃, and Figure 10 illustrates the differences between the sensitivities of 2, 3, 4℃. The highest and the lowest loci of all published cases are shown in this figure. The temperature increase would range from 1.5 to 10 ℃ in 2080.

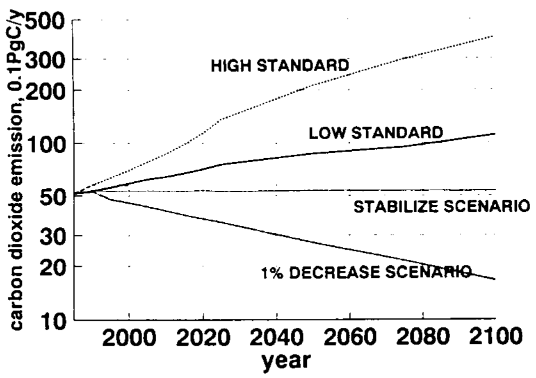

Fig.6 CO_2 Emission Forecasts by AIM

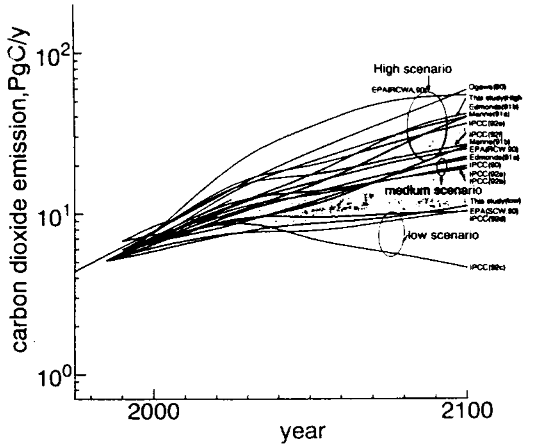

Fig.7 Recent Forecasts of CO_2 Emissions (The gray area is the range of calculations in the AIM simulations)

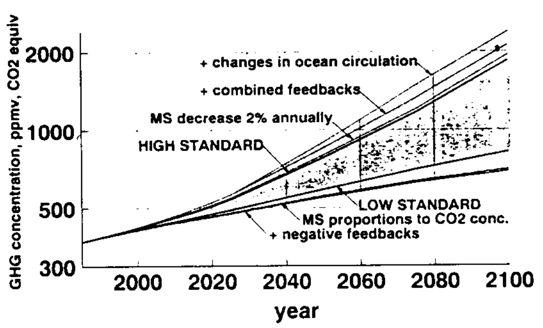

Fig.8 Change in GHG Concentrations

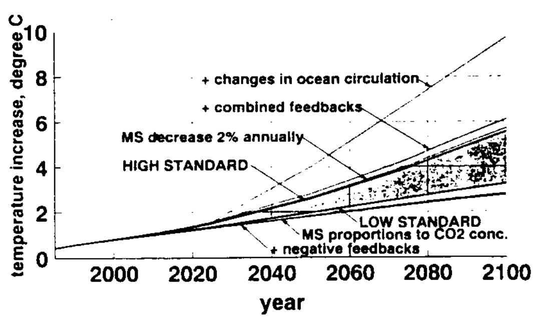

Fig.9 Change in Temperature Over Time

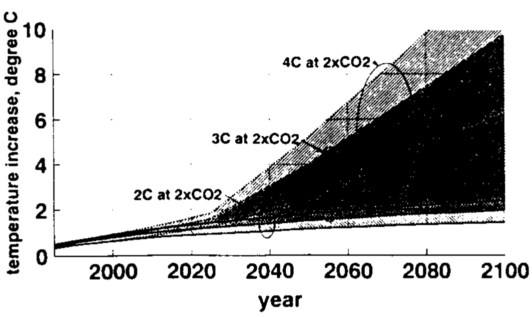

Fig.10 Rises in Temperature with climate Sensitivity of 2 - 4 degree C

(3) Findings

Our sensitivity analysis produced the following conclusions:

1) It is extremely likely that the earth will become warmer.

2) The range of potential temperature increases is quite wide.
3) The appropriate political responses vary substantially depending on the temperature change. Therefore, the basic foundations of policy development need to be prepared now by examining the potential political options, reducing the uncertainties, and preparing for the worst case scenario.
4) The main uncertainties in the natural systems are climate sensitivity, the impacts of the oceans, and feedbacks. Reducing these uncertainties will take time, but unexplained phenomena will remain. The uncertainty of some socioeconomic factors can also be reduced, but it will take long time.
5) Preventive measures should be introduced that create the widest possible range of options for future generations, and allow all uncertainties to be more accurately determined. The flexibility available within socioeconomic systems to respond to the worst global warming scenario should be analyzed.

4. Concluding Remarks

This research project assessed GHG emissions and potential socio-economic impact. Detailed databases were established, the available scenarios of future CO_2 impacts reviewed and their sensitivity analyzed. The findings are particularly important as they show that the issue of global warming is a concrete one and cannot be dismissed as merely a vague theory and/or ignored politically. Not only is further research shown to be needed, but positive directions for future political actions are indicated.

However, the problems that remain unresolved relating to this research need to be understood. First, although the latest scientific knowledge was used, the uncertainties of solar variability, aerosols and innovative technology introductions, such as backstop technologies were omitted to keep the analysis and logic simple. These issues are being examined separately. Also, assumptions such as population increase and economic growth were considered as independent rather than related variables in this project. The relationships between these and other factors will need to be built into the structure of the model and become endogenous, so that changes in one will automatically be reflected in the others.

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