ALternative **P**athways toward **S**ustainable development and climate stabilization (ALPS) – Project Outline

– Development of alternative scenarios under the world countries having multiple objects and the different priorities

■ Background and Objective

The purpose of this study is to develop alternative scenarios with realistic assumptions that nations, as actors in the global community, have multiple objectives with different priorities. A variety of emissions scenarios for climate change research have been developed so far, and made a due contribution to policy-making in the climate change mitigation efforts. The traditional approaches in modeling exercises for scenario development, however, tend to describe a simplified world under which mitigation or adaptation costs are minimized with the ideal conditions. The reality is more complex: different actors have different policy priorities based on their economic level, natural circumstances and other constraints, which leads to difficulty in creating a coordinated uniform policy, as observed in the COP15 negotiations and in the domestic policymaking processes. Climate change is not the only issue on the global agenda, so it should be addressed in a balanced manner across multiple dimensions. Traditional global abatement scenarios may be too simplified to capture richness of detail and context of the real world situation. The results reveal that climate policy with the highly-idealized premises sometimes does not deliver relevant outcomes, or rather causes unduly confusion to the society.

The ALPS project aims at providing alternative plausible future scenarios and through quantification of multiple aspects of society on the assumptions that the real-world society is intrinsically consist of a wide range of values. This approach allows us to inform decision makers of more appropriate strategies toward sustainable development and climate stabilization from longer and wider perspectives. Another focus is to gain a clearer understanding of CO_2 emissions structure on a national, sectoral and technological basis in order to deal with short and mid-term climate challenges. The scenarios on combinations of macro and micro views would generate further insights into climate change mitigation and sustainable development.

■ Socio-economic Scenario Development

Modeling simulations are powerful tools to support decision making even though they tend to assume perfect information or perfectly rational behavior. At the same time, it is important to bear in mind that the real world is less elegant and simple. The gap between the real world and virtual model world creates a risk of sending wrong message. Therefore this ALPS project starts from a deep understanding of the current world situation and learns from historical trends in order to avoid such trap. Based on the insights gained from the socio-economic analysis above, narrative storylines with great details are worked out from broader perspectives.

There are three pillars for core narrative scenarios; 1) Socio-economic scenarios, 2) Climate Change Policy scenarios, and 3) Representative Concentration Pathways (RCP) scenarios. Furthermore sub-scenarios focus on the subject matter of development and diffusion of climate friendly technologies, economic growth of least developed countries and impacts of inter/intra national economic gap (see Figure 1).

With regard to the socio-economic scenarios, a key scenario driver is technological progress, which involves significant uncertainty. Although policy can have impact on technology progress to some extent, other factors can bring larger uncertainty about the future technological change beyond policy impact. It is quite difficult to forecast future innovation and technological progress with high accuracy, so we prepare two discrete scenarios to cover the uncertainty. Scenario A (Medium technological progress scenario) illustrates a gradual shift from dynamic economic development toward a well matured economy especially in developed countries. Scenario B (High technological progress scenario) describes a future world of very rapid economic growth with brilliant innovation.

As for scenarios of climate change priority in the broader global agenda, we develop three different narratives. Scenario I named "Pluralistic society scenario" is approximate to the current real world situation with people's diverse values in nature. This scenario is premised on the existence of various barriers to technology diffusion. Scenario II is a "Climate policy prioritized scenario" is a one under which climate change policy is prioritized and people's behavior are rational in the sense that mitigation measures are taken in a cost effective way. This assumption was implicitly adopted by most of the traditional climate change assessment. Scenario III called "Energy security prioritized scenario" in which each nation puts high priority on domestic energy resources from energy security perspective.

Our future emissions scenarios are fully harmonized with a set of four RCPs for IPCC AR5. The RCPs have been selecting from existing literature to span the full range of possible trajectories for future greenhouse concentration: a very high emission scenario leading to 8.5 W/m2, a high stabilization scenario leading to 6 W/m2, an intermediate stabilization scenario leading to 4.5 W/m2 and a low mitigation scenario leading to 2.6 W/m2 (RCP 3-PD). Additionally we go over 3.7 W/m2 scenario, which comes to five emission pathways in total.

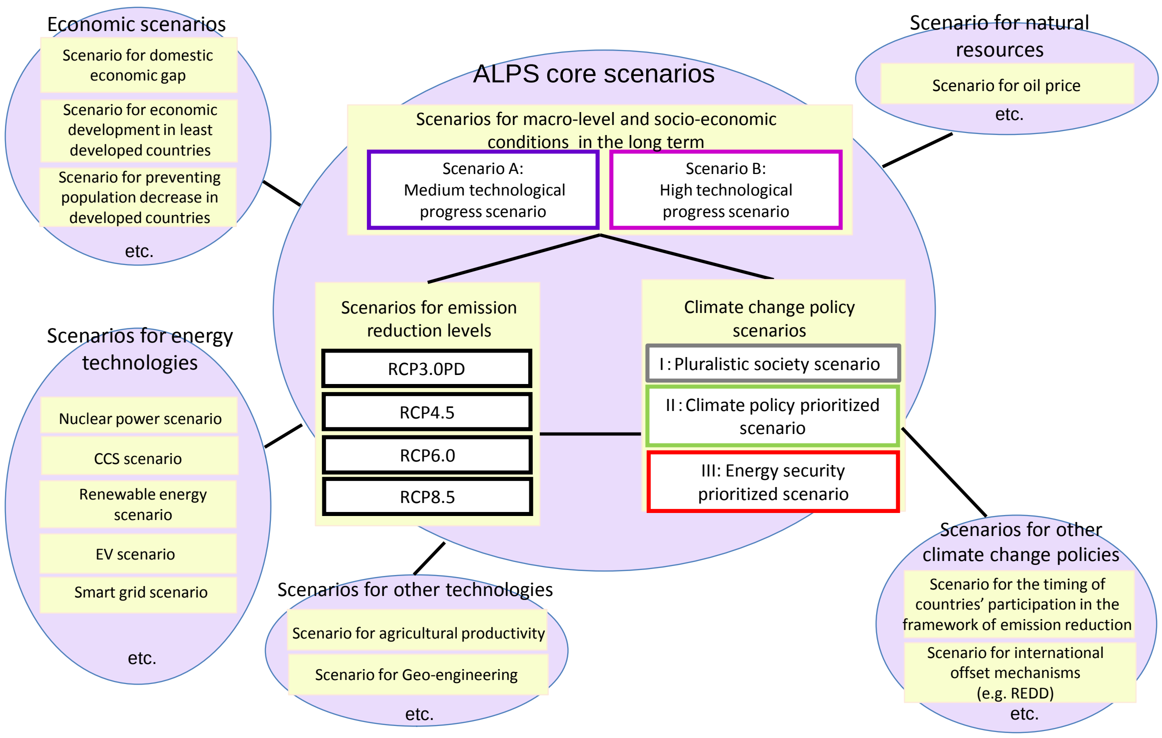

Figure 1: Scenarios to be developed in the ALPS project

■ Model Group

The ALPS project performs comprehensive modeling scenarios supplemented with the existing models developed by RITE. Scenarios associated with climate change need to be developed in the context of sustainable development with a wide-ranging set of models to reflect a multifaceted reality. The DNE21+ Model assesses CO_2 emissions from fuel combustion with great details of national, sectoral and technological descriptions. Along with the food demand-supply model, fresh water model, and land use model, a wide variety of plausible future scenarios and narratives are assessed in an integrated and consistent manner.

The models are chosen appropriately in accordance with time frame and objectives of the assessment. For near and medium term analysis, detailed descriptions of the nation, of sector and of technology are underscored. For longer term analysis, interactions between climate impacts and socio-economic activities are more highlighted.

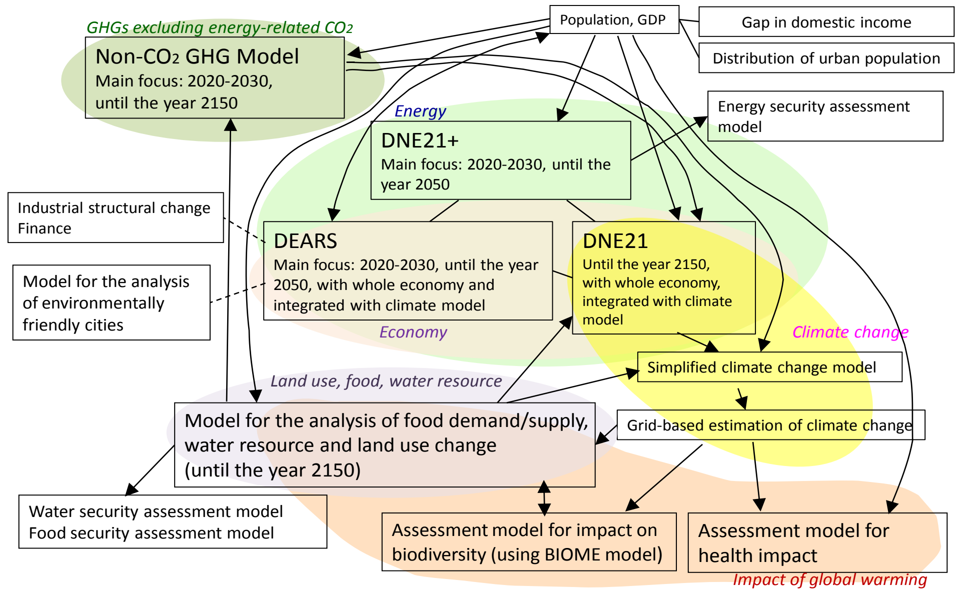

Figure 2: Models for the development of ALPS quantitative scenarios

■ Future perspectives based on quantitative understanding of the world

Adequate understanding of complicated real world situation is necessary to address climate change because challenges of global warming are closely linked to the various global agenda. They may not be captured by a simplified index. In this study, we explore a range of indices from both macro perspective and micro perspective, to understand current situation and to depict future prospects.

- Socio-economic trends and future perspectives

Figure 3 and Figure 4 respectively show global population and global GDP of the socio-economic scenarios, “Scenario A: Medium technological Progress Scenario” and “Scenario B: High Technological Progress Scenario.” For Scenario A, we assume medium population growth, referring to the UN medium population projection of the “2008 Revision of the World Population Prospects” In this scenario global population will get to 9.1 billion by 2050, and expected to grow stably to reach 9.3 billion by 2100. Alternatively Scenario B is characterized by rapid economic growth due to higher technological progress. In this scenario global population moderately increases from 6.1 billion in 2000 to 8.6 billion people by 2050, and then peaks out at 7.4 billion by 2100. The average global GDP growth rate over the period of 2000-2050 is 2.5% per year for Scenario A and 2.8 % year for Scenario B. Over the 21st century GDP increases at a growth rate of 2.0% per year in Scenario A and 2.3% per year in Scenario B.

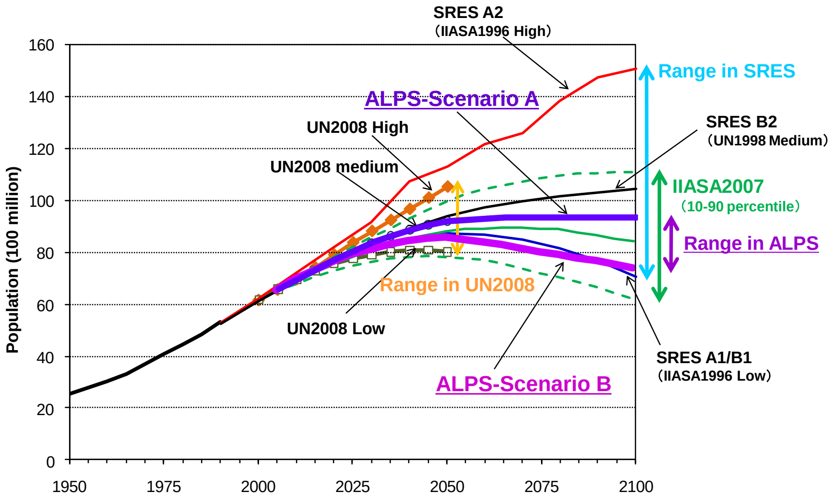

Figure 3 Global Population Scenarios

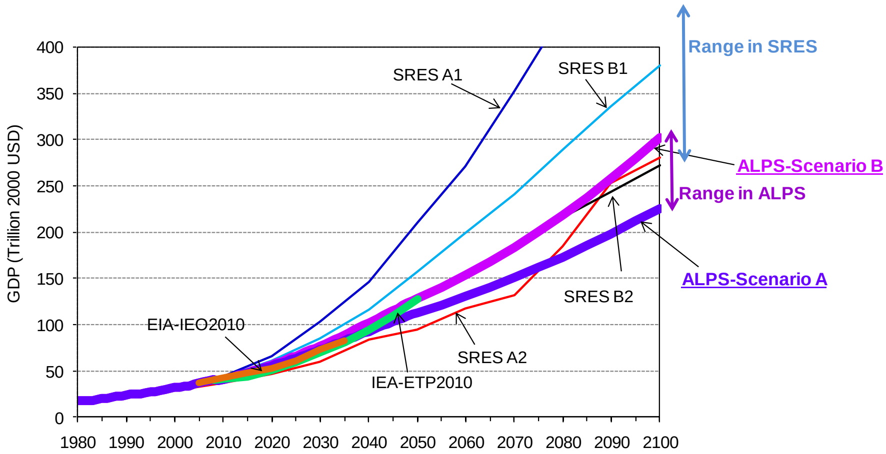

Figure 4 Global GDP Scenarios

Note: Historical data to 2008 and RITE projection after 2009. SRES stands for the "Special Report on Emissions Scenarios", a report prepared by the IPCC. We adjust them at 2000 prices since SRES is based on the 1990 prices. EIA-IEA 2010 data at 2005 prices is also aligned with the base-year. PPP based IEA-ETP 2010 is converted into MER accounts in accordance with the global average ratio of PPP/MER under the ALPS Scenario A's assumptions.

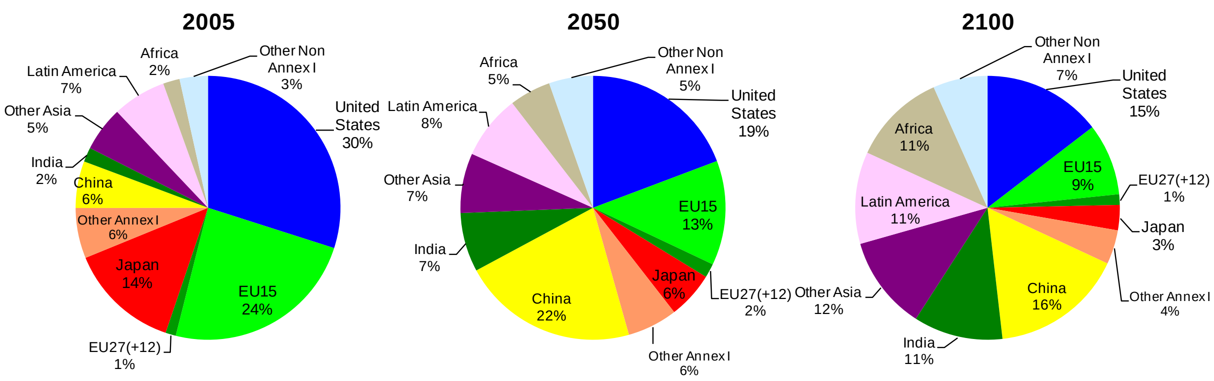

Figure 5 Share of world GDP in Scenario A

- **The current state of energy efficiency**

The widespread deployment of a range of energy efficient technologies can lead to a more secure and sustainable future. Keeping track of details of technology situation at sector and national level, sector wise energy efficiency is estimated on a technology basis. This allows to analyze potential impact of CO_2 emissions reduction through accelerating technology deployment.

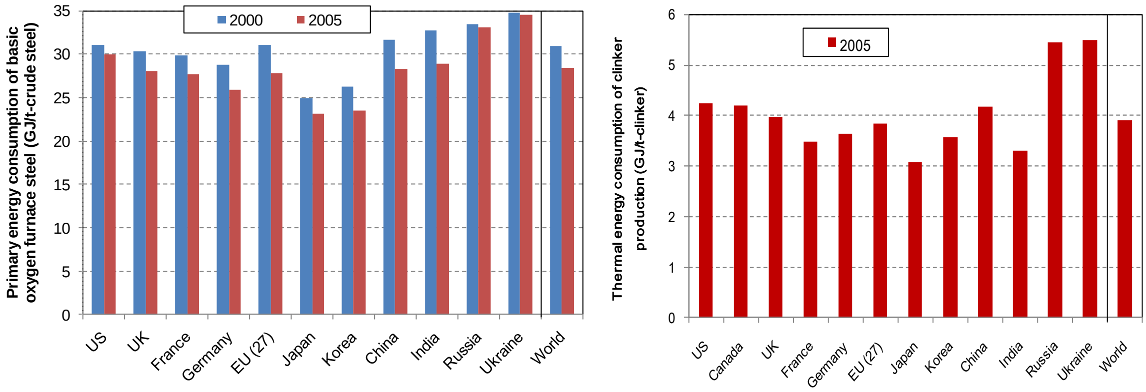

Figure 6 Energy efficiency in steel and cement sector

Note: The analysis above was carried out by RITE through other research project.

- **Power generating costs and their projections**

As for power sector, current and future generation costs and technology perspectives were widely surveyed. Figure 7 shows projections of power generating costs including grid costs. Costs of coal-fired power plants and nuclear power range between 8yen/kWh and 12yen/kWh, of gas-fired power plants between 10yen/kWh and 14yen/kWh, of wind power plants between 16yen/kWh and 18yen/kWh, and of solar PV between 55yen/kWh and 63yen/kWh. Costs of renewable sources themselves are expected to decline as capacities expand, whereas their ancillary costs are expected to grow because locational conditions become less favorable and because additional investments are required for grid stability to secure reliable power supply. While the costs of wind power generation is nearly equivalent to the costs of fossil power plants when its installed capacity is small, wind power is getting lack of competitiveness in the power market as its capacity grows.

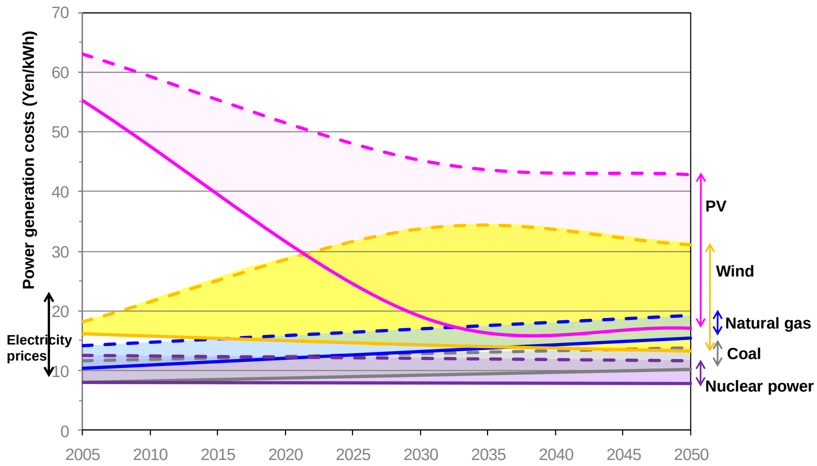

Figure 7 Projections of power generating costs by generation type in Japan

- Future outlook of crude steel production

The Iron and Steel sector is one of the largest energy intensive industries and has a significant impact on global energy consumption and CO_2 emissions. As shown Figure 8 and Figure 9 we extrapolate future crude steel production and scrap availability. Crudes steel production in China has expanded rapidly in the past decade, but their production level will be saturated sooner or later, judging from historical data on apparent steel consumption per capita. Alternatively steel production in India is expected to increase. We estimate global steel production is expected to reach approximately 2.2 billion tons per year by 2050.

There are mainly two types of steel production process, the scrap/EAF route and the BF/BOF route. In terms of energy/carbon-intensity, the scrap/EAF is less intensive because there is no need to reduce iron ore to iron and because it cuts out the need for the ore preparation and coke-making steps. In that sense it is crucial to estimate scrap availability and potential of EAF in projecting global CO_2 emissions from iron and steel sector. One of the biggest challenges in the estimation is to know the volume of social stock of steel scrap and their availability. With limited information and data, we explore two approaches to assess future scrap availability in the world, referring to previous studies. Global availability of process scrap and obsolete scrap increases ranging from 0.8 to 1.0 billion tones per year in 2050. The volume of home scrap is estimated to reach 0.15 million tones and the sum of the total scrap availability, including home scrap, process scrap and obsolete scrap, is expected to range from 0.95 billion tones to 1.15 billion tones whereas IEA(2009) estimates around 1.25 billion tones scrap availability in 2050. This suggests the fact that IEA overestimates scrap availability by about from 0.1 billion tones to 0.3 billion tones.

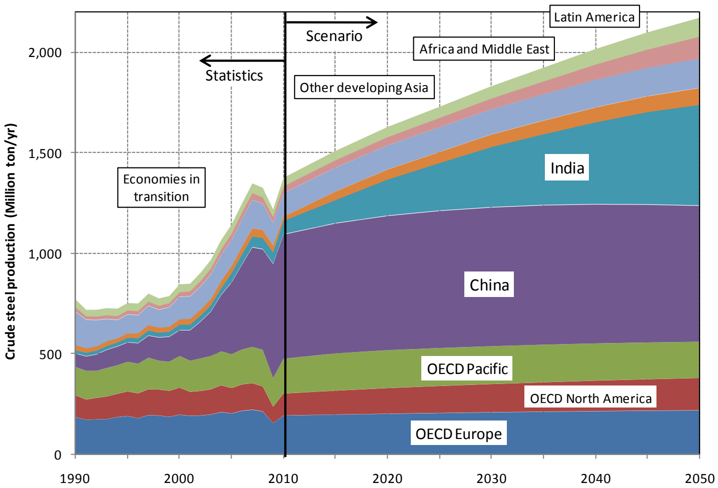

Figure 8 Historical crude steel production and its projection by region

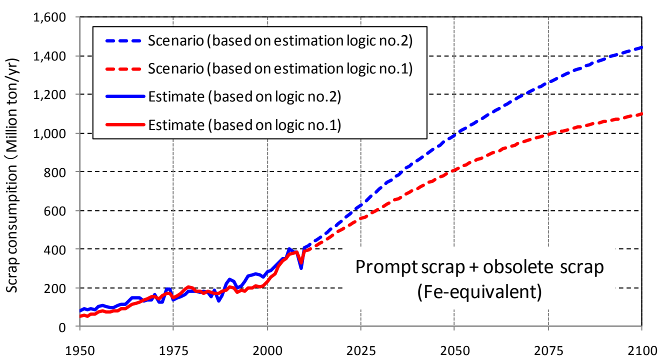

Figure 9 Global historical scrap (prompt scrap and obsolete scrap) consumption and projection of future scrap availability

■ GHGs emissions and their emissions reduction projections

Global GHGs emissions were 32 Gt CO_2 equivalent (CO_2-eq) in 1990 and 39 Gt CO_2-eq. Without climate policy, they are estimated to reach 55 Gt CO_2-eq in 2020 and around 79 Gt CO_2-eq in 2050, which is more than twice the current emissions level. Particularly emissions from developing countries are expected to grow faster as their economy expands.

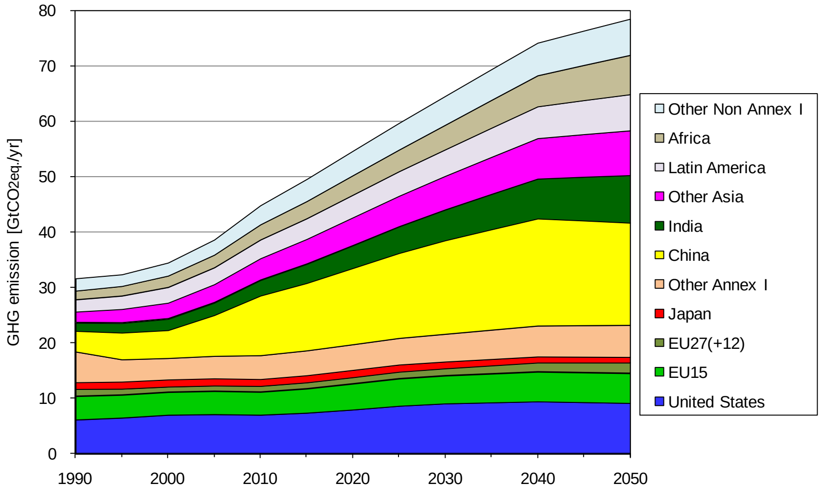

Figure 10 Global GHG emission outlook

Note: Historical data to 2008 and RITE projection after 2009 based on the "Scenario A: Medium technological Progress Scenario" in combination with "Scenario I: Pluralistic society scenario", which is approximate to the real-world social behavior. GHGs cover the Kyoto's six gases. Emissions from LULUCF, international aviation and maritime transport are excluded.

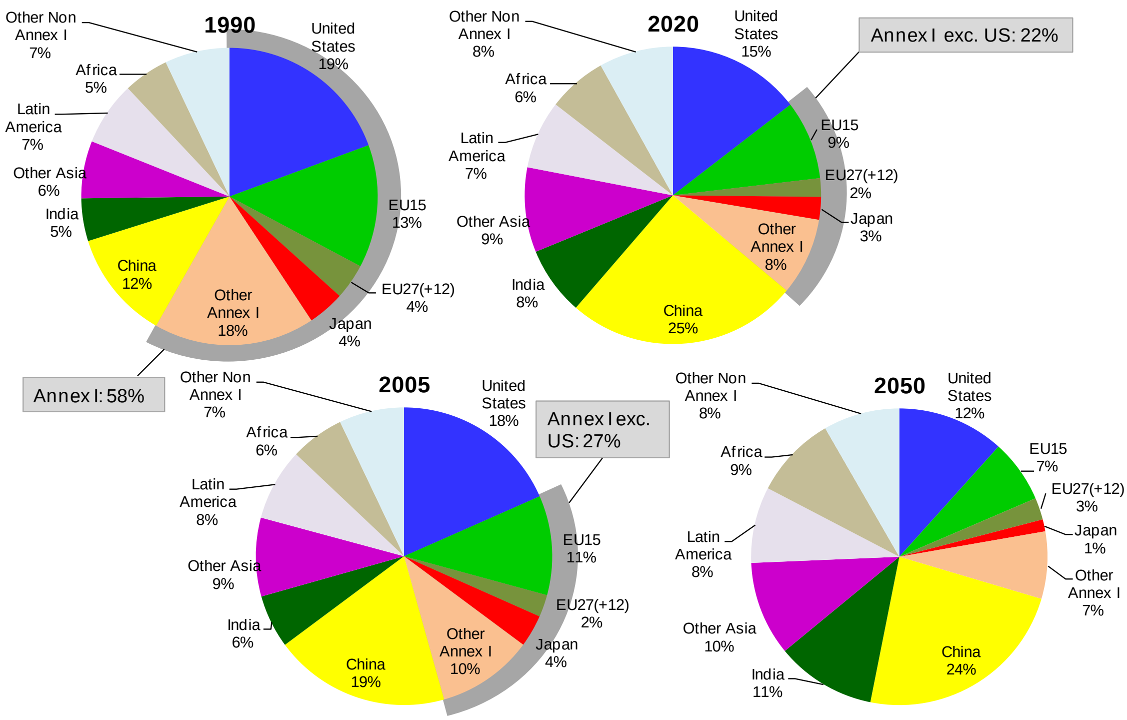

Figure 11 GHG emissions by region

Figure 12 and Figure 13 illustrate regional and technological contribution to cut global emissions in half by 2050 respectively. They imply significant contribution by energy efficiency to CO_2 reduction. From longer perspective, nuclear power generation, renewable energy and Carbon capture and storage (CCS) will play an important role in 2050. From regional perspective, developing countries have larger potential to reduce emissions, which suggests that global actions are necessary to meet the target.

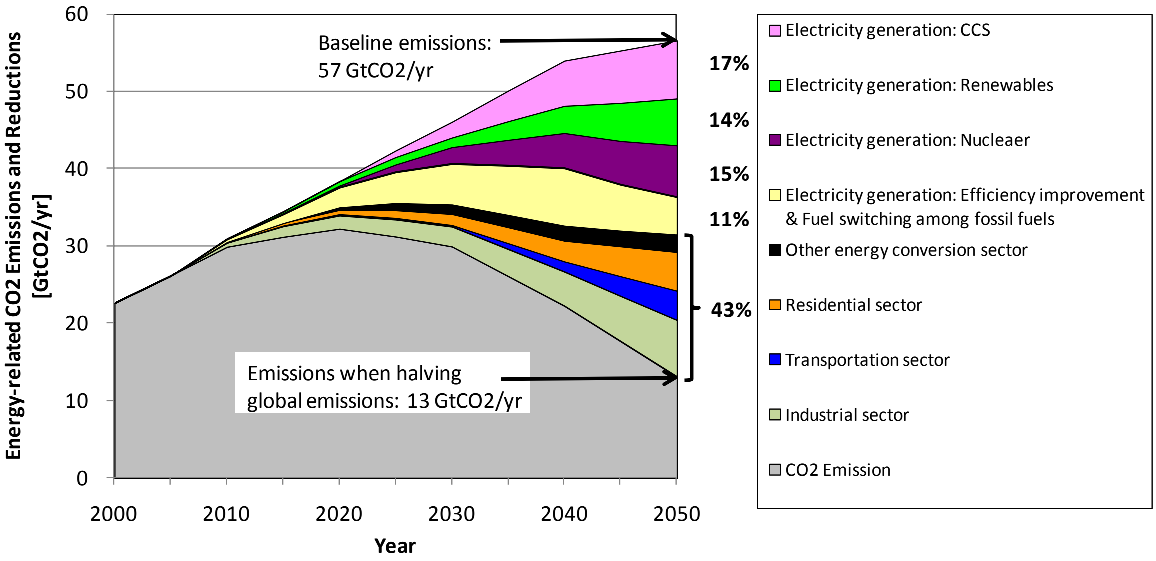

Figure 12 Reduction contribution by technology for halving global emissions by 2050 (Scenario A-I)

Note: Estimated by RITE DNE21+. CO_2 from fuel combustion only. Emissions from international aviation and maritime transport are excluded.

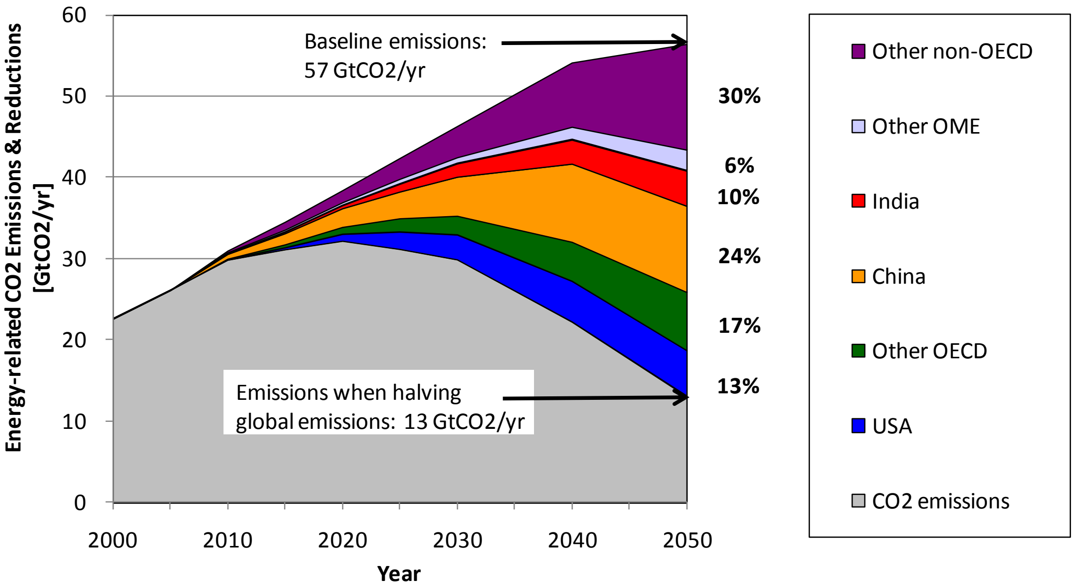

Figure 13 Reduction contribution by region for halving global emissions by 2050 (Scenario A-I)

■ Scenarios on the climate change priority in the broader global agenda

The differences among three scenarios (I, II and III) toward 2050 is analyzed by DNE21+ model with socio-economic assumptions of Scenario A. In our real world, energy efficient appliances and technologies are not necessarily chosen by consumer due to the existence of the efficiency gap. We assume relatively shorter payback period (or higher implicit discount rate) as observed in the real world situation for Scenario I, "Pluralistic society scenario", while Scenario II, namely "Climate policy prioritized scenario", is characterized by the longer payback period. Figure 14 provides an idea of difference in technology choice between Scenario I and Scenario II. Scenarios III "Energy security prioritized scenario" is differentiated in higher tariff barriers for oil and gas export.

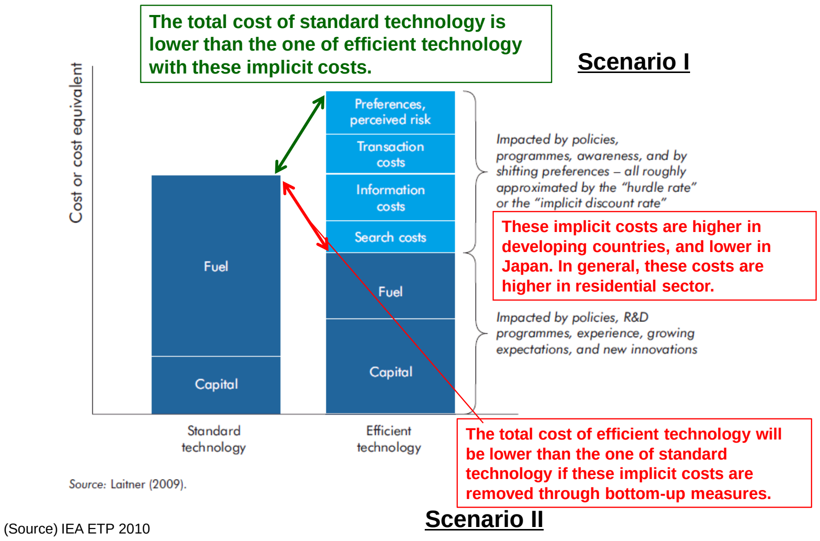

Figure 14 Image of technology choice

Figure 15 and Figure 16 identify differences in total primary energy supply and power generation mix respectively for the baseline case among Scenario I, II, and III. The share of nuclear power generation is higher in Scenario III than in Scenario I. Power generation mix of Scenario II is characterized by higher share of nuclear power generation and of highly efficient fossil fuel power plants regardless of their expensive initial costs.

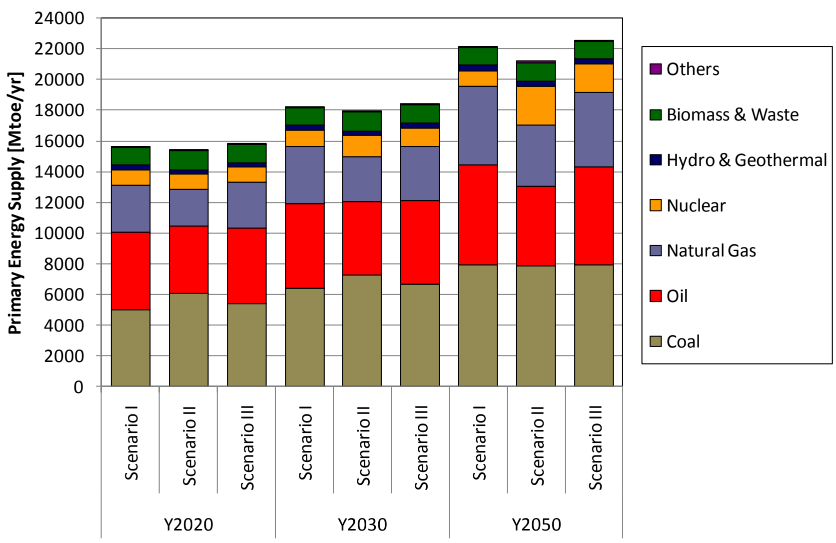

Figure 15 Baseline of total primary energy supply (Scenario I, II and III)

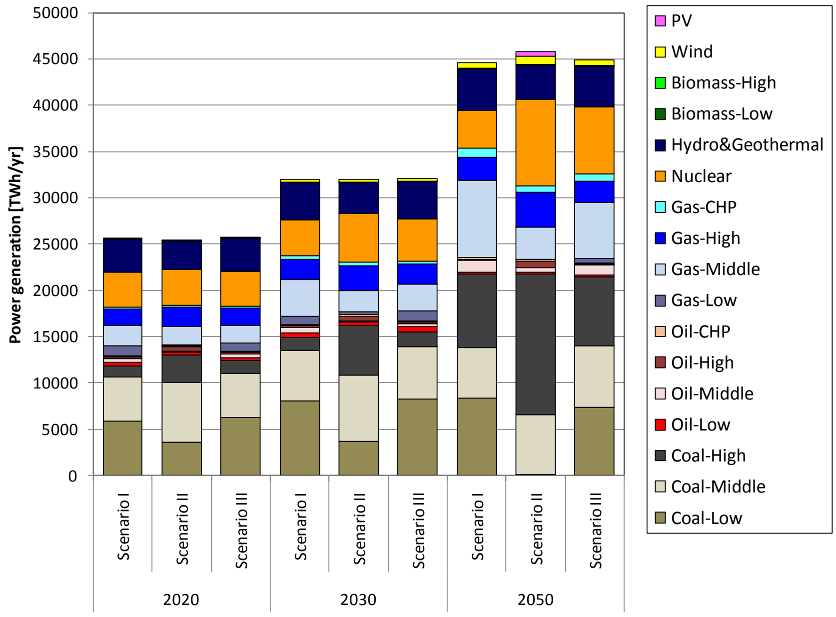

Figure 16 Baseline global power generation (Scenario I, II and III)

Figure 17 compares marginal abatement costs to reduce global emissions in half among Scenario I, III, and II. Scenario I and III imply higher carbon prices due to longer payback period in accordance with the real world situation, while Scenario II leads to lower marginal abatement costs. This result suggests that explicit carbon prices can be very high to meet the targets, which causes great difficulty in implementation, and that detailed measures to remove market barriers to energy efficiency can lower mitigation costs as described in Scenario II.

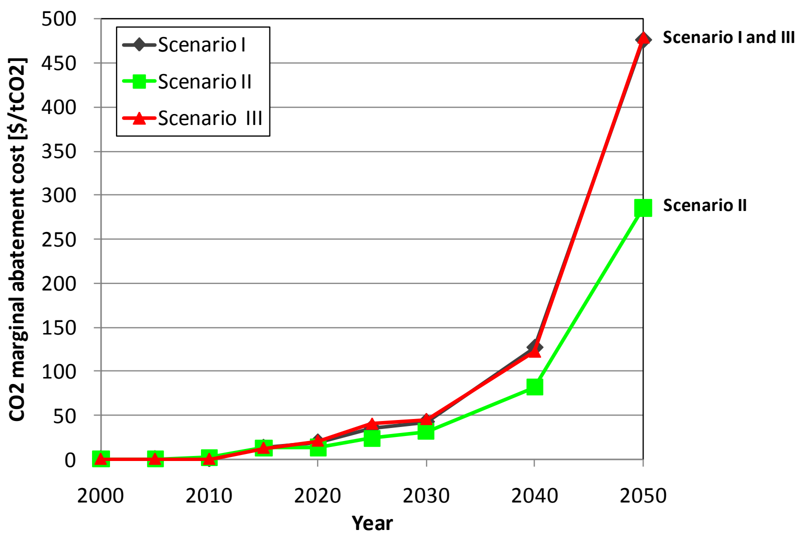

Figure 17 CO_2 marginal abatement cost in Scenario I, II and III

■ Socio-economic scenarios and emissions pathways

The divergence between Scenario A and Scenario B and among the RCP scenarios are analyzed with the underlying assumptions of Scenario I, using DNE21 model, which has a simpler structure but longer timeframe than DNE21+ has. Figure 18 shows global CO_2 emissions from fuel combustion for the baseline cases of Scenario A (Medium Technology Progress) and Scenario B (High Technology Progress), and emission pathways of each RCP category. Given the uncertainty of economic growth and technological change, it is assumed that the baselines for global CO_2 emissions make little difference between Scenario A and Scenario B. Their global CO_2 emissions are expected to double by 2050 and triple by 2100. The atmospheric CO_2 concentration in 2100 will range approximately from 700 to 770 ppm-CO_2.

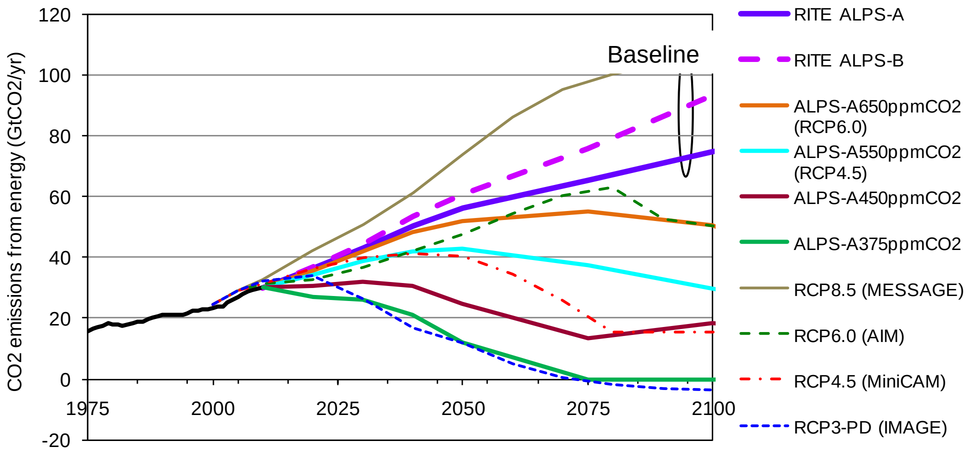

Figure 18 Baseline scenario for global CO_2 emissions from energy

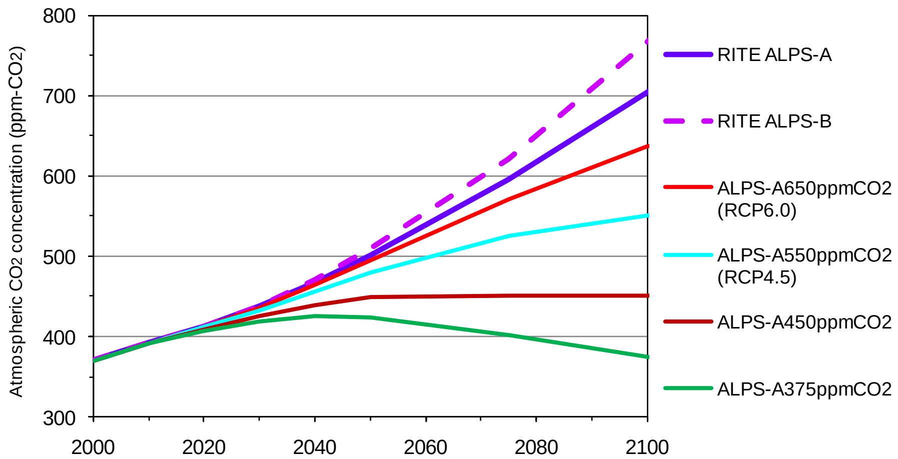

Figure 19 Trajectories of atmospheric CO_2 concentration

Figure 20 provides an insight into a loss of per cent GDP to meet the required mitigation target for a given RCP scenario. There are little differences in GDP loss between 2050 and 2100. The 375 ppm-CO_2 (corresponding to 350 ppm-CO_2 eq) scenario gives approximately 4% GDP loss and the 450 ppm-CO_2 (corresponding to 550 ppm-CO_2 eq) scenario is about 3%. The gap between Scenario A and Scenario B is also small.

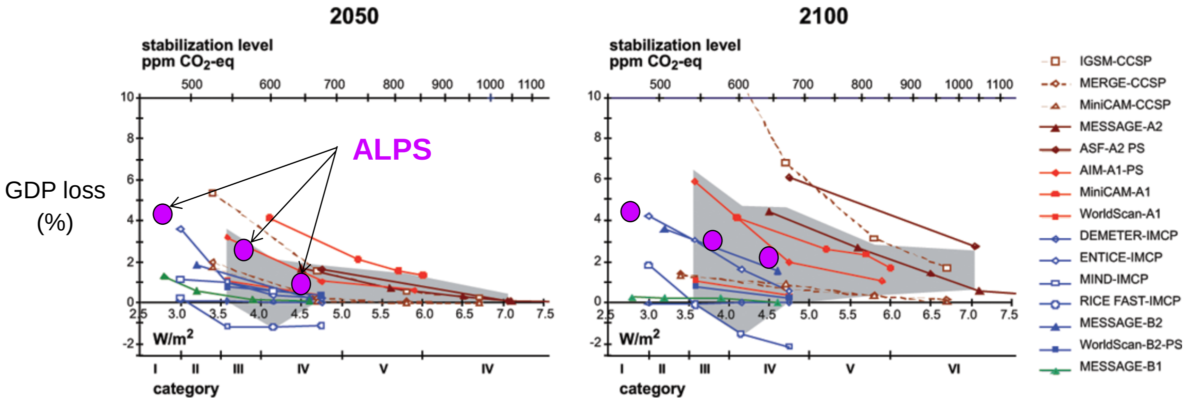

Figure 20 Global GDP loss for each stabilization level (Compared with IPCC AR4)

■ Analysis of indicators on sustainable development

Maintaining a subtle balance between mitigation efforts and other global challenges enhances social welfare and ensures sustainability of mitigation actions because a particular set of values and norms constitute our real world collectively. We therefore assess our scenarios from a broad set of aspects to understand climate change mitigation measures in the wider context of sustainable development.

Figure 21 and Figure 22 illustrate examples of energy security evaluation according to the IEA's index. The baseline scenario indicates that vulnerability to energy security risks is expected to increase toward 2050. It is noteworthy that energy system can be more vulnerable than the baseline in the scenario cutting global CO_2 emissions in half by 2050. Energy security will be enhanced in the "Energy Security Scenario" of our scenario III based on our assessment. Figure 23 shows water-stressed population. Scenarios are also examined by other indexes with multiple criteria.

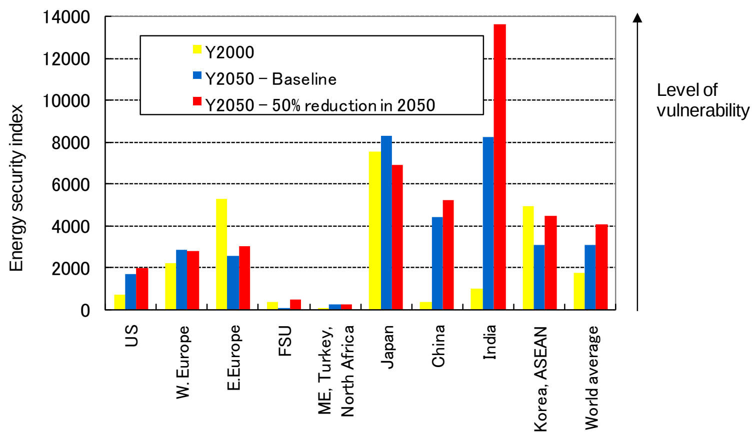

Figure 21 Energy security index by region (Scenario A-I)

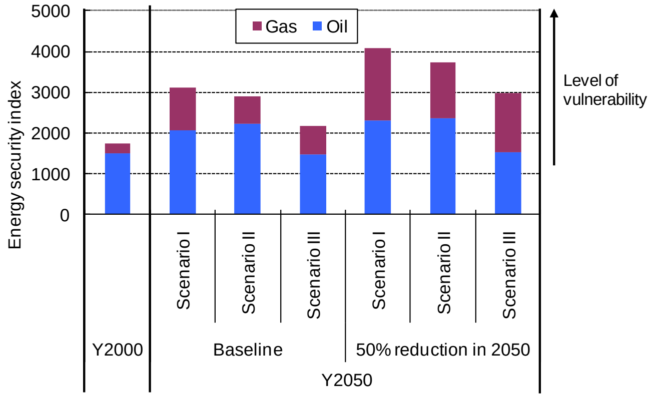

Figure 22 Global weighted average of energy security index for each scenario

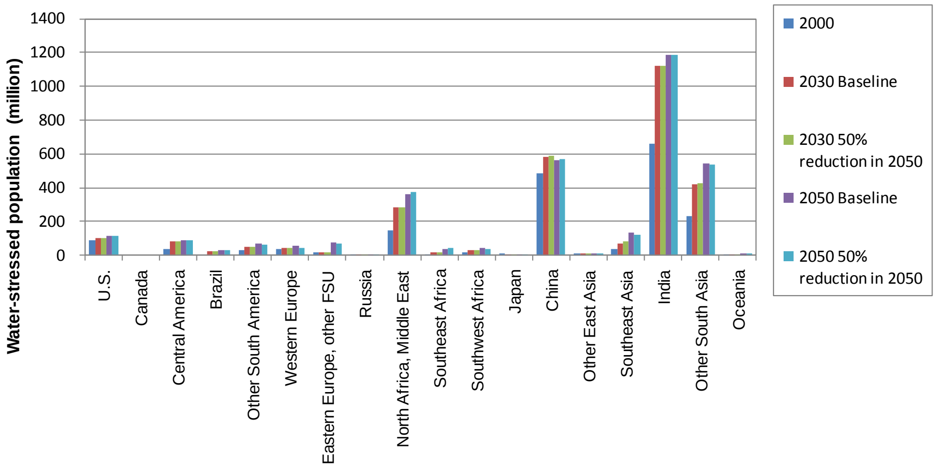

Figure 23 Water-stressed population by scenario, period and region

■ Expected Outcome

Synthetic scenarios toward sustainable development and climate stabilization are expected to be generated in a consistent and quantitative manner by the end of project period, March 2012. This study will provide substantial insight into alternative pathways and catches the implied meaning from the quantitative assessment in order to guide our future actions.

Findings and lessons learned from this research project, including scenario analysis, are returned to society. The results of this study are expected to not only make scientific contribution to the IPCC but also to serve as fundamental information for decision making on global and domestic climate change policy.

■ Project Period

From April 2007to March 2012

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