Scenario analysis of halving global CO_2 emissions by 2050

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1. Introduction

RITE has been developing comprehensive scenarios toward sustainable development and climate stabilization since FY2007 as a part of the "International Research Promotion Program for Global Environment", which is supported by the Japanese government (The ALPS project, ALternative Pathways toward Sustainable development and climate stabilization)[1)-4)]. In this paper, the scenario analysis of halving global CO_2 emissions by 2050 by using the DNE21+ model which is a world energy systems model[6)7)] is outlined. This scenario was developed based on the medium growth socioeconomic scenario (Scenario A)[5)] of the ALPS project where the latest world economic conditions are taken into account.

2. Scenario Analysis of halving global CO_2 emissions by 2050

The scenario of halving global CO_2 emissions by 2050 relative to 2005 (the halving global CO_2 emission scenario) was analyzed by using the DNE21+ model. The evaluated greenhouse gas is limited to energy-related CO_2 only. Uniform CO_2 marginal abatement cost over all the regions is adopted in this analysis, as the criterion for the minimization of the total world cost.

Scenarios of halving global energy-related CO_2 emissions by 2050 relative to 2005 were also analyzed in IEA ETP2010[8)] (BLUE Map scenario). In this paper, the analysis in the ALPS is summarized with the comparison between the ALPS and the IEA ETP2010.

2.1 CO_2 emissions and reductions

Figure 1 shows energy-related CO_2 emission reductions relative to the Baseline scenario (scenario without GHG mitigation policy) by technology and sector for the halving global CO_2 emission scenario. Figure 2 shows energy-related CO_2 emission reductions relative to the Baseline scenario by technology for the BLUE Map scenario in IEA ETP2010. The global CO_2 emissions in 2050 for the halving global CO_2 emission scenario of the ALPS are a little smaller than those of the BLUE Map scenario, because CO_2 emissions from international aviation/marine bunkers are treated exogenously in the DNE21+ model.

The baseline global CO_2 emissions in 2050 are $57GtCO_2$/yr and are almost double of the current emissions. Therefore, three quarters of the baseline global CO_2 emissions have to be reduced, meaning that the global CO_2 emissions have to be one quarter of the baseline emissions for halving the global CO_2 emissions by 2050.

The emission reductions are required for various sectors and technologies in order to halve the global CO_2 emissions. In figure 1, the total emission reductions relative to the Baseline scenario in 2050 are $44GtCO_2$/yr, and the shares of emission reductions of electricity generation technologies are 17% by carbon capture & storage (CCS), 14% by renewables, 15% by nuclear and 11% by improvements in efficiency and fuel switching among fossil fuels, respectively. Large emission reductions in energy end-use sectors (industrial sector, transportation sector and residential & commercial sector) are also required, and the share of these sectors is almost 40% of total emission reductions. The emission reduction share of energy end-use sector is almost 50% in the ETP2010. Although the contribution of energy end-use sectors to emission reductions in the ETP2010 is slightly larger than that in the ALPS, the emission reduction share by sector and technology in the ETP2010 is quite similar to the ALPS scenario.

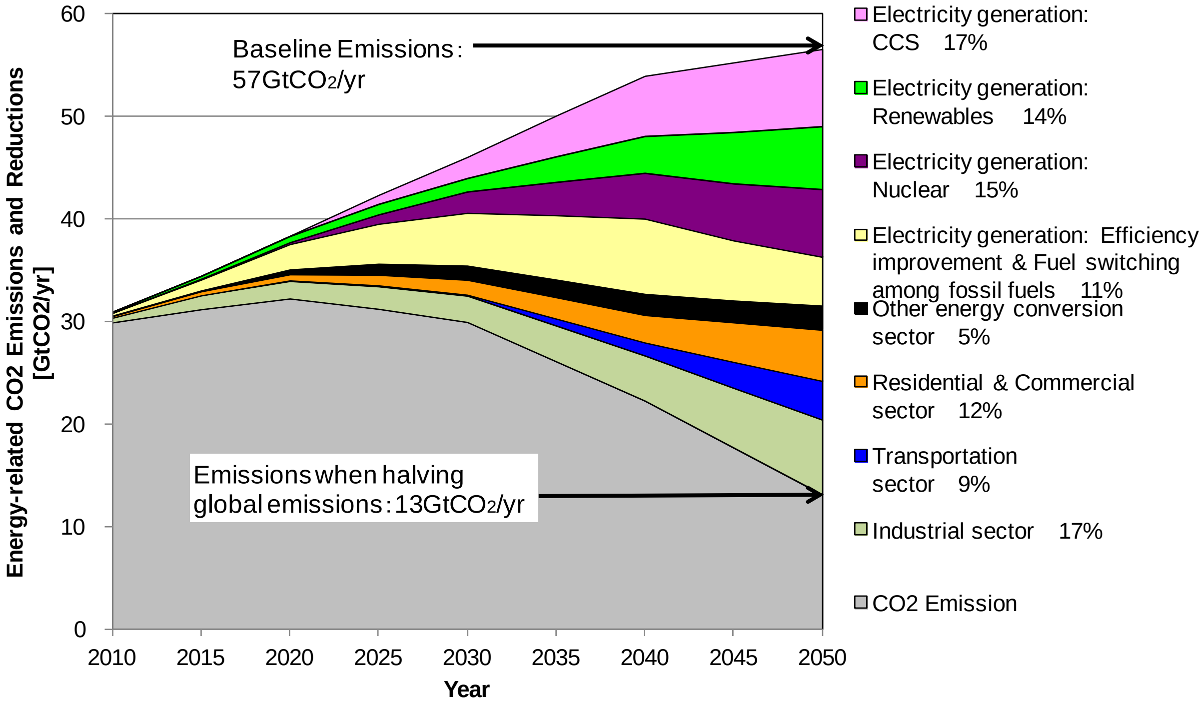


Figure 1 Halving global CO_2 emission scenario by sector and technology

Note) CO_2 emissions from international aviation/marine bunkers and land use, land use change, and forestry (LULUCF) are not included.

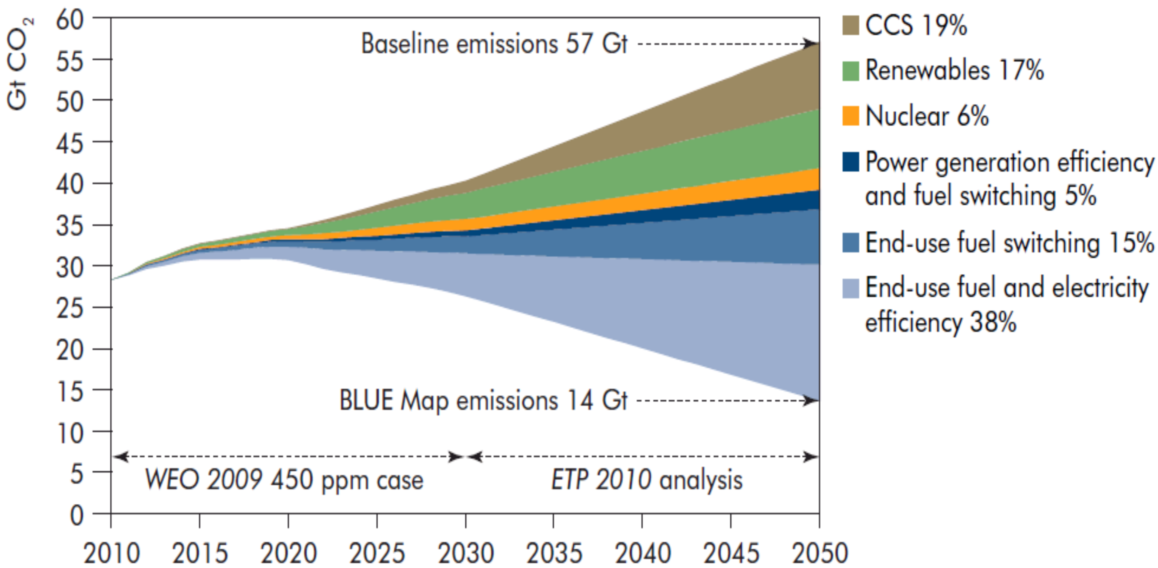


Figure 2 CO_2 emission reductions by technology for the BLUE Map scenario (halving global CO_2 emissions) in the IEA ETP2010[8)]

Figures 3 and 4 show energy-related CO_2 emission reductions by region in the ALPS and the IEA ETP2010, respectively. The share of emission reductions of developed countries in global emission reductions in 2050 is almost 30% in both the scenarios (USA: 13 % and Other OECD: 17% in ALPS, USA: 11% and Other OECD: 17% in ETP2010). For developing countries, the emission reductions in China are large and that share in global emission reductions is 24% and 27% in the ALPS and the ETP2010, respectively. For India, that share is 10% in the ALPS and 12% in the ETP2010. It is almost impossible to achieve deep global emission reductions such as halving global CO_2 emissions only by developed countries. Emission reductions would require the effective participations of all major emitters.

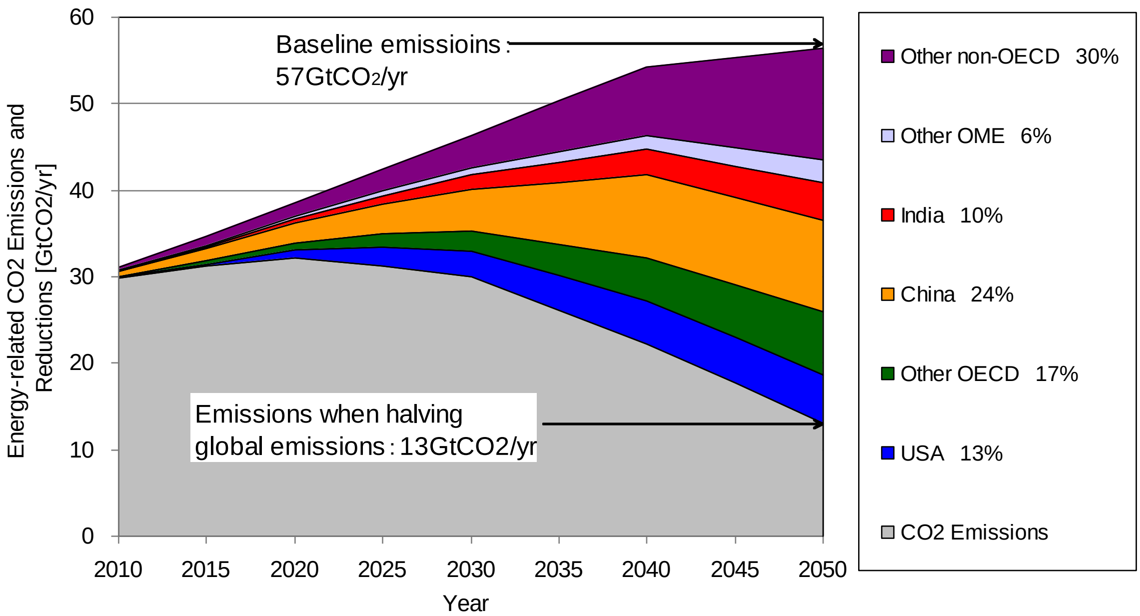


Figure 3 Halving global CO_2 emission scenario by region

Note 1) CO_2 emissions from international aviation/marine bunkers and land use, land use change, and forestry (LULUCF) are not included.
Note 2) Other OME (Other Major Economies) : Brazil, Russia and South Africa

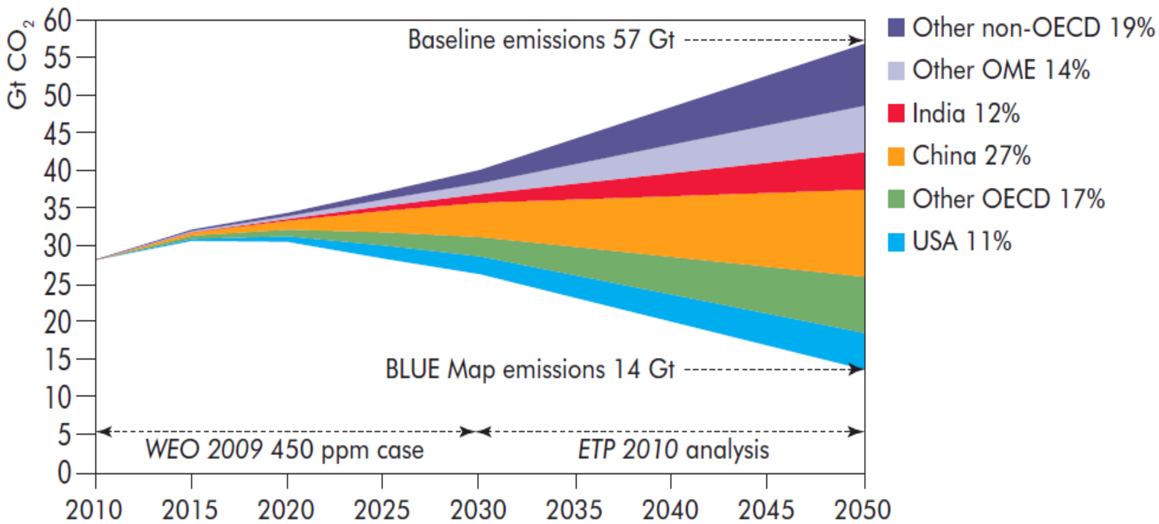


Figure 4 CO_2 emission reductions by region for the BLUE Map scenario (Halving global CO_2 emissions) in the IEA ETP2010[8)]

2.2 Primary energy supply

Figure 5 shows global primary energy supply in the Baseline scenario and the halving global CO_2 emission scenario in 2030 and 2050. In the Baseline scenario, fossil fuels, especially coal, are main energy source as in the current situation. Costs of wind power and PV which are categorized in “Others” are higher than other energy sources and their supplies are small in 2050, even though their future cost reductions are assumed.

In the halving global CO_2 emission scenario, coal and oil supply is substantially reduced relative to the Baseline scenario. On the other hand, nuclear and renewables such as biomass, wind power and PV are induced. Compared with the IEA ETP2010 analysis as shown in Figure 6, there are no large differences between the ALPS and the ETP2010. However, "Others" in the BLUE Map scenario is slightly larger than that in the halving global CO_2 emission scenario (The difference is mainly caused by the difference in wind power. See the next section.).

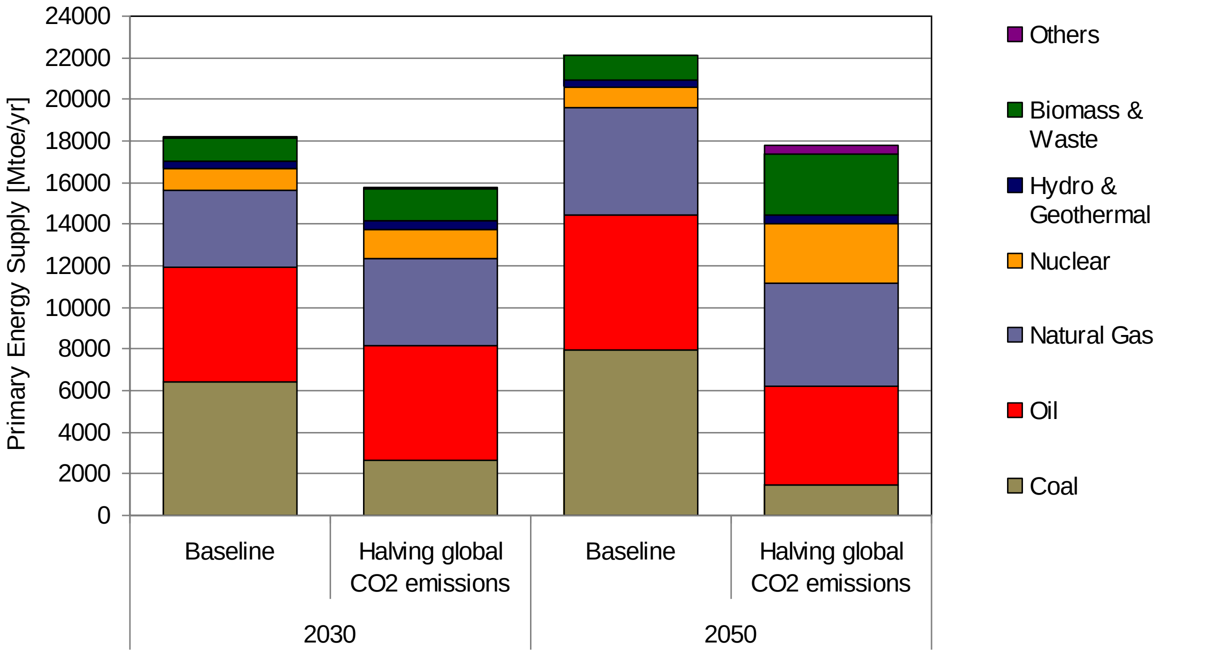


Figure 5 Global primary energy supply in the Baseline scenario and the halving global CO_2 emission scenario

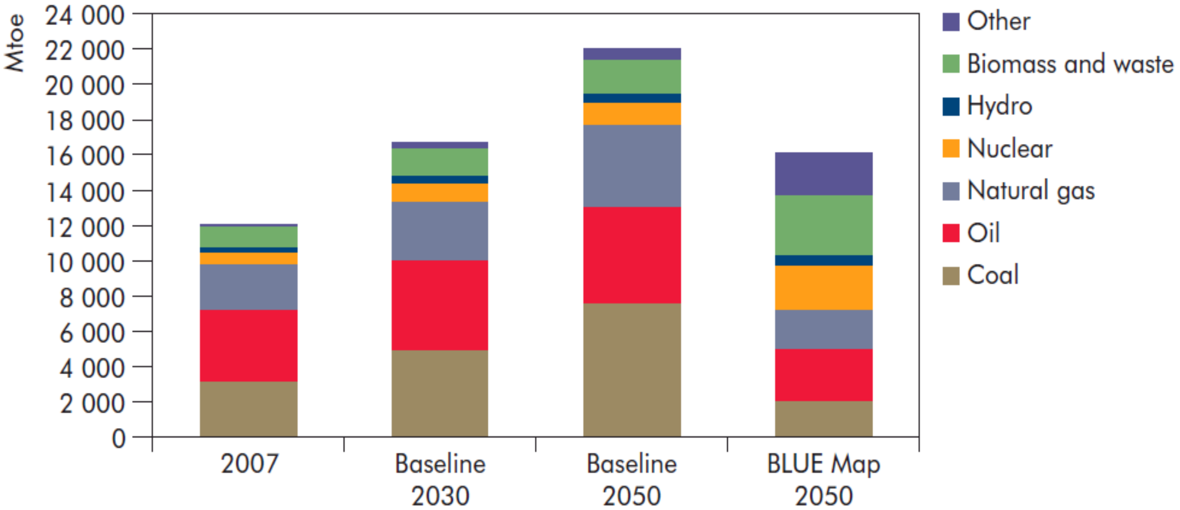


Figure 6 Global primary energy supply in the Baseline and the BLUE Map scenario in the IEA ETP2010[8)]

2.3 Electricity generation

Figure 7 shows global electricity generation in the Baseline scenario and the halving global CO_2 emission scenario with IEA ETP2010 analysis. In the Baseline scenario, coal power generation is widely used as a cost efficient technology until 2050. Nuclear power generation is used at almost the same level as the current usage. Wind power generation is not so large, but steadily grows in future.

In the halving global CO_2 emission scenario, large diffusion of CCS and substantial expansion of nuclear and renewables (biomass, wind power, PV, etc.) are cost efficient measures for reducing CO_2 emissions in 2050. Wind power generation in the halving global CO_2 emission scenario of the ALPS is smaller than that in the BLUE Map scenario of the ETP2010 as mentioned in the previous section. There is no much difference in PV between the two scenarios. Biomass power generation in the halving global CO_2 emission scenario of the ALPS is larger than that in the BLUE Map scenario of the ETP2010. In addition, CCS is introduced to almost all biomass power generation in the halving global CO_2 emission scenario of the ALPS in 2050. In the halving global CO_2 emission scenario of the ALPS, energy efficiency improvement in energy end-use sector is smaller than that in the BLUE Map scenario of the ETP2010. Therefore, larger improvements of CO_2 intensity in energy supply sectors are required compared to the ETP2010. For example, greater biomass power generation with CCS which enables net negative CO_2 emissions is required in the ALPS. However, the primary supply of biomass is almost the same in both the ALPS and the ETP2010 as shown in Figure 5 and Figure 6 because the greater use of biomass in the transportation sector, etc. is estimated in the ETP2010.

Figures 8 and 9 show, respectively, renewable electricity generation in 2050 by region for the halving global CO_2 emission scenario of the ALPS and the BLUE Map scenario of the ETP2010. The above mentioned difference in biomass power generation is observed in Africa and Latin America. For China, PV in the ALPS is larger than that in the ETP2010, but wind power in the ALPS is smaller than that in the ETP2010.

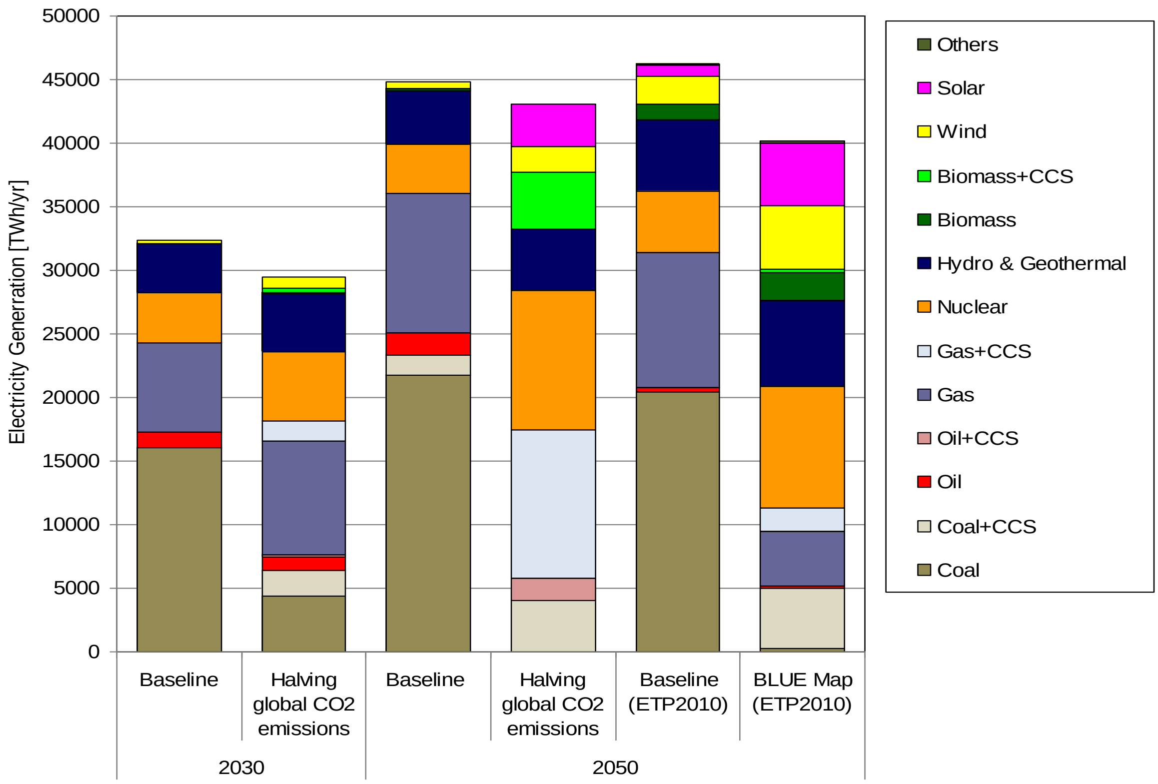


Figure 7 Global electricity generation in the Baseline scenario, the halving global CO_2 emission scenario and the BLUE Map scenario

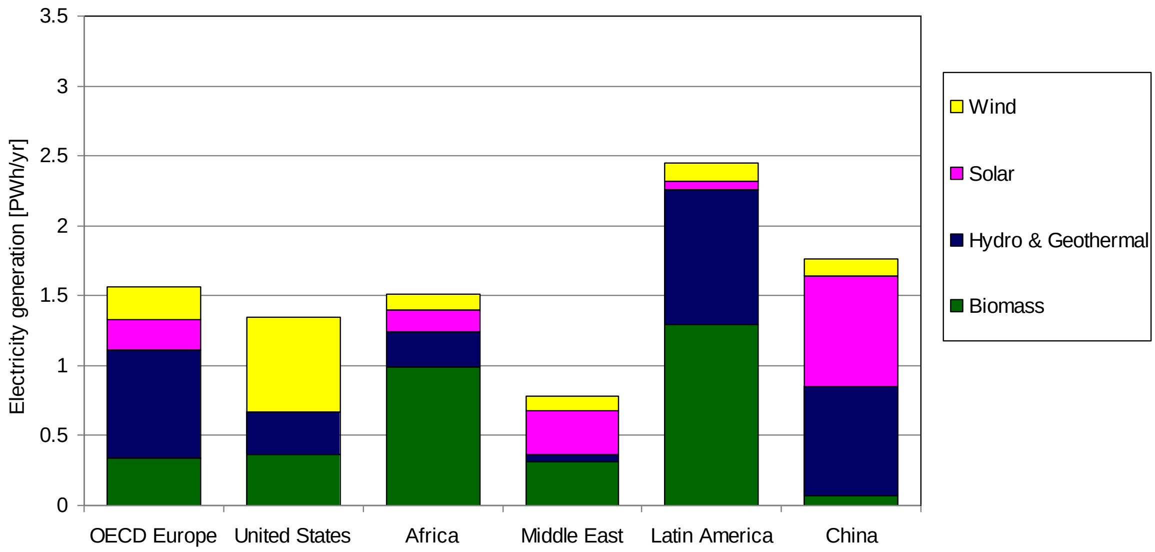
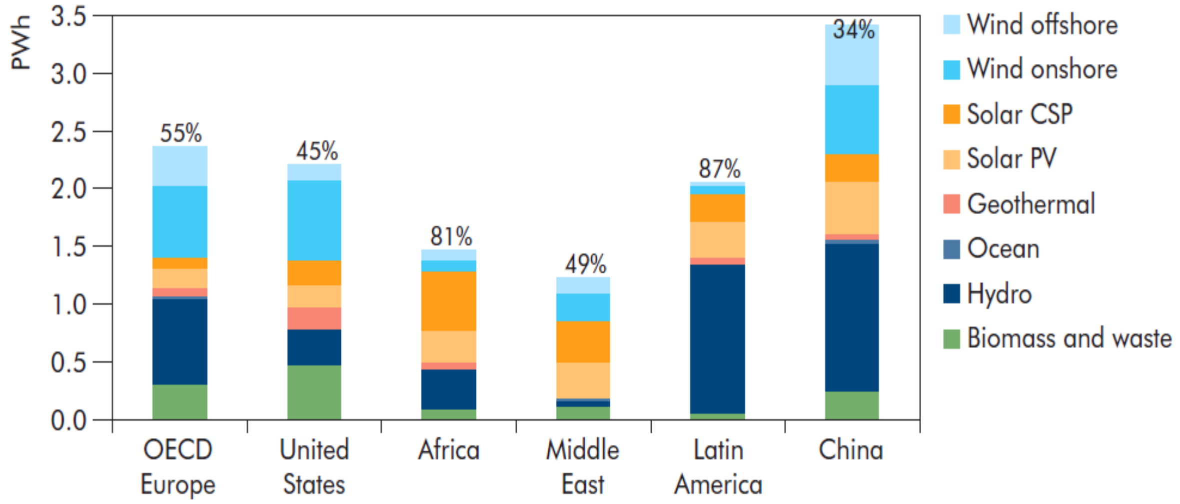


Figure 8 Renewable electricity generation by region in 2050 for the halving global CO_2 emissions



Note: Percentages above columns show the share of renewables in total electricity generation.

Figure 9 Renewable electricity generation by region in 2050 in the BLUE Map scenario of the IEA ETP2010 [8)]

2.4 Carbon capture & storage (CCS)

Figures 10 and 11 show captured CO_2 by region in the ALPS and the BLUE Map scenario of the IEA ETP2010, respectively. CCS diffusion in early stage will be affected by not only costs but also other uncertain factors. Therefore, CCS introduction until 2020 is not considered in the model analysis of the ALPS.

If the amount of CO2 storage per site is assumed to be 3MtCO_2/yr, the storage sites of 850 are needed in the world in 2030 in both the scenarios, and those of 3,400 and 4,500 are needed in 2050 in the ETP2010 and the ALPS, respectively. Large scale diffusion of CCS will be required for achieving the emission target.

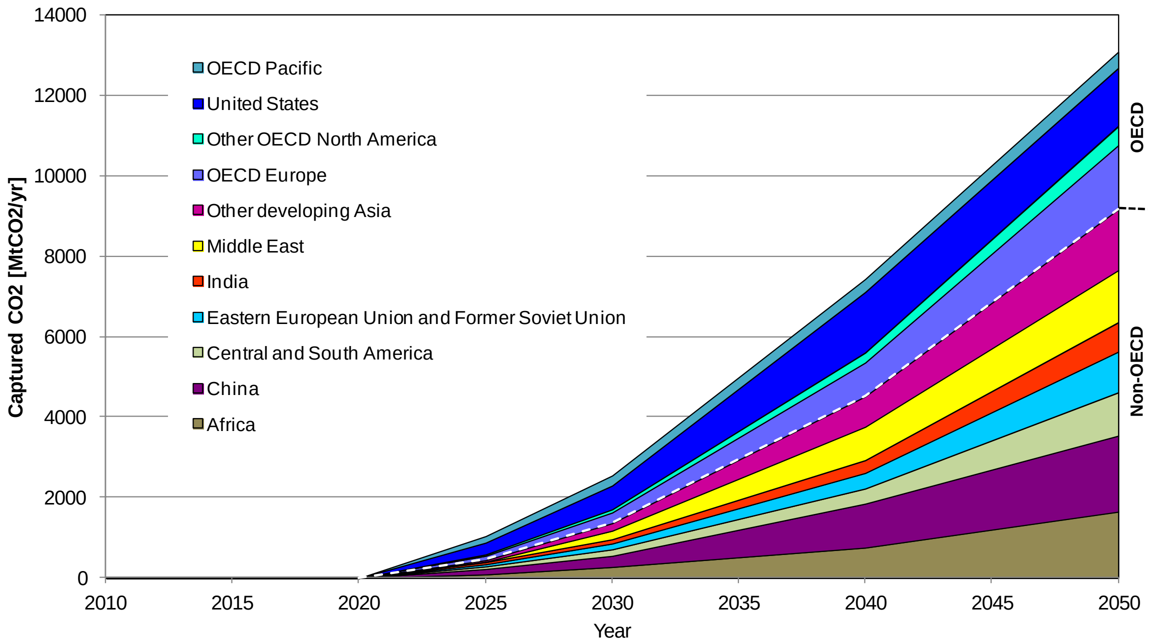


Figure 10 Captured CO_2 by region for the halving global CO_2 emission scenario

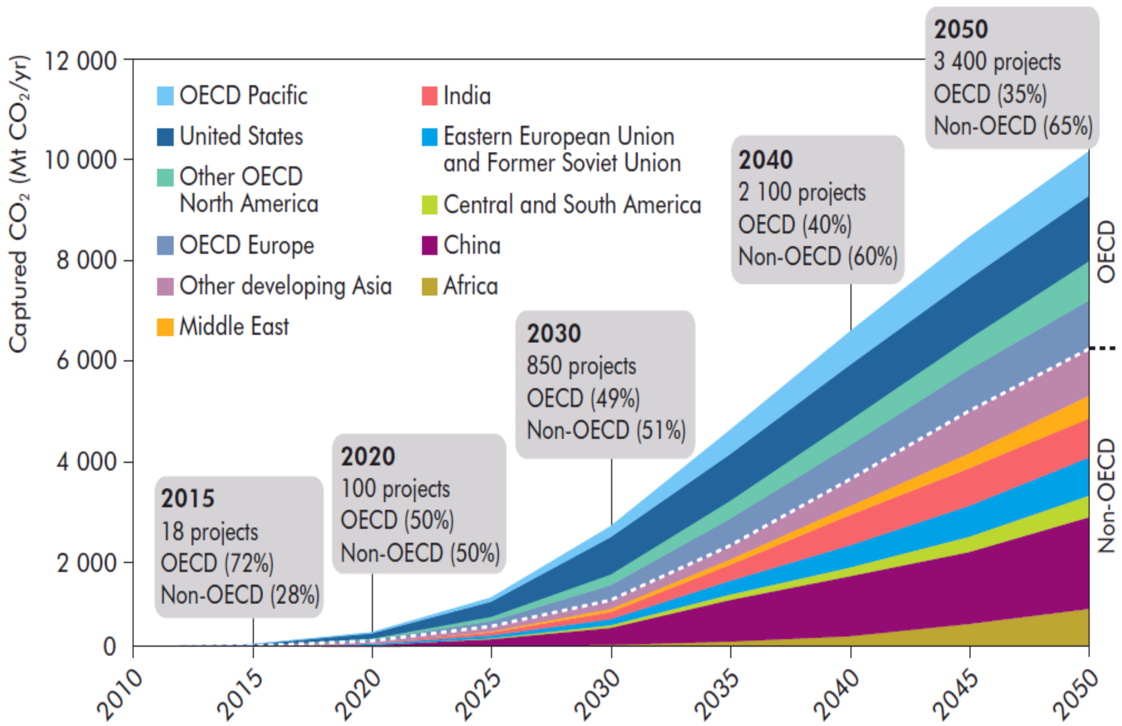


Figure 11 Captured CO_2 by region in the BLUE Map scenario of the IEA ETP2010[8)]

2.5 Emission reduction costs

Figures 12 and 13 show, respectively, the CO_2 marginal abatement costs and emission reduction costs per GDP (The emission reduction cost is defined as increase in the global energy systems cost relative to the Baseline scenario.) for the halving global CO_2 emission scenario.

The CO_2 marginal abatement cost steadily increases and reaches \$476/tCO_2 in 2050. The CO_2 marginal abatement cost in the BLUE Map of the IEA ETP2010 is \$175/tCO_2 in 2050 (technology optimism: \$200/tCO_2 – technology pessimism: \$500/tCO_2 in the ETP2008[9)]) and the CO_2 marginal abatement cost in the ALPS is higher than that in the ETP2010. This difference is considered to be caused by technology development perspective, regional resolution (the DNE21+ model: 54 regions, the ETP model: 17 regions), and etc. The emission reduction cost per GDP also increases and reaches 3% in 2050.

The scenarios with such a high CO_2 marginal abatement cost will be very unlikely to be realized in the real world even in 2050. It seems really difficult to achieve halving global CO_2 emissions without almost inconceivable technology revolution which is not naturally taken into account in the assessment model. It is important to plan flexible strategy for climate change with considering more moderate emission reduction targets, adaptation to climate changes, and etc.

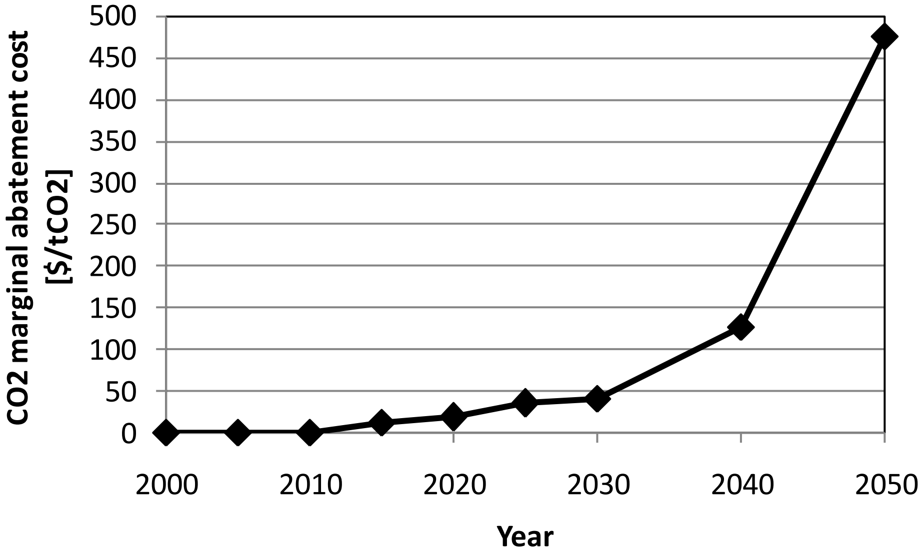


Figure 12 CO_2 marginal abatement costs

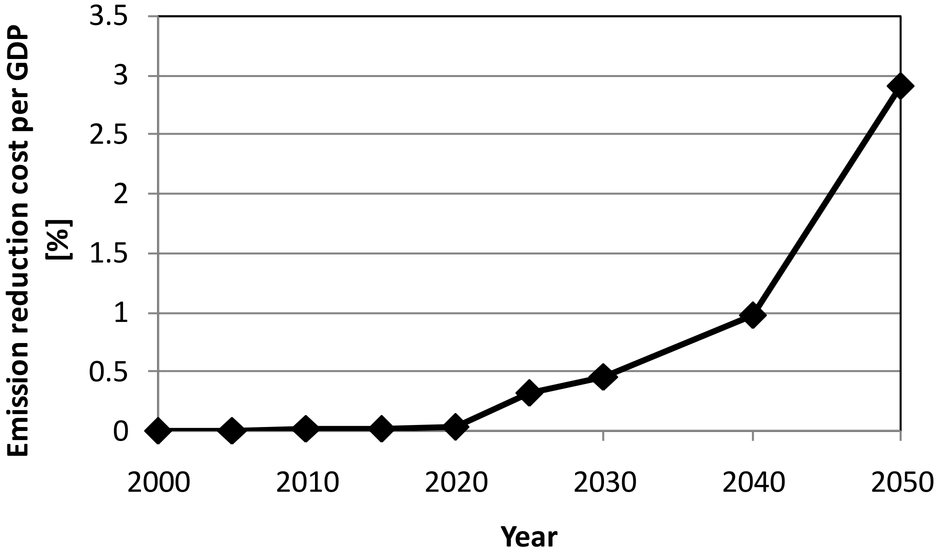


Figure 13 Emission reduction costs per GDP

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