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Consistent Analysis of Different Scenarios of Climate Stabilization and Sustainable Development

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Background and Objective

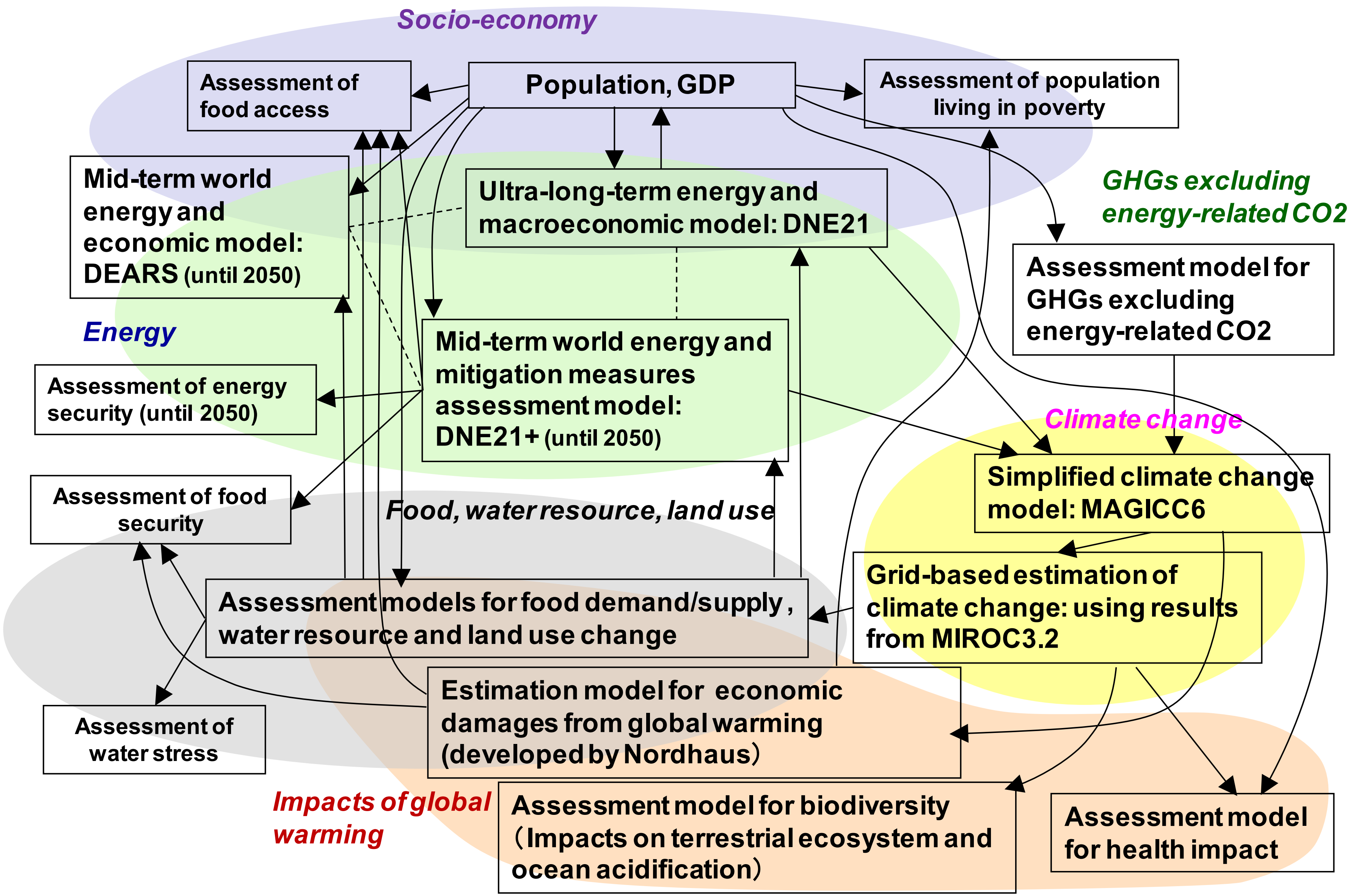
- The world is facing various issues to be solved in many of which are related to sustainable development.
- It is really important to achieve such multiple objectives with well-balanced priorities, in order to improve our well-being in the future.
- Consistent analyses for climate change and other sustainable development challenges are required to seek better future including considerations of different conditions among countries.

- This study presents consistent and quantitative analyses for climate change and sustainable development.

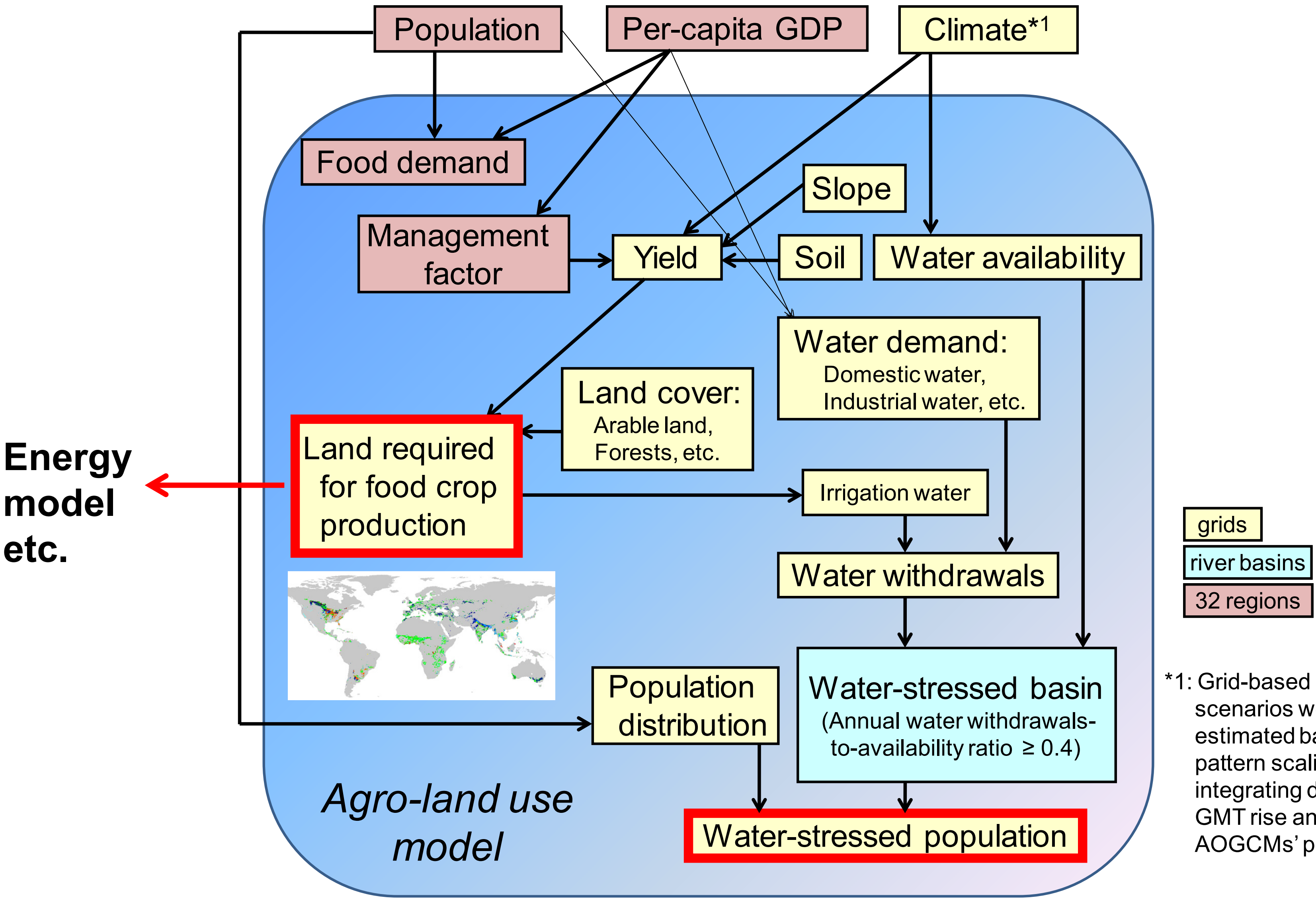
Overview of ALPS* Models, Assessed Indicators and Scenarios

* ALPS: ALternative Pathways toward Sustainable development and climate stabilization

Relationships among Models for Consistent Scenario Analysis



Overview of the Module for Assessments of Food Demand/Supply, Water and Land-use



*1: Grid-based climate scenarios were estimated based on pattern scaling method, integrating data on GMT rise and AOGCMs' projection.

Energy Assessment Model: DNE21+

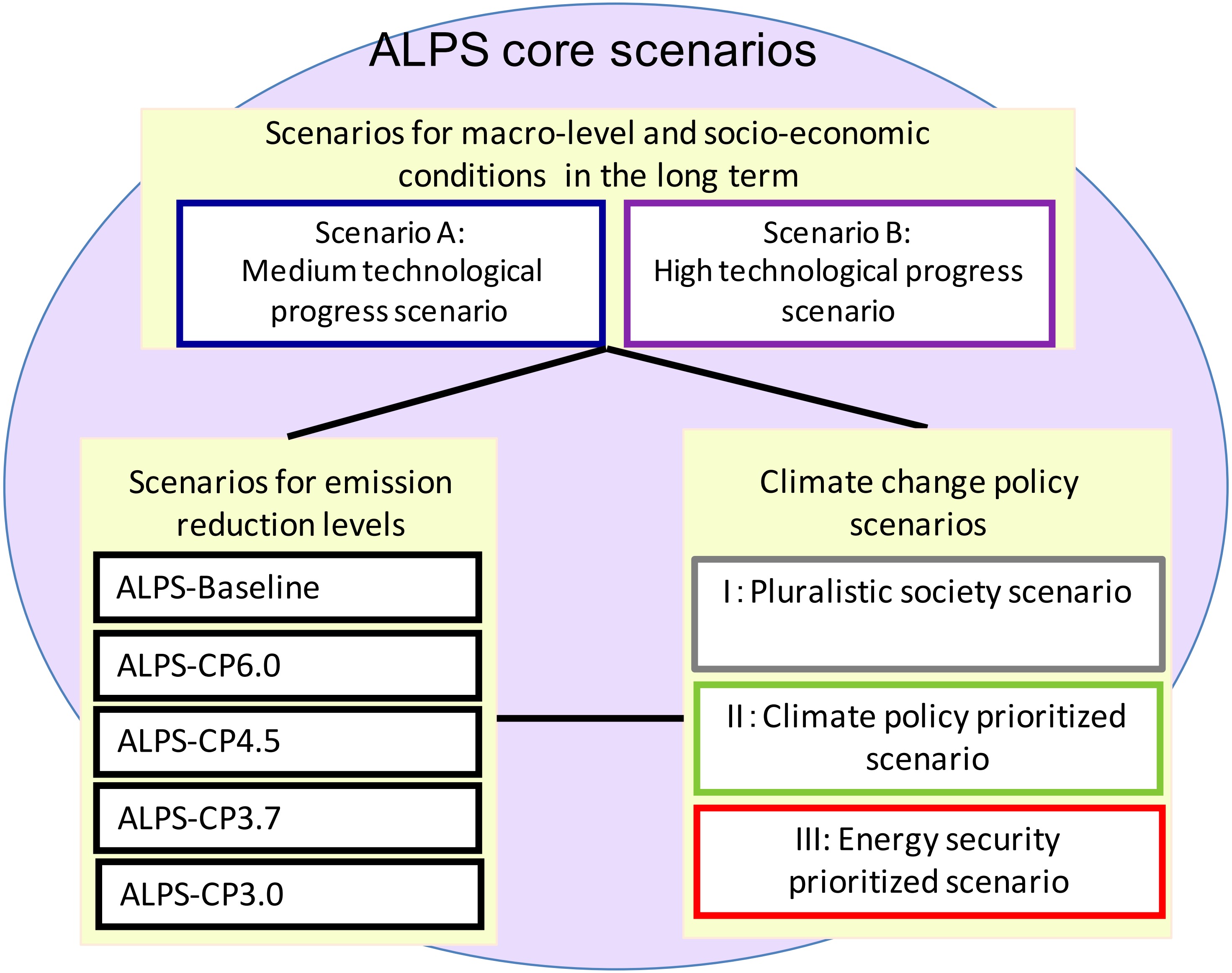
- Linear programming model (minimizing world energy system cost)
- Evaluation time period: 2000-2050
  Representative time points: 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050
- World divided into 54 regions
  Large area countries are further divided into 3-8 regions, and the world is divided into 77 regions.
- Bottom-up modeling for technologies both in energy supply and demand sides (200-300 specific technologies are modeled.)
- Primary energy: coal, oil, natural gas, hydro&geothermal, wind, photovoltaics, biomass and nuclear power
- Electricity demand and supply are formulated for 4 time periods: instantaneous peak, peak, intermediate and off-peak periods
- Interregional trade: coal, crude oil, natural gas, syn. oil, ethanol, hydrogen, electricity and CO_2
- Existing facility vintages are explicitly modeled.

- The model has detailed information in regions and technologies enough to analyze sectoral approach.
- Consistent analyses among regions and sectors can be conducted.

Assessed Major Indicator

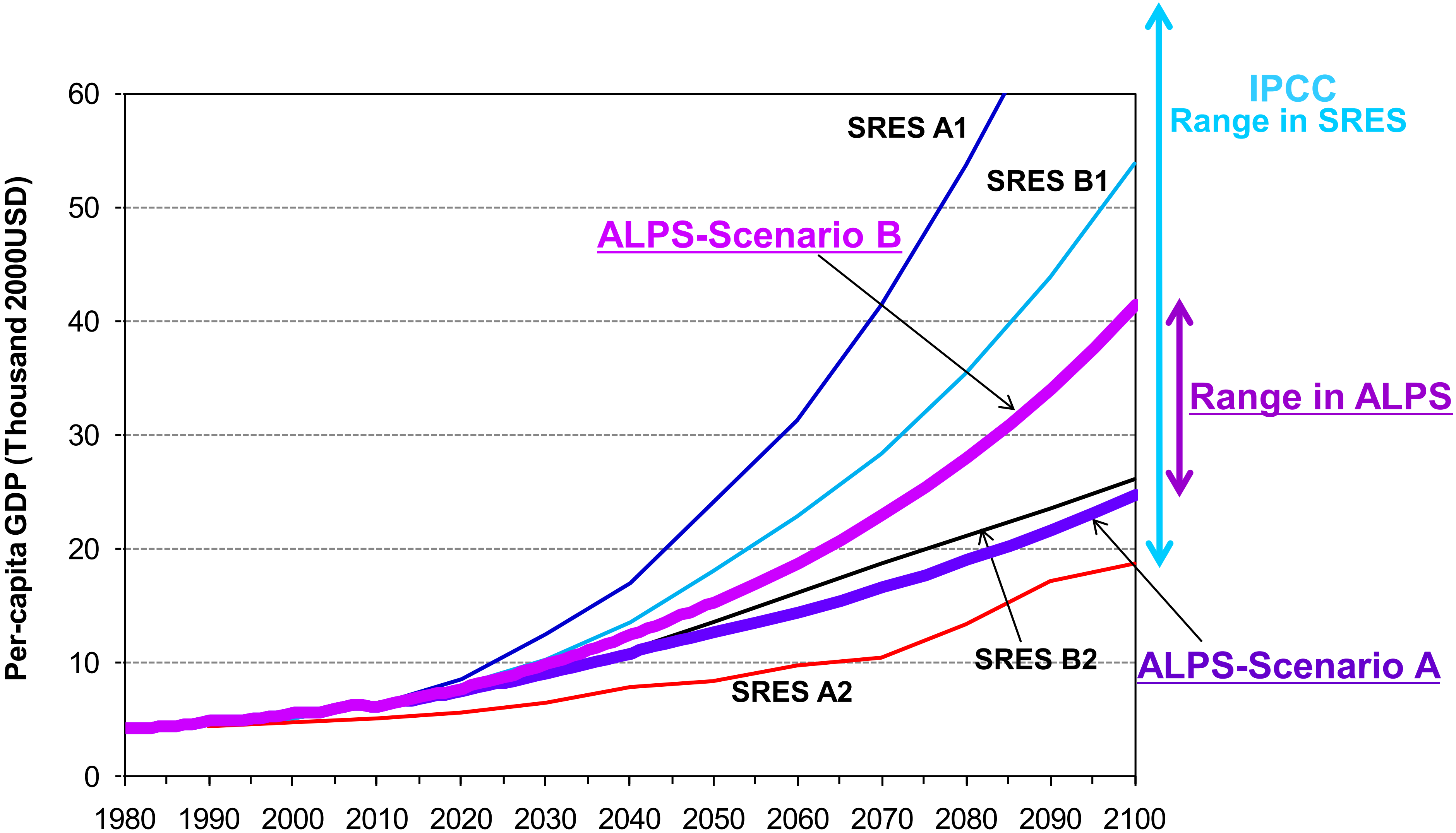
Category	Indicator
Economic and poverty	Income (GDP per capita)
	People living in poverty (including impacts of climate change and mitigation measures)
	Food access (amount of food consumption per GDP) (including impacts of climate change and mitigation measures)
	Energy access (access to grid electricity; People relying on the traditional use of biomass for cooking)
Agriculture, land-use, and biodiversity	Agriculture land area (including impacts of climate change)
	Food security (amount of food imports per GDP) (including impacts of climate change and mitigation measures)
Water	People living under water stress (including impacts of climate change)
Energy	Sustainable energy use (cumulative fossil fuel consumption)
	Energy use efficiency (primary energy consumption per capita and per GDP)
	Energy security (share of total primary energy consumption accounted for by oil and gas imports with country risks)
Climate change	Economic impact of mitigation measures (marginal abatement cost (carbon price) and GDP loss)
	Global mean temperature change
	Aggregated economic impact of climate change

Assumed Scenarios



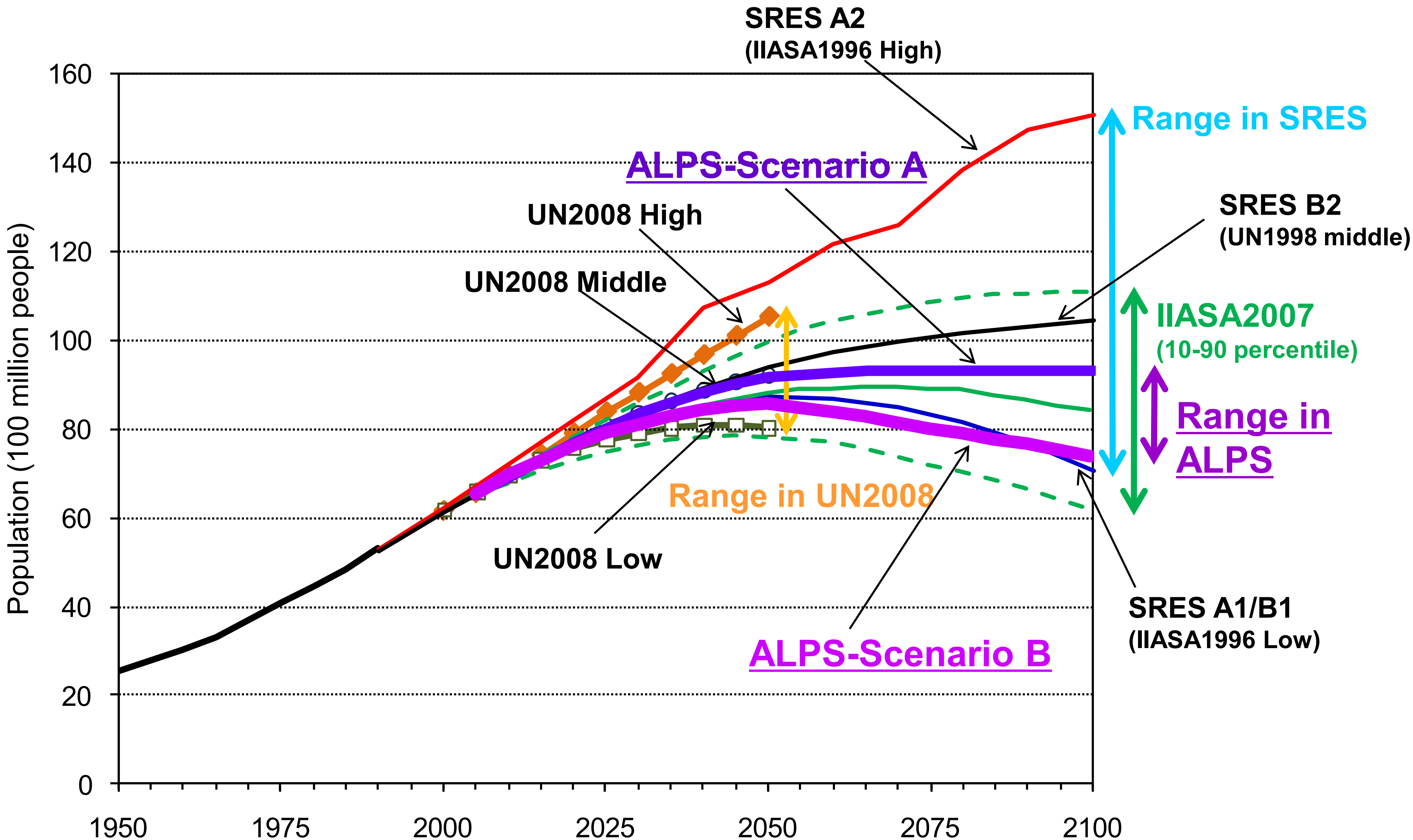
Assumed Socioeconomic Scenarios

ALPS Per-capita GDP Scenarios (Global Average, Baseline)



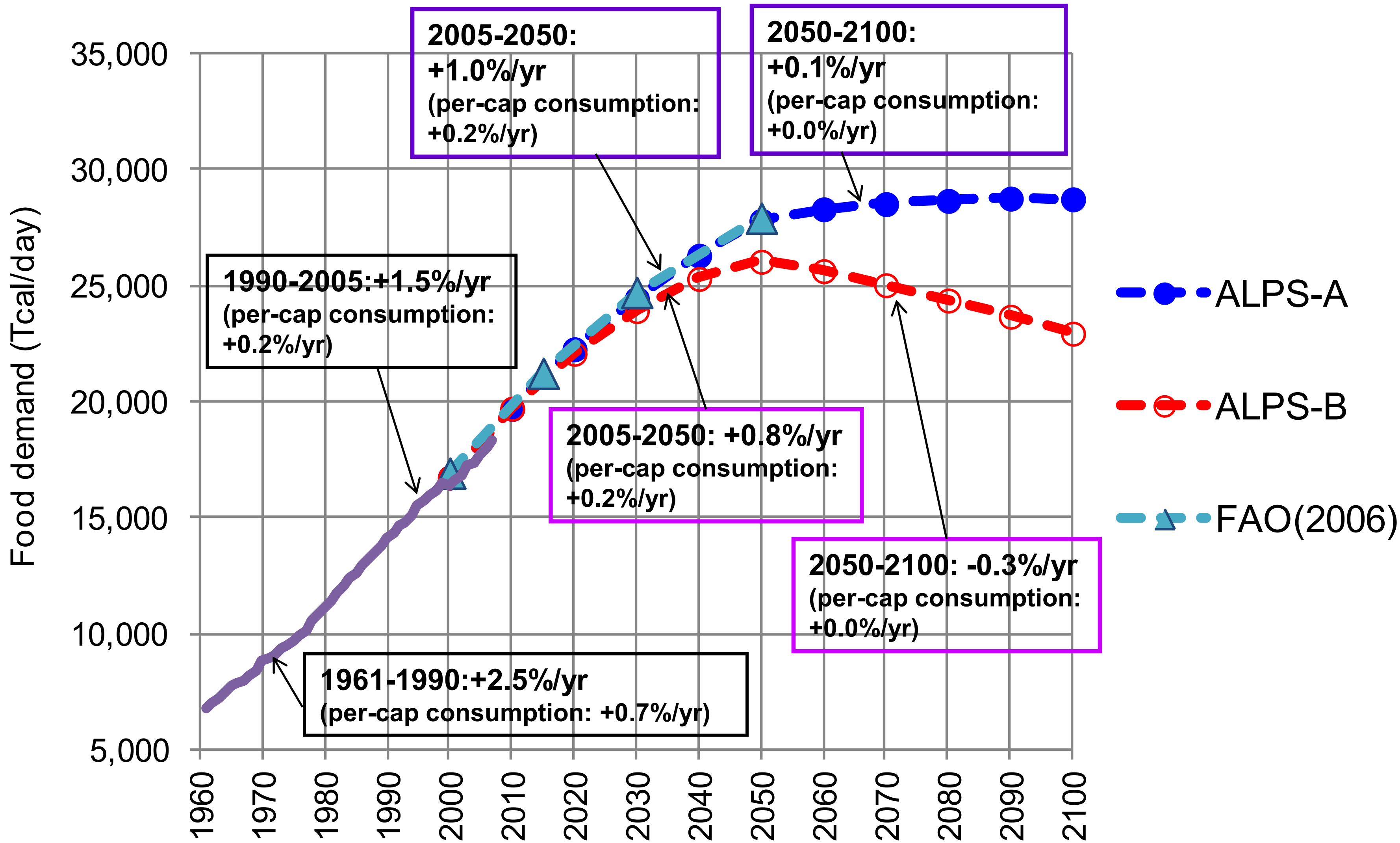
Note: GDP of SRES scenarios are adjusted to the price in 2000 from that in 1990.

ALPS Global Population Scenarios



High per-capita GDP will induce low population. Scenario A: medium population, Scenario B: low population

ALPS Global Food Demand Scenarios

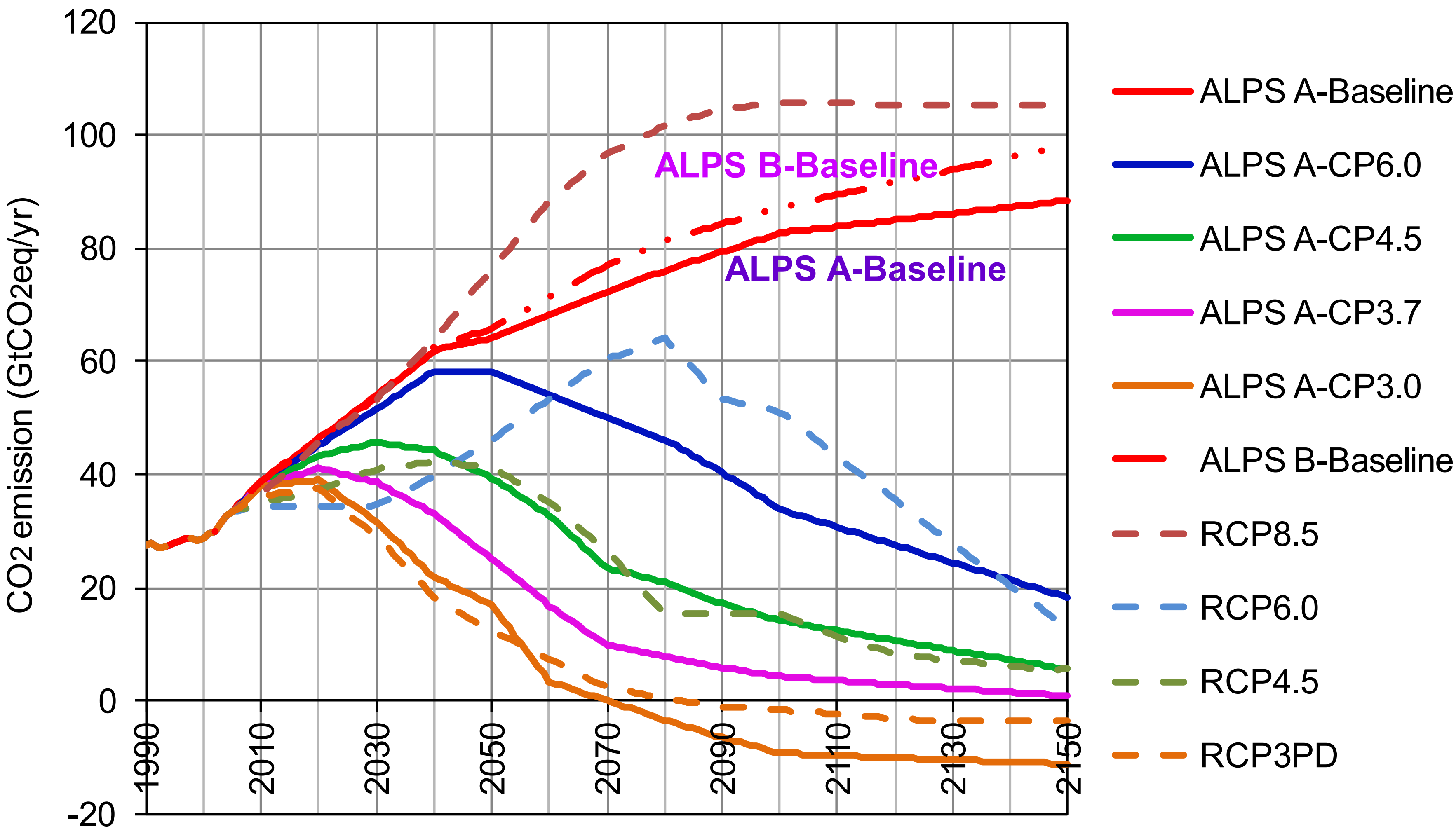


The effects of population decrease on food demands are larger than those of per-capita income increase. Hence, the global food demands in Scenario B are smaller than those in Scenario A.

GHG Emission Outlook and Emission Reduction Scenarios

—Baseline, CP6.0, CP4.5, CP3.7, CP3.0—

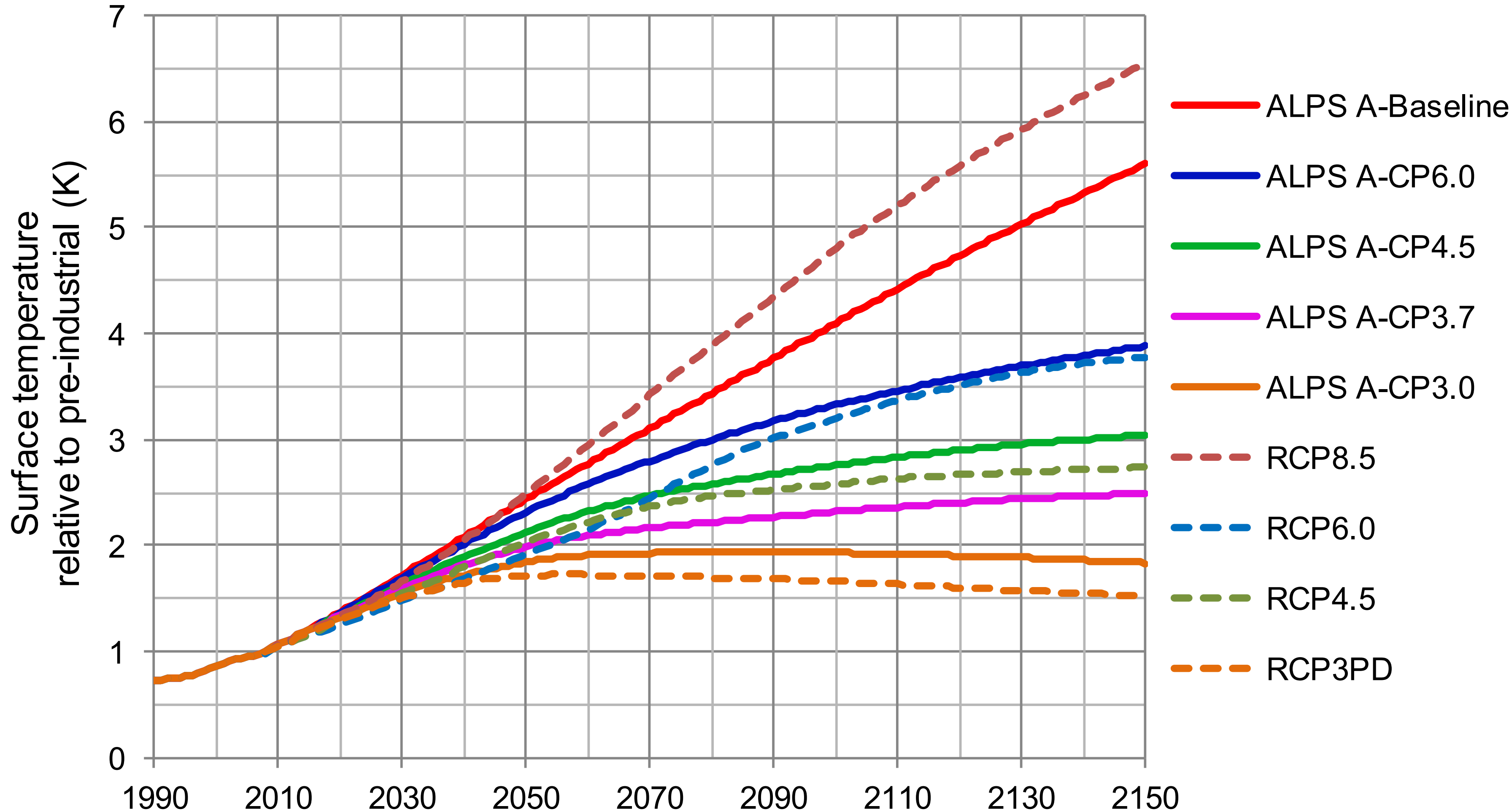
ALPS CO_2 Emission Scenarios



Note: CO_2 emissions including those from industrial processes and LULUCF

RCP (Representative Concentration Pathway): IPCC new scenario

Global Mean Temperature Rise



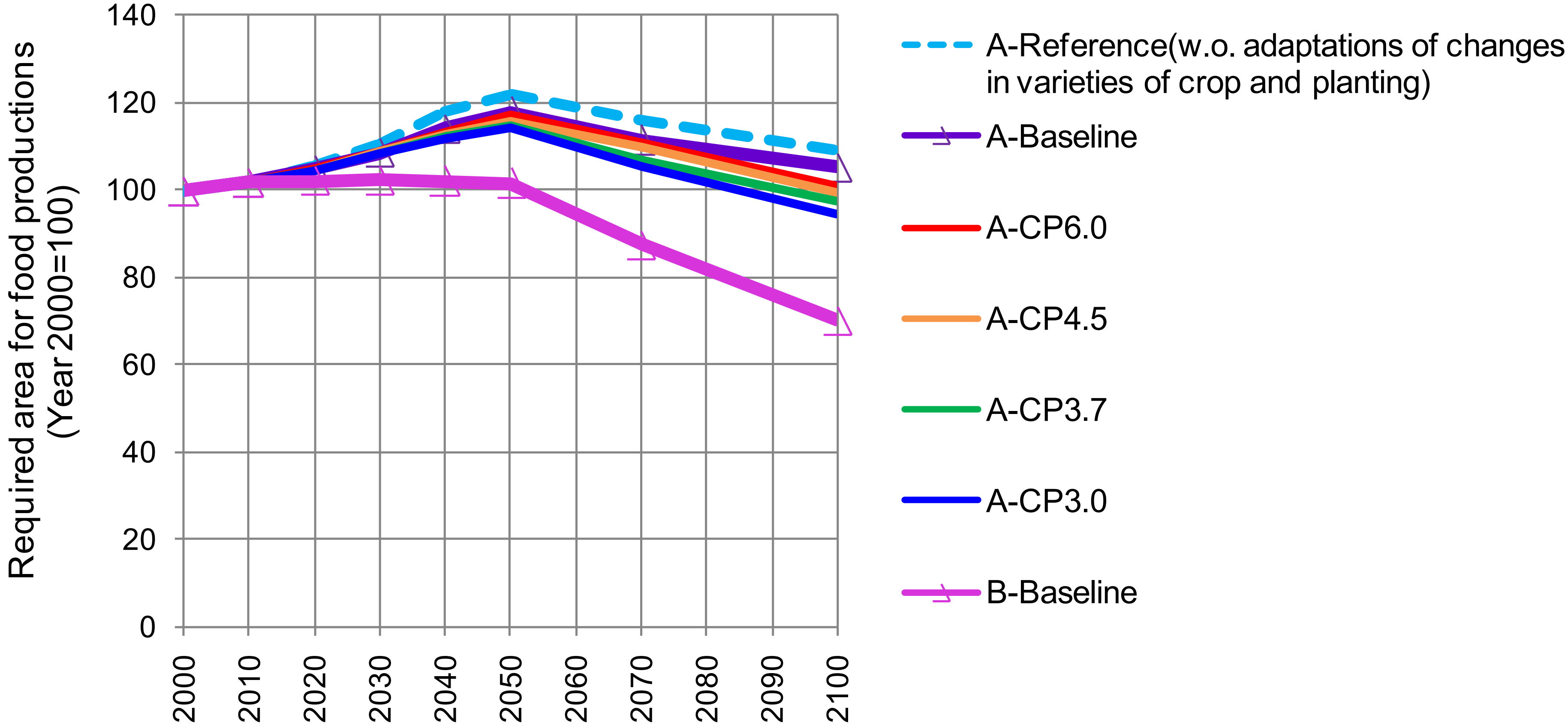
Note: Equilibrium climate sensitivity is assumed to be 3 °C, which is a "most likely value".

The maximum global mean temperature change relative to the pre-industrial level is about 2 °C (1.94 °C) for the ALPS CP3.0.

Assessments of Sustainable Development Indicators

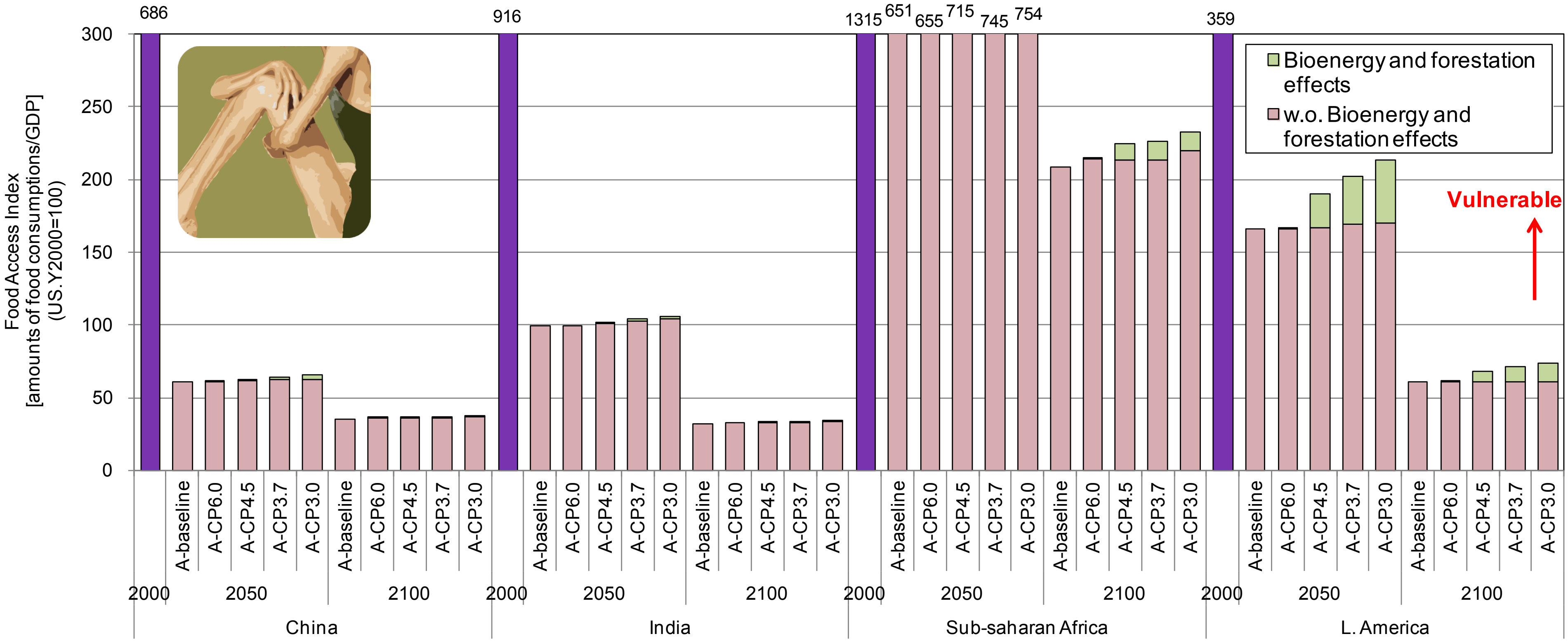
Agriculture Land Area

Required area for food productions to meet food demands



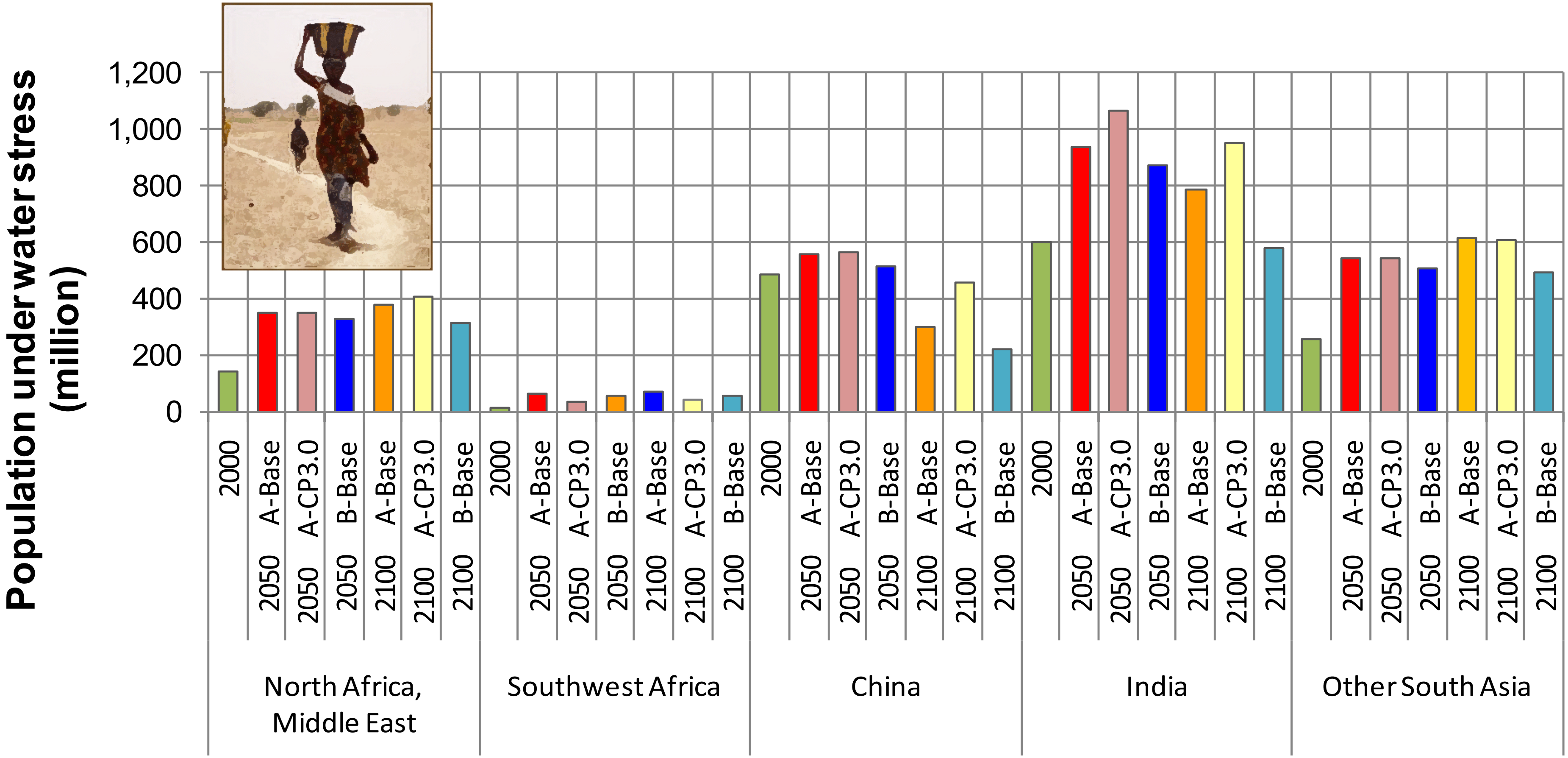
The additional required area for crop productions will be about 20% in 2050 under Scenario A-Baseline. The area in the case of climate stabilization at a low level will be smaller than that of the baseline. However, socioeconomic conditions, such as population, will have larger effects on the required area.

Food Access Indicator
(Amounts of food consumption per GDP)



Vulnerabilities of food access will decrease in most countries and regions in the long-term under any emission scenarios, because future incomes are expected to increase in the future.
Global warming impacts on food productions are relatively small compared with the effects of income increase.
Global warming counter-measures of large scale of forestation and bioenery use slightly increase vulnerabilities of food access.

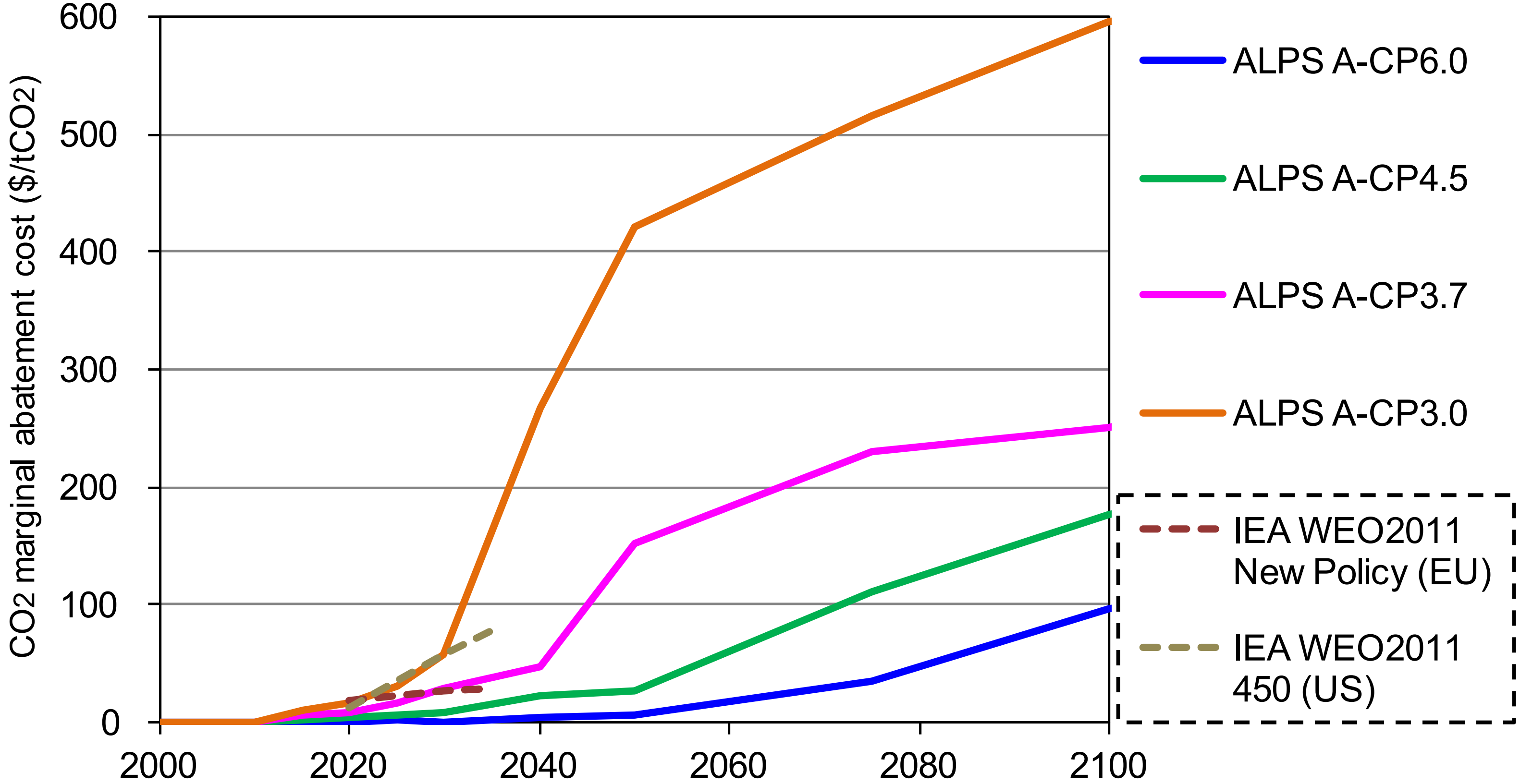
People Living under Water Stress



Water stress: annual water withdrawal-to-availability ratio ≥ 0.4

People under water stress will increase in many Asian countries mainly due to population increase. GHG emission cuts will not contribute to the mitigation of the stress. The water stress decreases after 2050 in the Scenario B mainly due to population decrease.

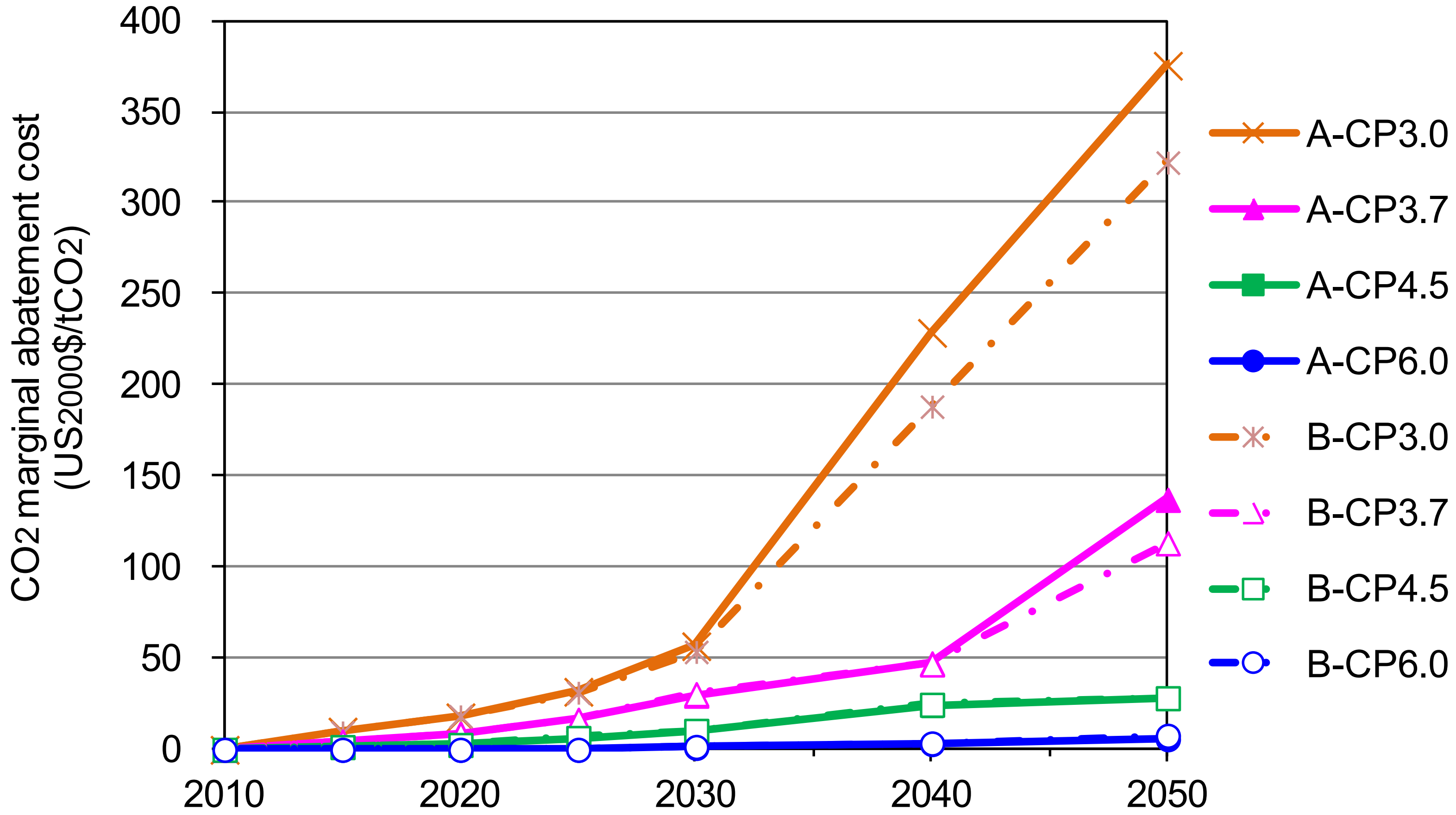
CO_2 Marginal Abatement Cost for Different Stabilization Levels



Note: The costs until 2050 are estimated by DNE21+, and those after 2050 are estimated by DNE21.

High marginal abatement costs are estimated after 2040 particularly for CP3.0. even if all the countries make the coordinated efforts (uniform marginal abatement cost) and the least cost mitigation measures are achieved.

CO_2 Marginal Abatement Cost (Comparisons of Scenarios A and B)



The baseline emission in Scenario B which is assumed to have higher GDP is larger than that in Scenario A. However, the marginal abatement cost in Scenario B is lower than that in Scenario A under deeper emission reductions such as CP3.0, CP3.7, because there are larger area for forestation and bioenergy productions due to population decreases, higher technology improvement, and electrification ratio.

Conclusion

Conclusion

- Climate change is a dangerous issue. Emission reductions are surely required. But there are not only synergy effects between climate change and other sustainable development issues but also exist trade-offs, e.g., food access, under deep emission reductions, according to our study.
- Balanced climate target and balanced measures across climate change and many other sustainable development issues including climate change adaptations are required.
- Some indicators are strongly affected by socioeconomic changes rather than global warming impacts.
- Socioeconomic conditions expecting high emissions in BaU do not necessarily expect high mitigation costs for deep emission reductions.
- Distribution issues within countries and regions will be important for sustainable development. Distribution issues should be more focused in future works.

Appendix

Overview of the GHG Assessment Model
(2 Models and 1 Scenario)

1. DNE 21+ Model

- Assessment model for **energy-related CO_2** emissions
- **54 regions** in the world
- **Bottom-up** modeling (**200-300 specific technologies** are modeled)

Non-Energy CO_2 Emissions Scenario

- Projection module for **non-energy CO_2** emissions
- **54 regions** in the world
- **Estimations of sectoral** non-energy CO_2 emissions to be consistent with GDP and production activities

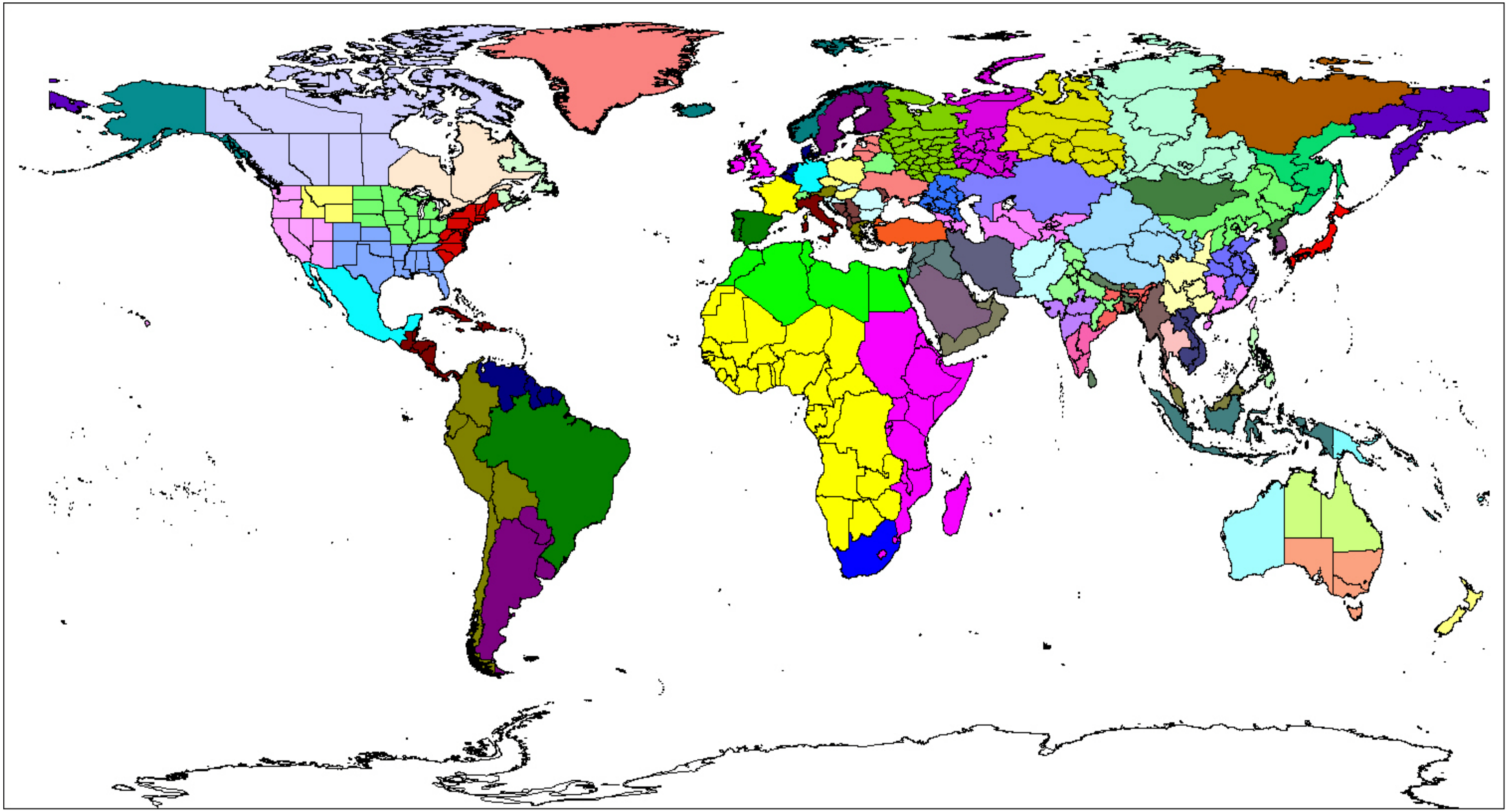
2. Non-CO_2 GHG Assessment Model

- Assessment model for the **5 non-CO_2 GHG** emissions (CH_4, N_2O, HFCs, PFC, SF_6)
- **54 regions** in the world
- The methodology is **similar to the USEPA** assessment

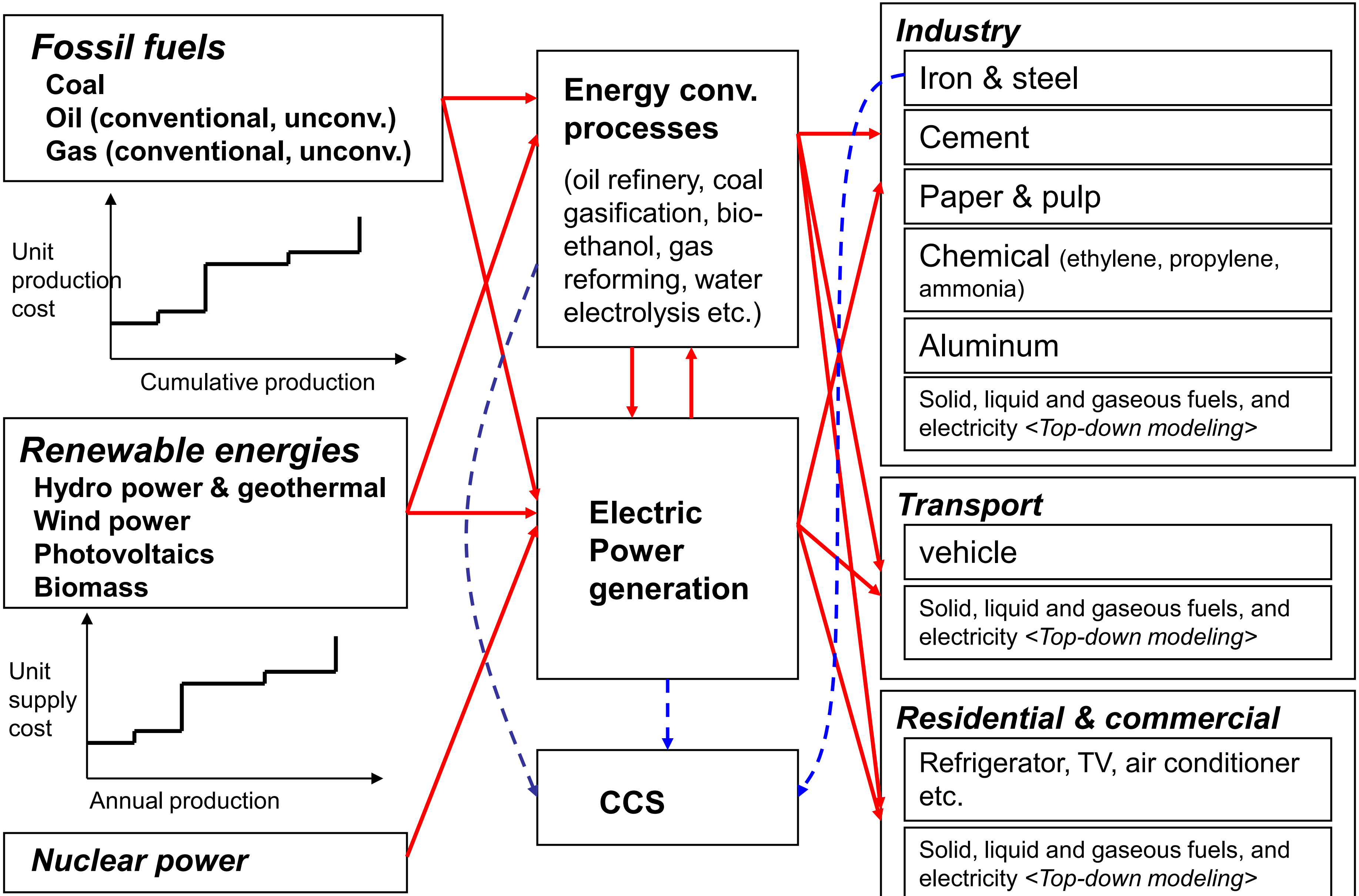
Estimates of the 6 GHG emissions, emission reduction costs and potentials, and specific cost-effective measures for emission reductions

Note: LULUCF is excluded for the estimates.

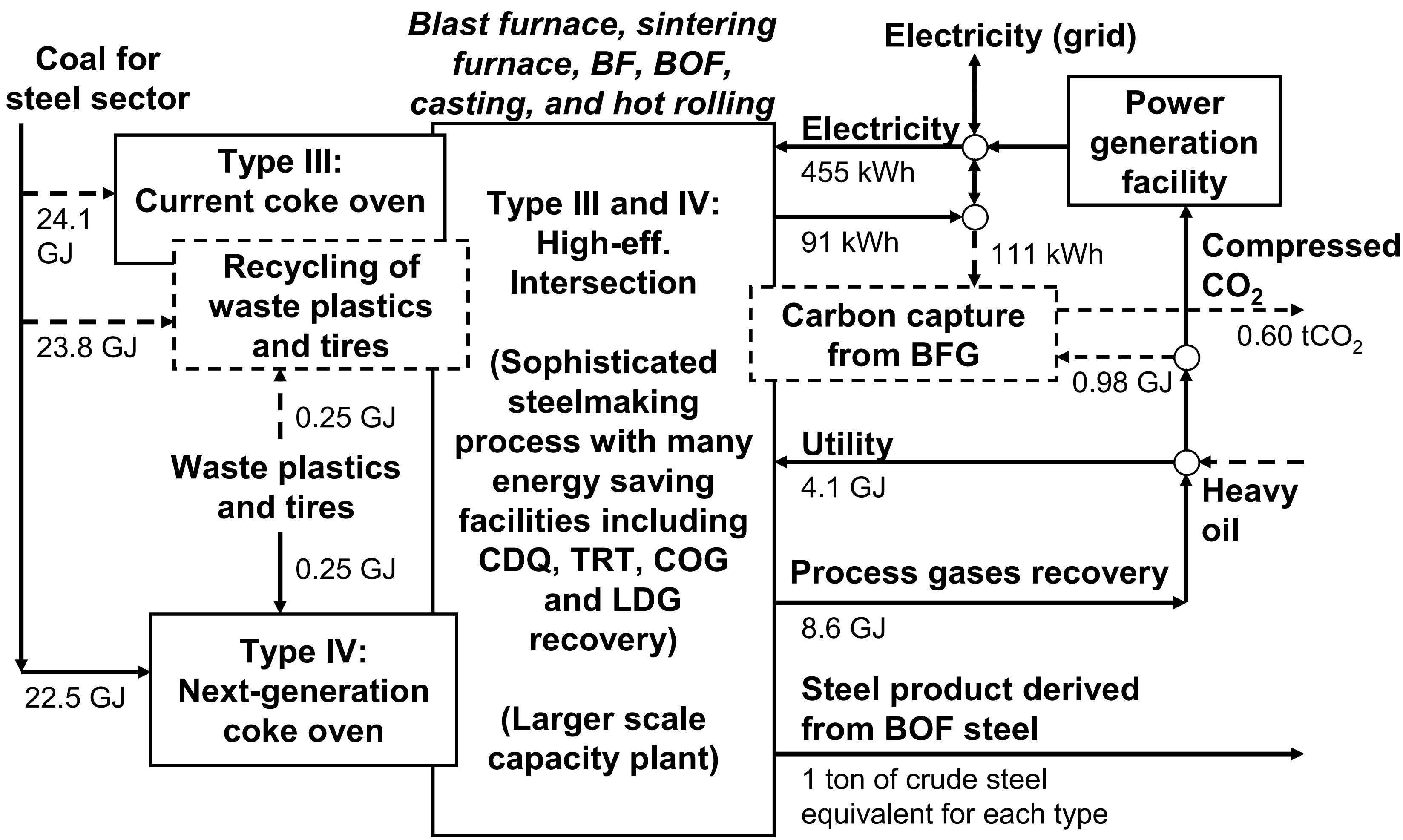
Region divisions of DNE21+



Technology Descriptions in DNE21+ (1/2)

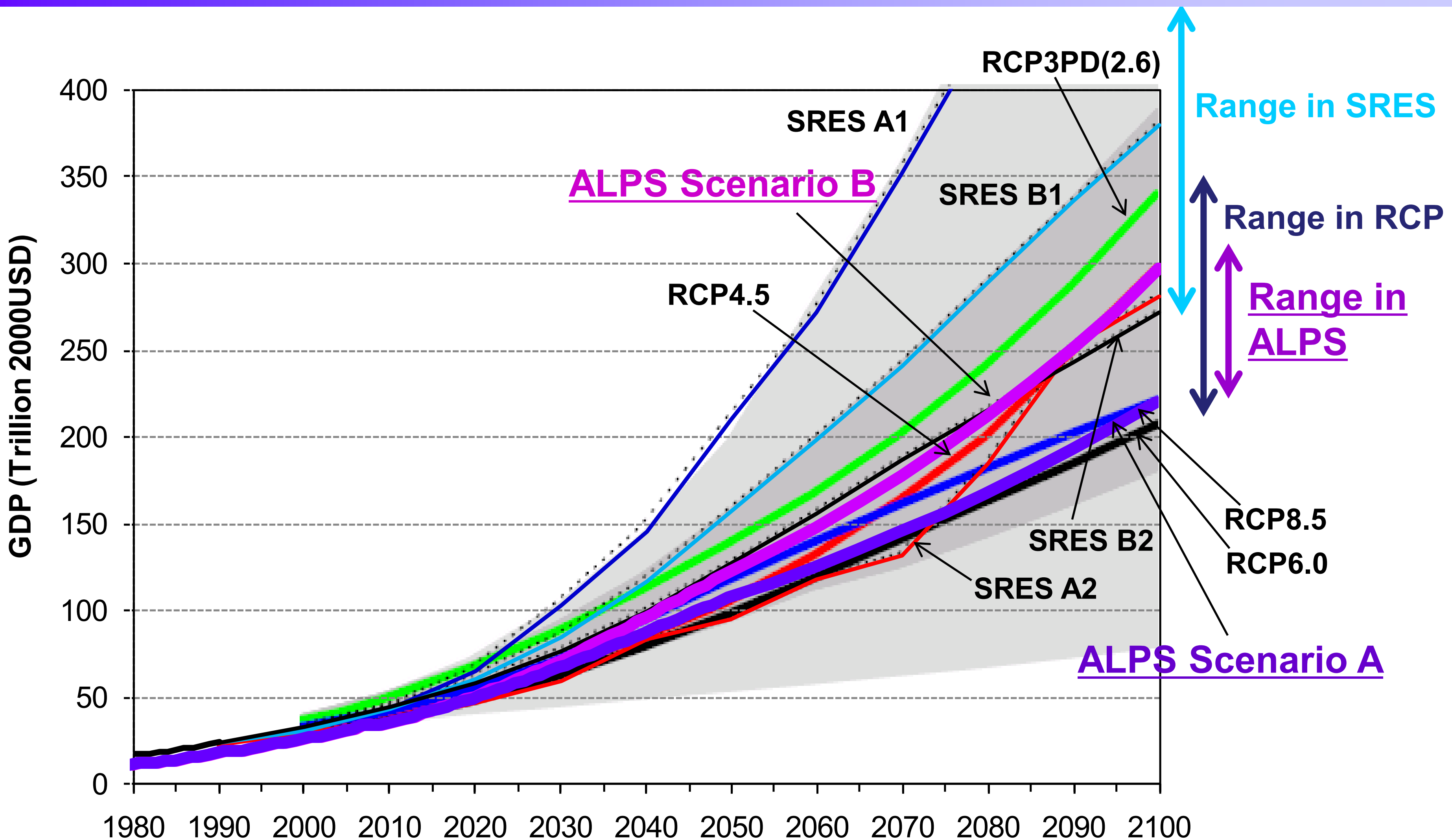


Technology Descriptions in DNE21+ (2/2)
–An Example for High Energy Efficiency Process in Iron & Steel Sector–



BF: blast furnace, BOF: basic oxygen furnace, CDQ: Coke dry quenching, TRT: top-pressure recovery turbine, COG: coke oven gas, LDG: oxygen furnace gas

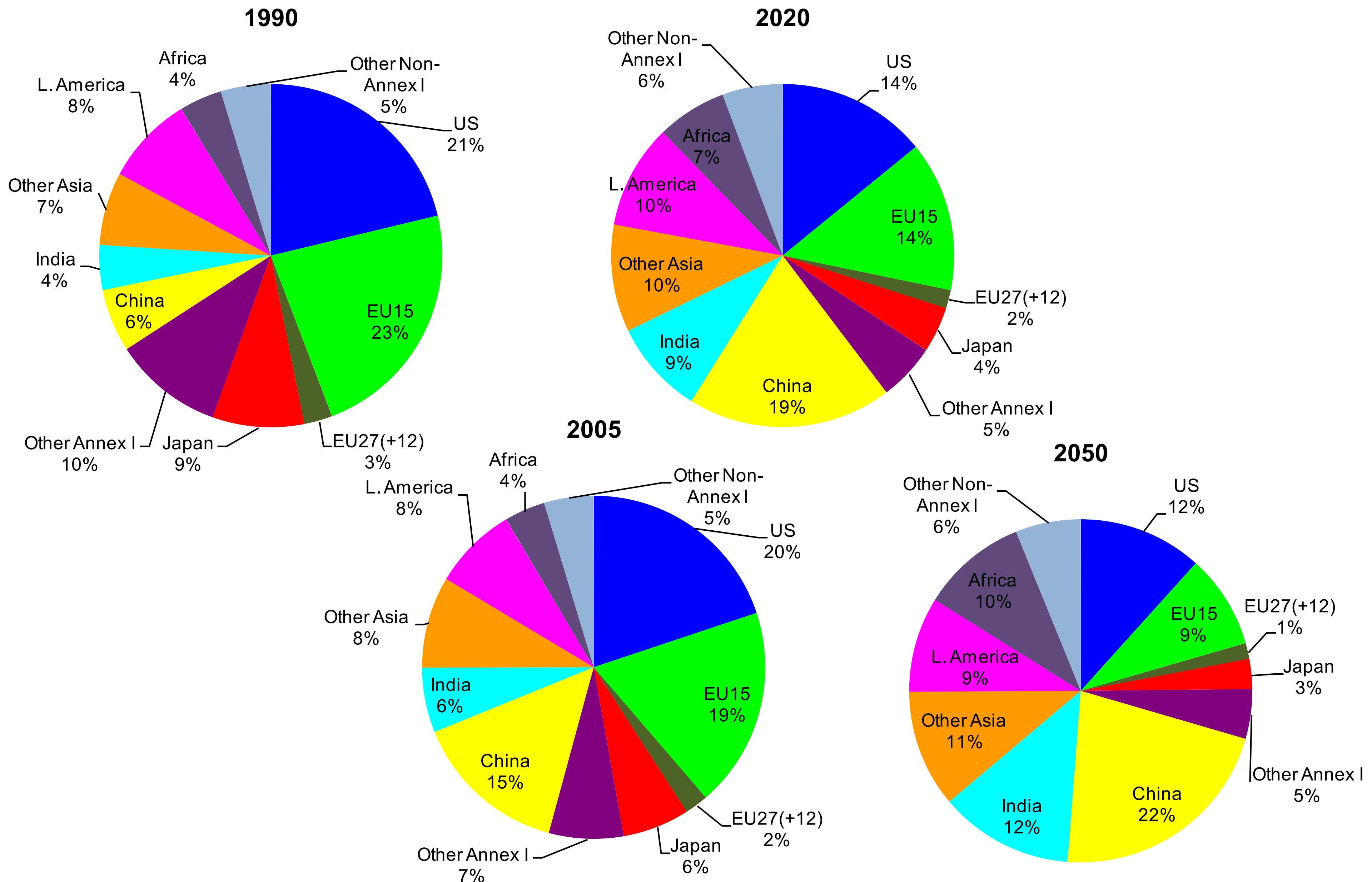
ALPS GDP Scenarios
(Global, Baseline, MER)



Note: GDP of SRES scenarios are adjusted to the price in 2000 from that in 1990.

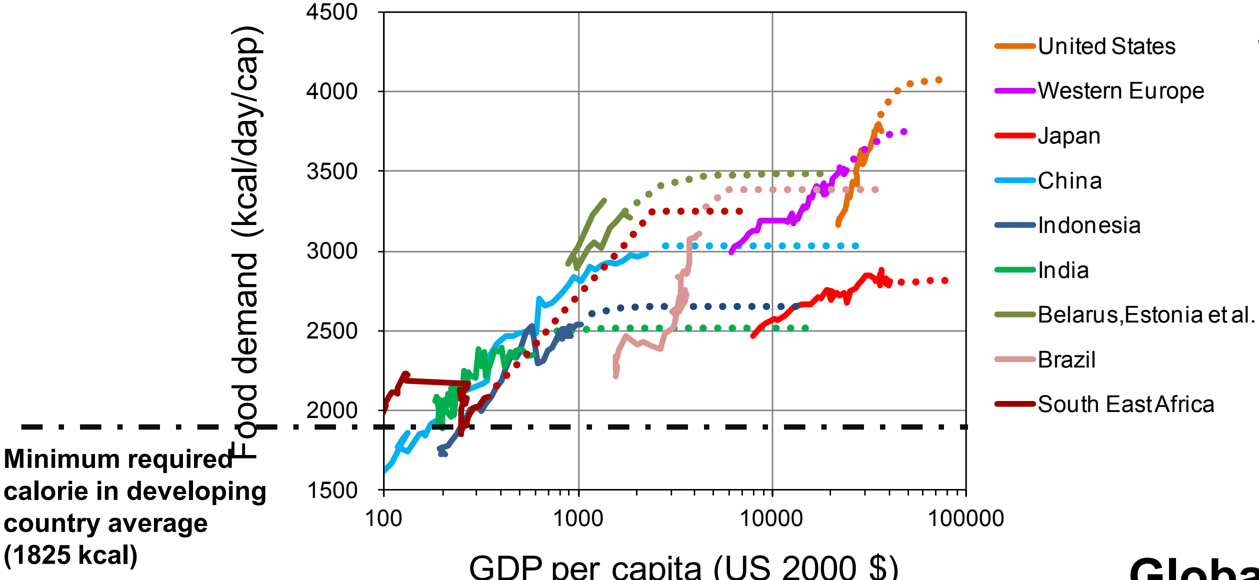
GDPs of SRES A1 and B1 are much higher than the ALPS assumptions. The GDP of Scenario A is close to that of RCP8.5 and RCP6.0; the GDP of Scenario B is close to that of RCP4.5.

Regional GDP$_{PPP}$: Scenario A



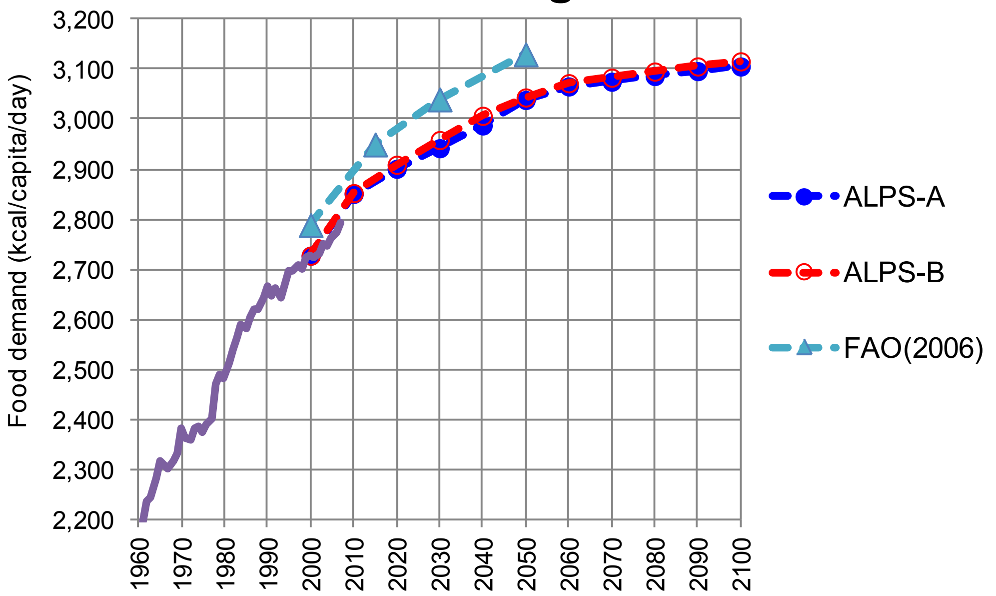
Per-capita Food Demand Scenarios

Scenario A



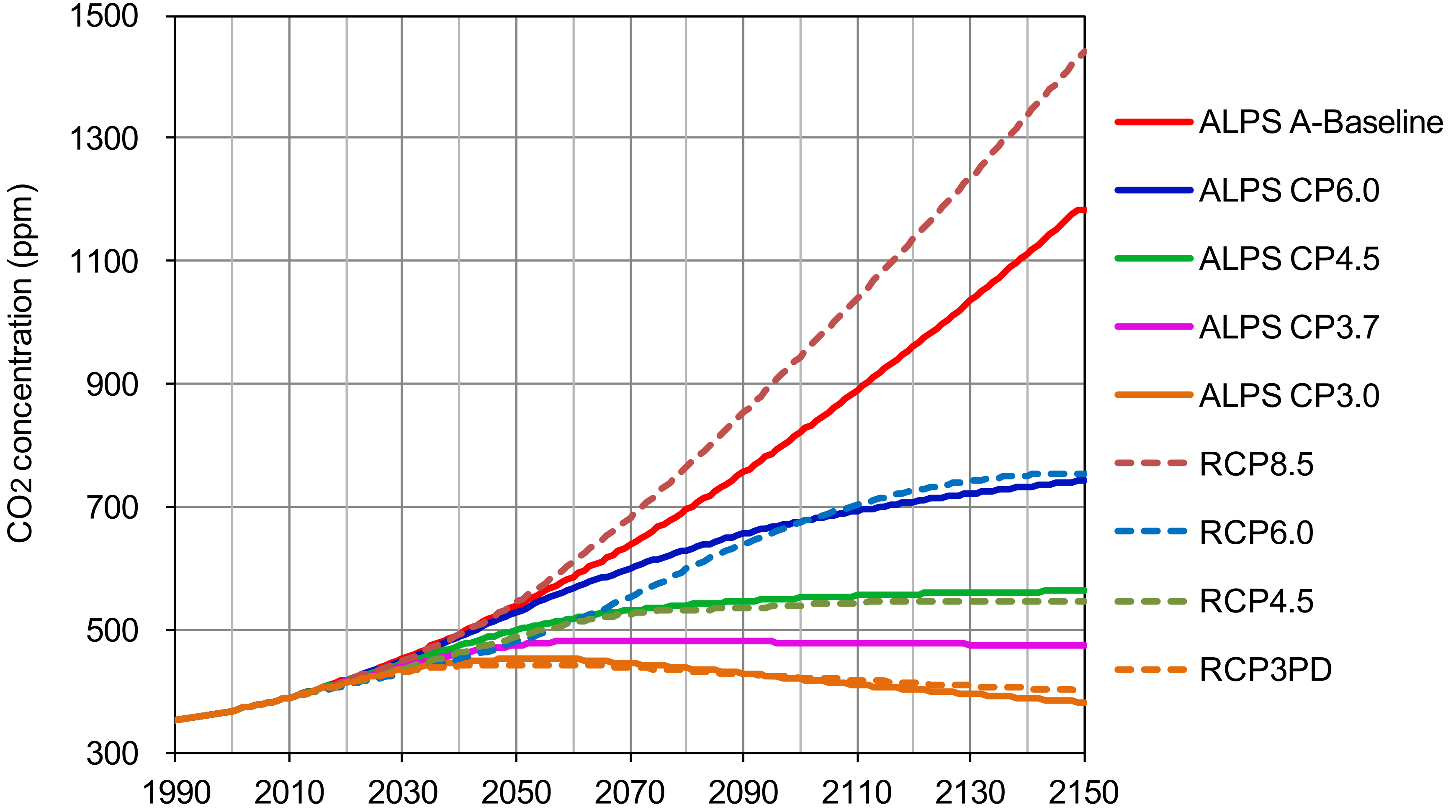
Solid line: historical, dashed line: future scenarios

Global average



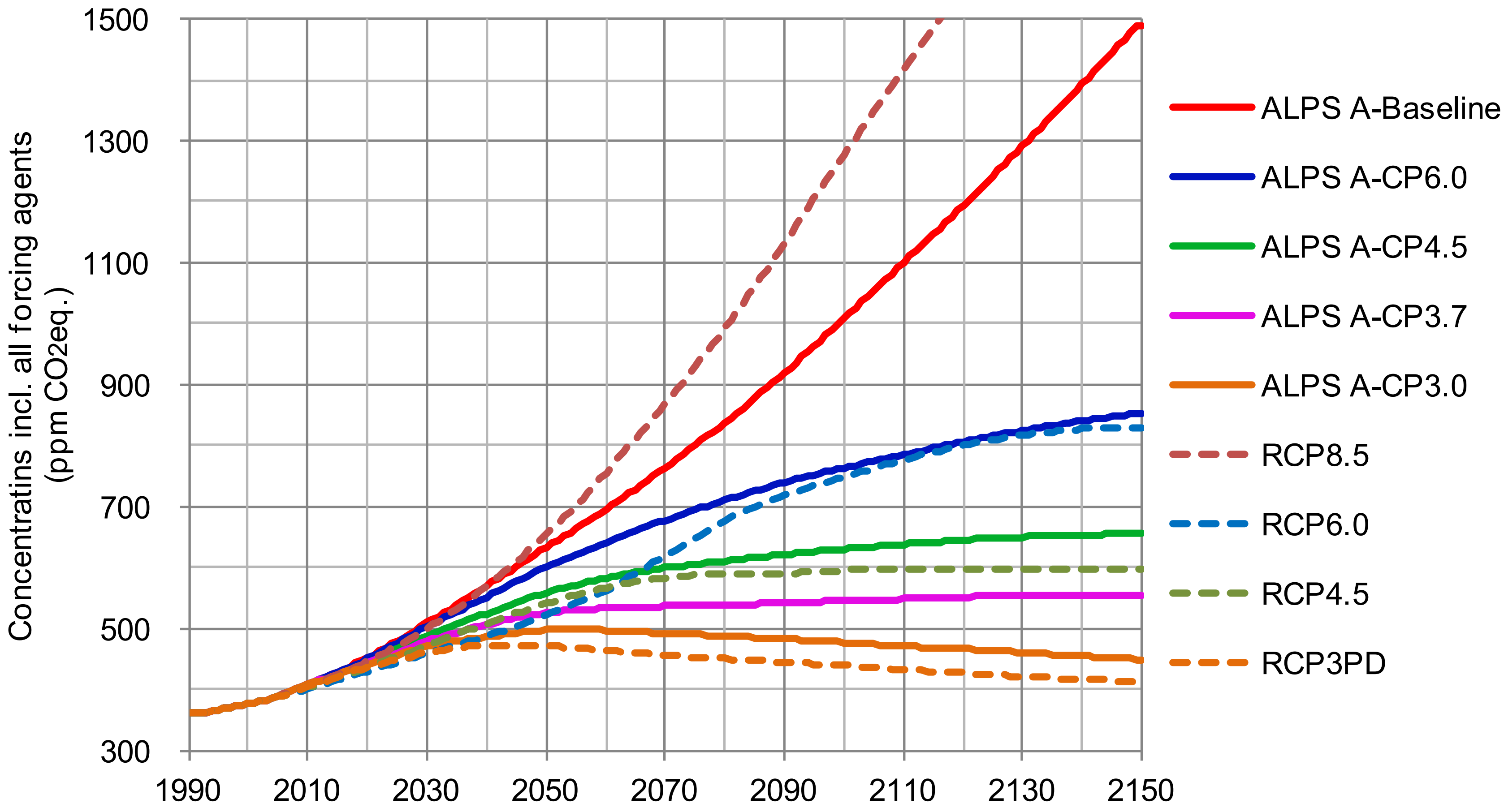
"The increase in food insecurity is not a result of poor crop harvests but because high domestic food prices, lower incomes and increasing unemployment have reduced access to food by the poor". (FAO, 2009)

ALPS Scenarios for Atmospheric CO_2 Concentration



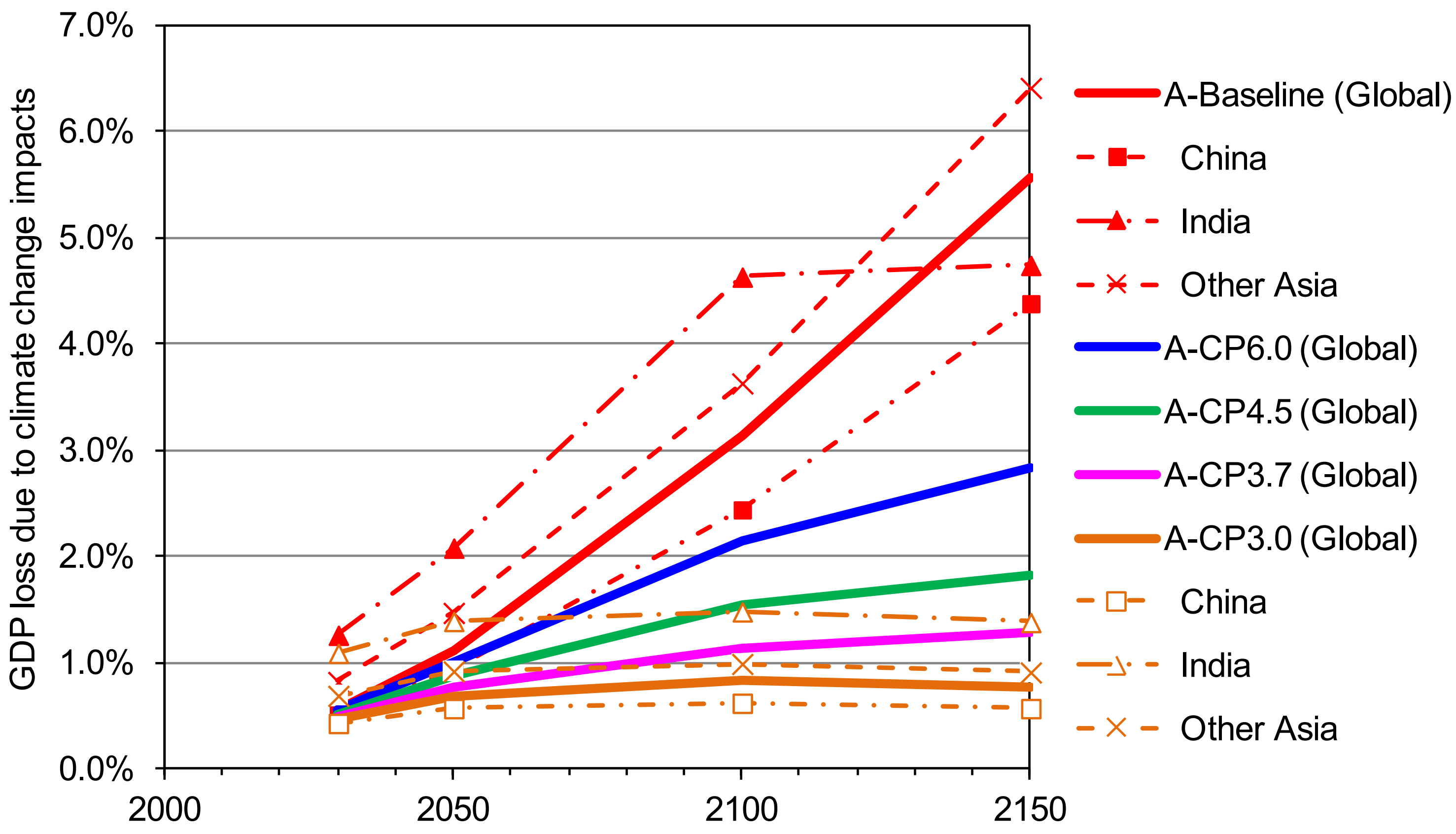
Note: only CO_2

CO_2 Equivalent Concentration Trajectory



There are differences in CO_2 equivalent concentration between RCP3PD and ALPS CP3.0 due to differences in estimates of CH_4 and N_2O emission reduction potentials. There are differences in CO_2 equivalent concentration between RCP4.5 and ALPS CP4.5 due to differences in estimates of baseline emissions of F-gases.

Aggregated Warming Damages



Aggregated global warming damages proposed by Nordhaus, 2010

$$\frac{D(t)}{GDP_{Base}(t)} = a_1 T(t) + a_2 (T(t))^{a_3}$$

GDP_{Base}: Baseline GDP; T(t): Global mean temperature; a1, a2: coefficients for 12 regions, a3：2.0

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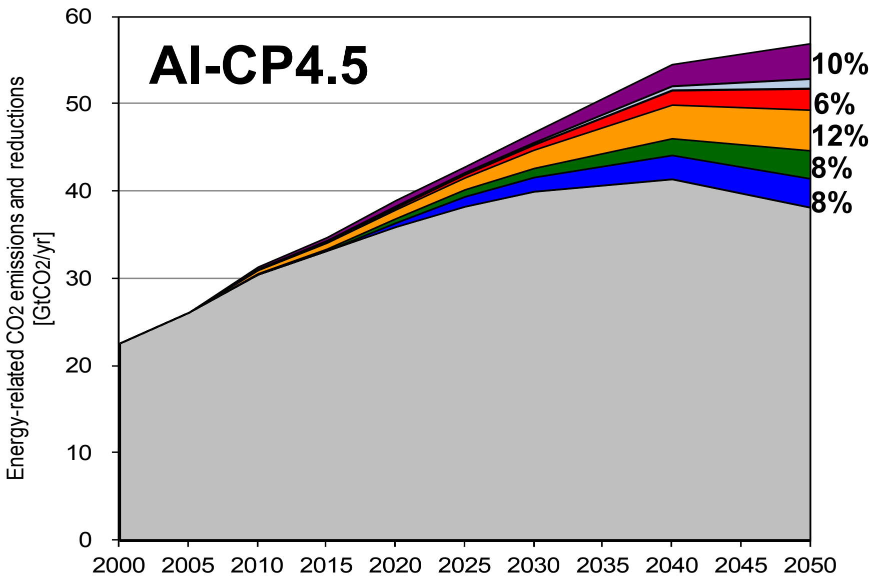
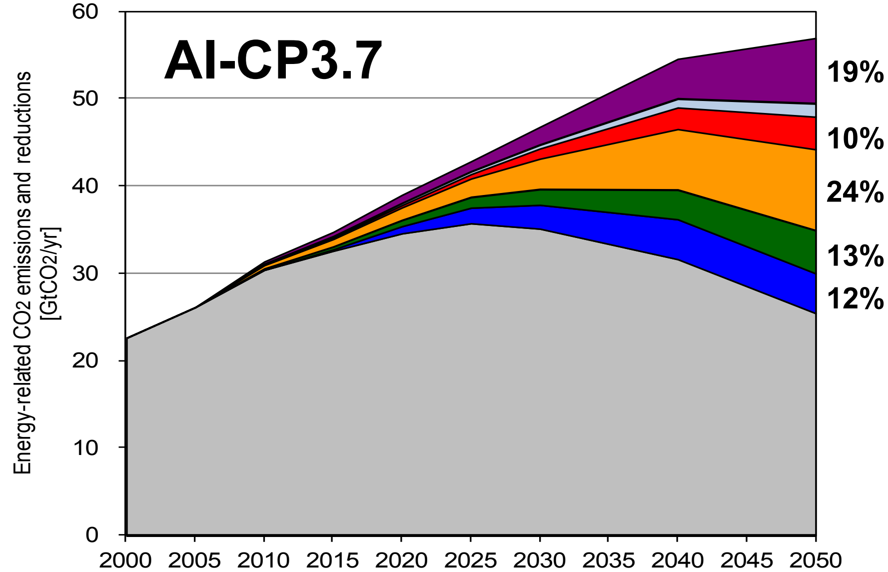
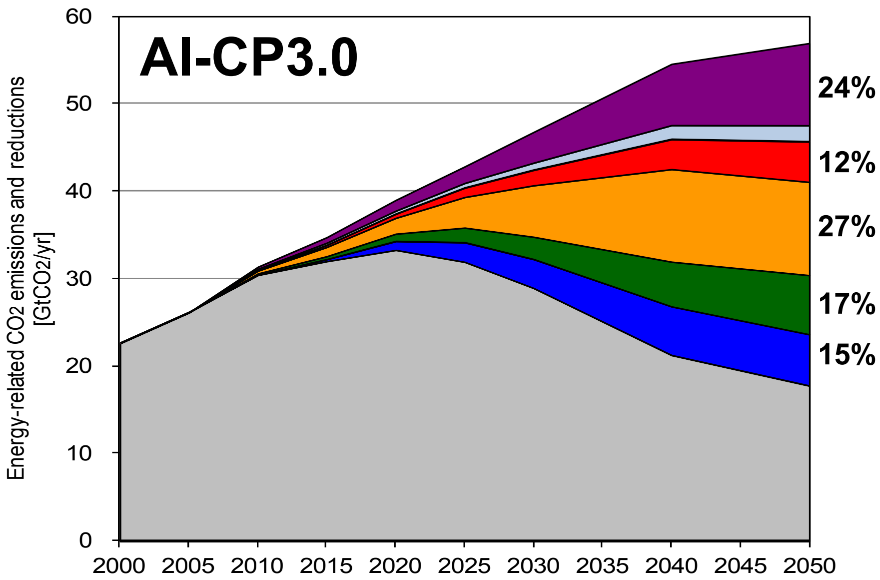
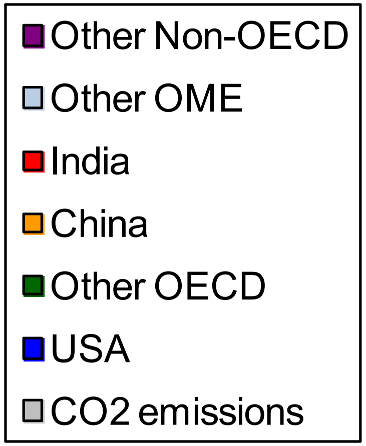
CO_2 Emission reductions by Region (Only energy-related CO_2 emissions)





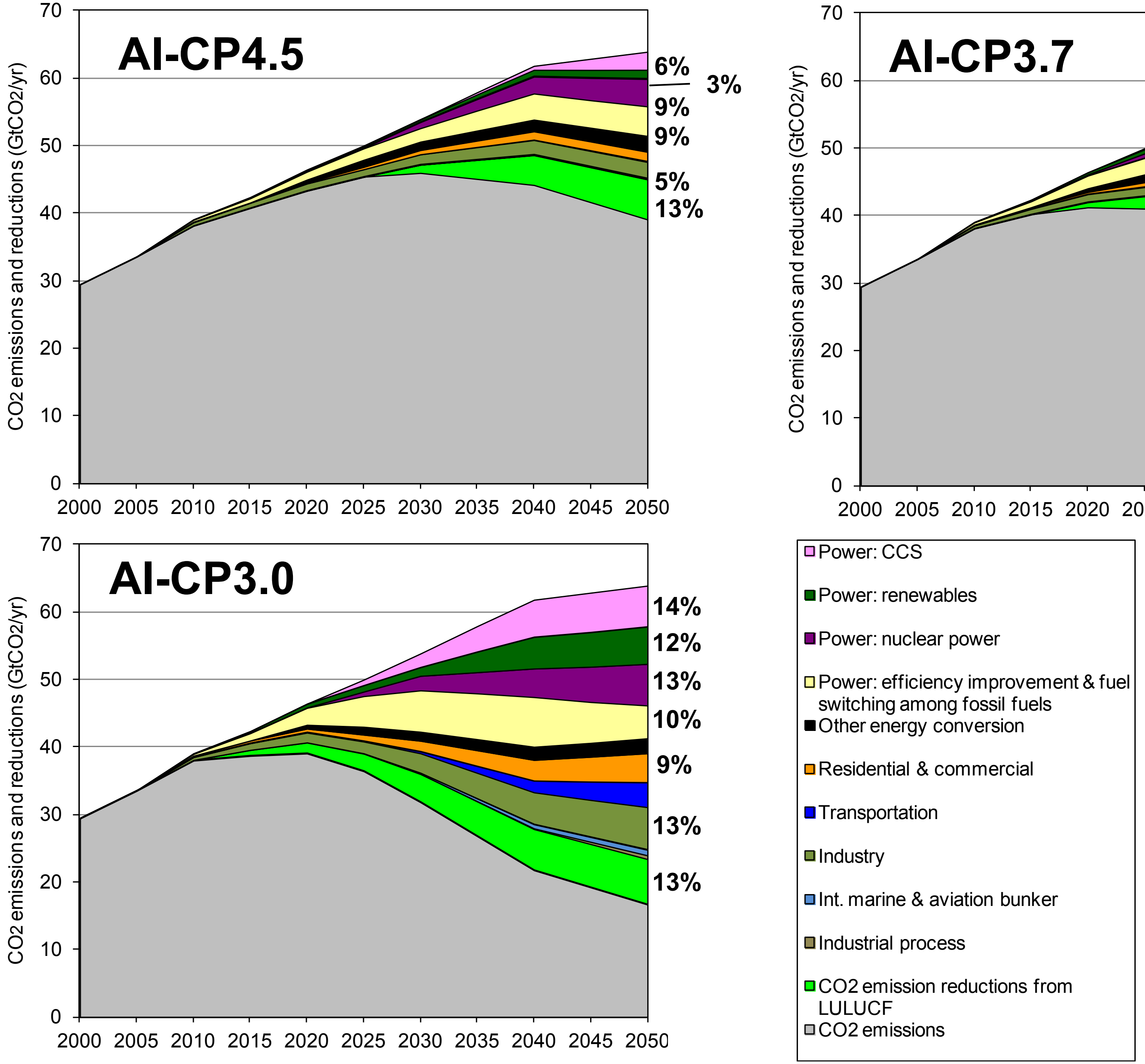




Note 1: All numbers of the emission reduction ratio are represented <u>by the rate in total emission reductions in 2050 in the case of CP3.0</u>.

Note 2: The reduction effects are represented as those relative to the baseline emissions.

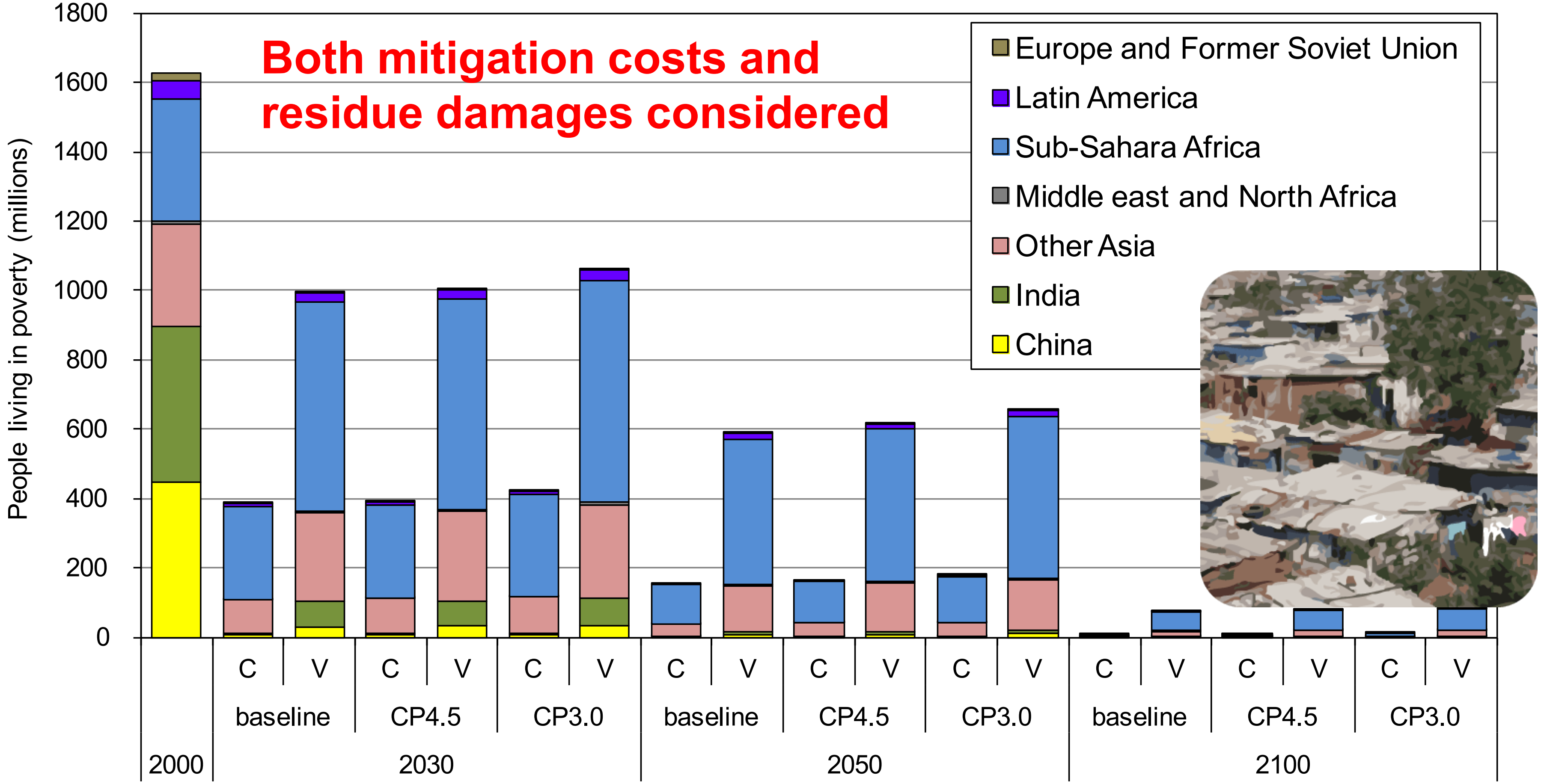
CO_2 Emission reductions by Sector and Technology



Note 1: All numbers of the emission reduction ratio are represented <u>by the rate in total emission reductions in 2050 in the case of CP3.0</u>.

Note 2: The reduction effects are represented as those relative to the baseline emissions. Some of the sectors, e.g., transportation sector, greatly reduce emissions even in Baseline.

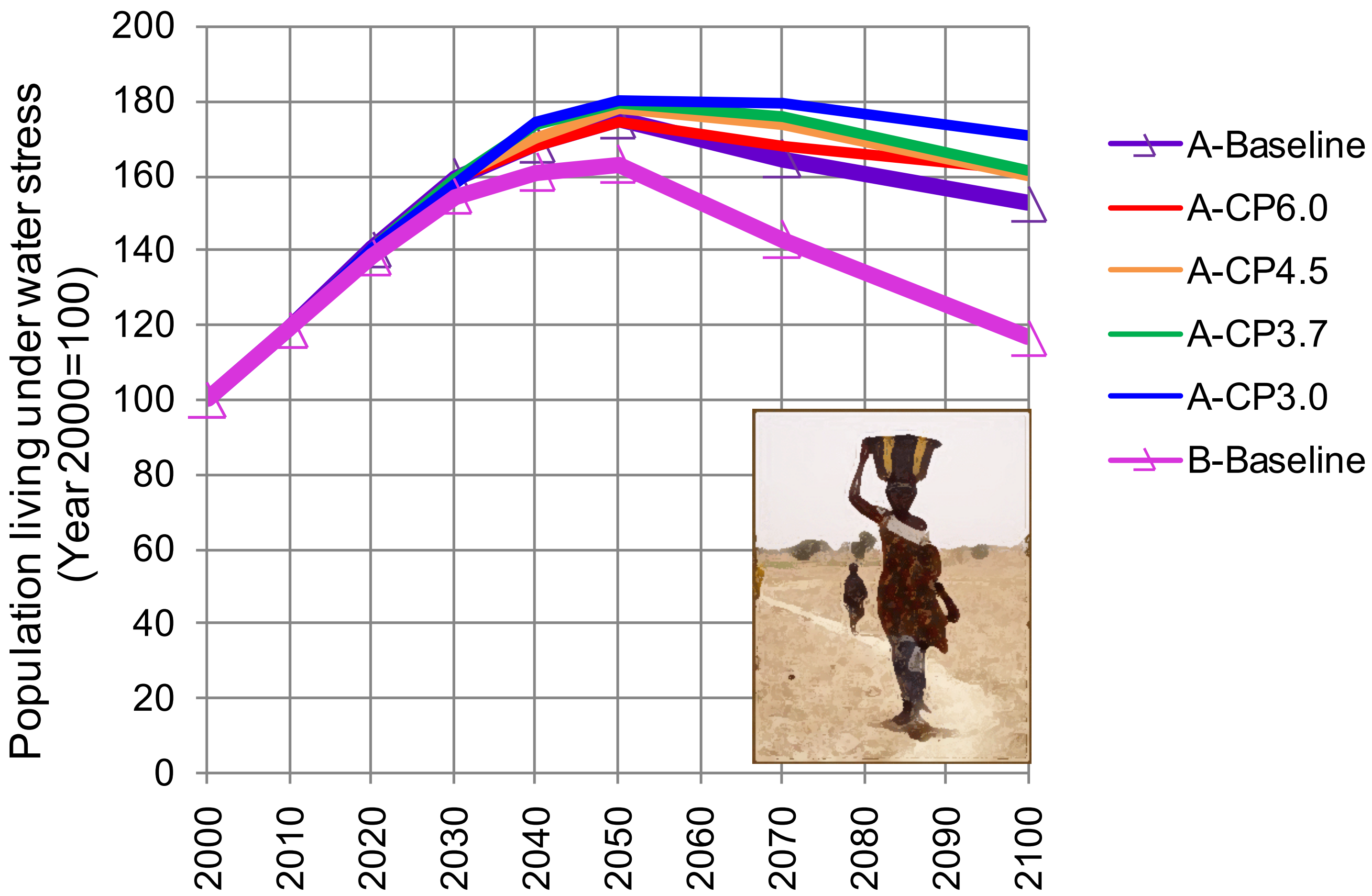
People Living in Poverty



Note: Constant and variant international poverty lines are adopted by using the poverty thresholds of income at constant 1.25$/day ('C') and at 1.25-2.83$/day affected by oil price increase ('V'), respectively.

People living in poverty will decrease drastically in the future, particularly in Asian regions. However, if the poverty threshold increases due to global social conditions, the decrease will be smaller. The people in CP3.0 will be slightly higher than in other emission scenarios.

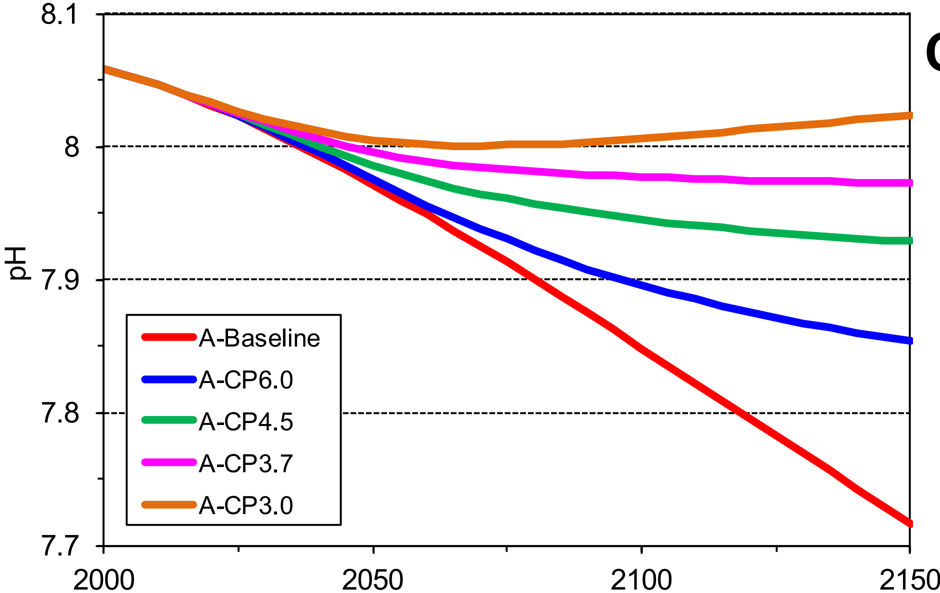
People Living under Water Stress



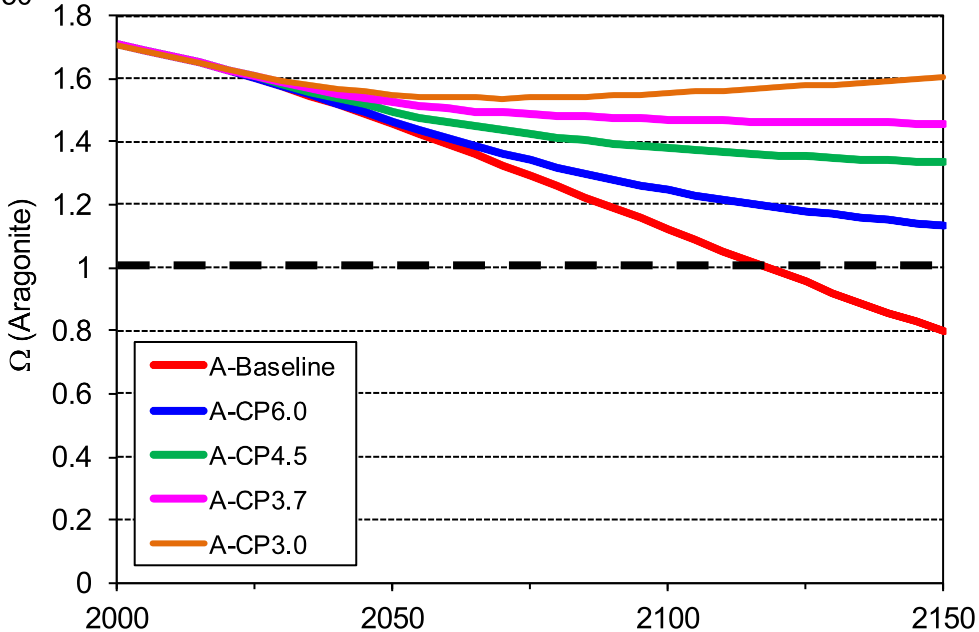
People under water stress will increase in the world mainly due to population increase and be about 80% increase relative to the 2000 level. GHG emission cuts will not contribute to the mitigation of the stress. The water stress decreases after 2050 in the Scenario B mainly due to population decrease.

Ocean Acidification

Change in pH



Saturation state of Aragonite (N60°)

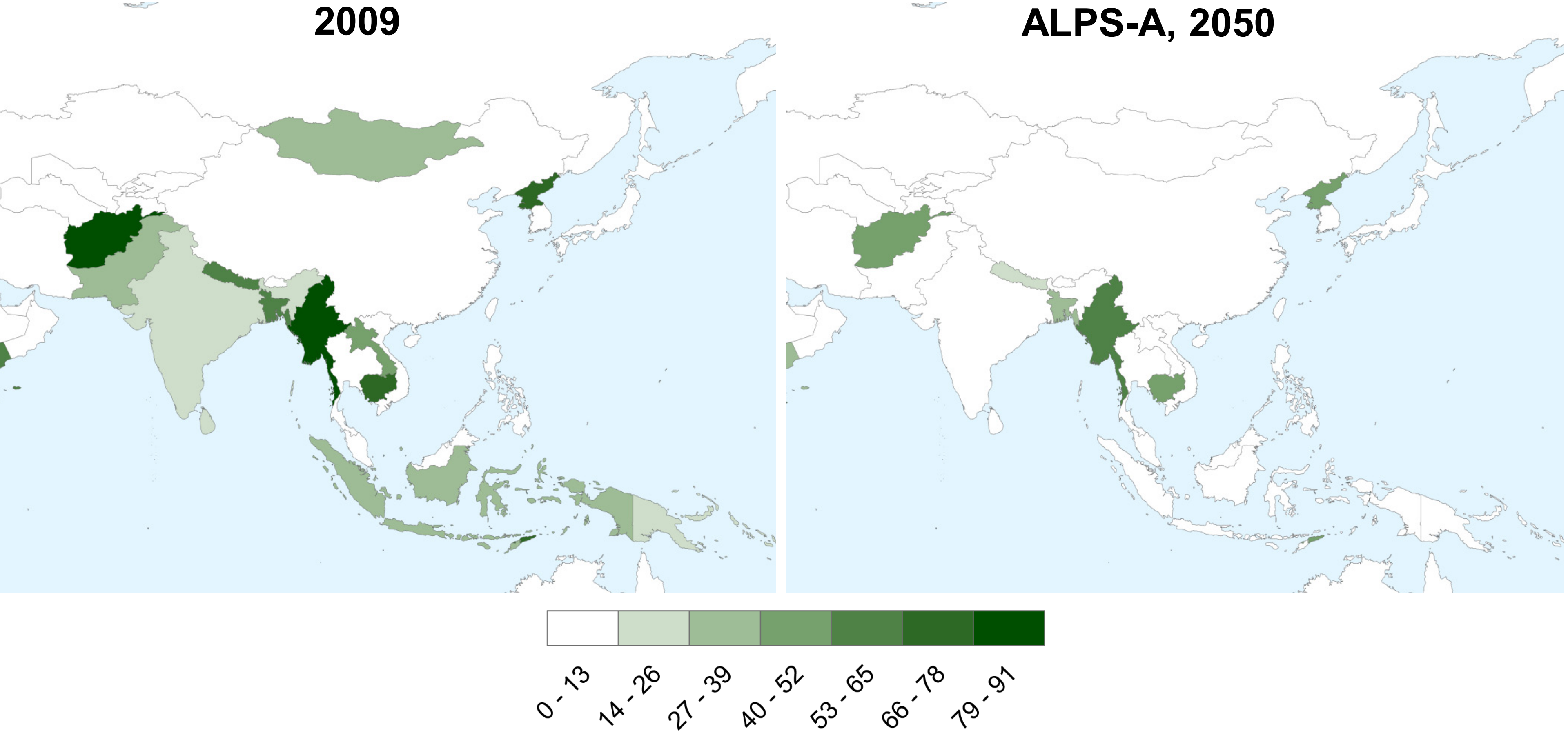


Aragonite which consists of $CaCO_3$ is undersaturated after 2100 in N60° sea under Baseline emissions.

Analyses on Energy Access and Energy Security

Modern Energy Access: Electricity

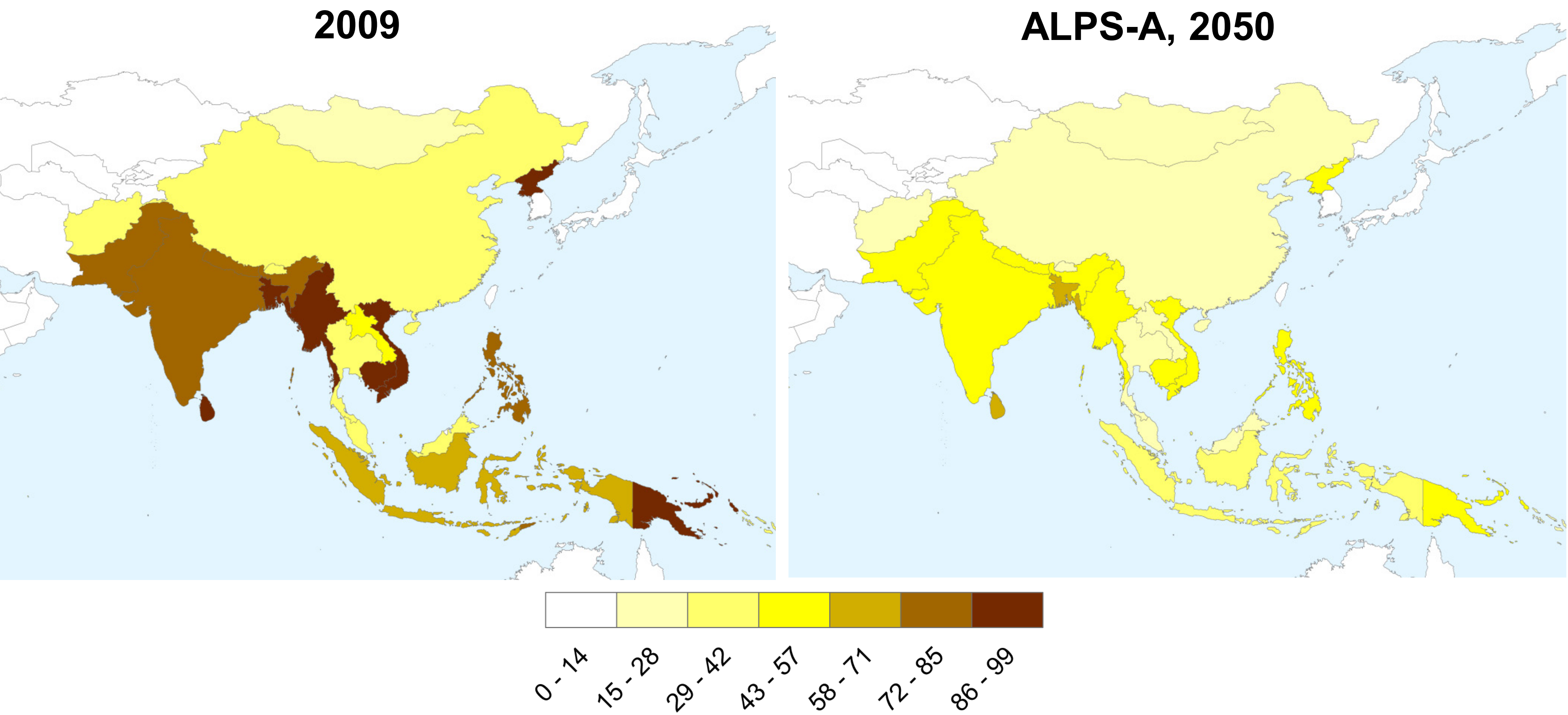
Without access to electricity (%)



- Access to electricity will improve in many Asian countries, while it is still a challenging issue in 2050 only for some countries.

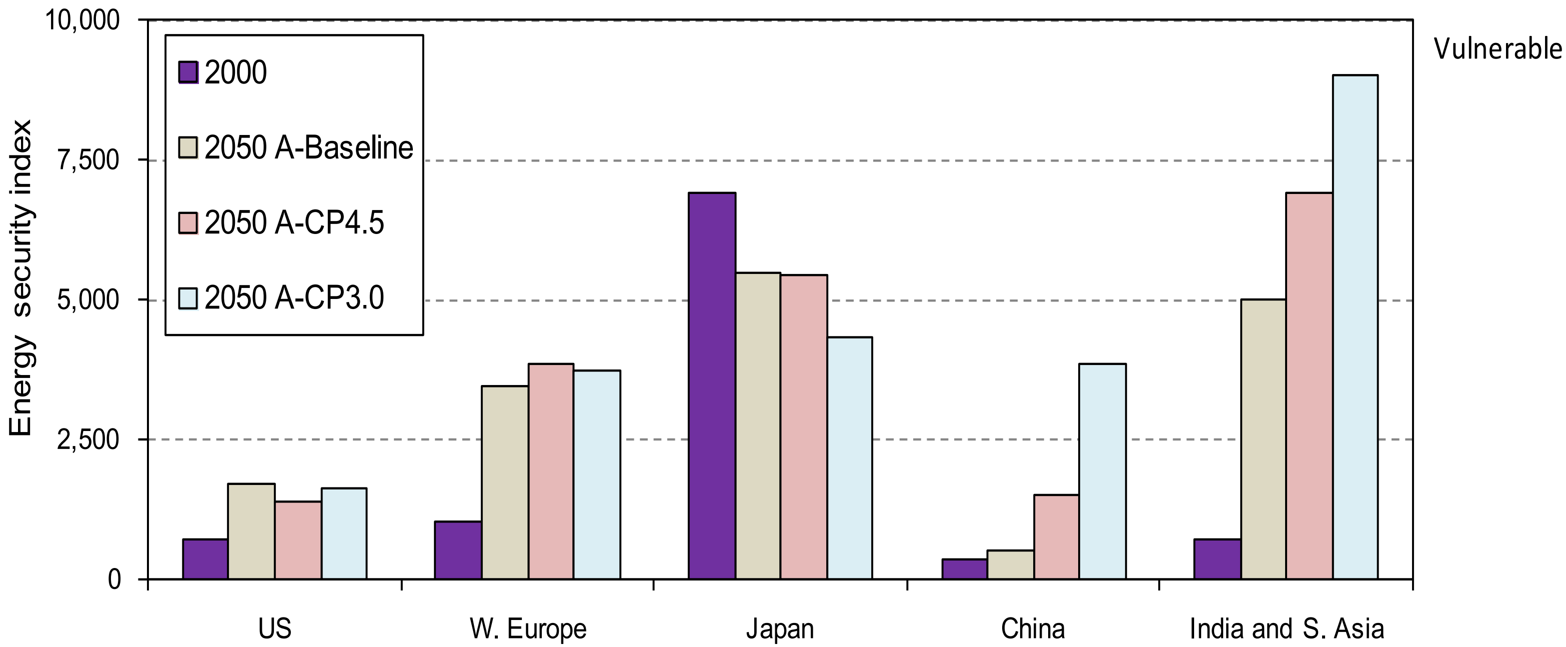
Modern Energy Access: Traditional biomass use

Without modern cooking facilities (%)
[People relying on the traditional use of biomass for cooking (%)]



- Traditional biomass use for cooking harms healths and avoids economic activities. The use in Asian countries will reduce toward 2050, but will be a challenging issue even in 2050 for some countries

Assessment of Energy Security
– For Different levels of concentration –



$$ESI = \frac{c_{oil}}{TPES}\sum_i \left(r_i \cdot S_{i,oil}{}^2\right) + \frac{c_{gas}}{TPES}\sum_i \left(r_i \cdot S_{i,gas}{}^2\right)$$

Share of imported oil in TPES — Political risks of region i — Dependence on region i

ESI : energy security index, TPES: total primary energy supply
Note: index based on IEA, 2007

While the energy security index of Japan decreases (less vulnerable) for CP3.0, that of China, India increases (more vulnerable) for deeper emission reductions due to increase in imported gas shares.