Energy Mix Change and Energy Security Improvement through Climate Change Mitigation

-Analysis of the RCP Cases-

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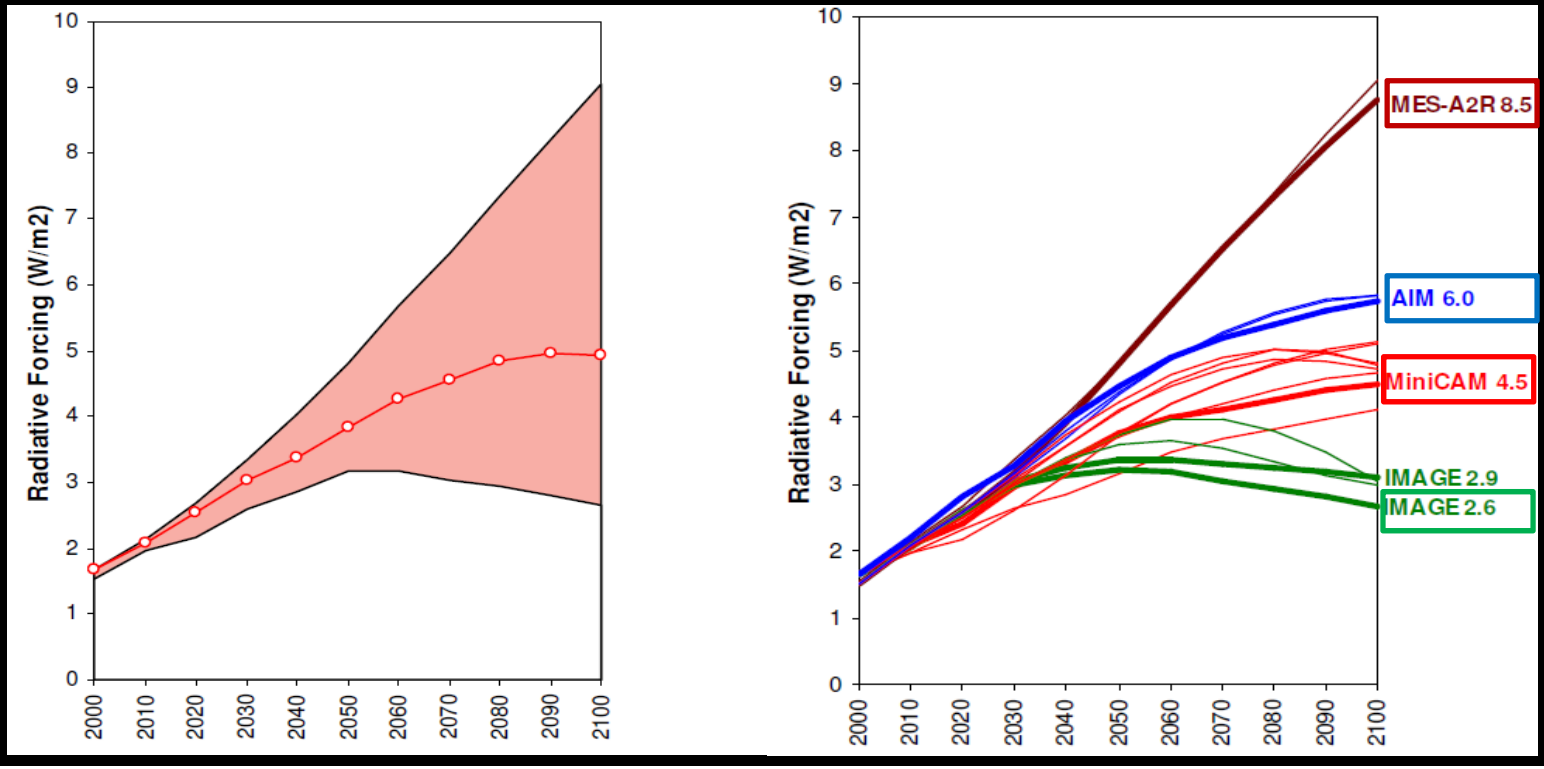
Representative Concentration Pathways (RCPs)

- The IPCC requested the preparation of a new set of scenarios to facilitate future assessment of climate change. This new set should be compatible with the full range of stabilization, mitigation and baseline emission scenarios available in the current scientific literature. The IPCC also decided that the research community itself would undertake development of scenarios for AR5, while the IPCC's role would be that of catalyzing and assessing such work.
- The research community has outlined three phases of scenario development: a preparatory phase and two main phases of scenario development. In the preparatory phase, four concentration and emissions scenarios will be chosen from the existing literature and provided to climate modelers. These scenarios are referred to as "*representative concentration pathways*" (RCPs). These scenarios will be used to produce a new set of climate model simulations that will subsequently used for mitigation, impacts, adaptation, and vulnerability analysis. The primary goal of the RCPs is to provide, the most up to date scenarios possible to be used to produce these new climate model simulations.

To Summarize RCPs…

- Representative Concentration Pathways
- Pre-scenarios to develop new scenarios for AR5
- Input for climate models and basis for development of socioeconomic scenarios
- The data are provided not only in the regional scale but also in the spatial scale (0.5 x 0.5 degrees) for gases emissions and land-use change.
- Four RCPs exist and each one scenario is analyzed by one modeling team.

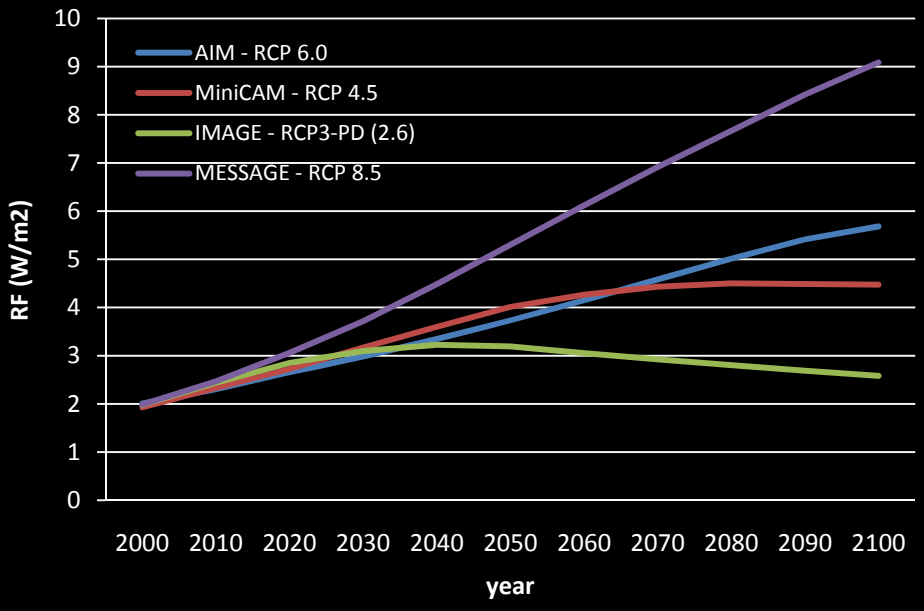
Selection of RCPs



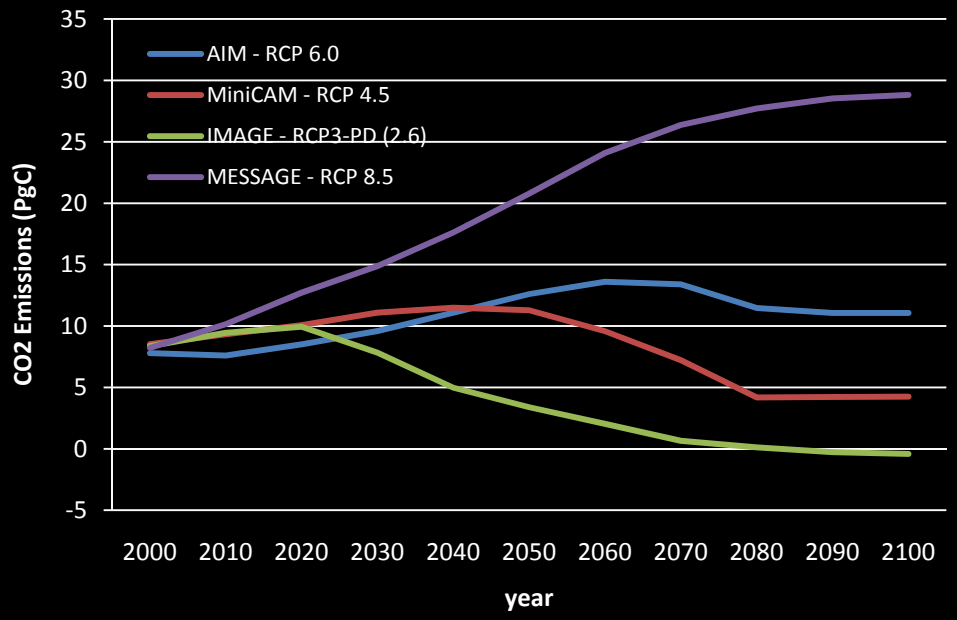
Name	Radiative Forcing	Concentration	Pathways Shape
RCP8.5	8.5W/m^2 (in 2100)	<= ~1370ppm CO_2-eq	Rising
RCP6.0	~6.0W/m^2 (stabilization after 2100)	~850ppm CO_2-eq	Stabilization without overshoot
RCP4.5	~4.5W/m^2 (stabilization after 2100)	~650ppm CO_2-eq	Stabilization without overshoot
RCP3-PD	< 3W/m^2 (peak and decline) ⇒ 2.6W/m^2	< ~490ppm CO_2-eq	Peak & decline

Source: Moss et al. (2008) revised

Four RCPs: RF and CO2 Emissions

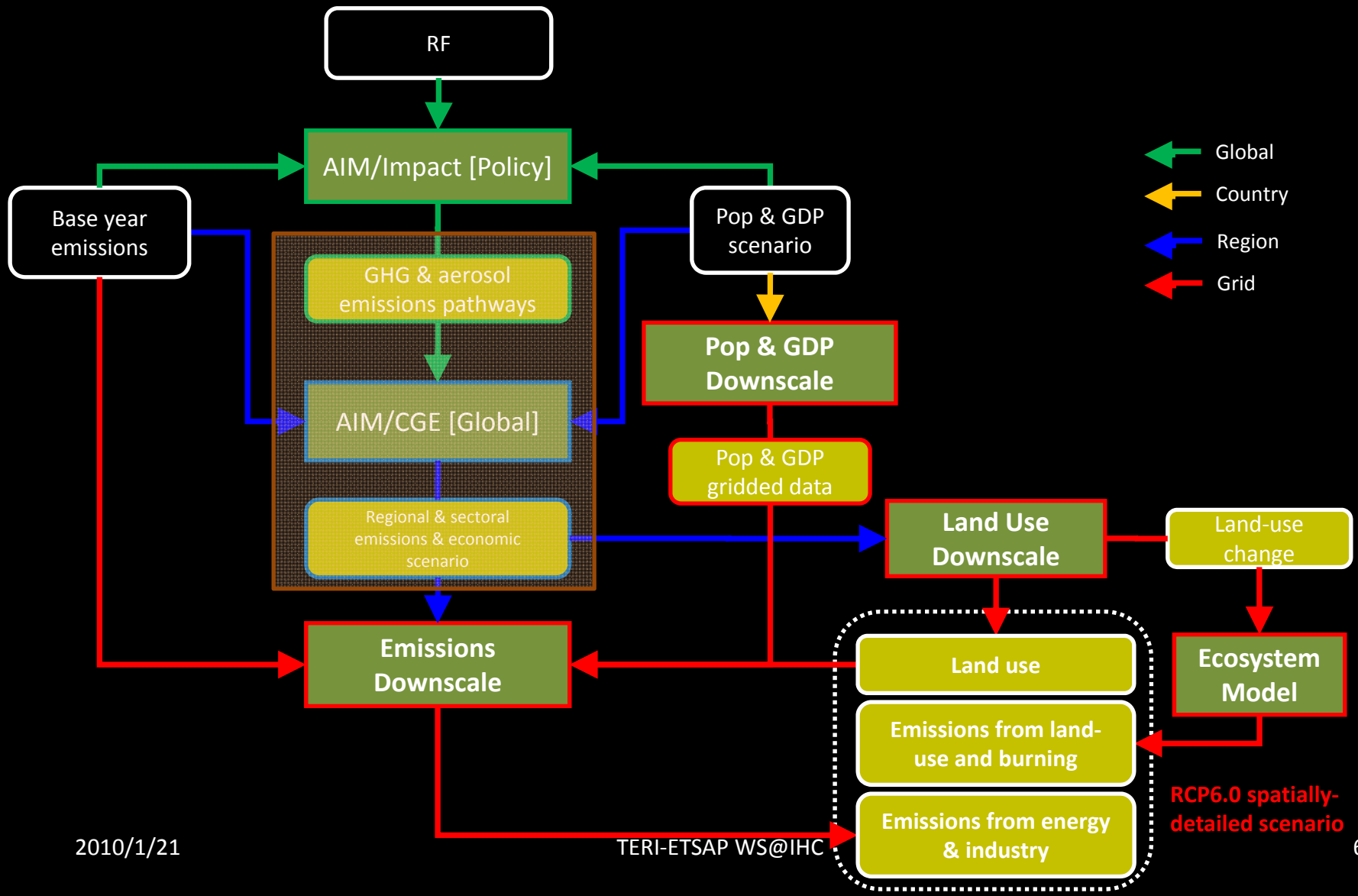


Radiative forcing 2000-2100



CO2 emissions 2000-2100

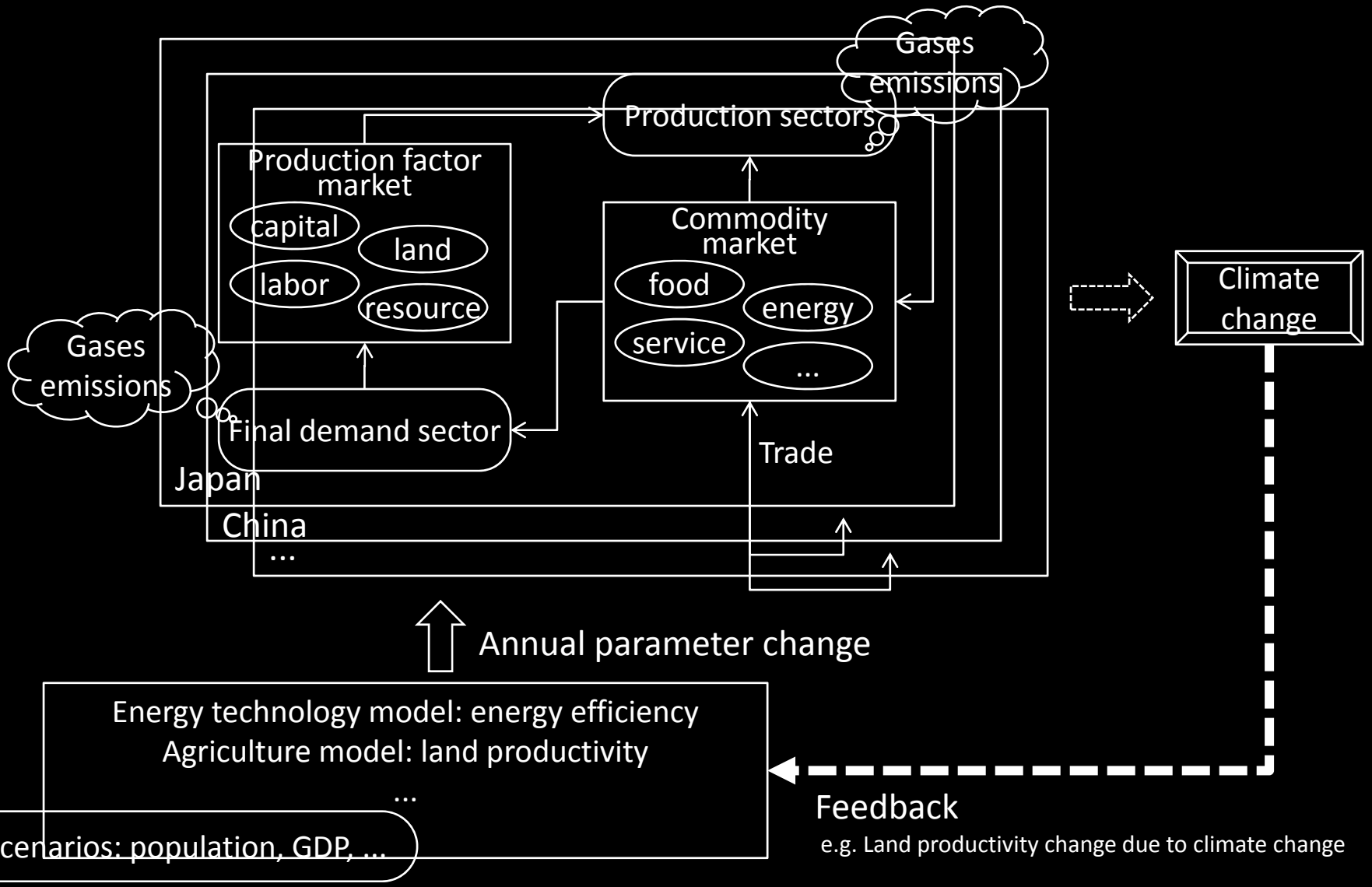
Flow of Analysis by AIM



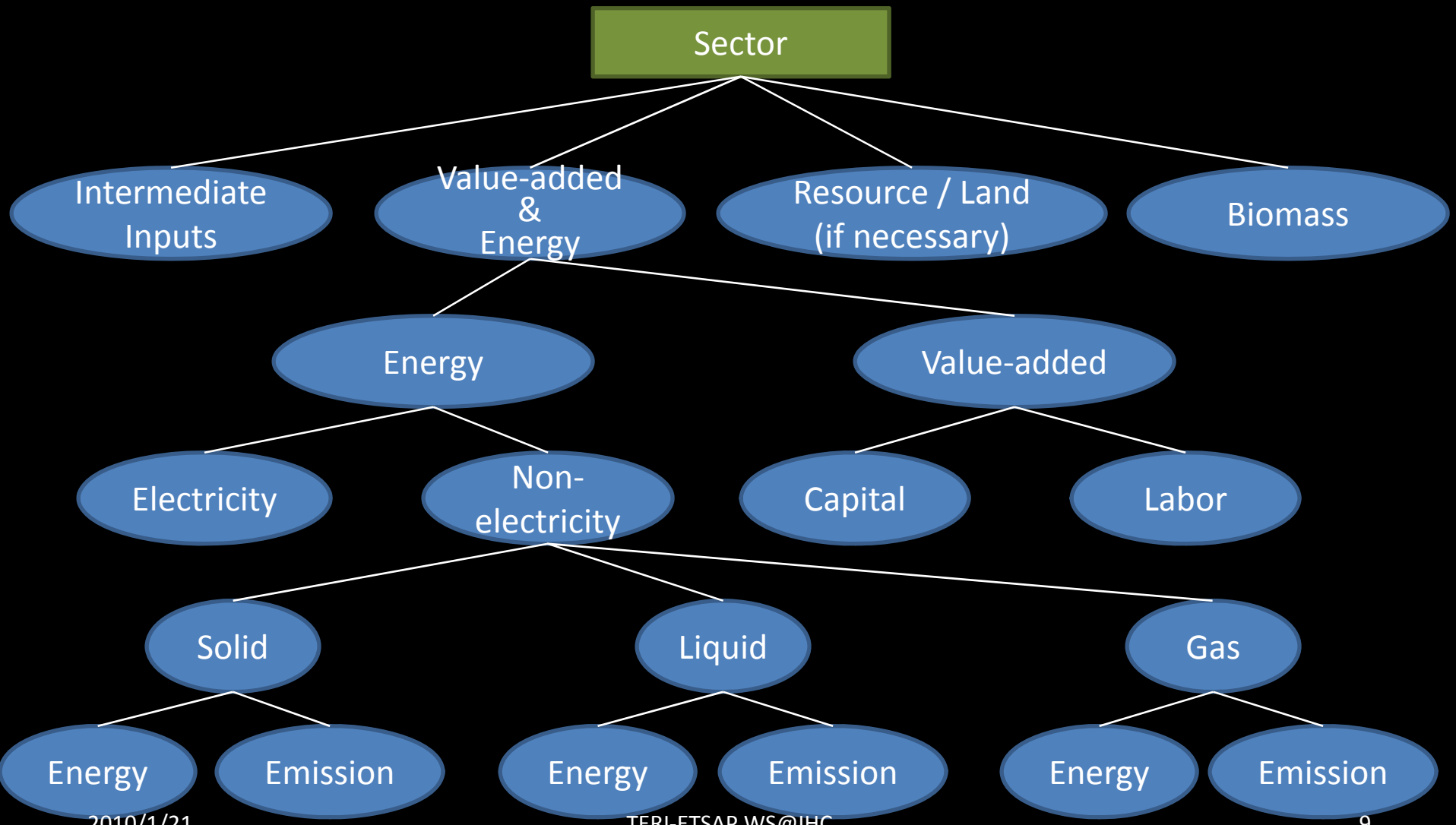
Overview of the AIM/CGE [Global] Model

- The main purpose: analysis of climate change issues/policies
- Type: multi-sector/multi-region recursive dynamic global CGE model (21 sectors, 24 world regions, 4 production factors)
- Gases: CO2, CH4, N2O, SO2, NOx, CO, NMVOC, NH3, BC, OC
- Energy
  - Sectors: coal, oil, natural gas, oil products, gas, electricity, (biomass)
  - Power generation: thermal powers, nuclear, renewables (hydro, biomass, waste, geothermal, solar, wind, others), CCS technology
  - Upper bound on the supply and potential amount of each renewable energy
  - The relationship between cumulative extraction amount and extraction cost for fossil fuels extraction
- Two types of Capital: existing and new
- Investment for new capital: acceleration principle
- Future scenarios: population, expected GDP, efficiency improvement, upper bound on energy resources, etc

Model Structure



Production Function



Industrial Sectors

Energy Sectors

Table: 21 Industrial Sectors

Code	Including Sectors	Code	Including Sectors
COA	Coal	OMN	Other mineral mining
OIL	Crude oil	M_M	Metals & manufacture
GAS	Natural gas	FOD	Food processing
P_C	Petroleum & coal products	OMF	Other manufacture
GDT	Gas manufacture & distribution	CNS	Construction
ELY	Electricity	TRT	Transportation
AGR	Agriculture	CMN	Communication
LVK	Livestock	WTR	Water
FRS	Forestry	OSG	Governmental services
FSH	Fishery	SER	Other services
EIS	Energy intensive industries		

with Land

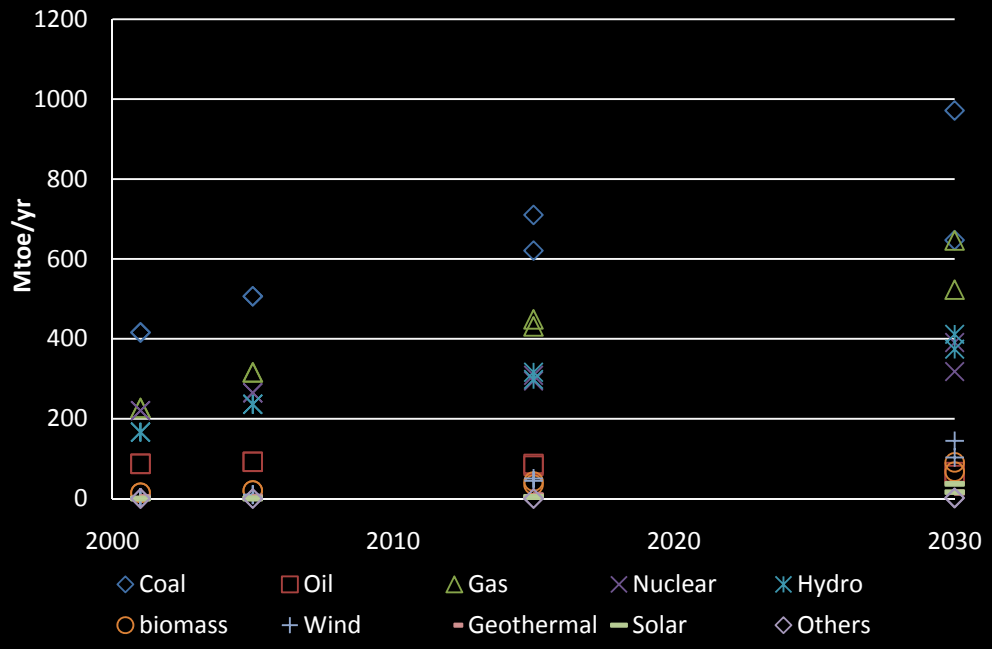
with Resources

World Regions

Table: 24 Regions

Code	Including Countries	Code	Including Countries
AUS	Australia	XRA	Rest of Asia-pacific
NZL	New Zealand	IDN	Indonesia
JPN	Japan	THA	Thailand
KOR	Korea	XSE	Rest of Southeast Asia
CAN	Canada	IND	India
USA	USA	XSA	Rest of South Asia
MEX	Mexico	ARG	Argentina
XE15	Western EU countries	BRA	Brazil
RUS	Russia	XLM	Rest of Latin America
XE10	Eastern EU countries	XME	Rest of Middle East
XRE	Rest of Europe	ZAF	South Africa
CHN	China & Hong Kong	XAF	Rest of Africa

Limits on Energy Supply



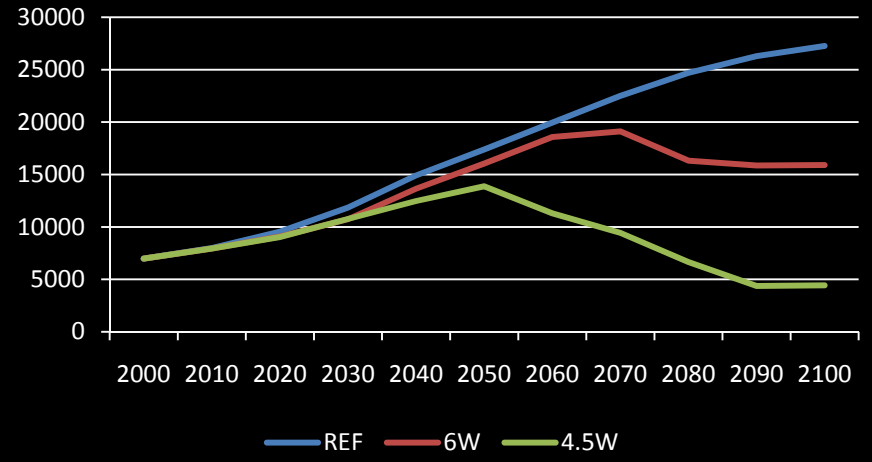
- Upper bounds of supply of renewables up to 2030 are set to be the projections of the IEA World Energy Outlook (reference and policy cases). After 2030, the trends are extended, but not exceeding their potential.

Framework of Analysis

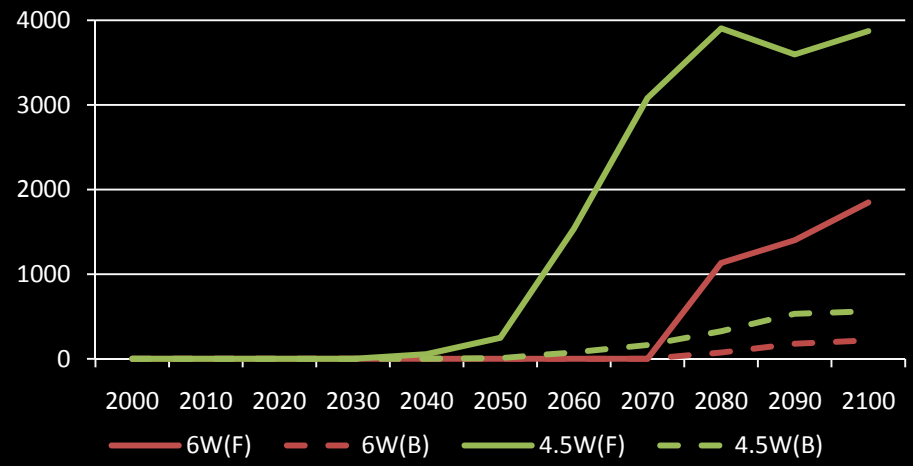
- The AIM/CGE [Global] model
- Population and expected GDP are given.
- Technology changes including energy and land productivity are also given.
- For reference case, there are no constraints on gases emissions. On the other hand, the emissions pathways are given for RCP scenarios (6.0W/m2 and 4.5W/m2 will be shown).
- Time period: 2000-2100

- Mainly observing energy aspects for this presentation.

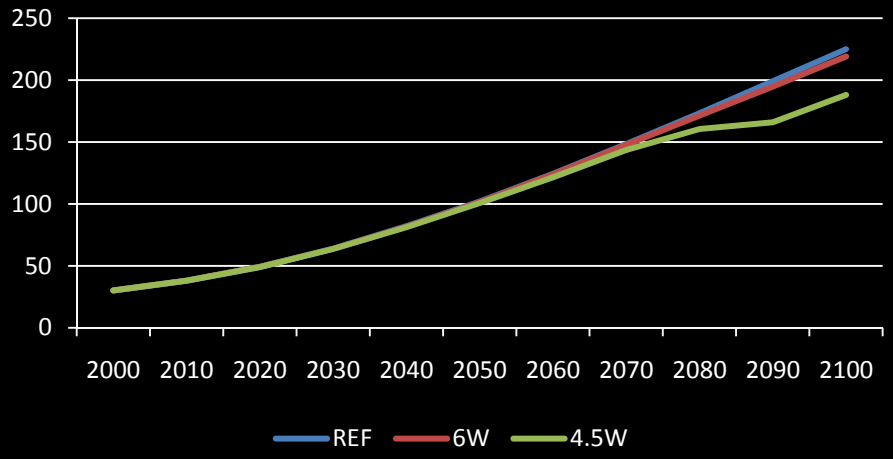
CO2, GDP, & Population



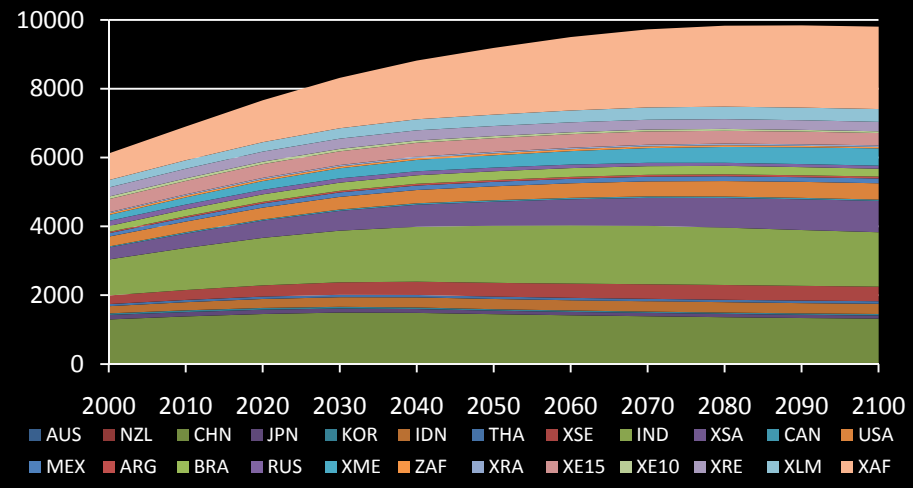
CO2 emissions from fossil fuels & industry (TgC/yr)



CCS Technology (TgC/yr)

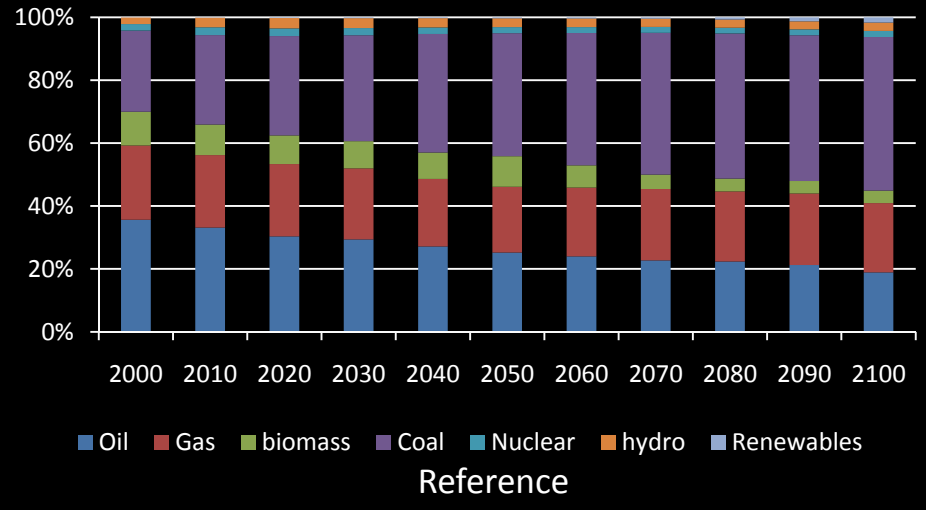


GDP (tri. US$2000)

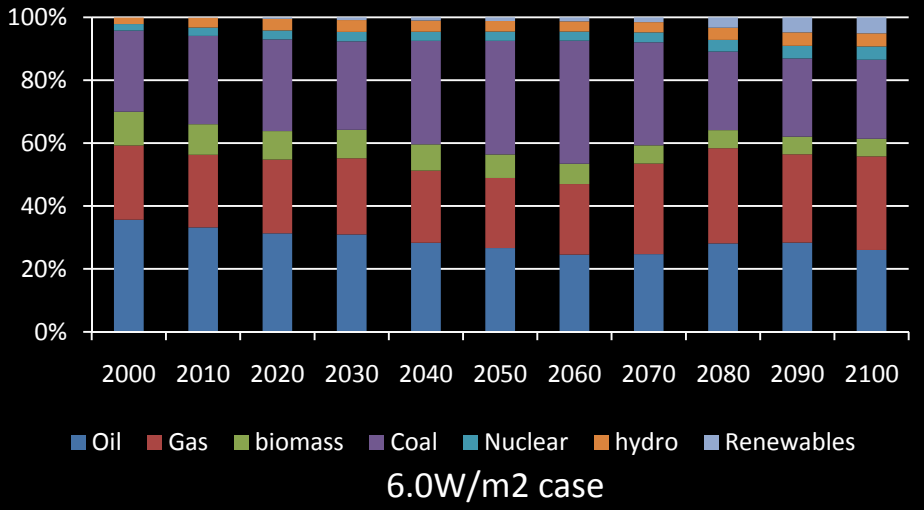


Population (mil)

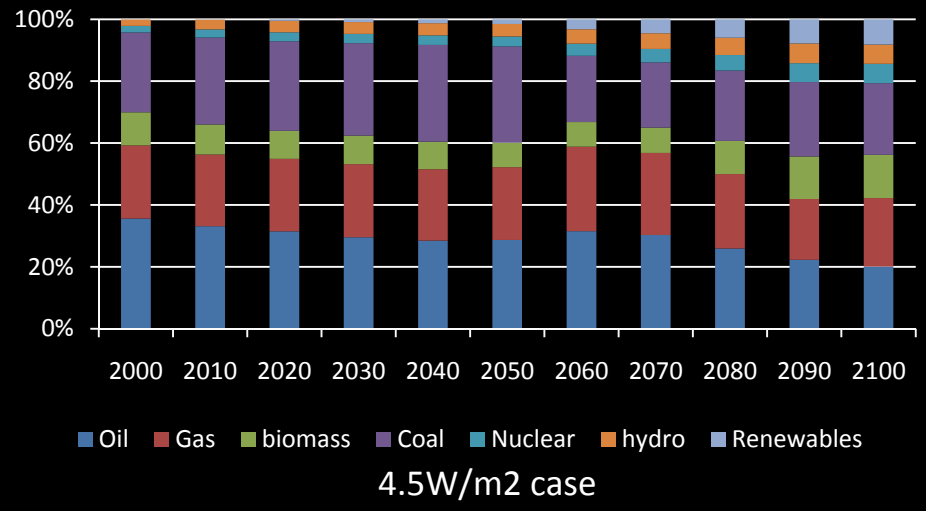
Energy Mix (Primary Energy: EJ)



Reference



6.0W/m2 case

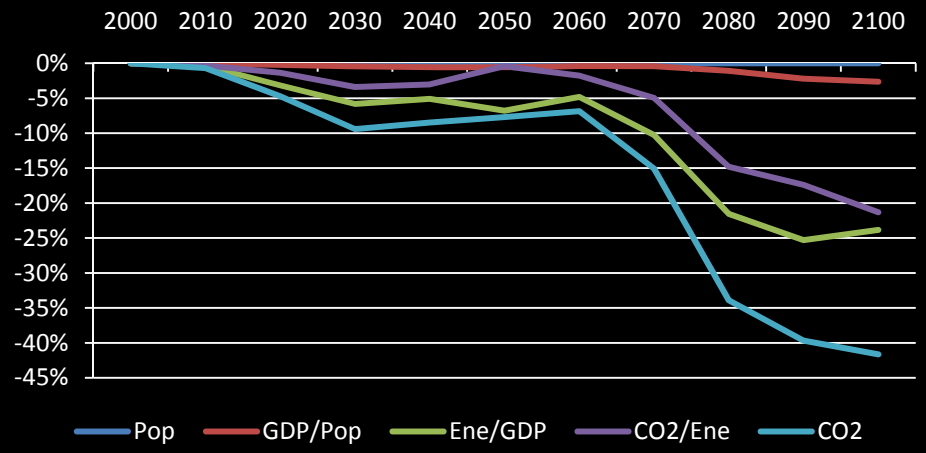


4.5W/m2 case

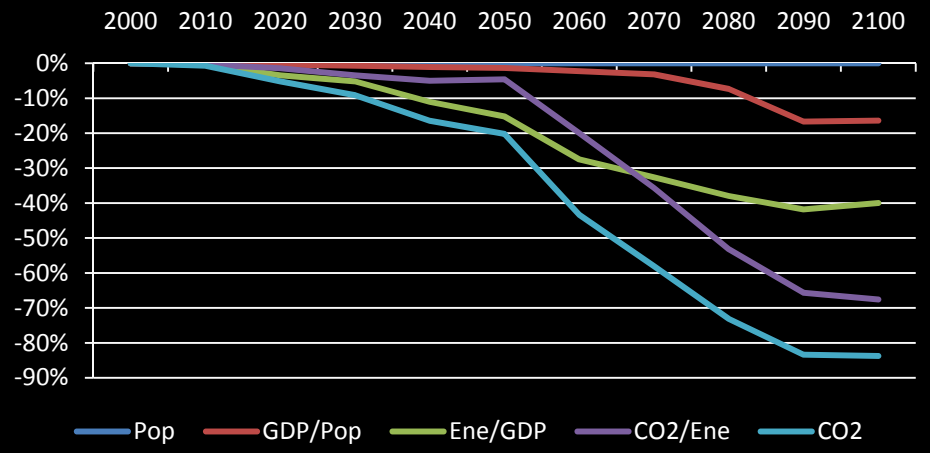
- The totals in 2100 are 1189EJ (REF), 881EJ (6.0W/m2), and 596EJ (4.5W/m2).
- The lower the emissions, the lower the ratio of fossil fuels and the higher that of biomass and renewables.
- Renewables are basically domestic sources.

Kaya Identity (Changes from Reference)

- CO2 = Population * GDP/Population * Energy/GDP * CO2/Energy

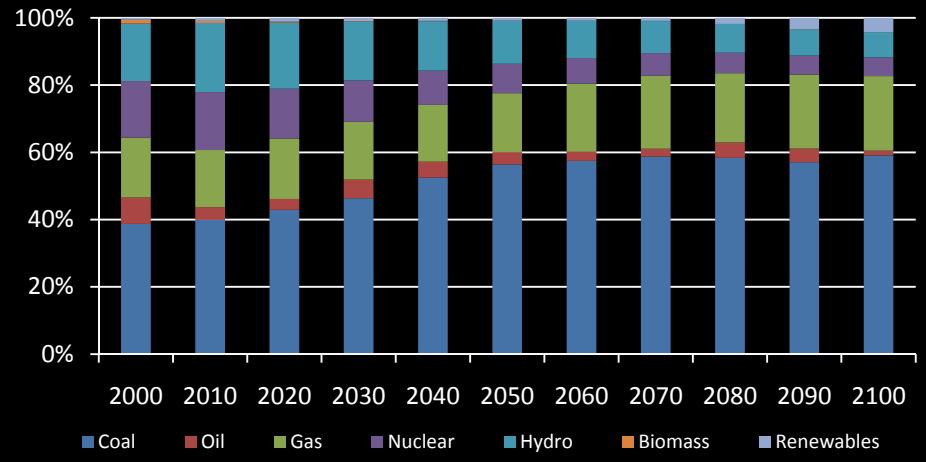


6.0W/m2 case

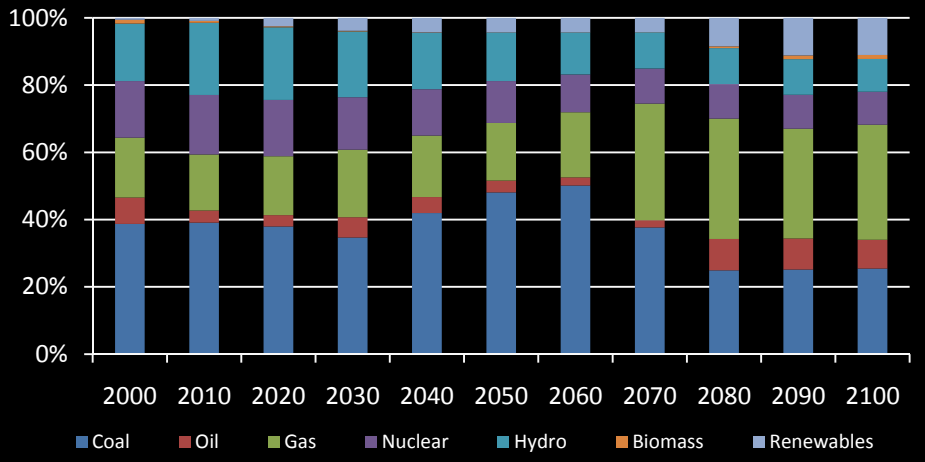


4.5W/m2 case

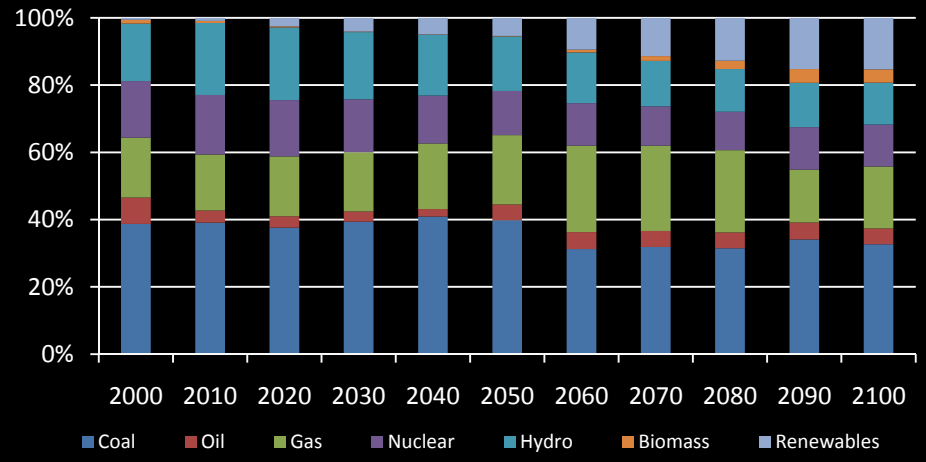
Power Generation Compositions (EJ)



Reference



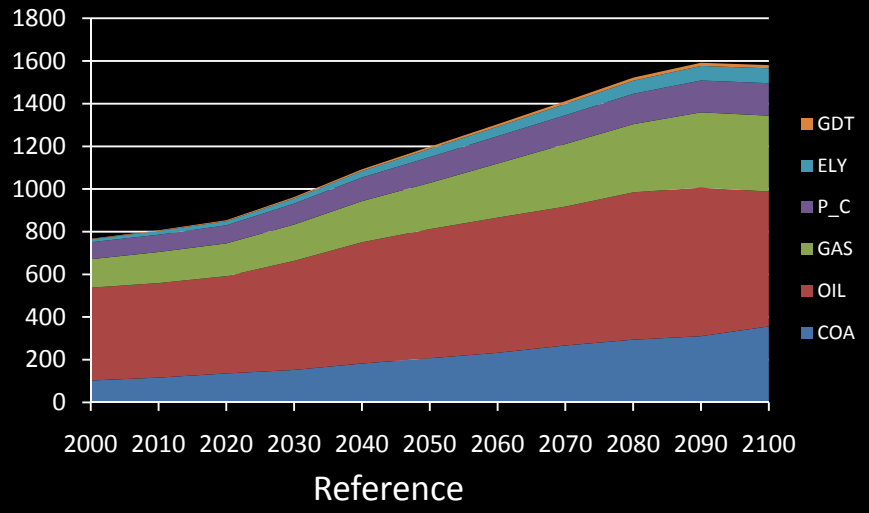
6.0W/m2 case



4.5W/m2 case

- The totals in 2100 are 417EJ (REF), 379EJ (6.0W/m2), and 298EJ (4.5W/m2).
- The lower the emissions, the lower the ratio of fossil fuels and the higher that of biomass and renewables.
- The ratio of oil increases due to the relative price.

International Trade of Energy (Monetary)



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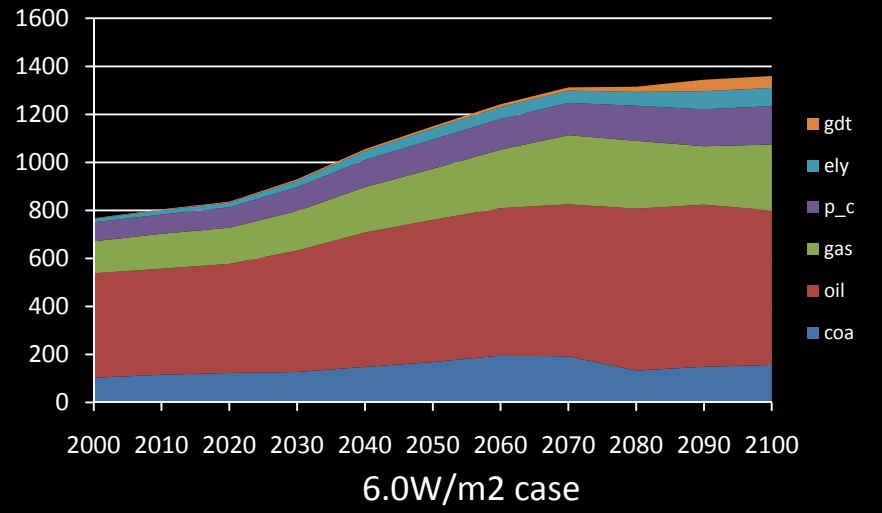
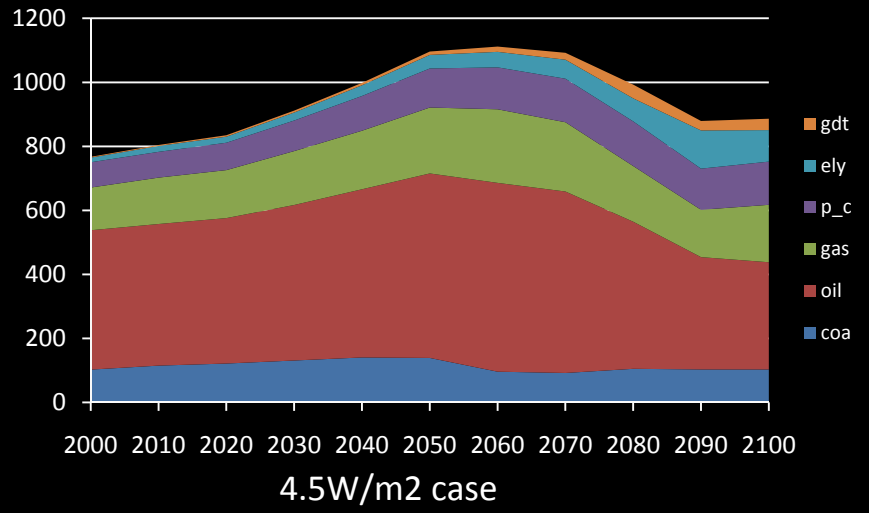


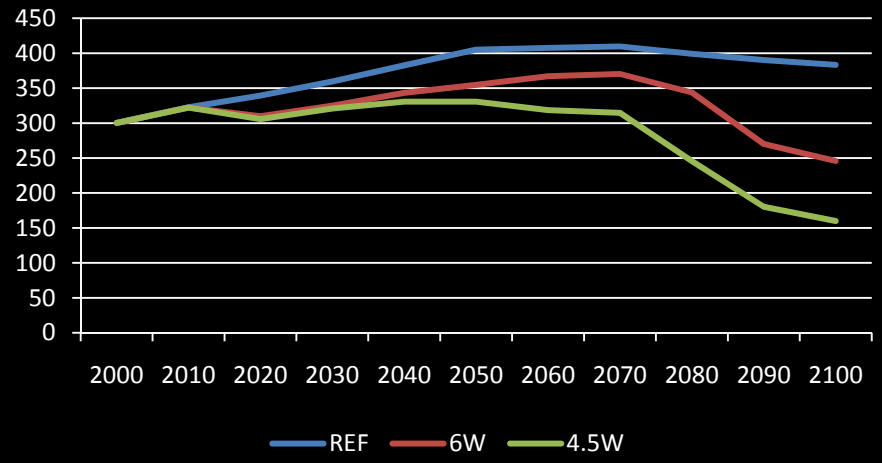
6.0W/m2 case



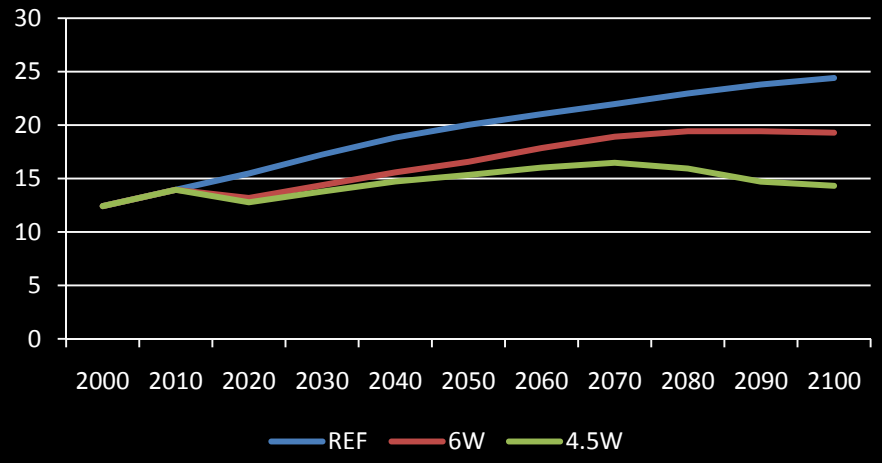
4.5W/m2 case

- In total, dependence on the trade decreases as CO2 abatement amount increases.
- This tendency is almost true for oil and gas.
- Change in the relative price is one of the most significant factor to determine the amount of trade.

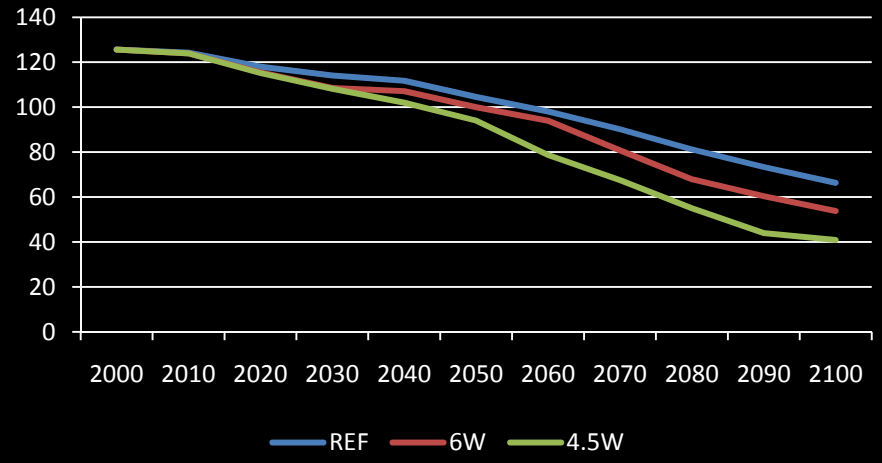
Co-benefits through CO2 Abatement



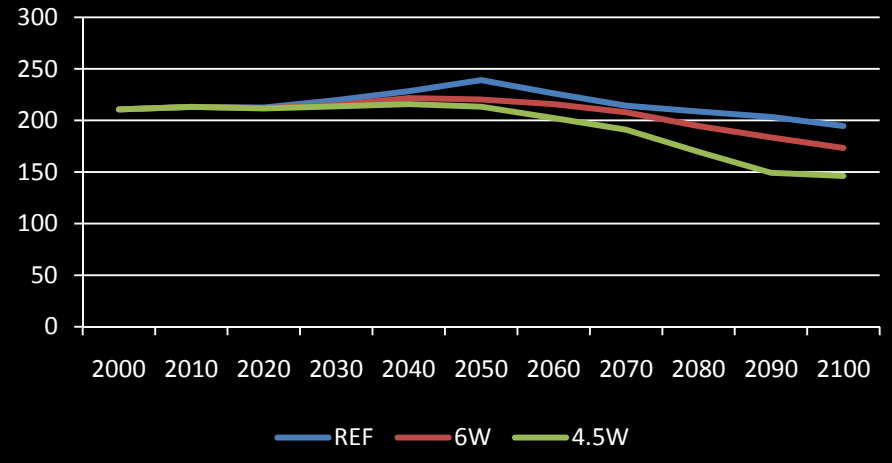
CH4 emissions (TgCH4/yr)



N2O emissions (TgN2O/yr)

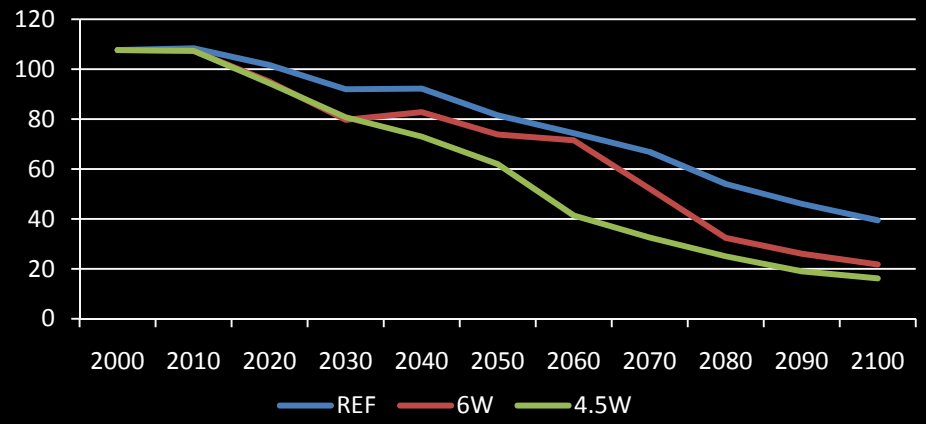


NOx emissions (TgNO2/yr)

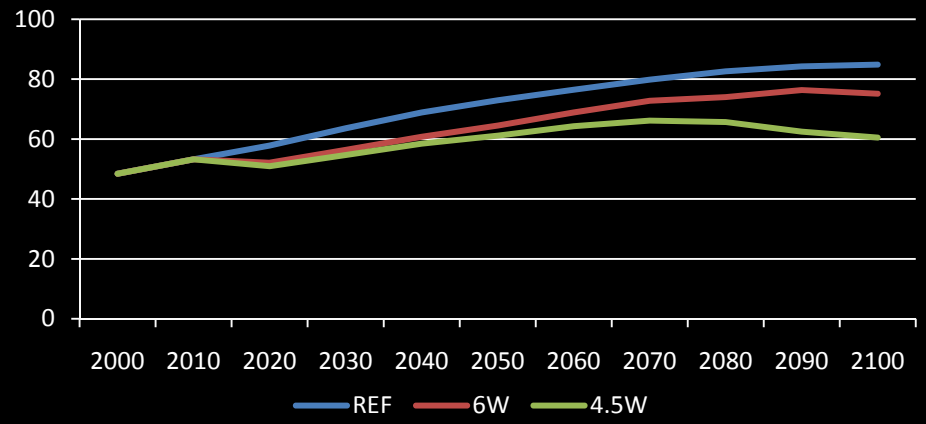


NMVOC emissions (Tg/yr)

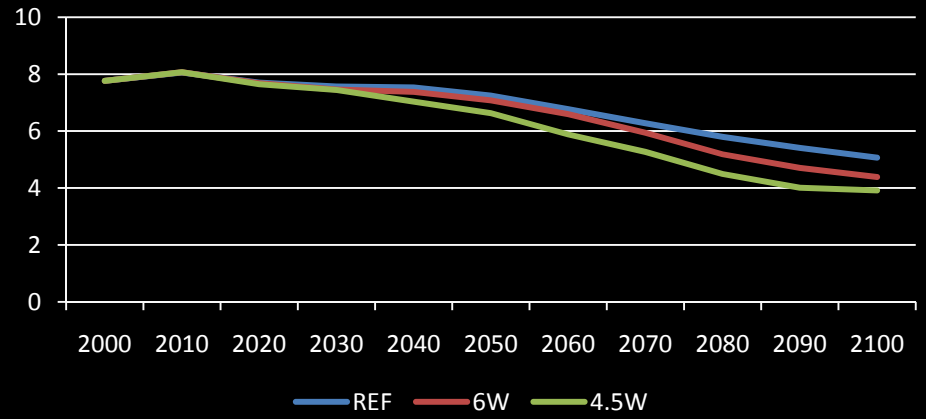
Co-benefits through CO2 Abatement



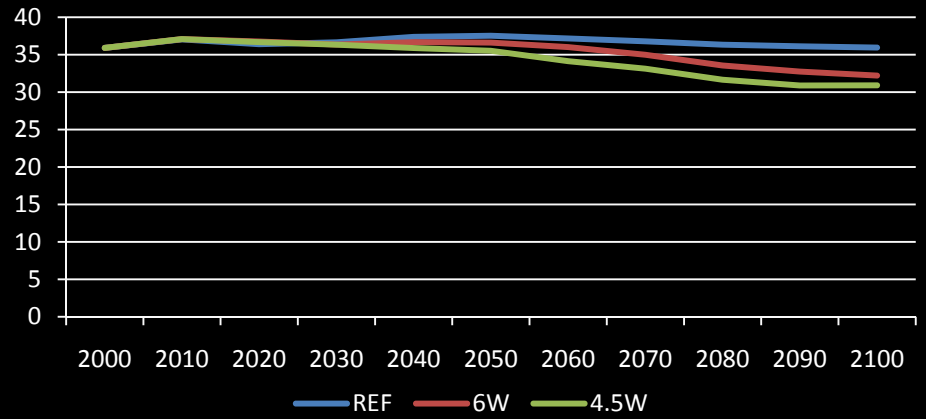
SO2 emissions (TgSO2/yr)



NH3 emissions (TgNH3/yr)



Black carbon emissions (Tg/yr)



Organic carbon emissions (Tg/yr)

- For all non-CO2 gases, lower emissions are observed in the case of higher CO2 emissions abatement amount.

Concluding Remarks

- Analysis applying the AIM/CGE [Global] model for the RCP cases (6.0W/m2 and 4.5W/m2) and results focused on energy security and co-benefit issues

- Energy security:
  - for primary energy, the ratio of fossil fuels decreases and that of renewables increases as the emissions become lower;
  - for power generation, the ratio of fossil fuels decreases and that of renewables increases as the emissions become lower as well;
  - the amount of trade of energy including all fossil fuels tends to decrease as the emissions become lower globally;
  - in regional basis, although net import of energy increases in some regions, the net import decreases in more regions as the emissions become lower;
  - the (relative) price is a significant factor to determine the energy composition;
  - as a result, energy security is expected to improve through CO2 emissions abatement.

Concluding Remarks

- Co-benefits:
  - non-CO2 gases emissions abatement is also observed through CO2 emissions abatement;
  - and the abatement amount becomes larger as CO2 abatement amount increases.