The Global ETSAP-TIAM Model: Features and Scenarios for a Low Carbon Society

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Overview

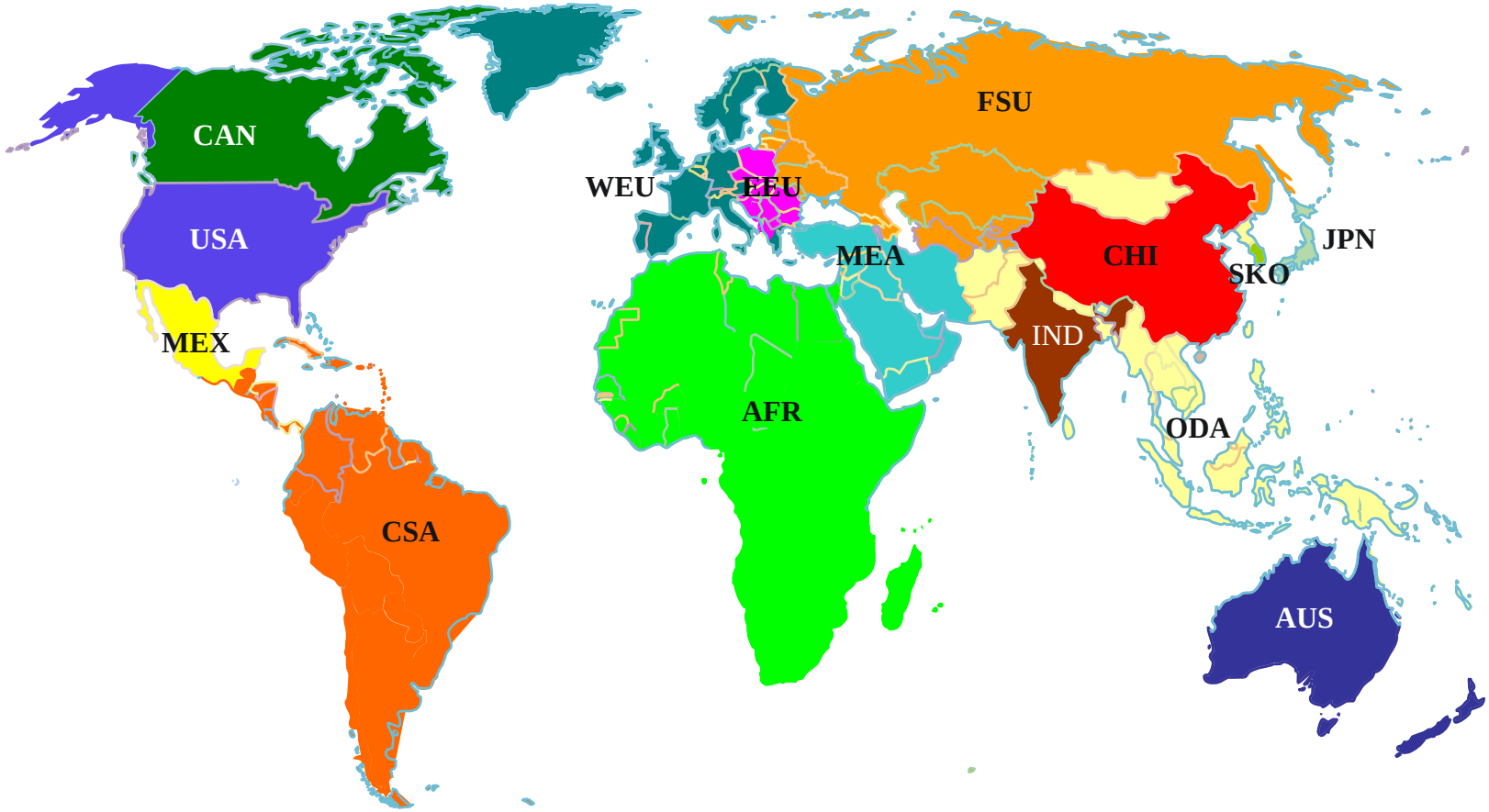
- ETSAP-TIAM model
  i. Model characteristics
  ii. Structure of the reference energy system
  iii. Additional features: Climate module
- Scenario analysis for a low-carbon society
- Conclusions & Outlook on future model developments

(other studies are reported at: http://www.etsap.org/applicationGlobal.asp or at http://www.etsap.org/Docs).

Analysis framework: ETSAP-TIAM Model

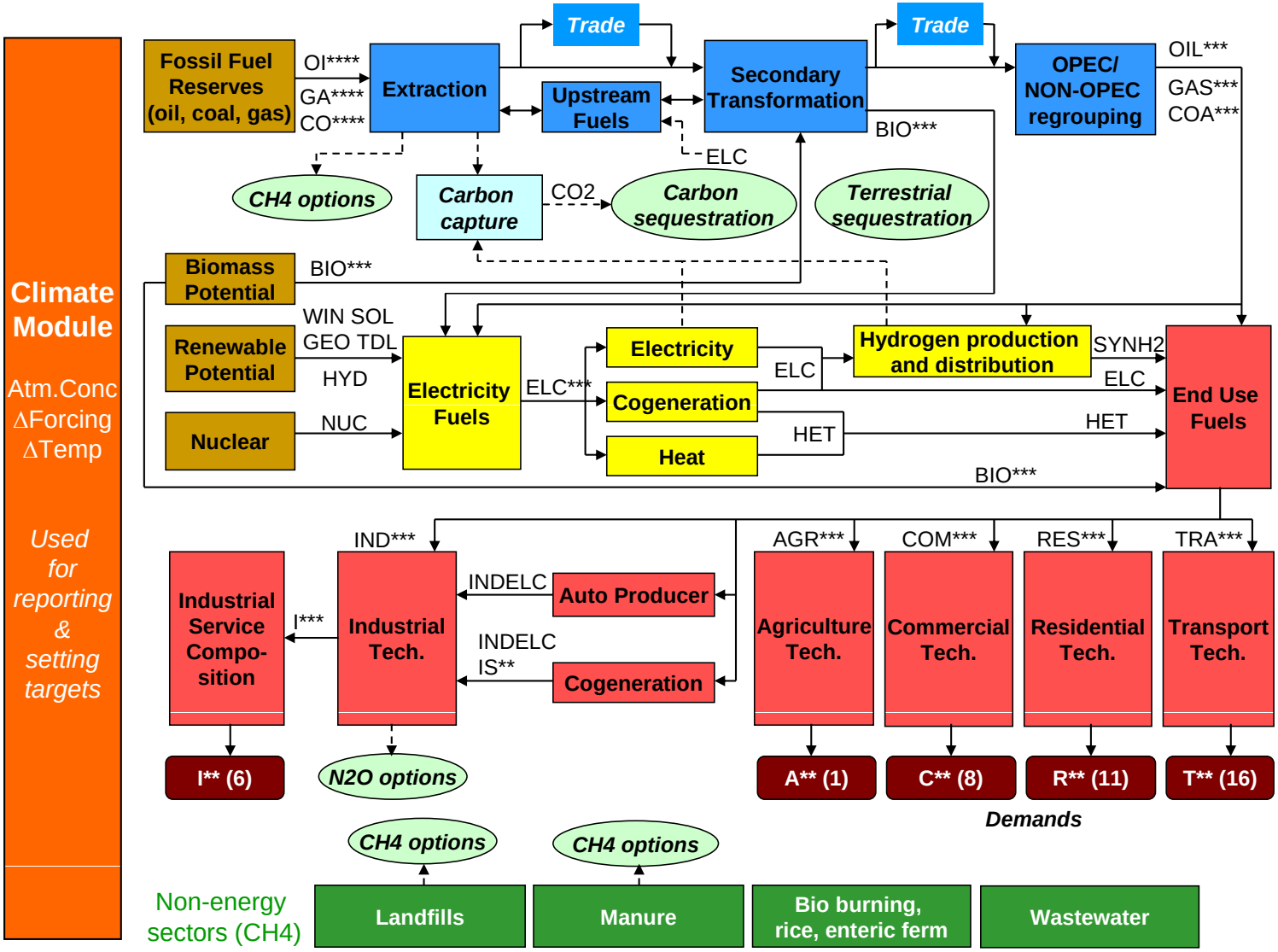
- ***T*IMES *I*ntegrated *A*nalysis *M*odel**
- **Based on TIMES model generator:**
  i. Developed by ETSAP (*E*nergy *T*echnology *S*ystems *A*nalysis *P*rogramme)
  ii. Dynamic partial equilibrium model approach with inter-temporal objective function minimizing total discounted system costs (alternative objective functions possible)
  iii. Clairvoyant or myopic approach with respect to foresight
  iv. Technologically detailed „bottom-up“ model for each region
  v. Covering energy flows from the useful energy demand over end-use sectors and conversion sector to the primary supply
- **Time horizon 2000 – 2100**
- **15 world regions:**
  i. Bilateral trade in hard coal, pipeline gas, LNG, crude oil, petroleum products (distillates, gasoline, heavy fuel oil and naphtha) and bio-ethanol
  ii. Global trade in emission permits possible
- **Emissions: CO_2, N_2O, CH_4**
  i. Carbon capture and sequestration (power generation and alternative fuel production)
  ii. Mitigation options for N_2O and CH_4
- **Climate module** (3-reservoir model for calculating atmospheric GHG concentrations and induced temperature changes)
- **Multi-stage stochastic programming** version to handle uncertainties, hedging strategies

TIAM model: Model regions

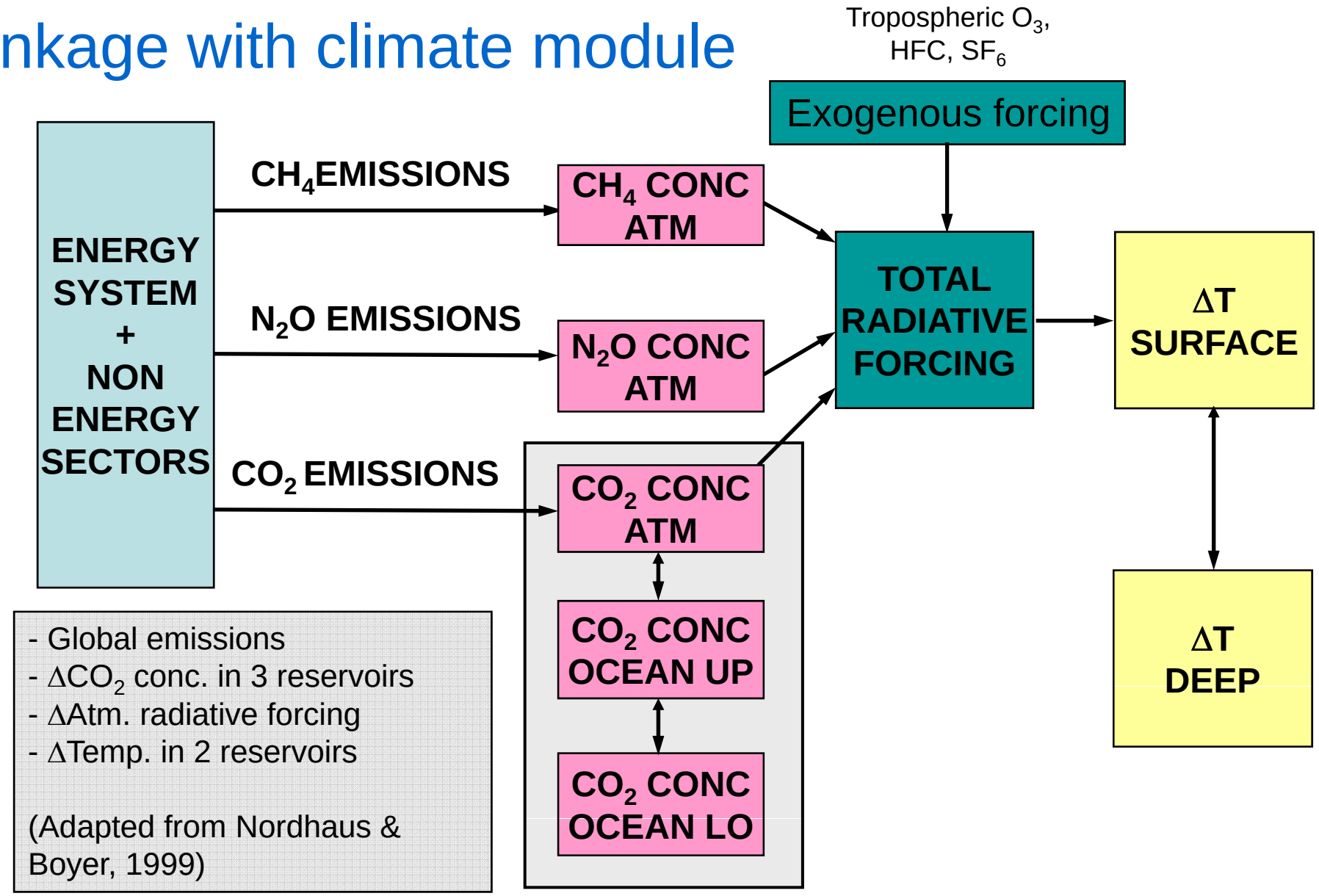


15 World regions:
CAN, USA, MEX, CSA (Central South America), WEU (Western Europe), EEU (Eastern Europe), MEA (Middle East), FSU (Former Soviet Union), CHI, IND, SKO (South Korea), JPN, ODA (Other Developing Asia), AUS (Australia+New Zealand)

Reference Energy System of TIAM



Linkage with climate module



- Global emissions
- ΔCO_2 conc. in 3 reservoirs
- ΔAtm. radiative forcing
- ΔTemp. in 2 reservoirs

(Adapted from Nordhaus & Boyer, 1999)

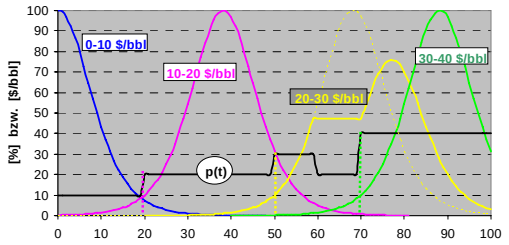
Linkage with oil market model

Cartel rent for crude oil,
Gas price linked to oil price

Oil market model LOPEX

Non-OPEC modul

Hubbert simulation



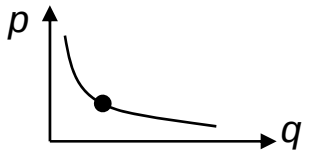
Oilprice

Iteration until convergence

Non-OPEC production

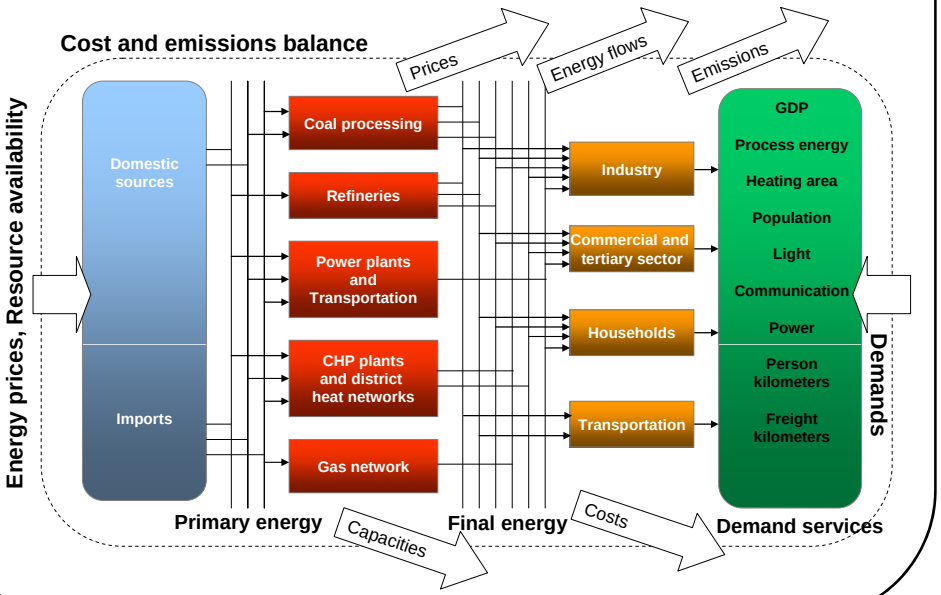
OPEC modul

$$[dem(P(t)) - nopt(t)] \leftrightarrow P(t)$$



Global energy system model

TIAM



Reference point (crude oil consumption and price) for demand function

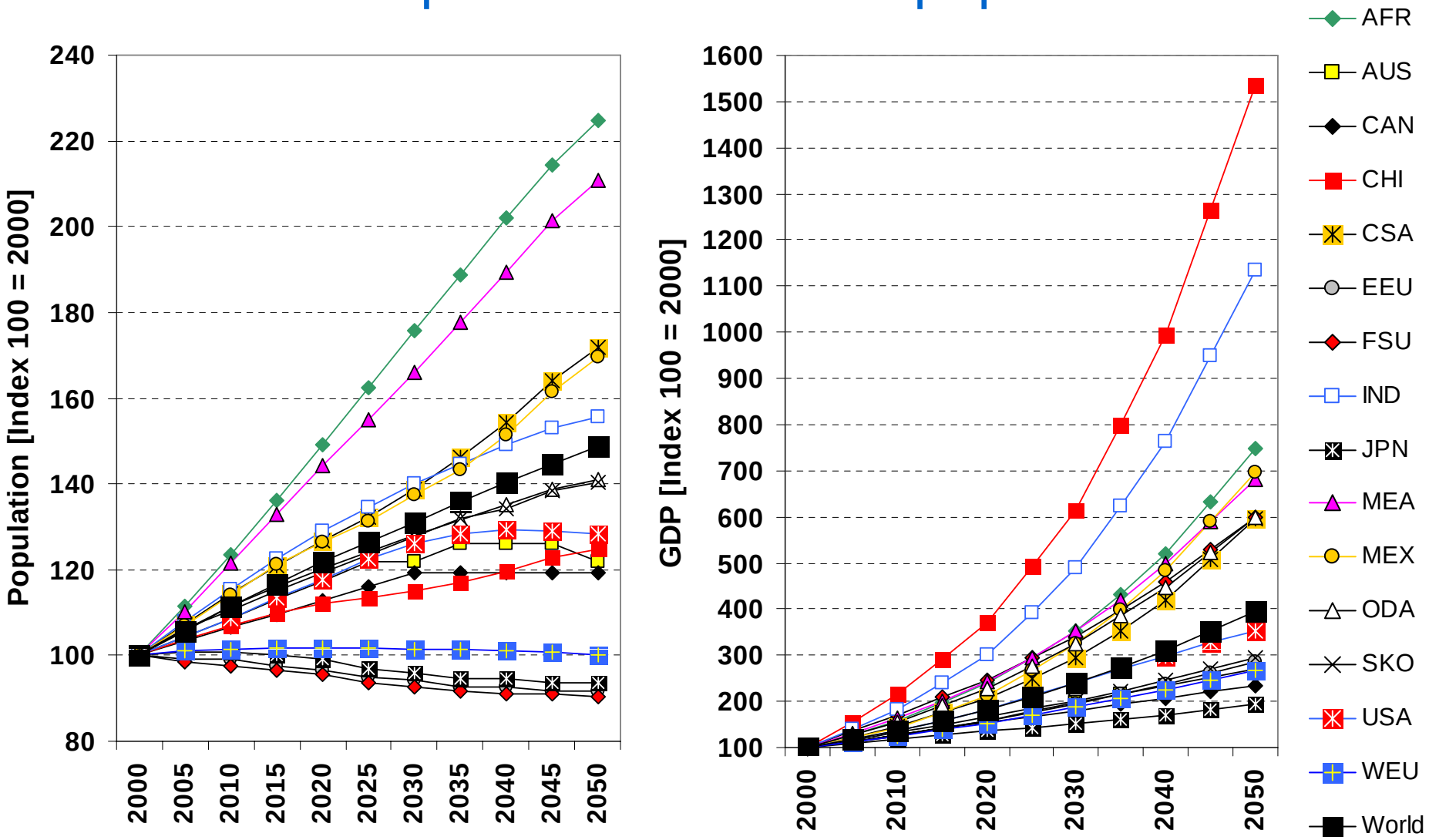
Scenario analysis to achieve a low-carbon society (LCS)

- **LCS scenarios (time horizon until 2050):**
  i. Baseline scenario (**BASE**): without explicit CO_2 mitigation efforts
  ii. CO_2 price scenario (**C10**): Global CO_2 price scenario increasing from 10$/t CO_2 in 2013 to 100 $/t in 2050
  iii. CO2 Plus scenario (**CPLUS**): Global reduction in CO_2 emissions by 50% relative to 2000; assumption Kyoto is realized in 2010 (-5.2% rel. to 1990)
- **Assumptions:**
  i. GDP:
    1. Global average GDP growth: 2000 – 2050: 2.8%, 2050 – 2100: 2.1%
    2. For comparison:
       – A1 scenario: 2000 – 2050: 3.9%, 2050 – 2100: 2.1%
       – B2 scenario: 2000 – 2050: 2.8%, 2050 – 2100: 1.5%

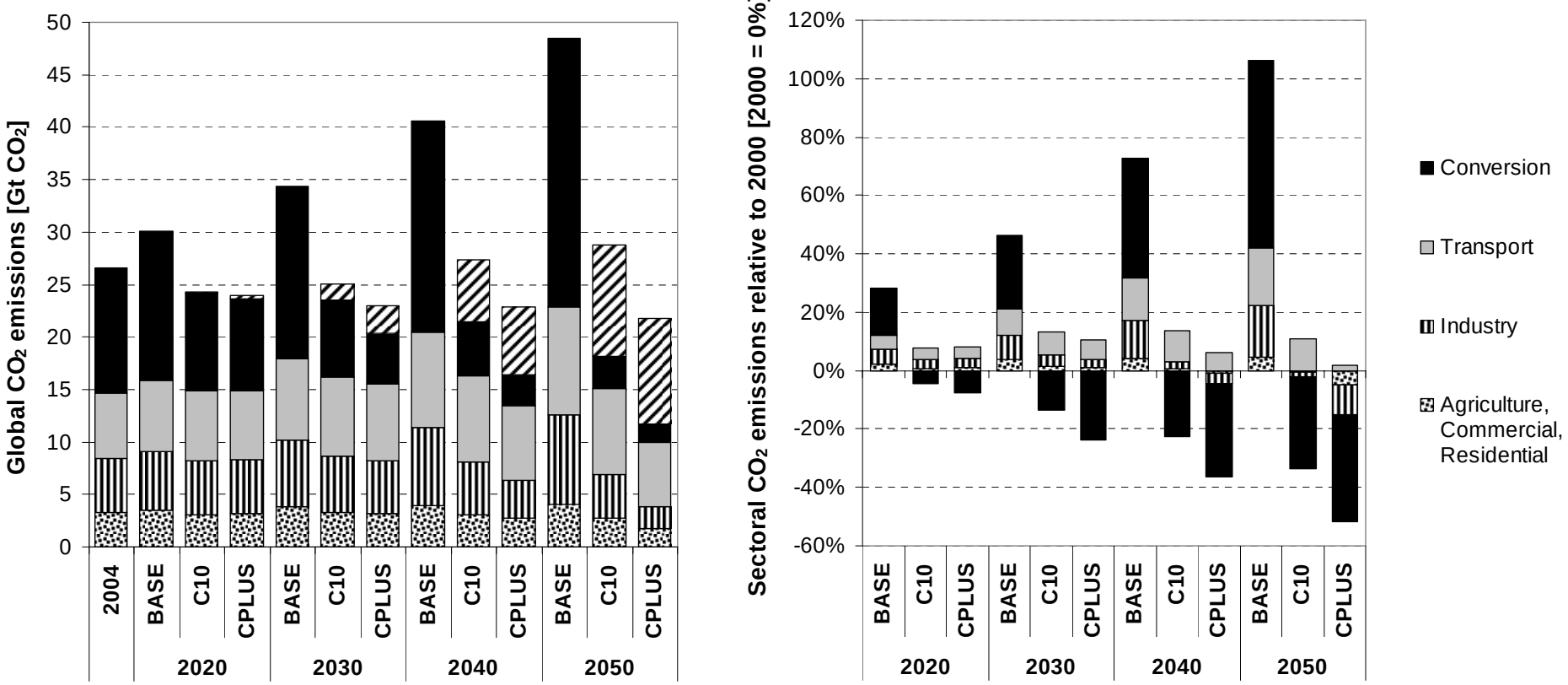
  ii. Discount rates:
    1. Global discount rate (social time preference rate): 5%
    2. Region and sector specific discount rates for investments: 10-20%

  iii. Oil price: 2005: 50 $/bbl 2010: 55 $/bbl 2020: 61 $/bbl 2030: 65 $/bbl 2050: 70 $/bbl

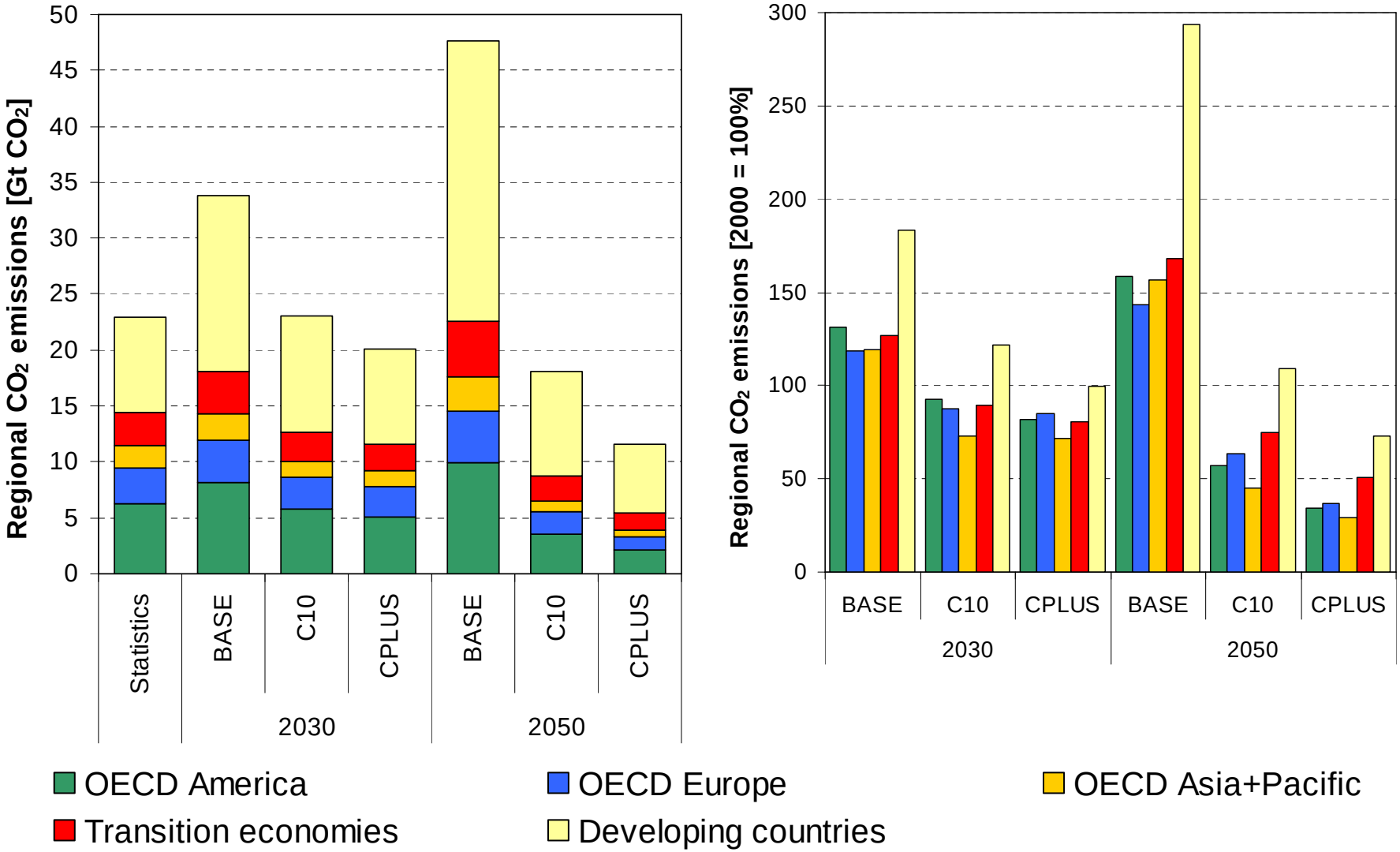
Assumed development of GDP and population



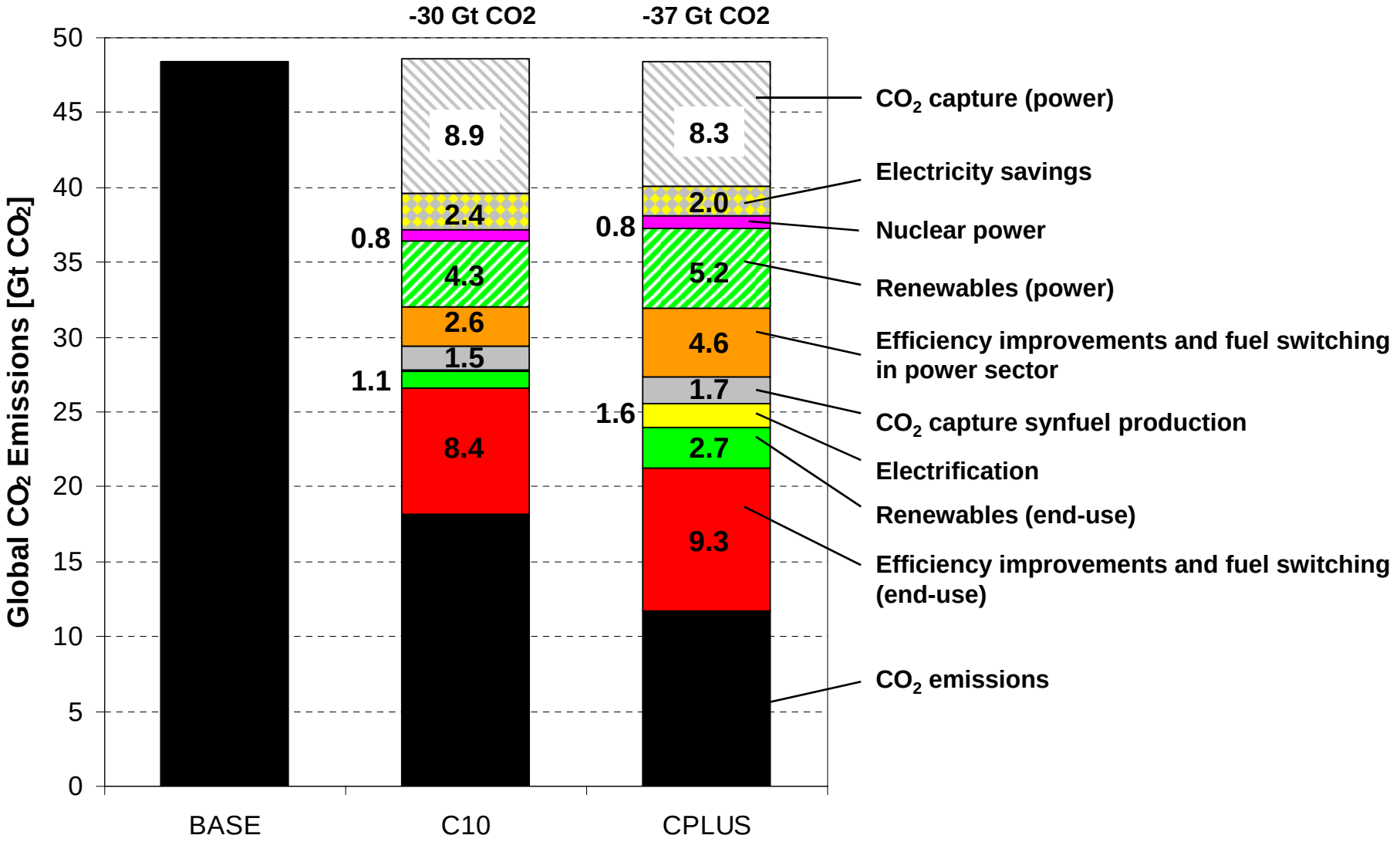
Global CO_2 emissions by sector



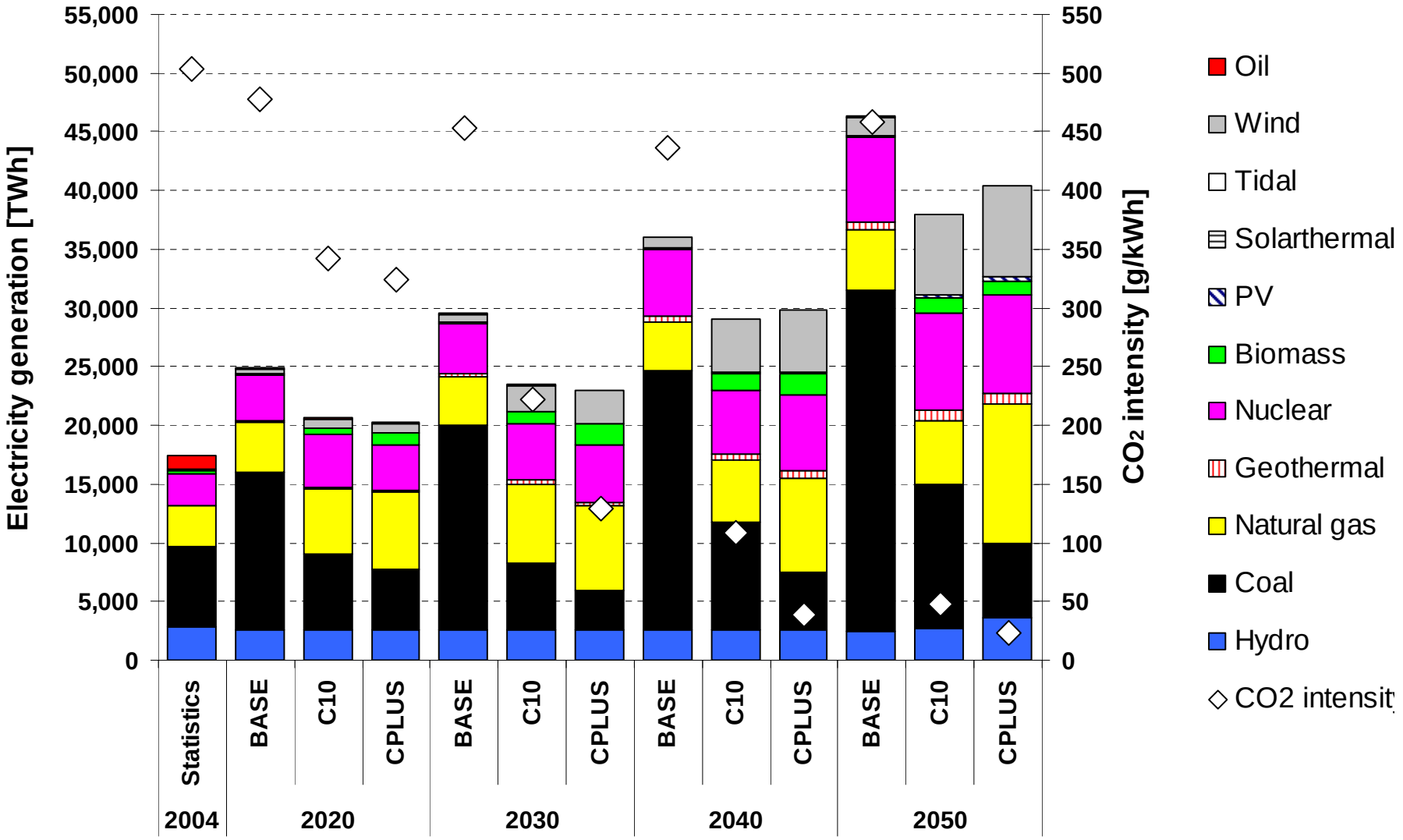
Regional CO_2 emissions



CO_2 mitigation measures



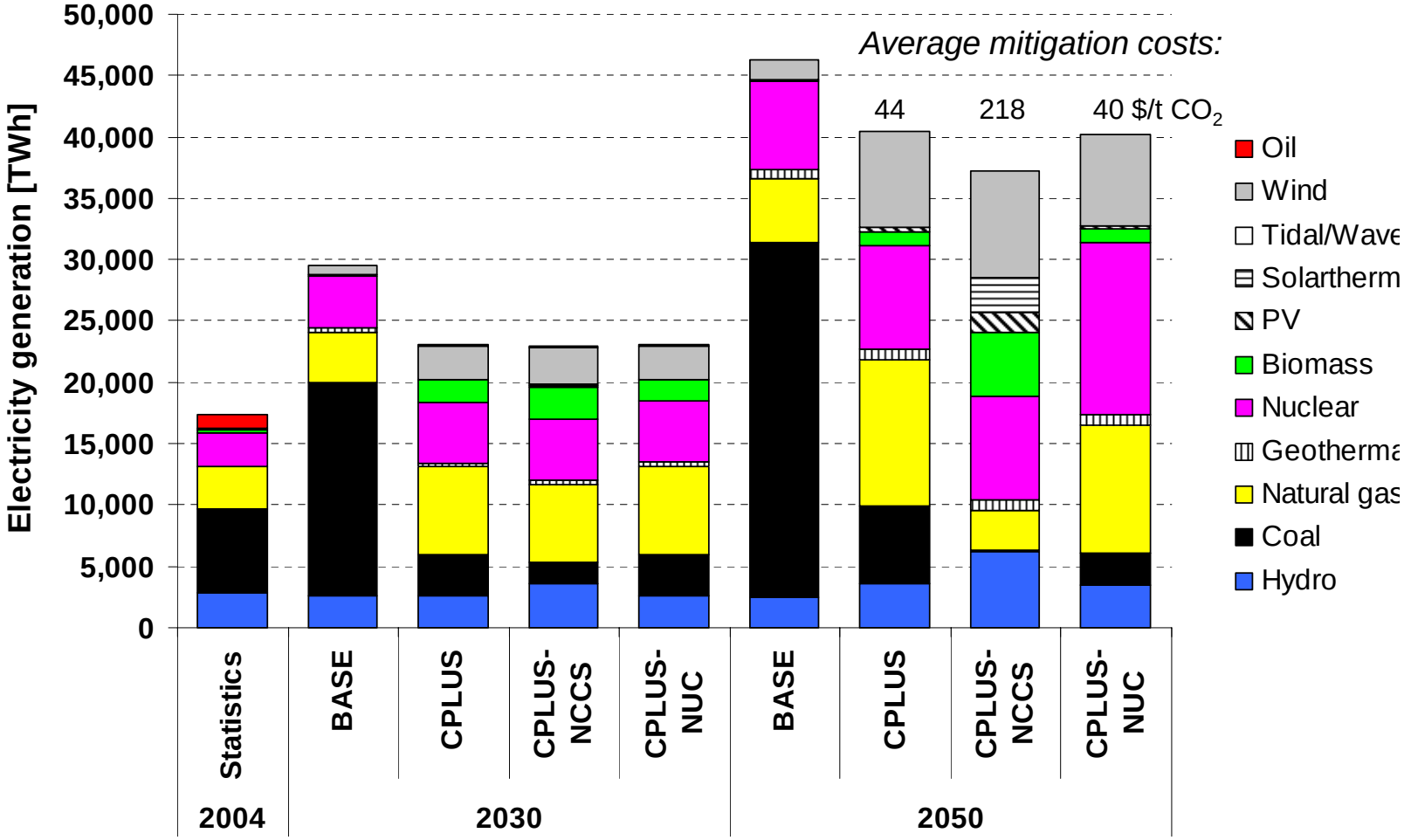
Electricity generation



Cost implications

Indicator	Region	Unit	Scenario			
			C10		*CPLUS*	
			2030	*2050*	*2030*	*2050*
Difference annual energy system costs rel. to base scenario	OECD	Bill. $\$_{2000}$	8	332	96	727
	Trans. economies	Bill. $\$_{2000}$	1	79	21	195
	Developing countries	Bill. $\$_{2000}$	4	230	10	711
	World	Bill. $\$_{2000}$	13	641	126	1633
Marginal abatement costs	World	$\$_{2000}$/t CO_2	29	100	63	330
Average abatement costs	World	$\$_{2000}$/t CO_2	2	21	10	44

Sensitivity analysis



- **CPLUS-NCCS:** No CCS available
- **CPLUS-NUC:** Increased nuclear generation; 14 GWh in 2050 compared to 8.4 GWh in CPLUS

Conclusions

- **LCS scenario analysis**:
  - i. C10: At a CO_2 price of 100 $/t a 23% reduction of CO_2 emissions relative to 2000 is achieved. Nearly 2/3 of the reduction are achieved in the power sector (CCS, renewables, CHP).
  - ii. To reach a 50% reduction target (CPLUS):
    1. Further reductions are mainly realized in the end-use sectors (electrification, biofuels, savings) with marginal abatement costs of up to 330 $/t CO_2.
    2. Regional mitigation: OECD countries reduce emissions 60-71% compared to 2000 levels, transition economies by 50% and developing countries by 23%. Relative to C10 (100 $/t), largest reductions are realized in developing countries.
    3. If CCS is not available global average mitigation costs increase from 44 $/t$CO_2$ to 218 $/t CO_2 in 2050.

Ongoing and Future developments

- **Ongoing model development**:
  i. Validating the regional data
  ii. Refining the regional resolution (merge EU states in EU27+, split-up of FSU into Russia, Central Asia Caucasus, redefinition of East Europe)
  iii. Improved representation of energy corridors for trade
  iv. Definition of a new objective functions for maximising the 'diversity' and studying trade-offs between emissions, security and costs
  v. Two way soft-linking with a general equilibrium model (GEM-E3)

- **Future model development**:
  i. Building common scenarios with the version of ETSAP-TIAM where one nation is extracted from its region and trade-offs are studied
  ii. Description of major industry sectors by process technologies
  iii. Detailed analysis of emission from land use
  iv. Study of retroactions of mitigation into the energy systems (hydro, cooling, etc.).

Thank you!

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