

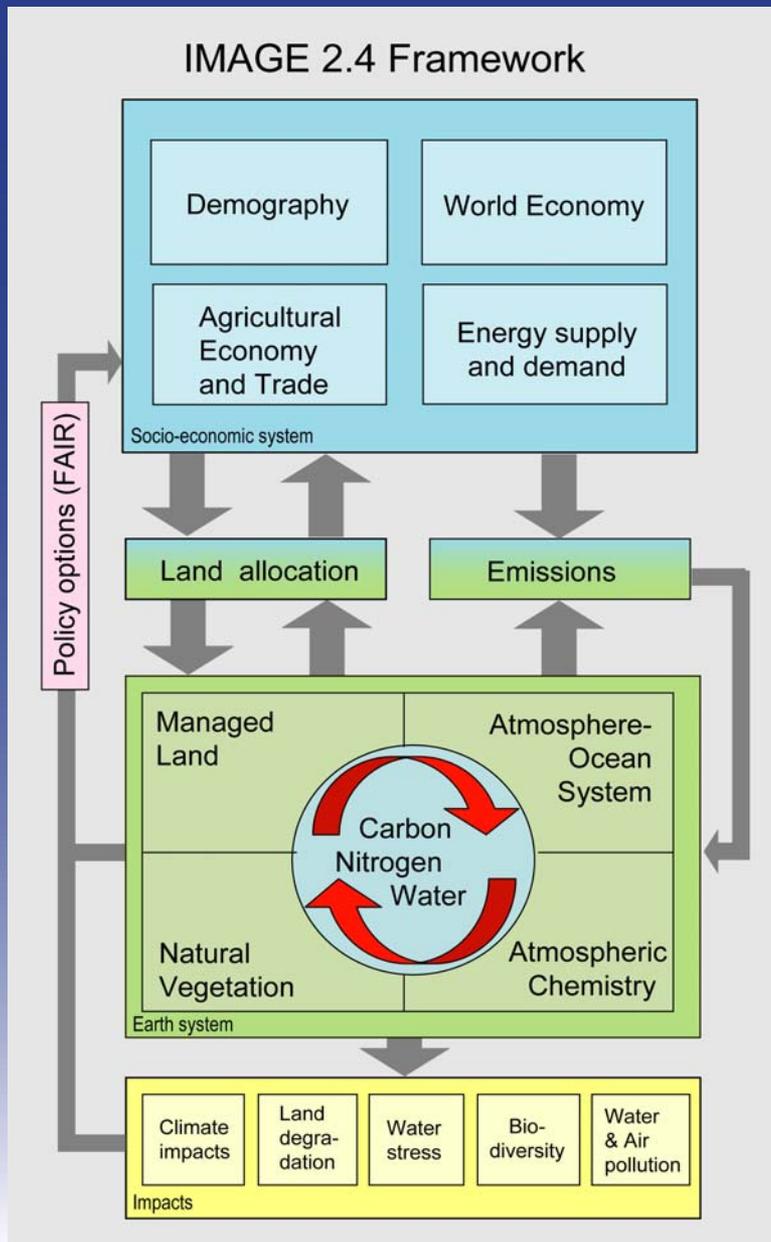
Detlef van Vuuren

Technologies in the context of (ambitious) mitigation scenarios



**Netherlands Environmental
Assessment Agency**

Overview of the IMAGE model

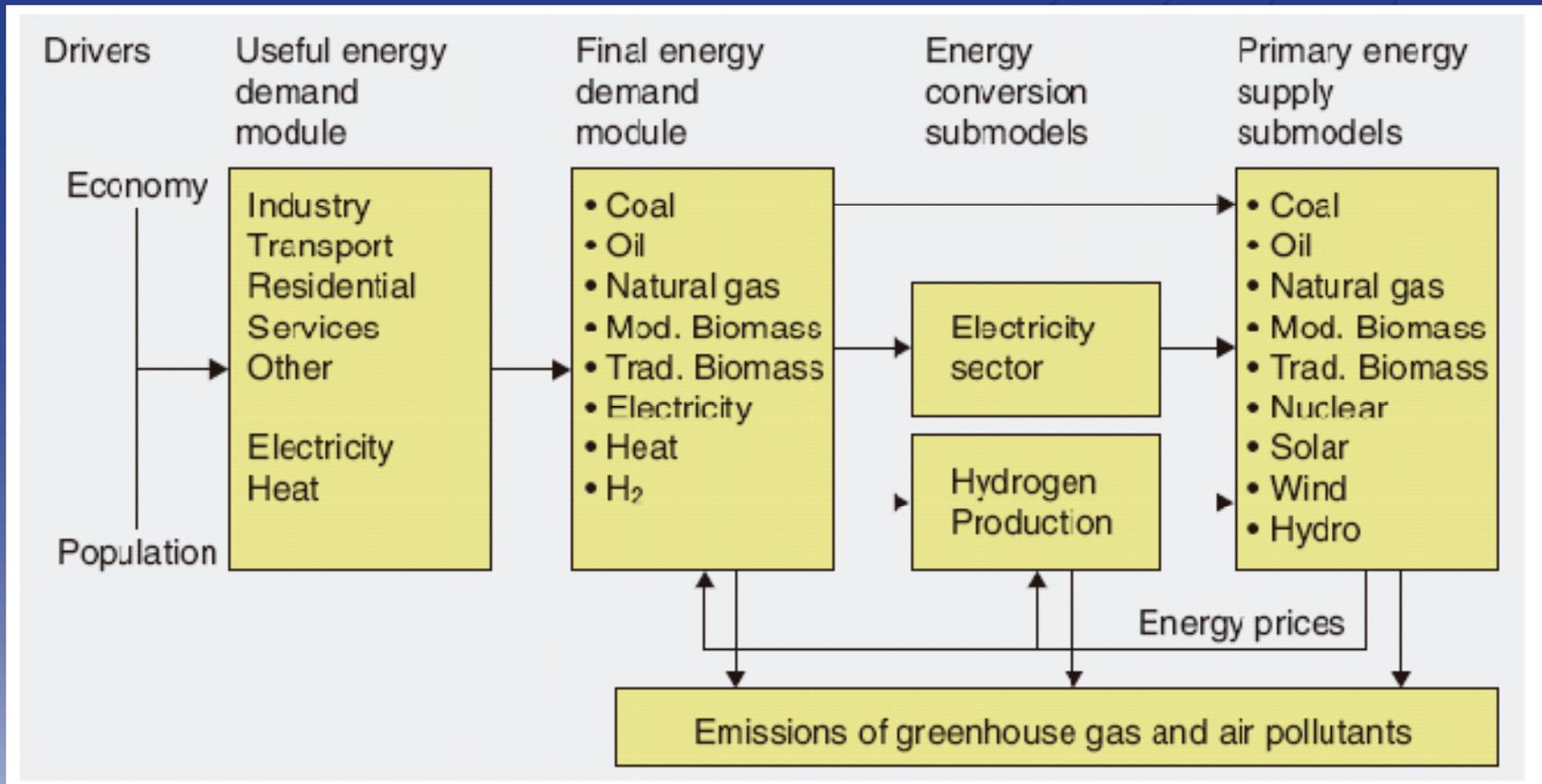


- Soft coupling with models that describe socio-economic system
- Fully coupled system for land use, biogeochemical cycles, climate.

<http://www.mnp.nl/image>

Netherlands Environmental Assessment Agency

Energy model TIMER



Technology representation

- Technologies represented sometimes explicitly (power plants), sometimes implicitly (energy efficiency, agricultural yield)
- Technologies improve over time (technology progress) and compete for investment
- Long-term production costs also determined by depletion (fuels, sites, etc) (thus cum. production for fossil fuels/ annual production for renewables)
- Capital vintage approach

Learning-by-doing

Learning curves assumed for many technologies

$$T = f(Q)^{-a}$$

Knowledge normally shared globally (faster learning)

- Careful with learning curves!!
1. How well calibrated (prices vs. costs)
 2. What value for p in future?
 3. Early phases and role of R&D?
 4. Physical/thermodynamic constraints
 5. Global / regional

Learning curves used for:

Fossil fuel production

Solar/wind

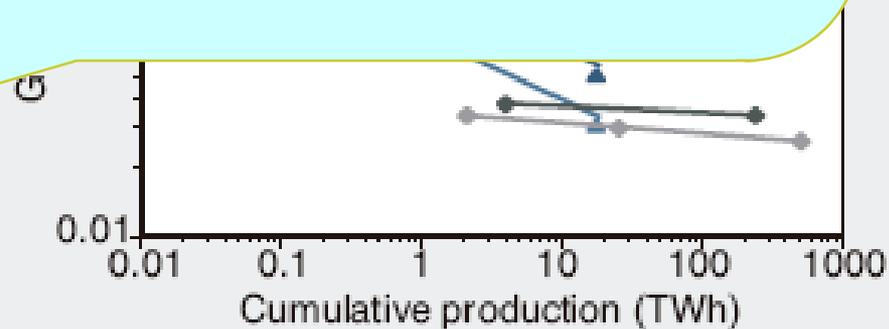
Biofuels conversion

Nuclear

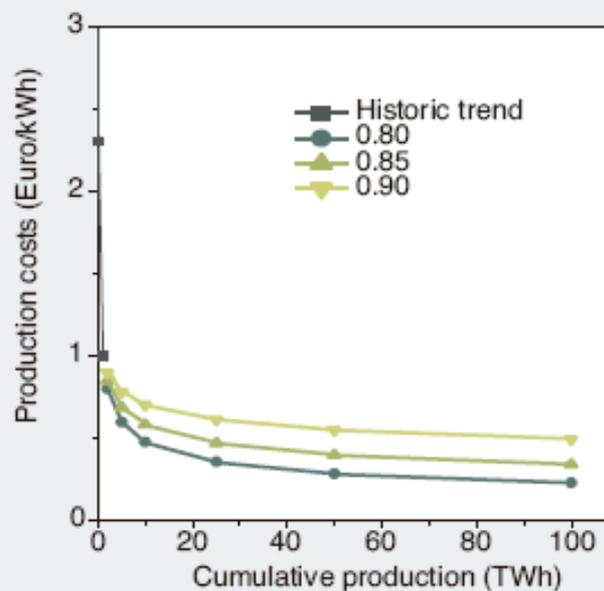
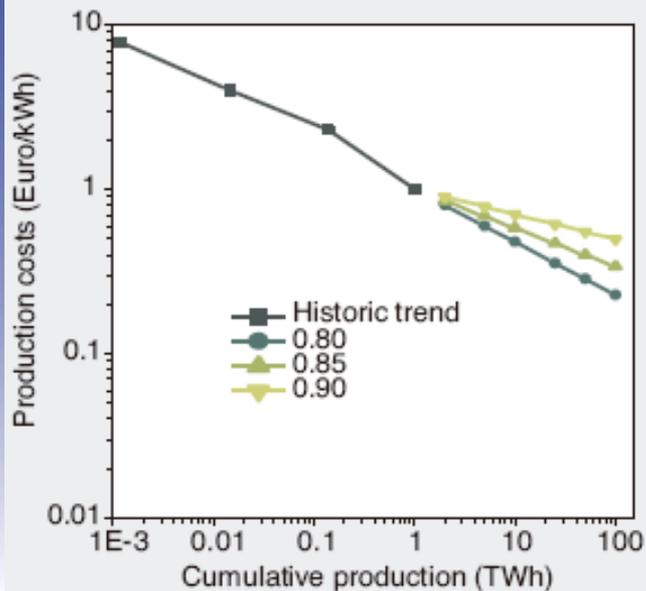
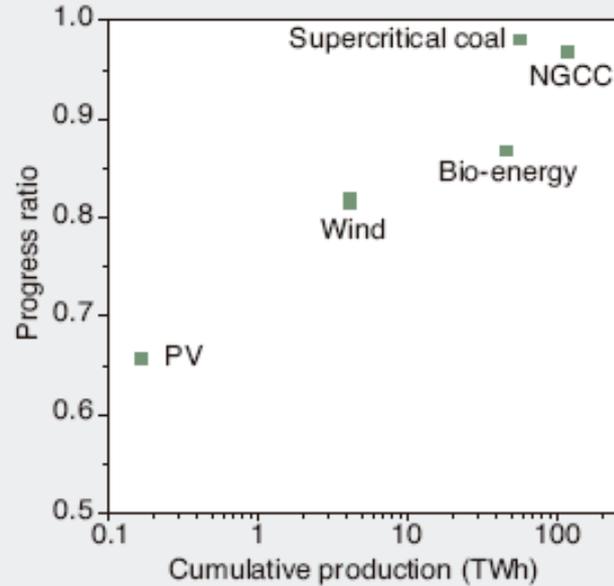
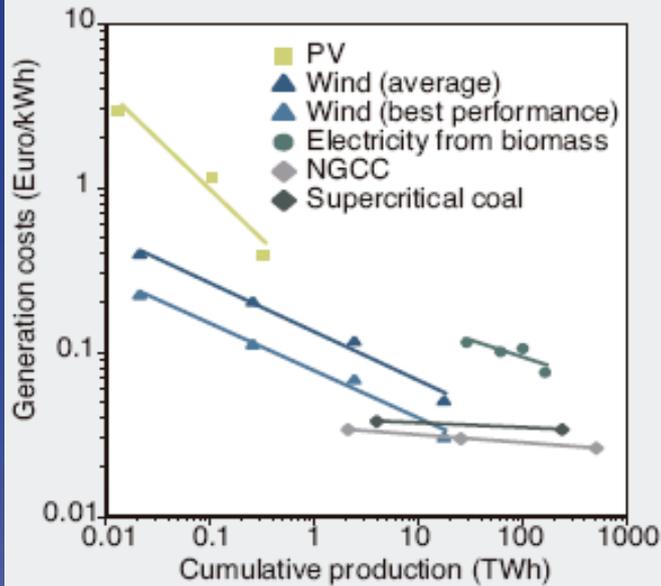
H₂ conversion technology

End-use efficiency

Exogenous technology
Energy efficiency

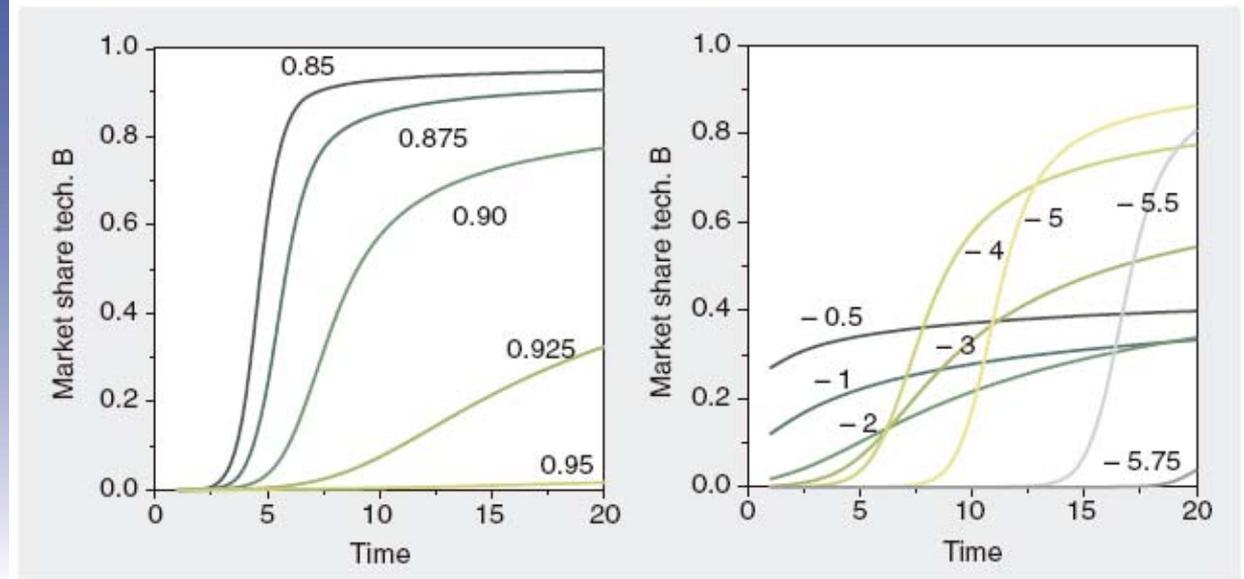
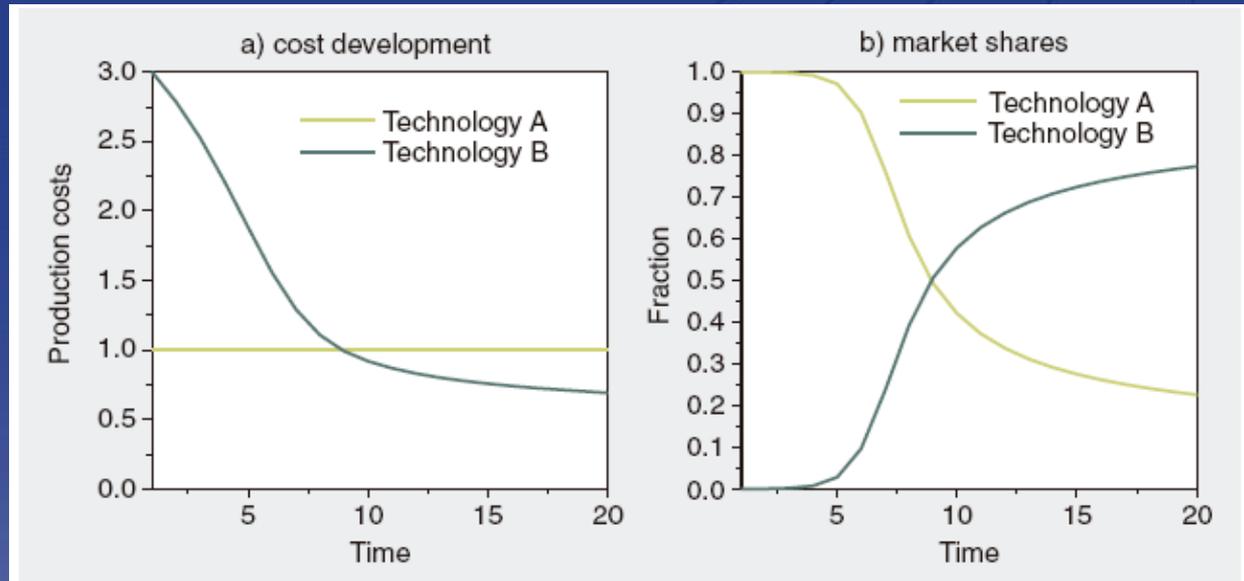
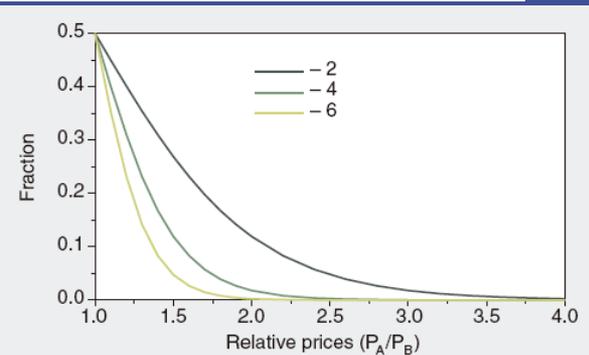


Learning-by-doing



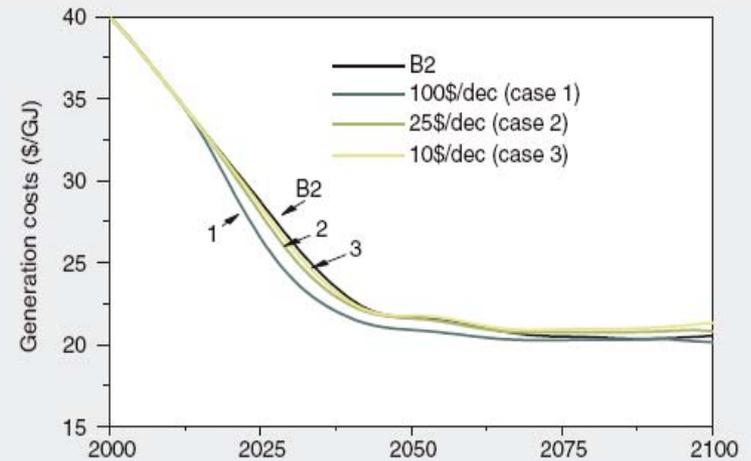
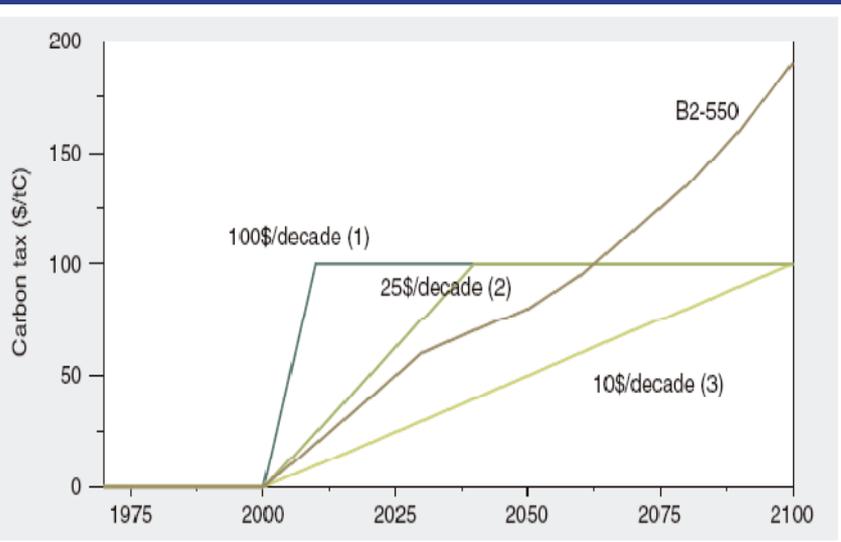
Learning-by-doing and competition

$$MS_i = \frac{e^{\lambda c_i}}{\sum_j e^{\lambda c_j}}$$



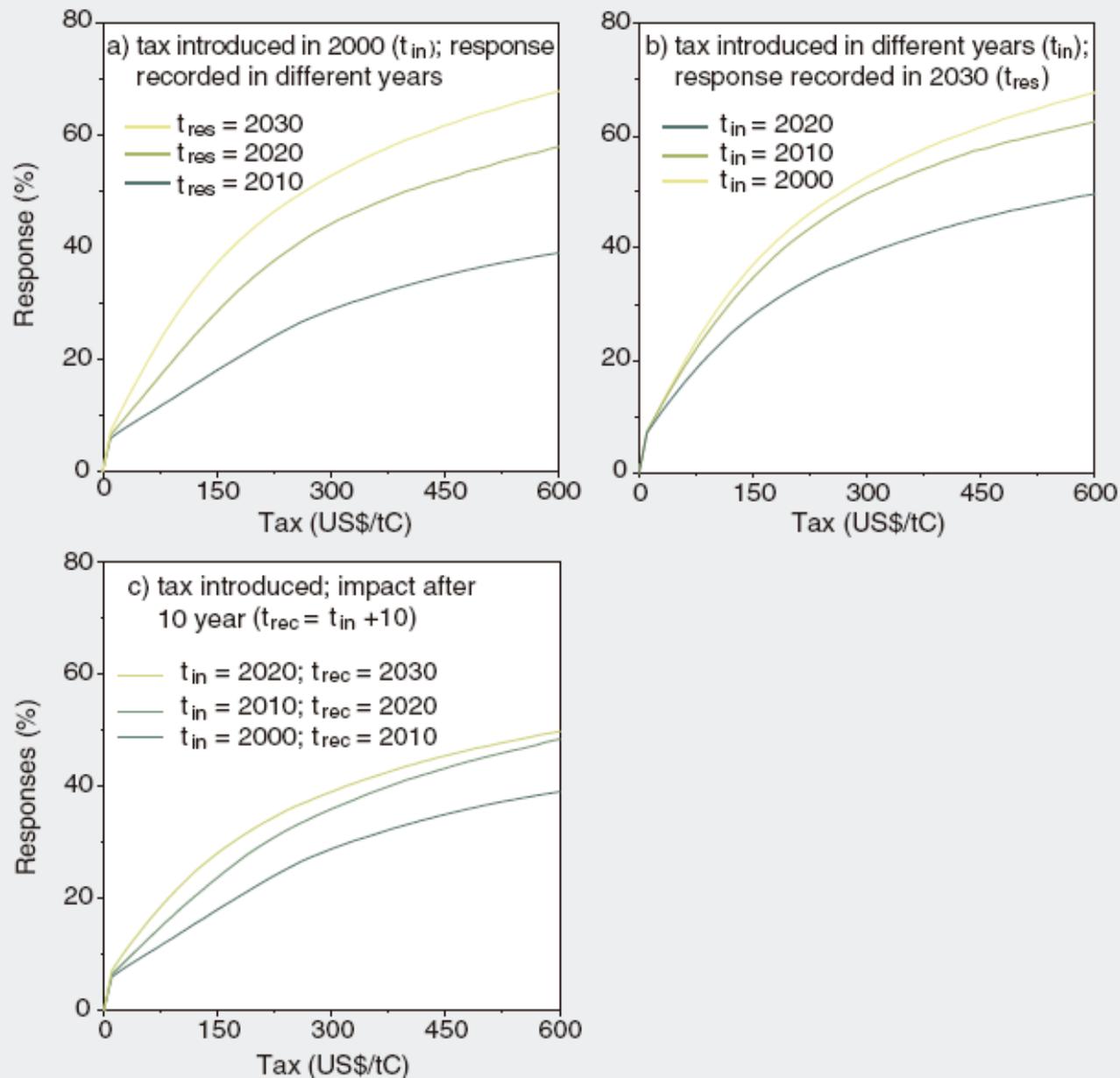
Learning-by-doing within the model

Other factors act as buffer

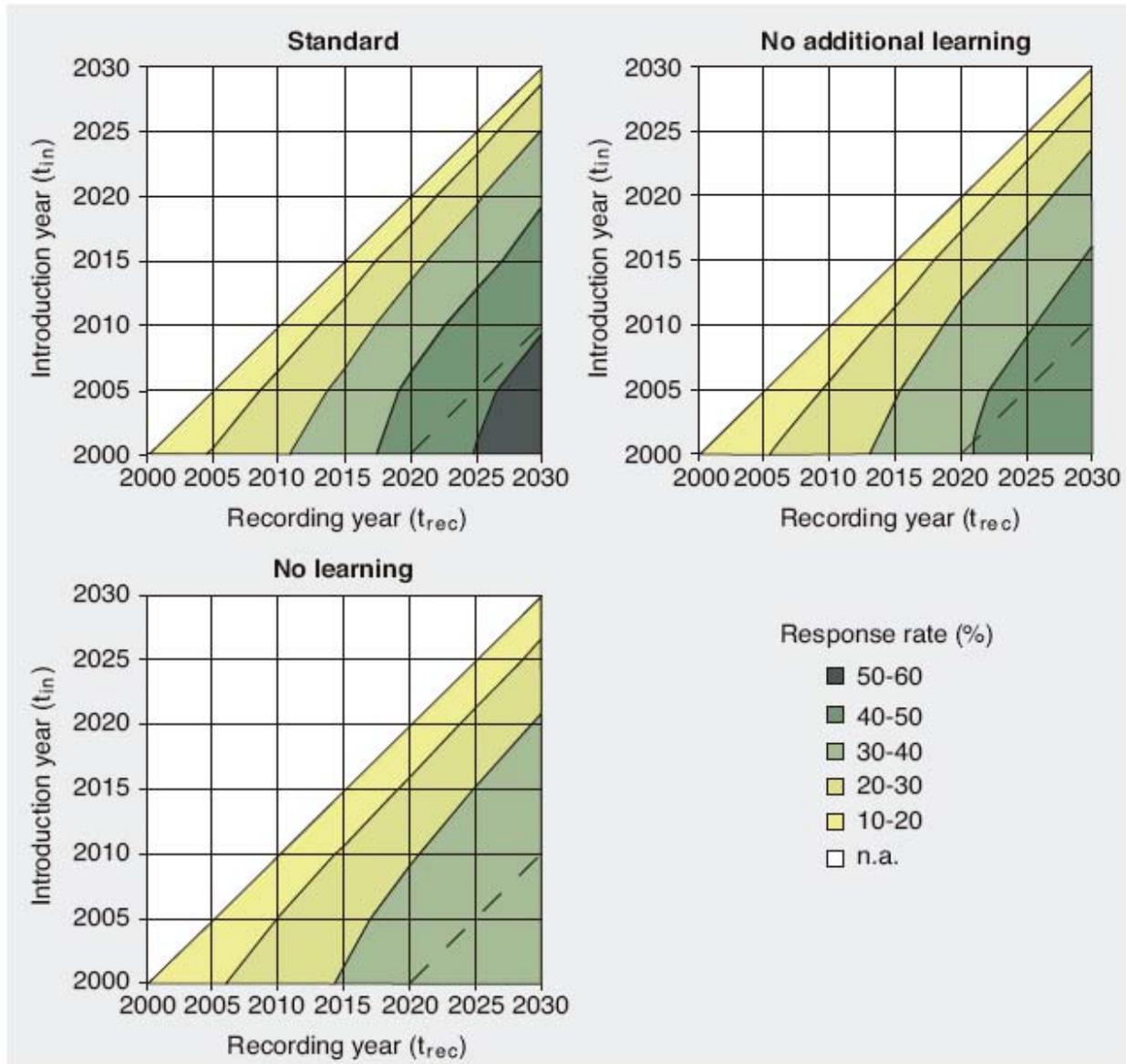


- Learning slows down with experienced gained
- High renewables production rates lead to depletion
- High renewables penetration rates lead to costs
- Cheap fossil fuel remains.

Learning-by-doing and timing of mitigation



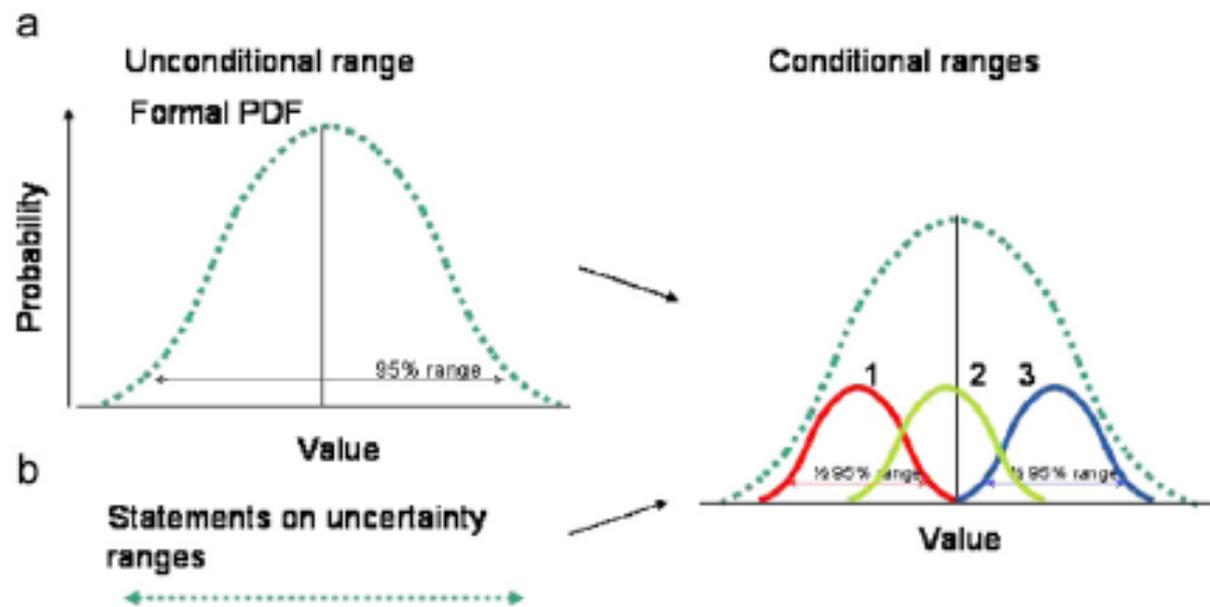
Influence of technology change in model response



Uncertainty analysis on the importance of technology assumptions

- Factors contributing to uncertainty
 - Ontic uncertainty (variability)
 - Epistemic uncertainty (limited knowledge)
 - Disagreement among experts
 - Reflexive uncertainty
- These occur at different scales
 - Parameters
 - Models
 - Theories

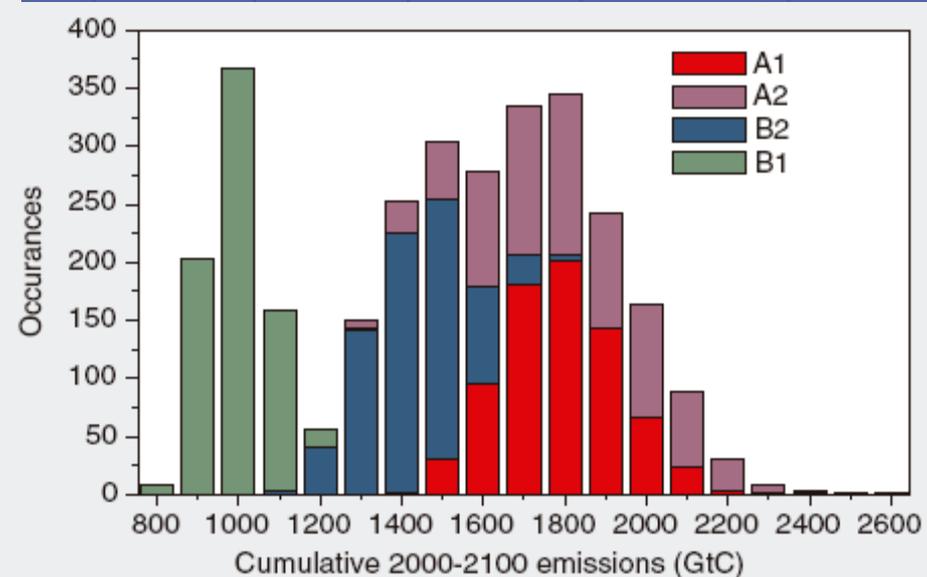
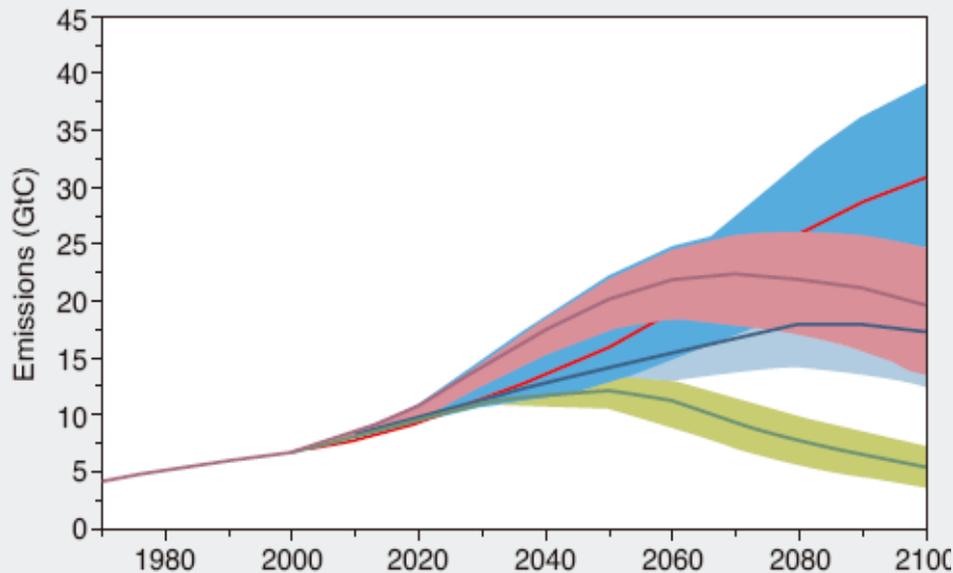
Combine different methods



Latin Hypercube sampling (3000 runs)

Table 5.1 Input parameters included in uncertainty analysis

Parameter category	Parameter	Central value	Sampling range around central value
Driving forces	Population	Scen, Reg	Scen, Reg
	GDP	Scen, Reg	Scen, Reg
	Size of industry sector	Scen, Reg	Indep.
Energy demand	AEEI	Scen, Reg	Indep.
	Pay-back time	Scen, Reg	Indep.
	Structural change	Scen, Reg	Indep.
Technology change	Fossil fuels	Scen, Reg	Indep.
	Renewables (electric power)	Scen, Reg	Indep.
	Nuclear power	Scen, Reg	Indep.
	Bio-energy	Scen, Reg	Indep.
	Energy demand	Scen, Reg	Indep.
	Hydrogen technologies	Scen, Reg	Indep.
	Thermal power plants	Scen, Reg	Indep.
Resources	Oil resources	Reg	Indep.
	Gas resources	Reg	Indep.
	Coal resources	Reg	Indep.
	Wind resource	Reg	Indep.
	Biomass resource	Scen, Reg	Indep.
	PV resource	Reg	Indep.

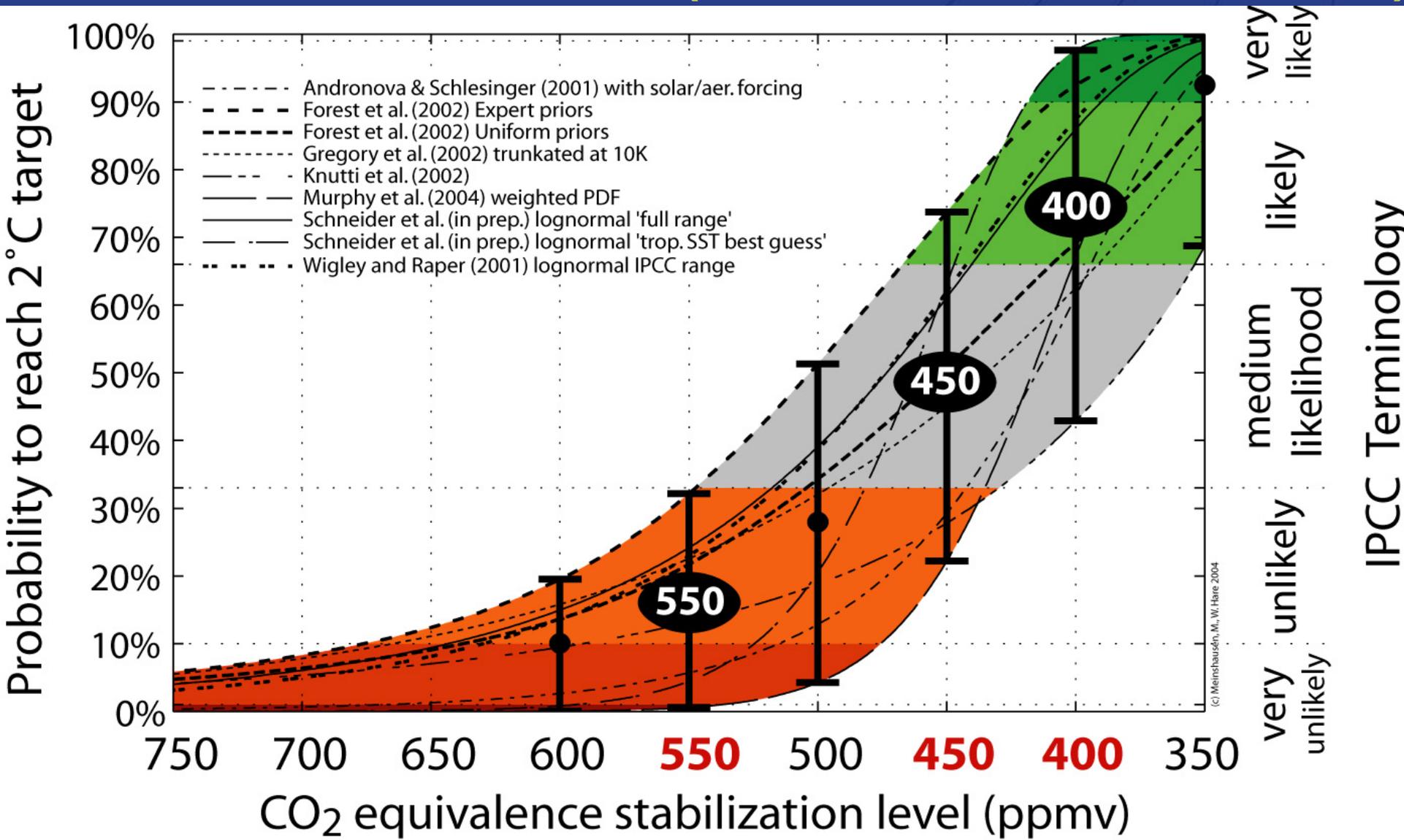


	Section	CO ₂		En/GDP		CO ₂ /En		Coal		Oil		Natural gas		Modern bio-energy		Nuclear power		Renew. energy	
	Output parameters																		
Input parameters																			
<i>Driving forces</i>																			
Population		0.29	0.26	0.01	0.01	0.04	0.11	0.19	0.16	0.18	0.22	0.17	0.22	0.11	0.16	0.2	0.18	0.19	0.23
		0.81	0.37	0.06	0.04	0.22	0.05	0.66	0.3	0.65	0.25	0.55	0.2	0.32	0.16	0.62	0.28	0.41	0.19
GDP		0.58	0.63	0.74	0.66	0.11	0.14	0.19	0.21	0.4	0.48	0.2	0.26	0.16	0.14	0.29	0.31	0.15	0.13
		0.5	0.69	0.59	0.66	0.21	0.2	0.34	0.35	0.43	0.45	0.28	0.25	0.19	0.2	0.37	0.49	0.23	0.19
Size of industry sector		0.07	0.07	0.1	0.11	0.02	0.02	0.04	0.03	0.05	0.08	0.03	0.04	0.03	0.03	0.02	0.02	0.03	0.04
		0.05	0.07	0.13	0.11	0.01	0.01	0.05	0.05	0.03	0.05	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.03
<i>Energy demand</i>																			
AEEI		0.53	0.4	0.57	0.55	0.14	0.16	0.34	0.27	0.19	0.17	0.29	0.3	0.23	0.22	0.37	0.28	0.25	0.27
		0.21	0.41	0.52	0.59	0.18	0.16	0.21	0.36	0.14	0.16	0.16	0.21	0.11	0.21	0.2	0.36	0.09	0.16
Payback time		0.07	0.07	0.09	0.11	0.01	0.02	0.03	0.03	0.06	0.06	0.04	0.05	0.02	0.04	0.04	0.03	0.04	0.05
		0.04	0.06	0.12	0.1	0.01	0.01	0.03	0.04	0.06	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03
Structural change		0.21	0.29	0.24	0.39	0.05	0.09	0.11	0.15	0.09	0.13	0.11	0.18	0.09	0.15	0.13	0.16	0.11	0.18
		0.21	0.29	0.53	0.42	0.15	0.09	0.18	0.2	0.17	0.14	0.15	0.14	0.11	0.14	0.18	0.22	0.11	0.13
<i>Technology dev. rates</i>																			
Fossil fuels		0.02	0.06	0.03	0.03	0.05	0.1	0.28	0.2	0.18	0.13	0.35	0.26	0.3	0.22	0.2	0.2	0.11	0.09
		0	0.01	0.03	0.03	0.08	0.11	0.12	0.19	0.12	0.16	0.21	0.26	0.18	0.25	0.12	0.14	0.05	0.06
Renewables (power)		0.09	0.13	0.03	0.05	0.19	0.2	0.12	0.19	0.02	0.02	0.06	0.08	0.05	0.03	0.25	0.42	0.74	0.72
		0.04	0.11	0.04	0.05	0.24	0.29	0.08	0.17	0.02	0.02	0.04	0.06	0.03	0.03	0.15	0.16	0.73	0.83
Nuclear power		0.03	0	0.01	0	0.07	0.01	0.04	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.38	0.18	0.02	0.01
		0.01	0.01	0.03	0.01	0.14	0.03	0.04	0.02	0.01	0.01	0.02	0	0.04	0.02	0.26	0.29	0.03	0.01
Bioenergy		0.04	0.08	0.01	0.01	0.17	0.17	0.06	0.02	0.04	0.14	0.05	0.08	0.27	0.28	0.01	0.02	0.02	0.01
		0.02	0.03	0.01	0.01	0.14	0.16	0.01	0.04	0.08	0.08	0.02	0.05	0.37	0.26	0.01	0.02	0.01	0.01
Energy demand		0.11	0.1	0.13	0.14	0.02	0.03	0.06	0.05	0.07	0.07	0.06	0.07	0.05	0.07	0.08	0.07	0.06	0.08
		0.05	0.08	0.13	0.13	0.02	0.02	0.04	0.06	0.06	0.06	0.04	0.04	0.03	0.05	0.05	0.07	0.03	0.04
Hydrogen technologies		0.01	0.01	0	0	0.02	0.01	0.03	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0
		0	0	0	0	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0	0
Thermal power plants		0.03	0.03	0.03	0.03	0.02	0.03	0.05	0.05	0.01	0.01	0.02	0.01	0.02	0.01	0.04	0.05	0.03	0.02
		0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.05	0.01	0.01	0.01	0.02	0.01	0.01	0.04	0.05	0.02	0.02

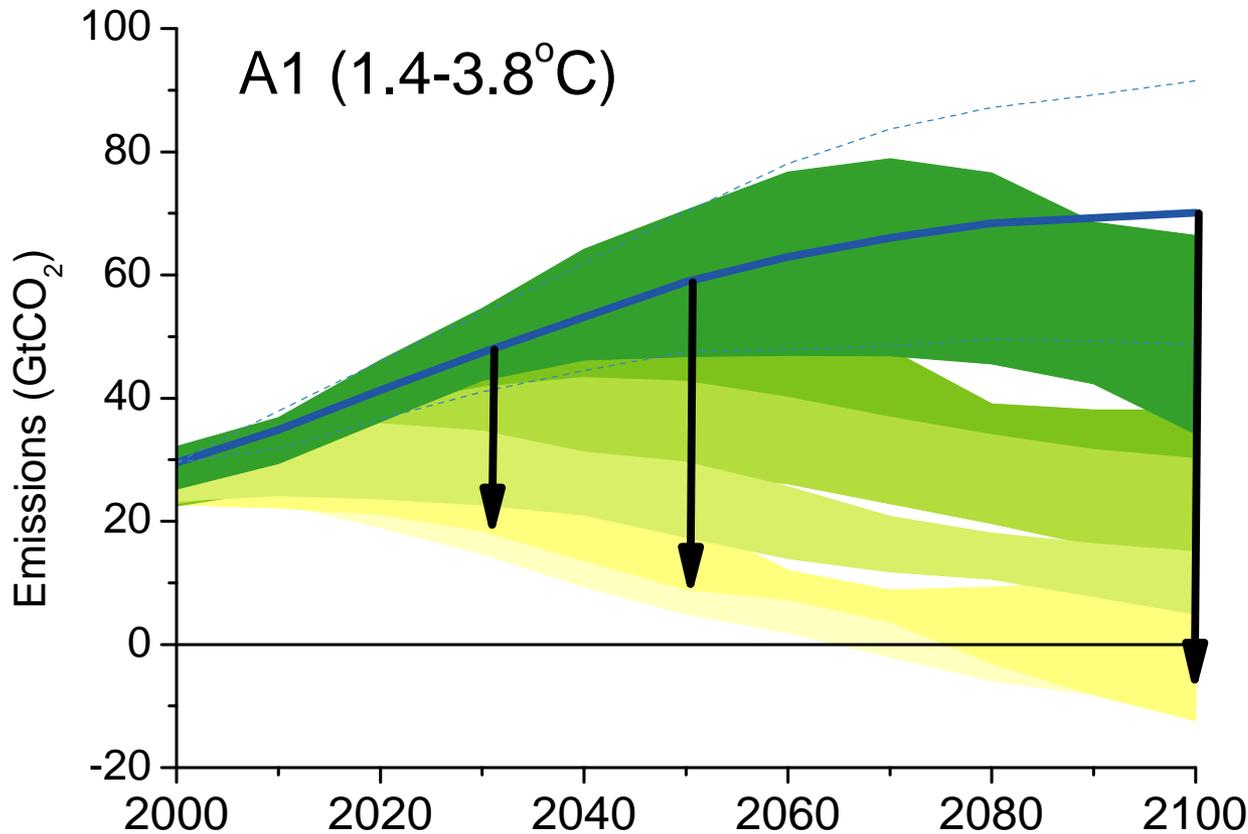
$$SRC = \beta_1 \frac{\sigma_{x_1}}{\sigma_Y}$$

The probability to reach the 2°C target

(Hare & Meinshausen, 2004)



Emission reduction for stabilisation



2030:

BL: 40% increase

450: 10% decrease
(30-80% probl)

400: 15% decrease
If negative (other-
wise upto 50%)
(50-95% probl)

Cumulative reduction

650: 650 GtC (30%)

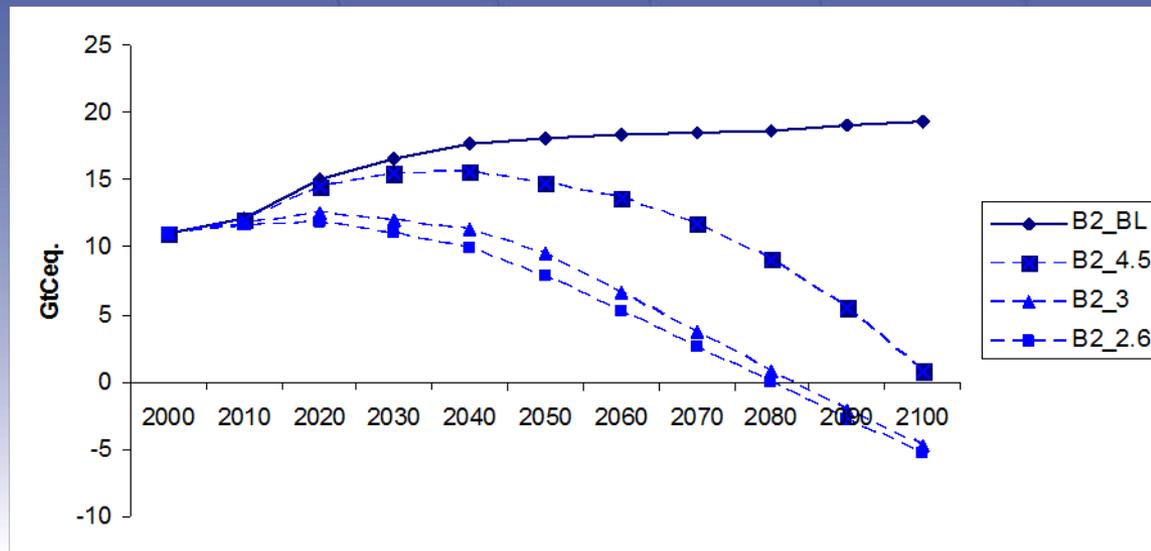
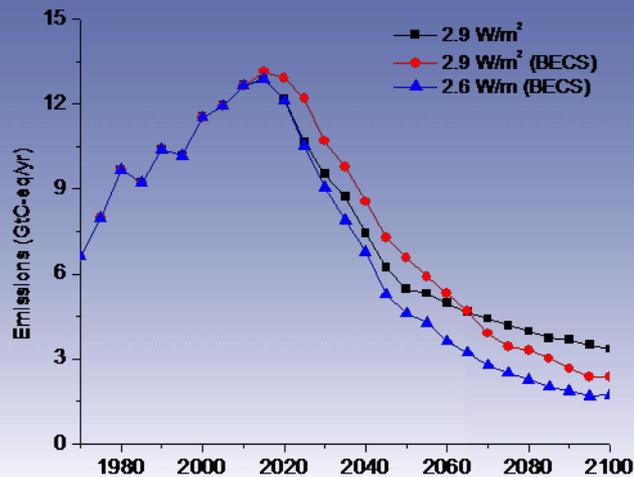
550: 850 GtC (45%)

450: 1200 GtC (60%)

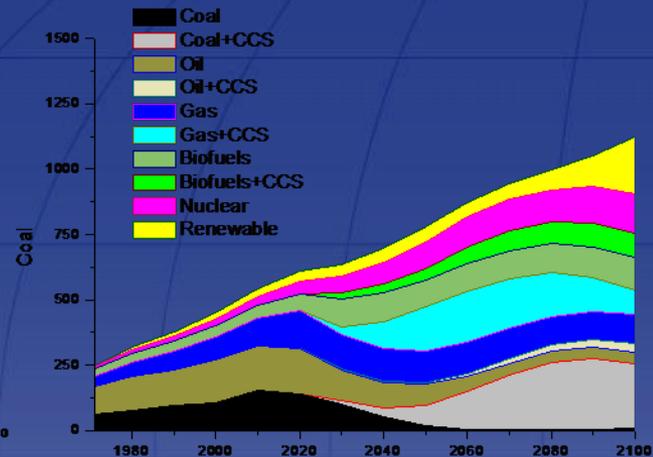
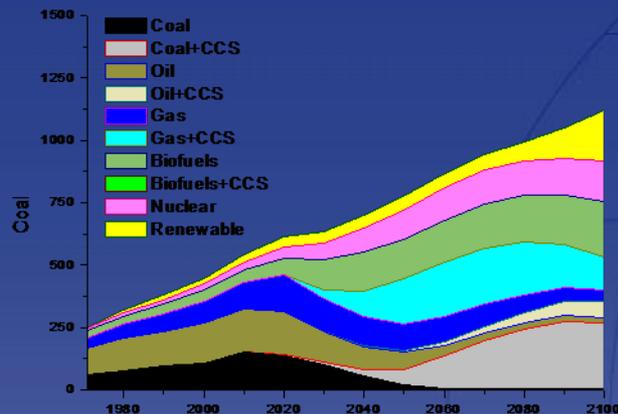
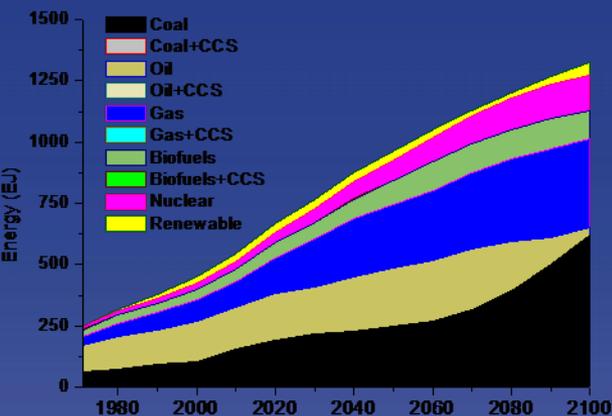
Netherlands Environmental
Assessment Agency

IIASA / PBL Report for the European Commission

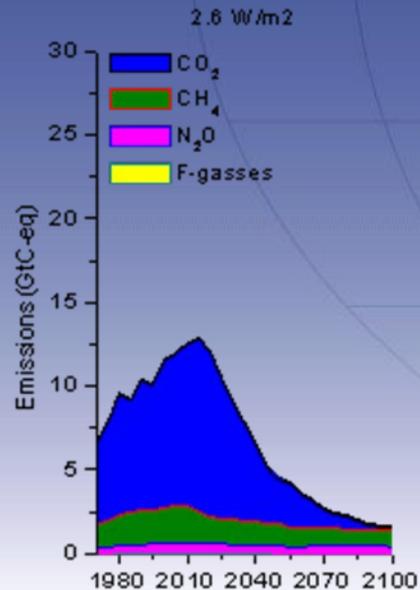
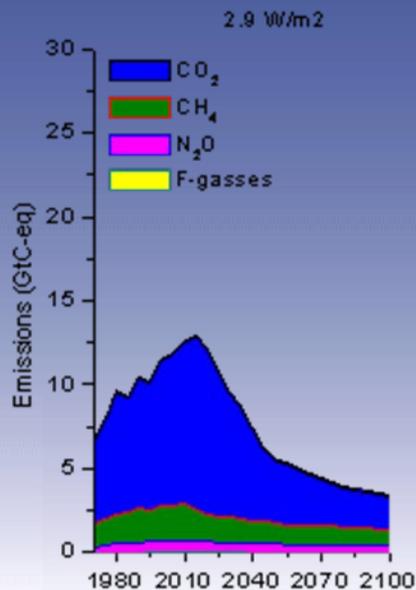
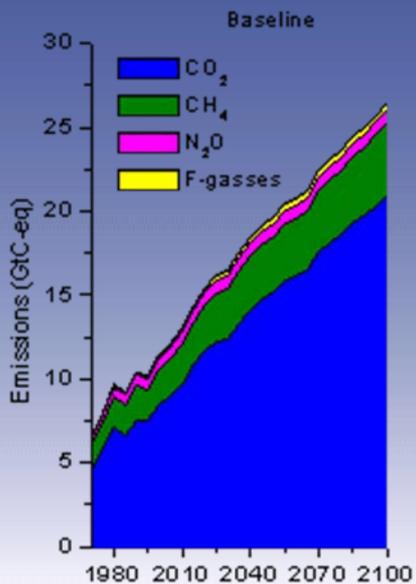
- Low targets such as the 2.6 and 2.9 W/m² forcing target are found **attainable** in the long term, but are conditional on a number of key technologies and other assumptions.
 - Global emission reductions from 2013 onwards
 - Large portfolio of emission reductions
- Achieving the 2.6 target requires the transition to **negative emissions from the energy sector** by the end of the century. While not all technological options are equally crucial for low targets, **reaching 2.6 W/m² is associated with larger uncertainties** than 2.9 W/m² target.



Low greenhouse gas scenarios



A

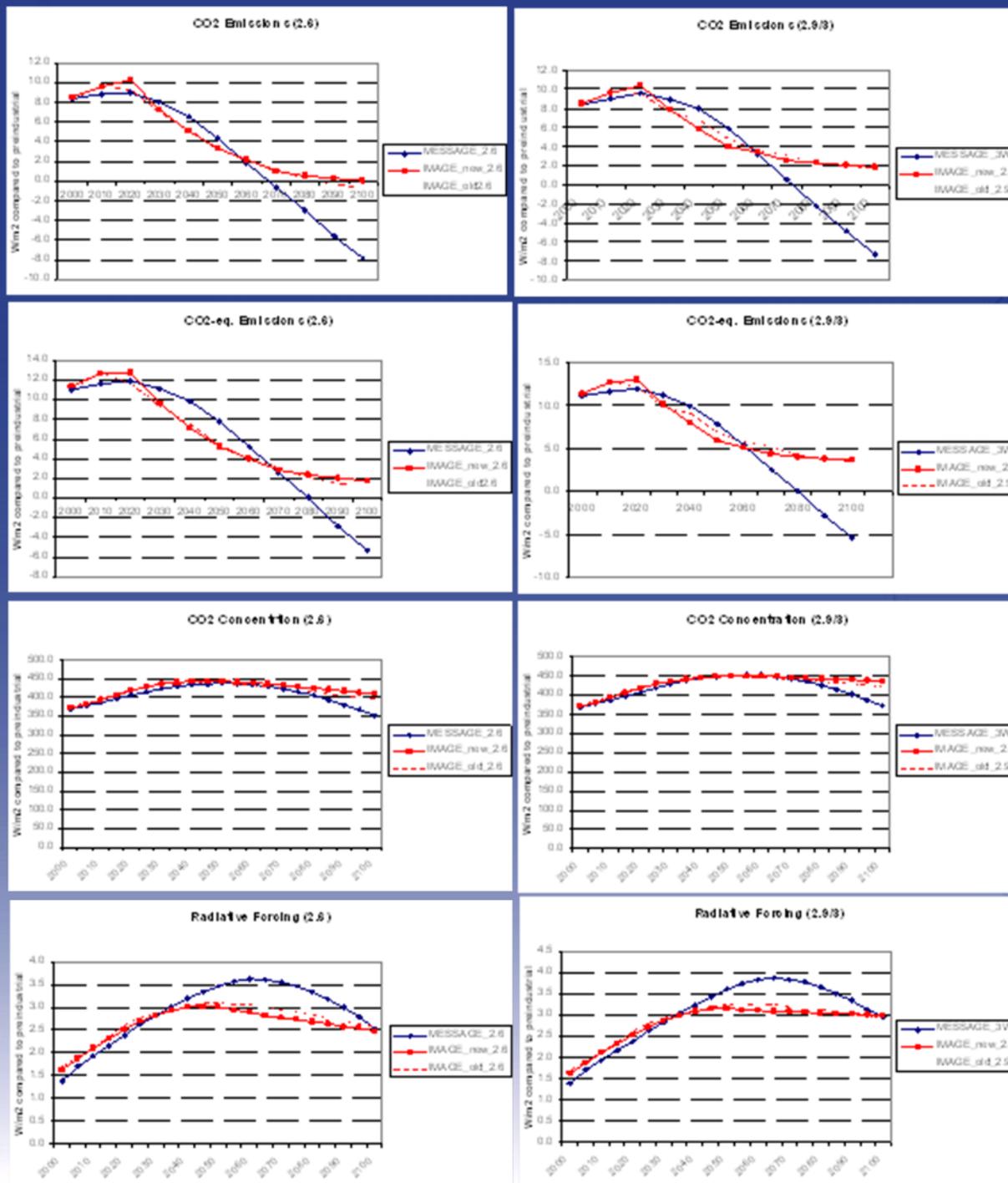


CO2 emissions

CO2-eq emissions

CO2 concentration

RF



Sensitivity analysis

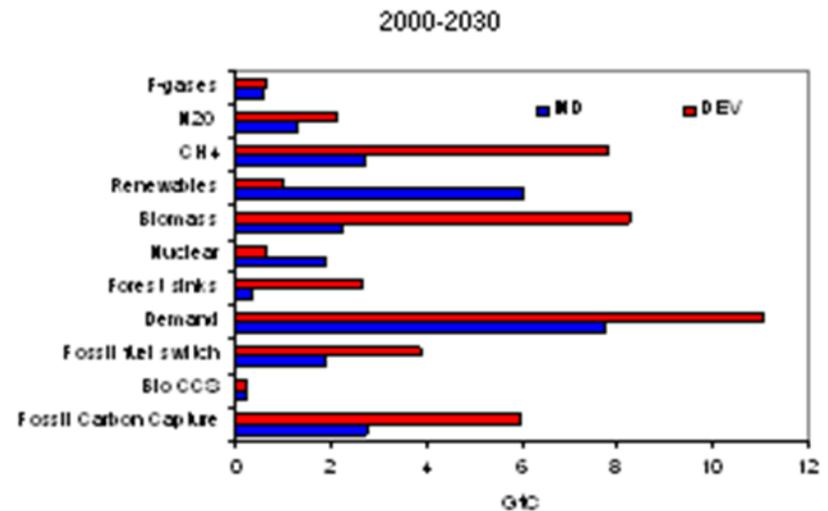
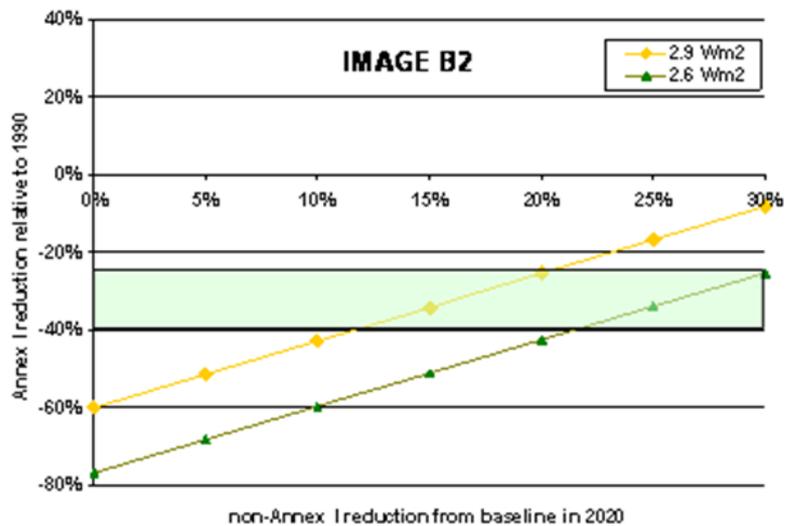
MESSAGE

	Default	Biomass constraint	Nuclear constraint	No CCS	No Bio-CCS	No sinks	Eff. constraint
	Yes /yes	Yes /yes	Yes / yes	No / yes	No /yes	No /yes	No / yes

IMAGE

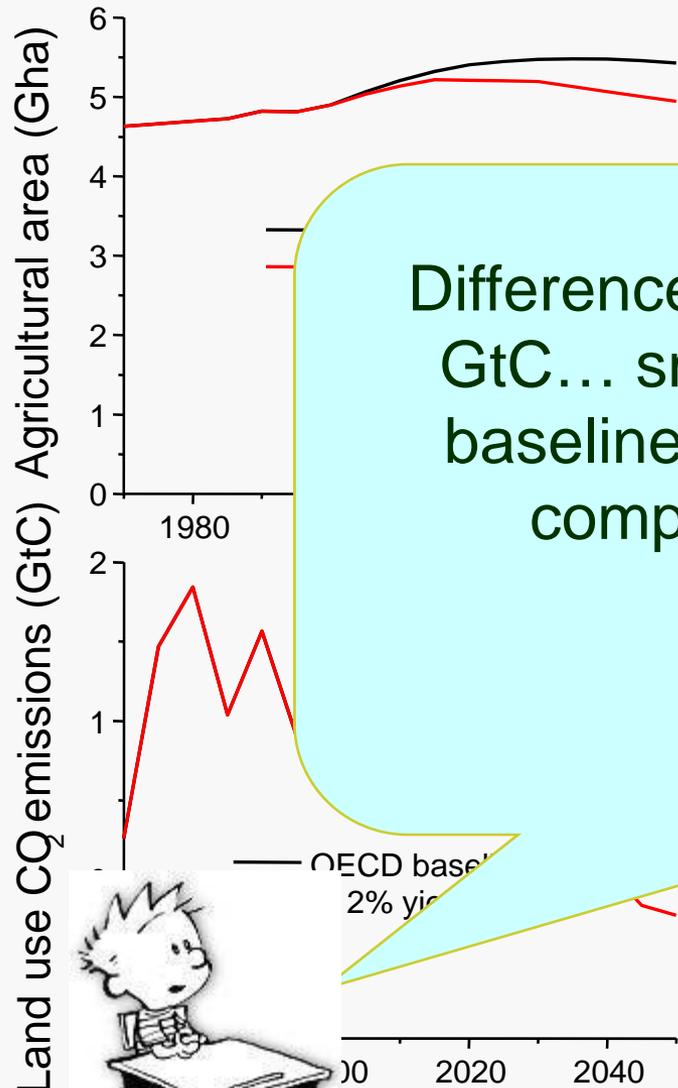
	Default	No Bio-CCS	No-CCS	Eff. constraint	A2 land use
	Yes	2.9	3.5	3.2	3

Greatest challenge in participation



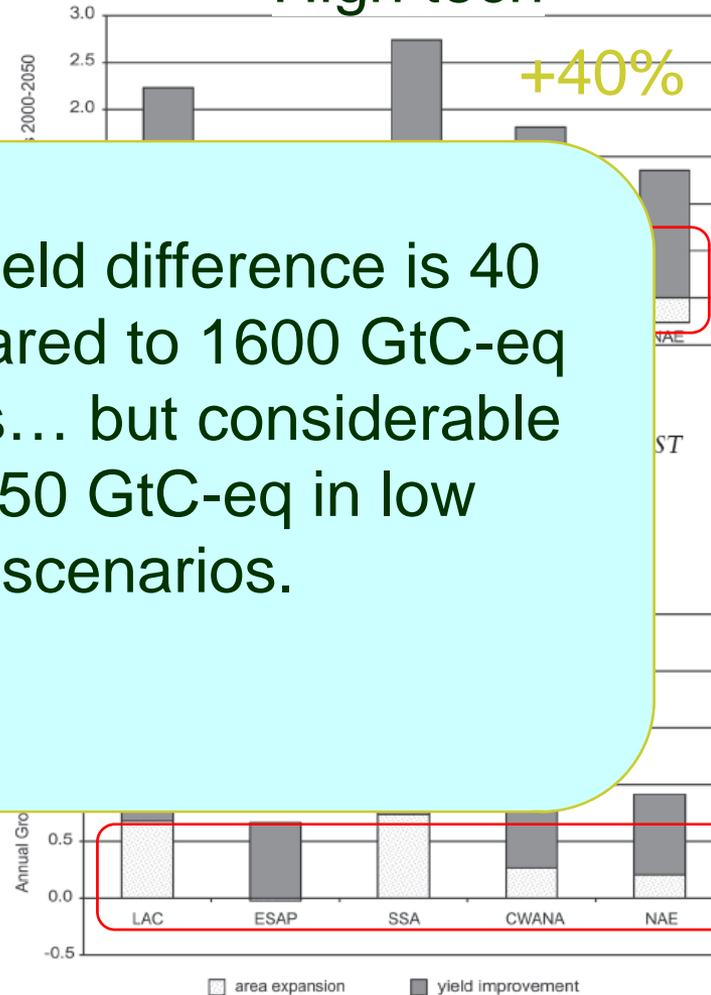
Impact of agriculture technology

IMAGE



Ag-assessment

High tech

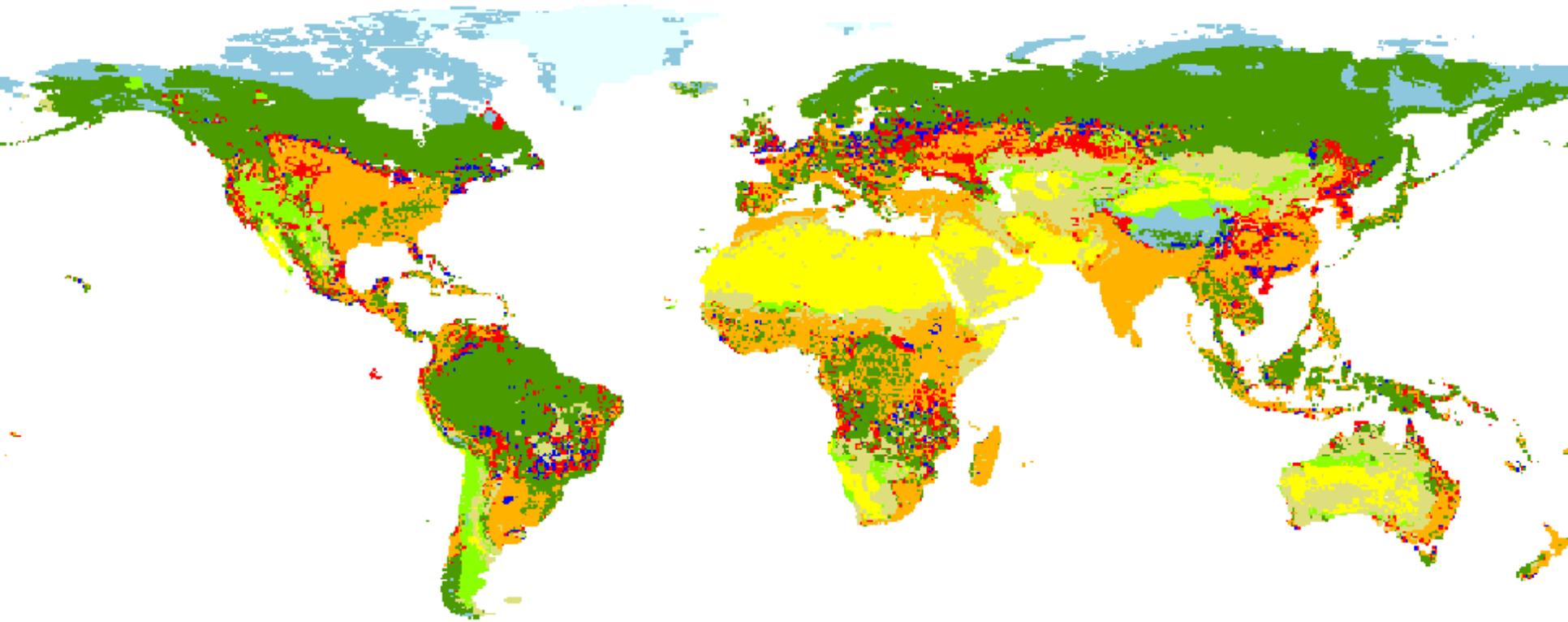


Difference of 12% yield difference is 40 GtC... small compared to 1600 GtC-eq baseline emissions... but considerable compared to ~450 GtC-eq in low emission scenarios.



Figure 5-33. Sources of cereal production growth, Low_AKST variant, by IAASTD region. Source: IFPRI IMPACT model simulations.

Land use pattern in 450 ppm mitigation scenario (2100)



How important is model bias in “technology advice”

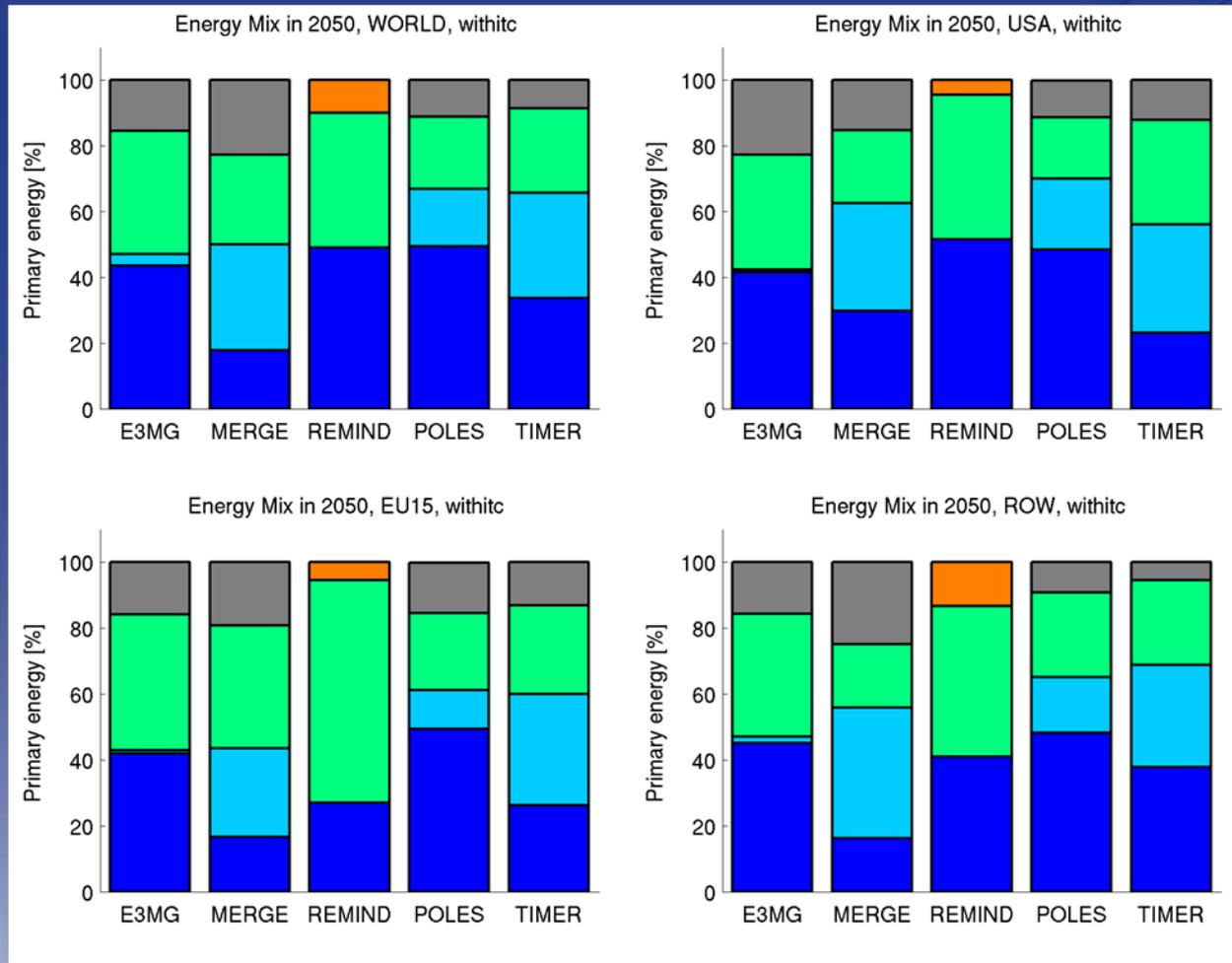


Figure 1: Comparison of energy mix for some selected regions: World, USA, Europe and ROW. Legend: dark blue: fossil energy, light blue: fossil energy with CCS, green: renewables, grey: nuclear, orange: others.

Some agreement on more general issues

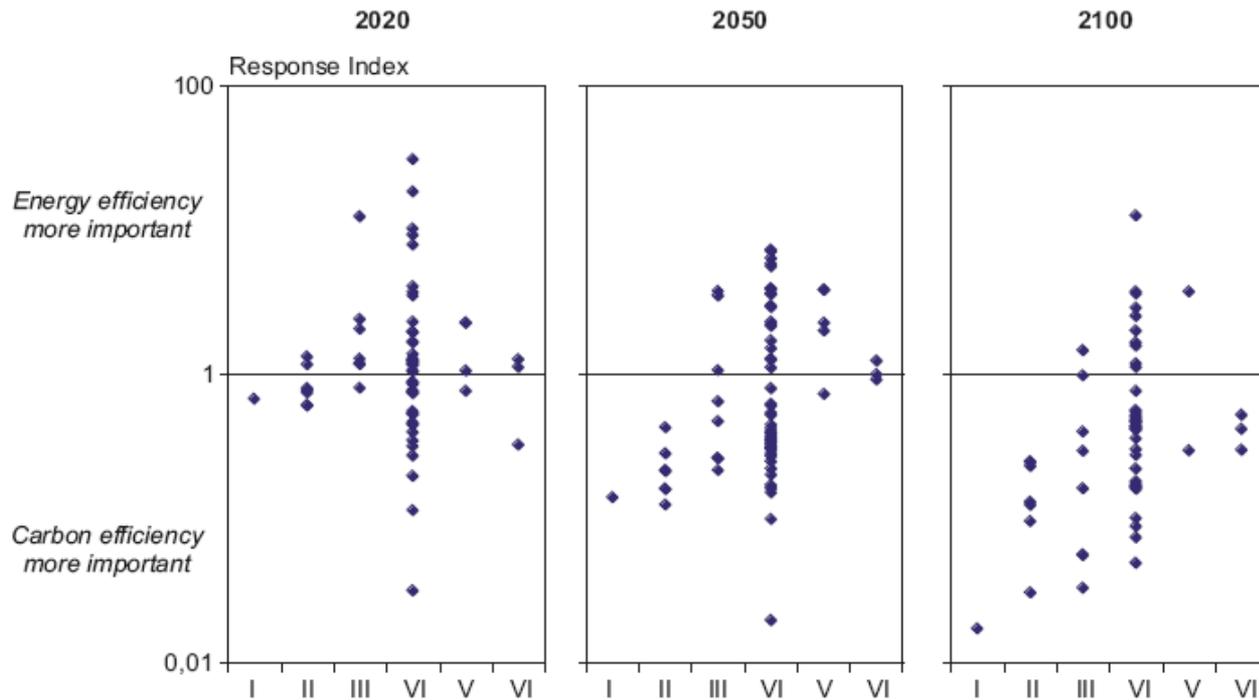


Figure 3.21: Response index to assess priority setting in energy-intensity reduction (more than 1) or in carbon-intensity reduction (less than 1) for post-TAR stabilization scenarios.

Note: The panels show the development of the index for the years 2020, 2050, and 2100 (66, 77, and 59 scenarios, respectively, for which data on energy, GDP and carbon emissions were available).

Data source: After Nakicenovic et al., 2006, and Hanaoka et al., 2006)

And sometimes even on technologies

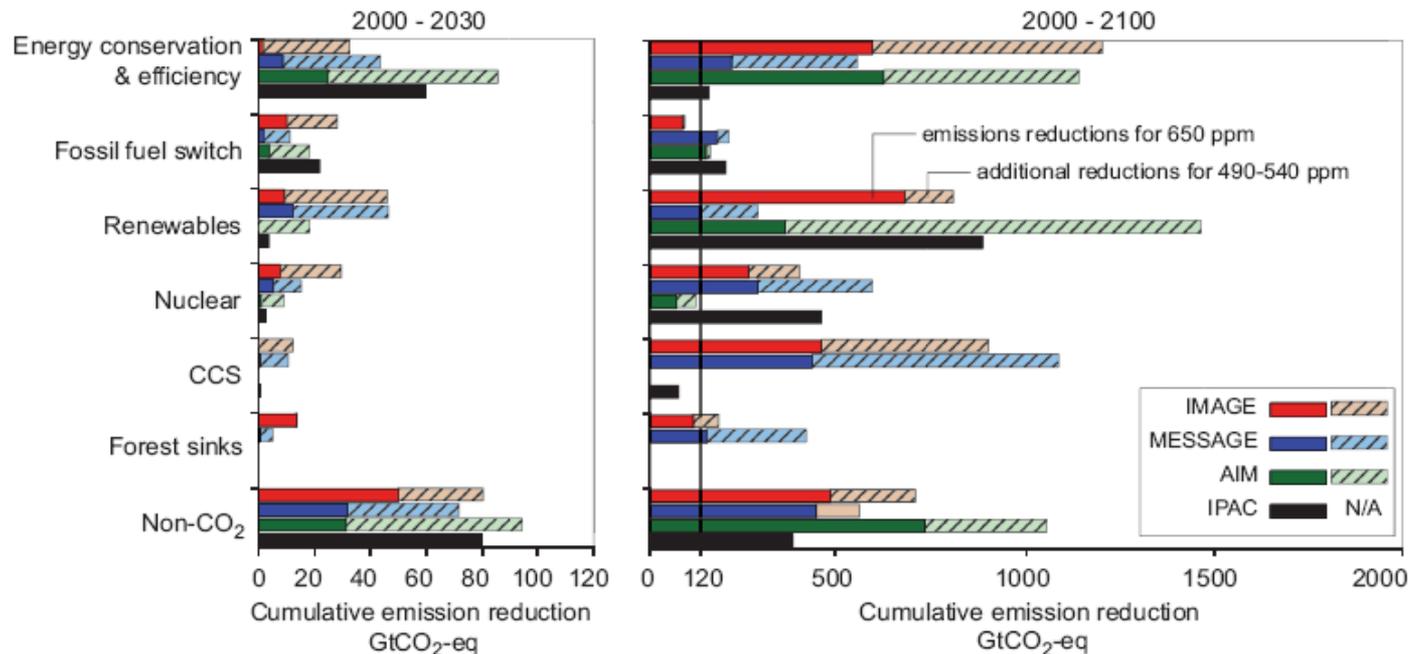


Figure 3.23: Cumulative emissions reductions for alternative mitigation measures for 2000 to 2030 (left-hand panel) and for 2000-2100 (right-hand panel). The figure shows illustrative scenarios from four models (AIM, IMAGE, IPAC and MESSAGE) for stabilization levels of 490-540 ppmv CO₂-eq and levels of 650 ppmv CO₂-eq, respectively. Dark bars denote reductions for a target of 650 ppmv CO₂-eq and light bars the additional reductions to achieve 490-540 ppmv CO₂-eq. Note that some models do not consider mitigation through forest sink enhancement (AIM and IPAC) or CCS (AIM) and that the share of low-carbon energy options in total energy supply is also determined by inclusion of these options in the baseline. CCS includes carbon capture and storage from biomass. Forest sinks include reducing emissions from deforestation.

Data source: Van Vuuren et al. (2007); Riahi et al. (2006); Hijioka, et al. (2006); Masui et al. (2006); Jiang et al. (2006).

Observations

- Regular updating of technology assumptions of models on the basis of expert information needed (as technology assumptions do matter) (either exogenous technology / learning-by-doing)
- Global vs. Regional technology / technology diffusion
- Ambitious scenarios require for most models about everything that is available in the models \leftrightarrow somewhat at odds with the historic observation of domination by single energy carriers/log-in.
- Key technologies for very low scenarios include bio-energy, efficiency, carbon-capture and storage, non-CO2 emission reduction.
- Or..... No meat 😊