



POTSDAM INSTITUTE FOR
CLIMATE IMPACT RESEARCH

The Role of Renewables in the Low-Carbon Transformation First-Best vs. Second-Best Worlds

Nico Bauer, Lavinia Baumstark, Marian Leimbach

Stanford, July 7, 2011

30th International Energy Workshop

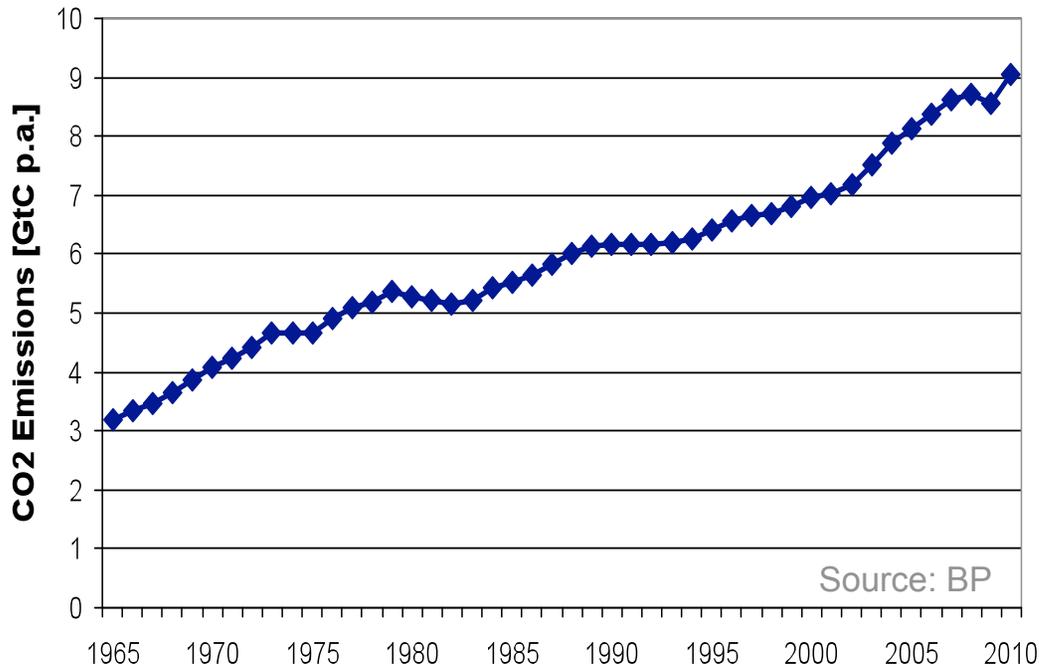


Content

- Introduction
- Methodology
- Results
- Discussion
- Conclusions

Introduction – Recent Developments

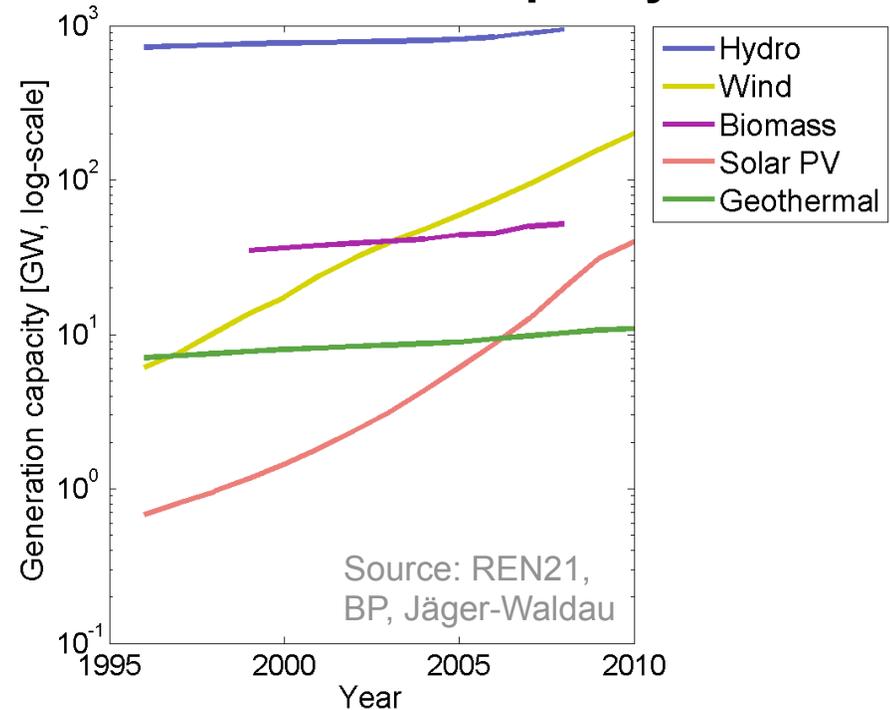
Global CO2 Emissions from Fossil Fuels



Copenhagen Accord

call for strong climate change stabilization, but no binding emission limitation

Global Renewable Generation Capacity



National Policies

Short term technology support because of – inter alia – climate change

Introduction – Policy Relevant Science

Climate Stabilization

- Optimal emission trajectories suggest that achieving strong stabilization targets are not in contradiction with short-term increasing emissions
→ IPCC TAR, WG III, Ch. 10, O'Neill, et al. (2009), etc. ...
- Delayed climate policies lead to (much) higher costs for achieving stabilization of GHG concentration
→ IEA-WEO'09, EMF-22, RECIPE

Renewable Energy Deployment

- RET are an important option for mitigating CO₂ emissions from the energy sector in a climate policy regime, especially due to learning by doing
→ IPCC SRREN SPM, Barreto (2001), Manne and Richels (2004), ...
- Not developing the RET option timely for large scale deployment increases mitigation costs significantly
→ EU-ADAM, RECIPE, (AMPERE, RoSE, ...)

Introduction – Climate and Energy Policy

Assume cap-and-trade is delayed until 2020 to achieve 450ppm CO₂ concentration target by 2100. What is the effect of early RET deployment on ...

- CO₂ emissions in 2020?
- the extra costs of delayed global emission mitigation?
- the regional mitigation costs and what how to explain them?

Main question: Is energy policy a temporary substitute for missing carbon price if climate policy is delayed?

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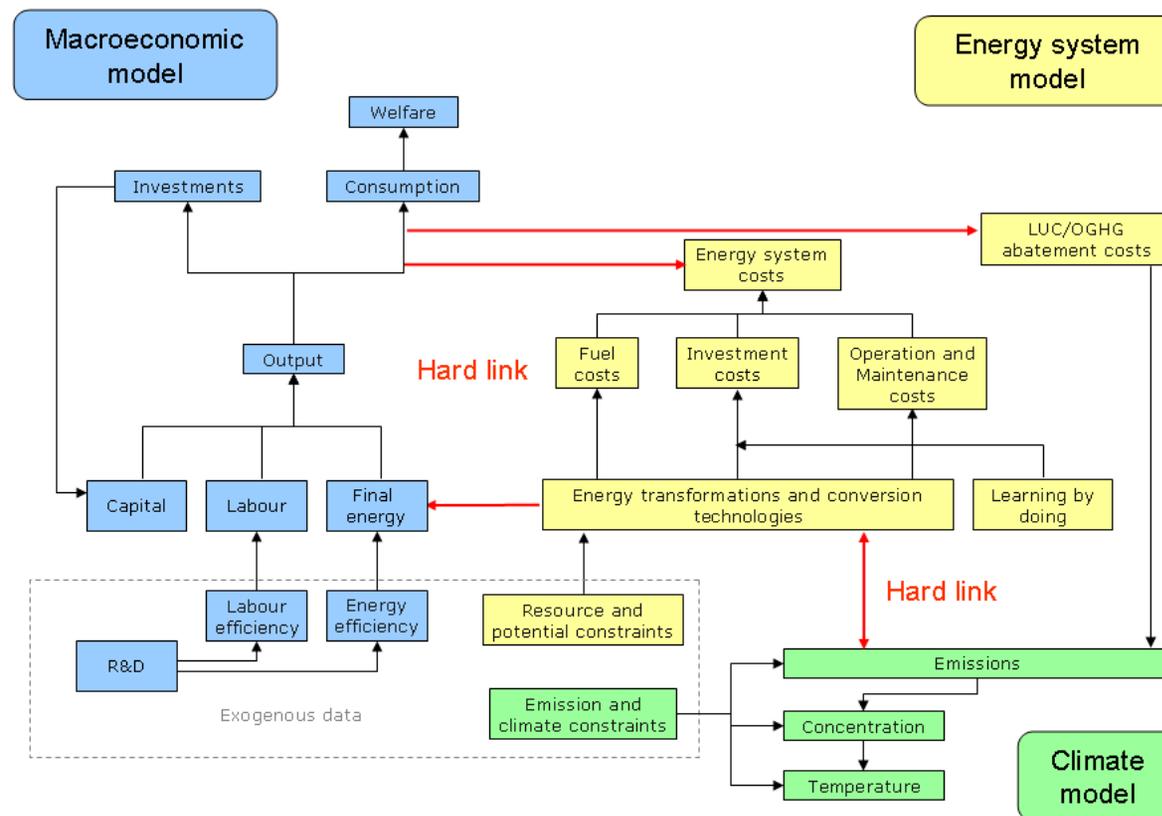
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Methodology – REMIND Model and Scenarios

- For generation of scenarios we use REMIND-R (version of the RECIPE project)
- Intertemporal general equilibrium multi-region hybrid model of energy-economy-climate with interregional trade in goods, energy carriers and emission permits

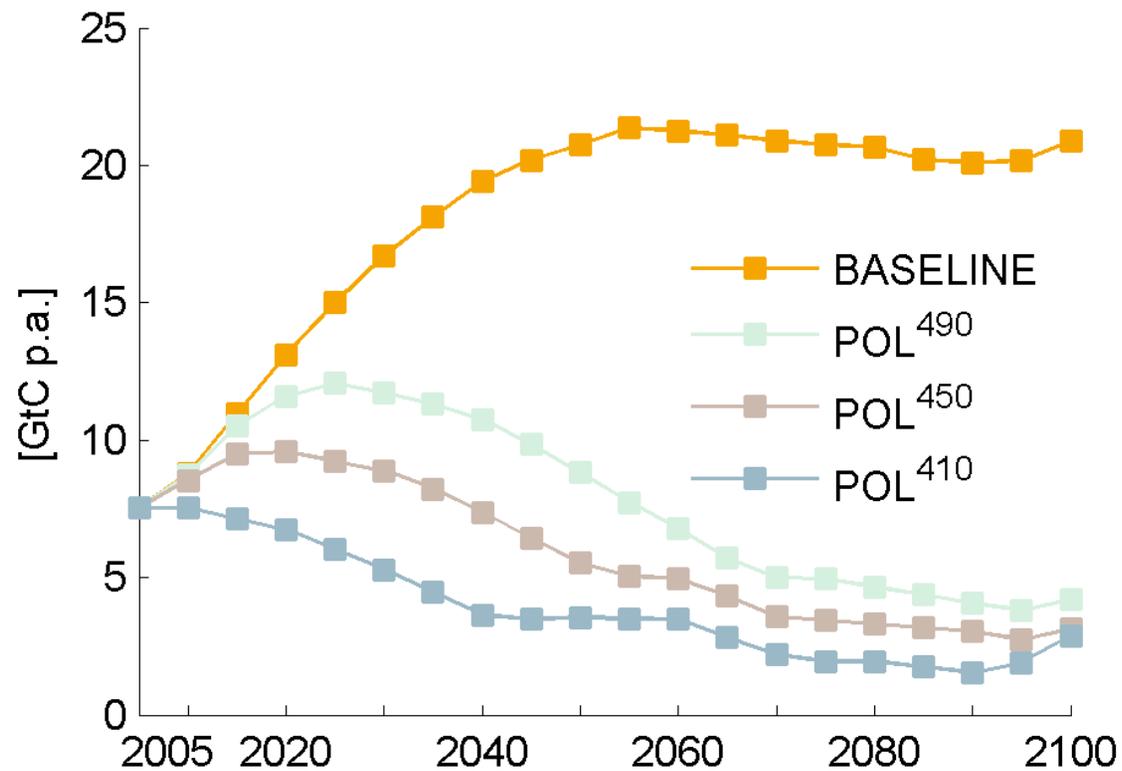


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- For generation of scenarios we use REMIND-R (version of the RECIPE project)
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- The Business of usual (**BAU**) is point of reference to assess the costs of additional climate change mitigation
- For climate policies it computes a first-best solution (**POL⁴¹⁰**, **POL⁴⁵⁰**, **POL⁴⁹⁰**)
 - Cap-and-trade system
 - Contraction and convergence distribution of permit right
- Second-best policy scenarios can be implemented via constraints (**POL^{DEL}**)
- Various constraints imply complex second-best scenarios (**POL^{D&R}** (**w,m,s**))

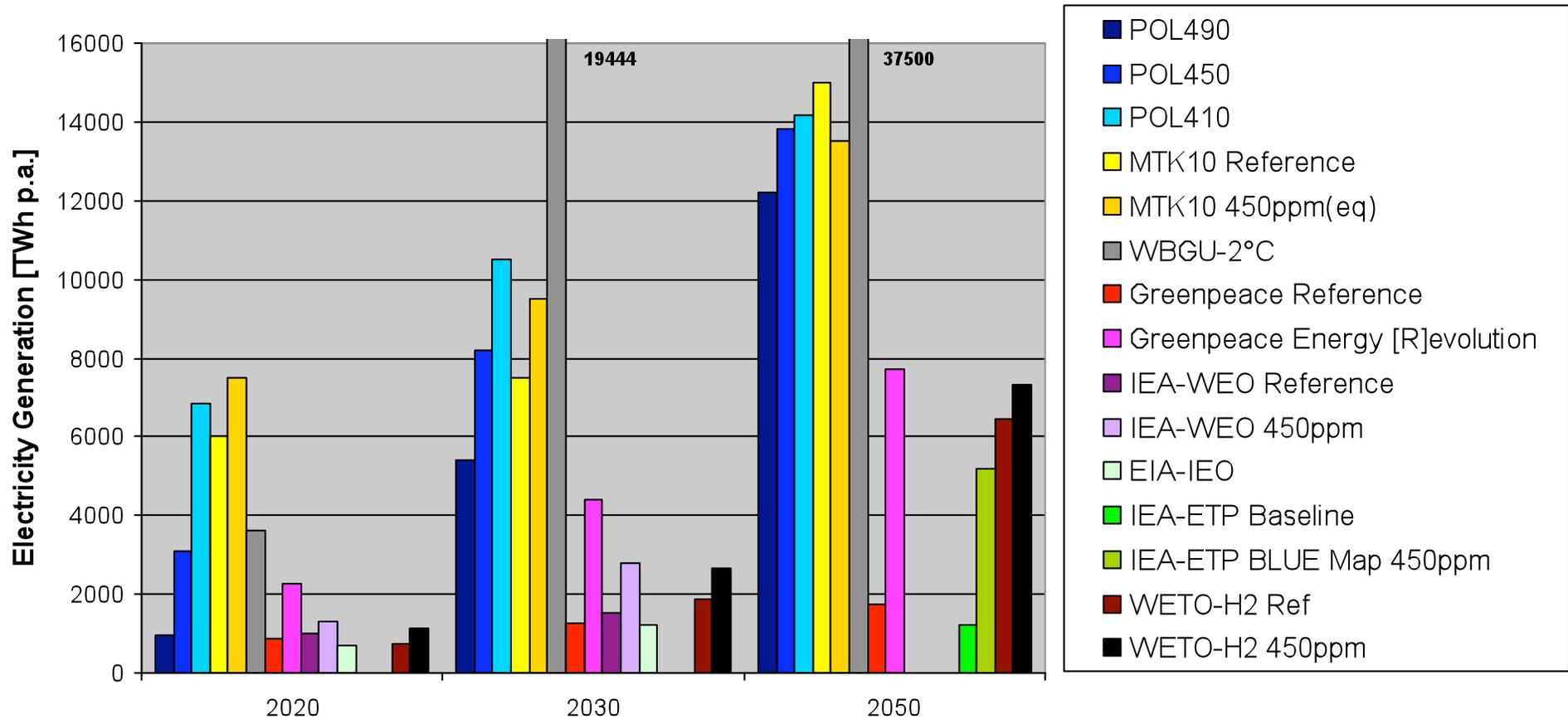
Results – First Best Solution

Global Fossil Fuel CO2 Emissions



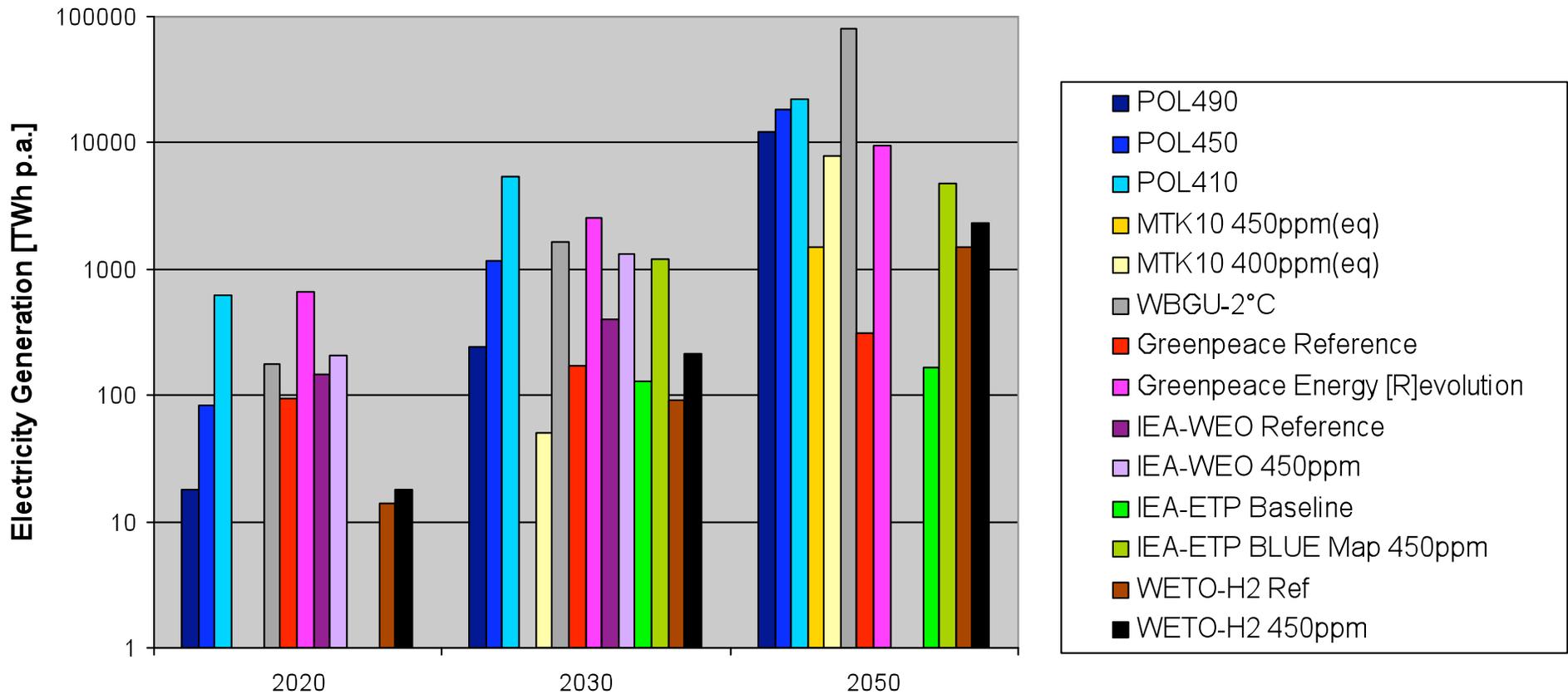
Results – Comparison of 1st Best Technology Deployment

Wind Electricity Production



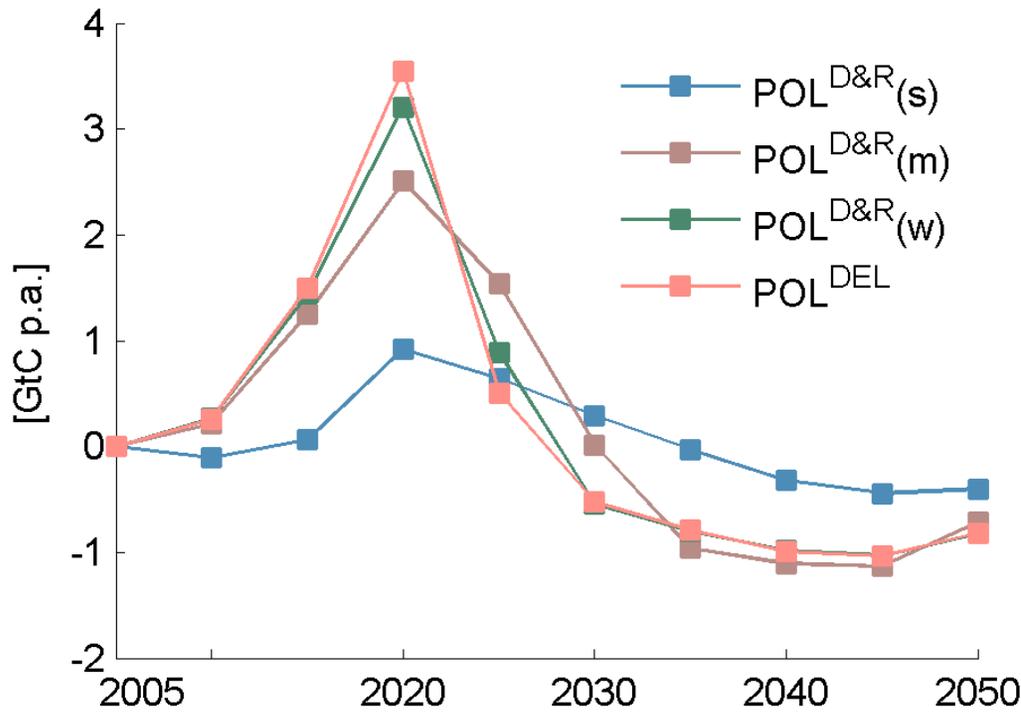
Results – Comparison of 1st Best Technology Deployment

Solar Electricity Production

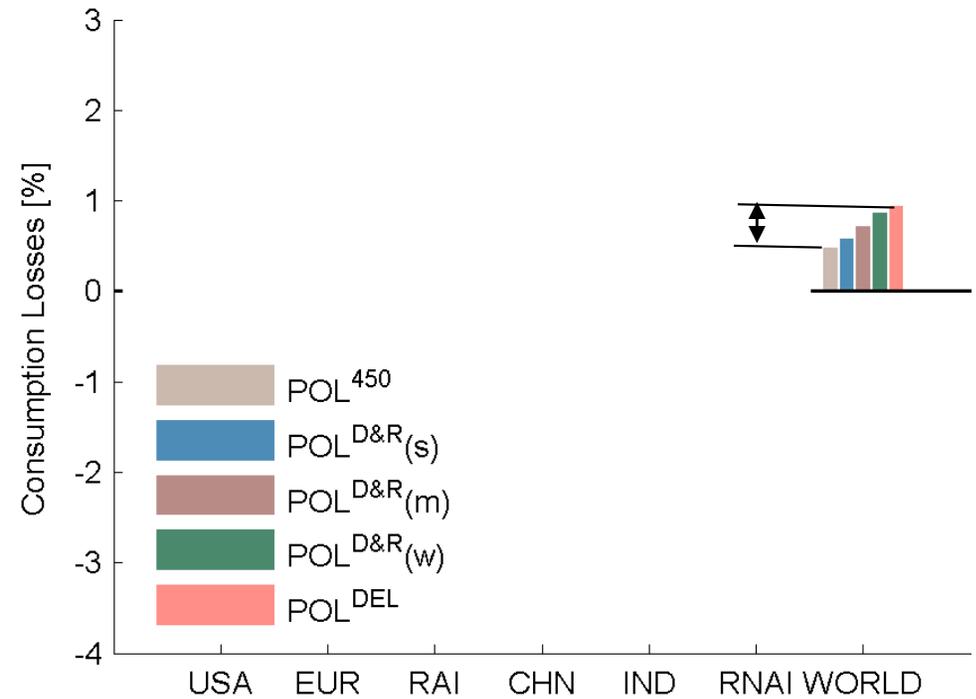


Results – Reducing the Costs of Delayed Climate Policy

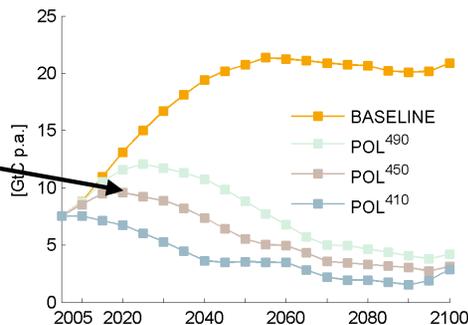
Emission Differences to 1st Best Solution



Consumption differences rel. to BAU



1st Best



Results – How to explain differences to delayed policy?

Permit prices in 2020

POL^{DEL} : 92\$US(05) per tCO₂

$POL^{D\&R(m)}$: 53\$US(05) per tCO₂

- Permit trade (net trade revenue)
- Fuel (domestic + net trade revenue)
- Energy system (Invest.+O&M)
- Macroeconomic (GDP-Invest)

Reasons for the permit trade effect

- Budget is less used up and committed emissions are lower
- Renewable capacities are already installed
- Endogenous LbD is induced earlier

Discussion – Are the results a REMIND artefact?

CO2 price in 2020 in \$US(2005) per tCO2	550ppm-e os	
	Full	Delay
ETSAP- TIAM	8	13
FUND	51	147
GTEM	27	28
IMAGE	11	12
MERGE (pessi.)	29	154
MESSAGE	7	35
MiniCAM (Base)	8	10
MiniCAM (LoTech)	34	169
POLES	27	51
SGM	40	67
WITCH	4	36

Source: Clarke et al. (2009)

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CO2 price in 2020 in \$US(2005) per tCO2	550ppm-e os		550ppm-e nte	
	Full	Delay	Full	Delay
ETSAP- TIAM	8	13	10	24
FUND	51	147	52	239
GTEM	27	28		
IMAGE	11	12	16	92
MERGE (pessi.)	29	154	35	256
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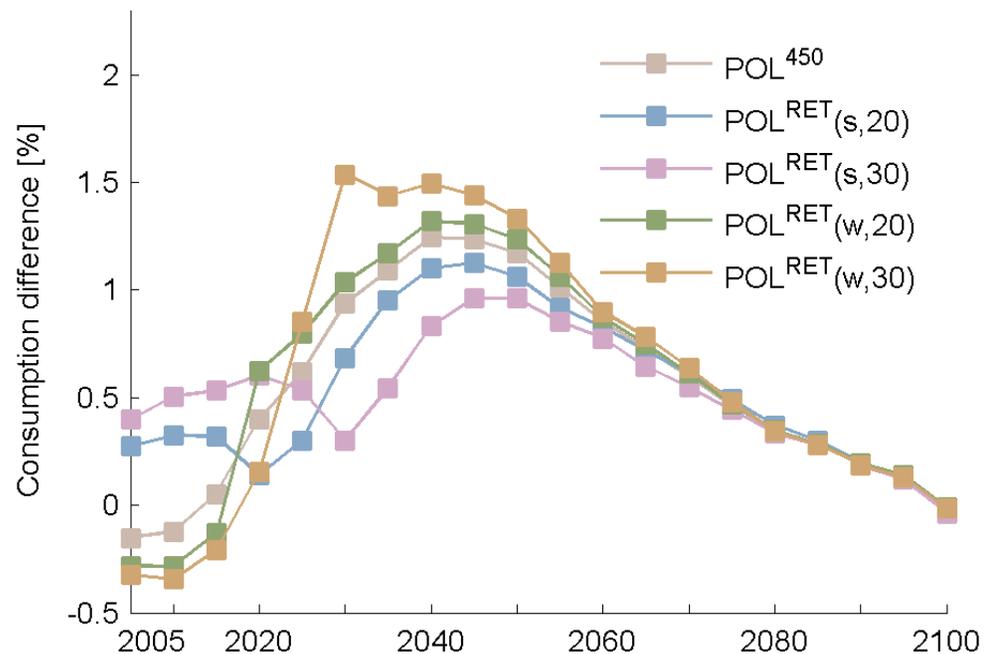
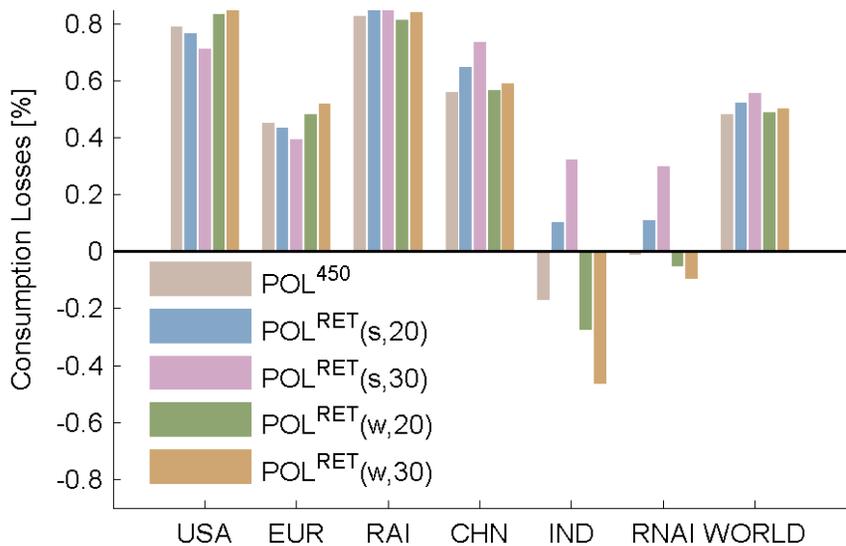
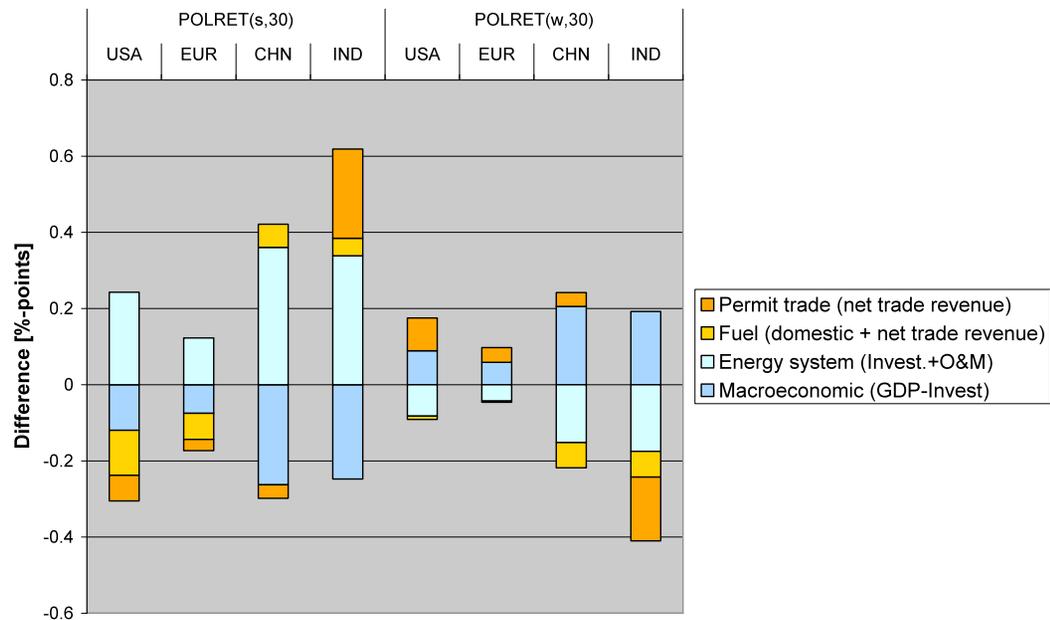
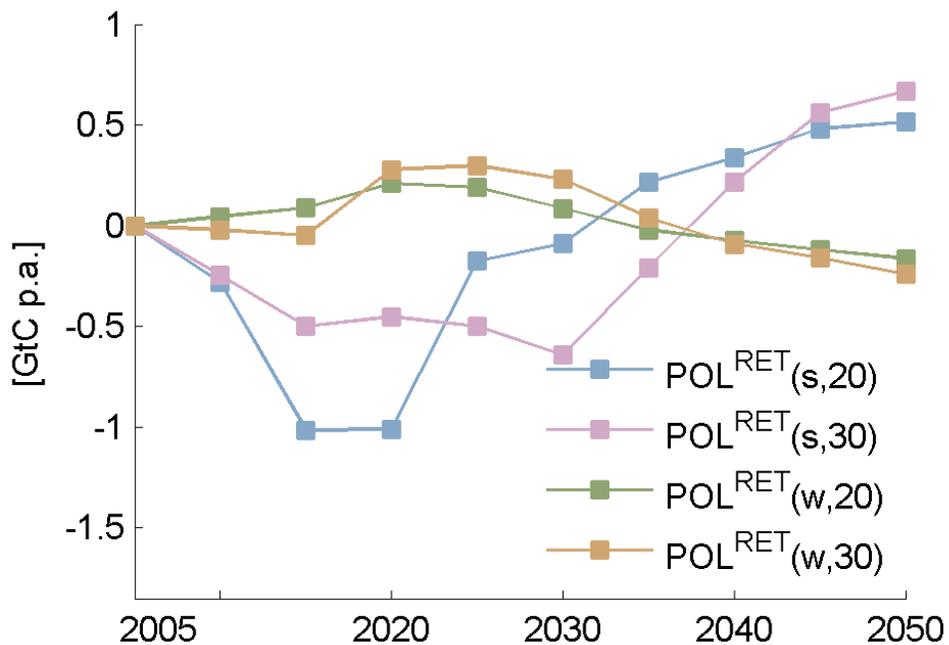
Source: Clarke et al. (2009)

Conclusions

- Early technology policy is a temporary substitute for missing carbon price, if climate policy is delayed, and the effect is significant
- It reduces emissions in the short-term and closes the gap to the first best solution
- The distribution effects suggest that potential importers of emission certificates profit most from early renewable deployment
→ incentive to initiate such policy
- The potential loss, if climate policy is never imposed, is relatively small
- The crucial question is whether additional renewable deployment (beyond the basecase) is feasible and policies well-targeted

ADDITIONAL MATERIAL

Results - POL^{RET} Scenarios



ReMIND – Technology Matrix

		Primary energy carriers						
		Exhaustible				Renewable		
		Coal	Oil	Gas	Uranium	Solar, Wind, Hydro	Geo-thermal	Biomass
Secondary energy carriers	Electricity	PC*, IGCC*, CoalCHP	DOT	GT, NGCC*, GasCHP	TNR, FNR	SPV, WT, Hydro	HDR	BioCHP, BIGCC*
	H2	C2H2		SMR*				B2H2*
	Gases	C2G		GasTR				B2G
	Heat	CoalHP, CoalCHP		GasHP, GasCHP			GeoHP	BioHP, BioCHP
	Liquid fuels	C2L*	Refin.					B2L*, BioEthanol
	Other Liquids		Refin.					
	Solids	CoalTR						BioTR

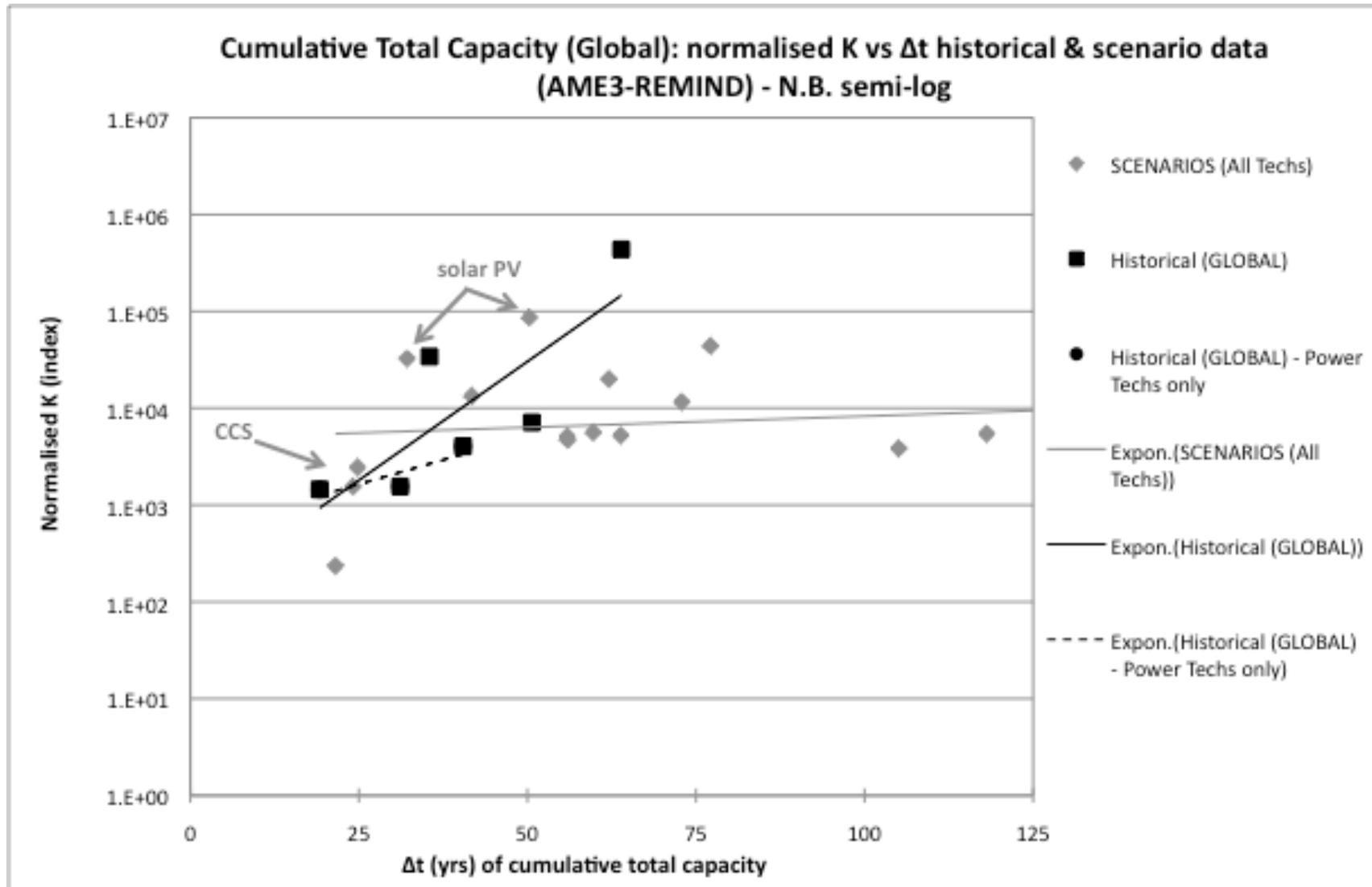
Abbreviations: PC = conventional coal power plant, IGCC = integrated coal gasification combined cycle, CoalCHP = coal combined heat power, C2H2 = coal to H2, C2G = coal to gas, CoalHP = coal heating plant, C2L = coal to liquids, CoalTR = coal transformation, DOT = diesel oil turbine, Refin. = Refinery, GT = gas turbine, NGCC = natural gas combined cycle, GasCHP = Gas combined heat power, SMR = steam methan reforming, GasTR = gas transformation, GasHP = gas heating plant, TNR = thermal nuclear reactor, FNR = Fast nuclear reactor, SPV = solar photovoltaic, WT = wind turbine, Hydro = hydro power, HDR = hot-dry-rock, GeoHP = heating pump, BioCHP = biomass combined heat and power, BIGCC = Biomass IGCC, B2H2 = biomass to H2, B2G = biogas, BioHP = biomass heating plant, B2L = biomass to liquids, BioEthanol = biomass to ethanol, BioTR = biomass transformation

* These technologies are also available with carbon capture.

Scenario Design

	Climate Policy (CO ₂ only)	RET deployment
BASELINE	None	Optimal
POL^x	Starting in 2010 x indicates the stabilization at 410ppm, 450ppm, 490ppm by 2100	Optimal
POL^{DEL}	Delayed (DEL) until 2020 450ppm by 2100	Optimal subject to delayed climate policy
POL^{D&R(s/m/w)}	Delayed (D) until 2020 450ppm by 2100	RET deployment is strong (s), medium (m) or weak (w) Until 2020

Validation of ReMIND's technology scale-up



Source: Wilson et al. (t.b.s)

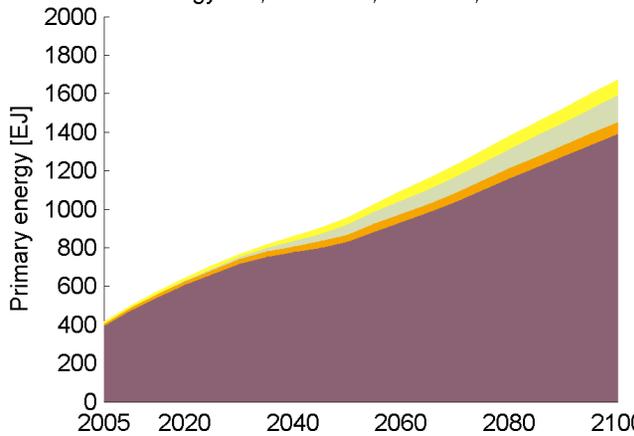
Bauer et al.
30th IEW, Stanford, July 7, 2011

The energy system transformation

Baseline

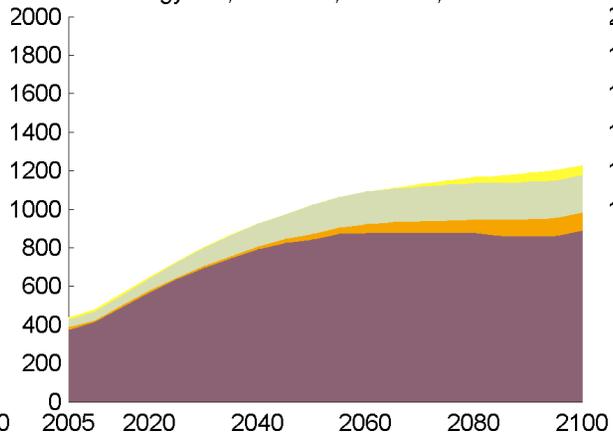
IMACLIM-R

Energy Mix, IMACLIM, WORLD, baseline



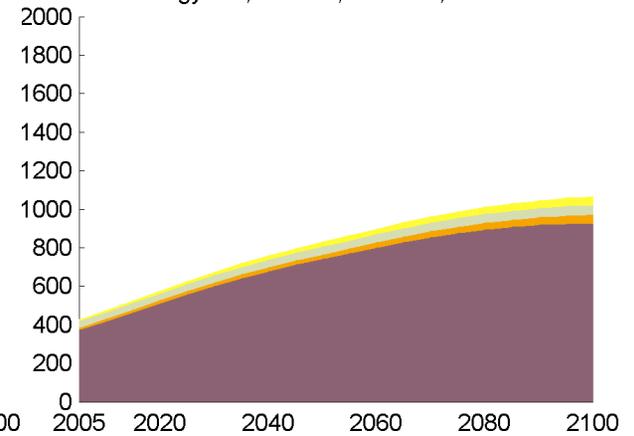
ReMIND-R

Energy Mix, REMIND, WORLD, baseline



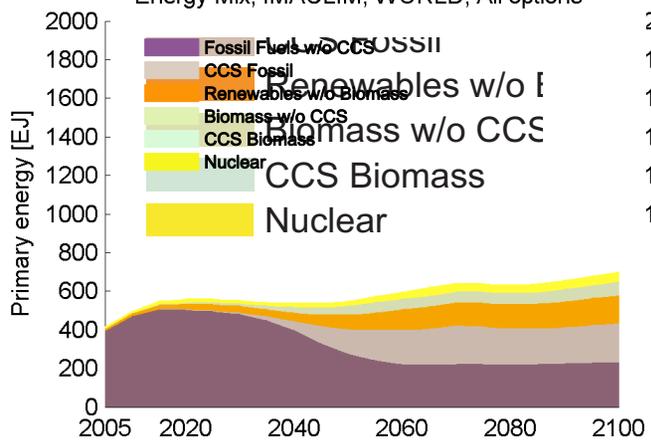
WITCH

Energy Mix, WITCH, WORLD, baseline

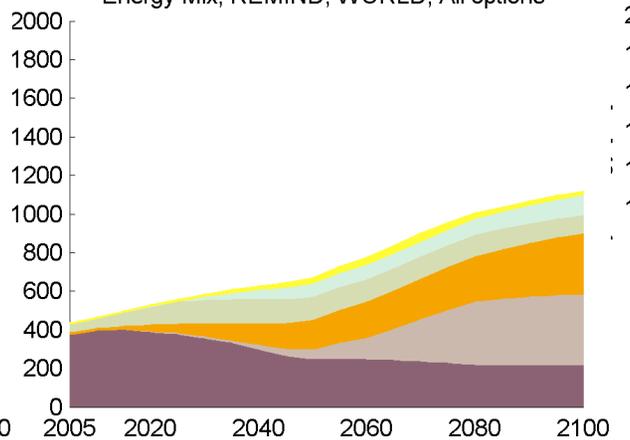


450 ppm CO₂

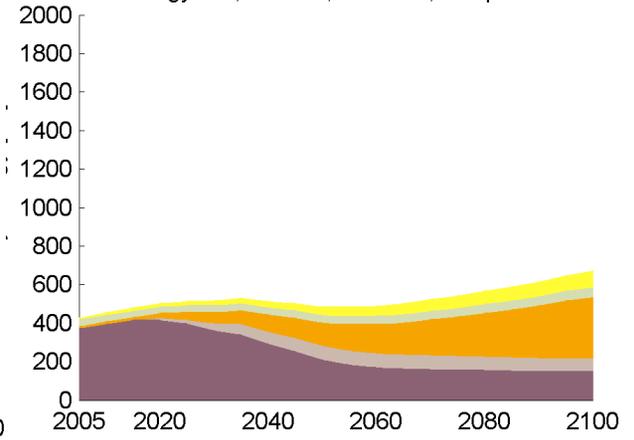
Energy Mix, IMACLIM, WORLD, All options



Energy Mix, REMIND, WORLD, All options



Energy Mix, WITCH, WORLD, All options

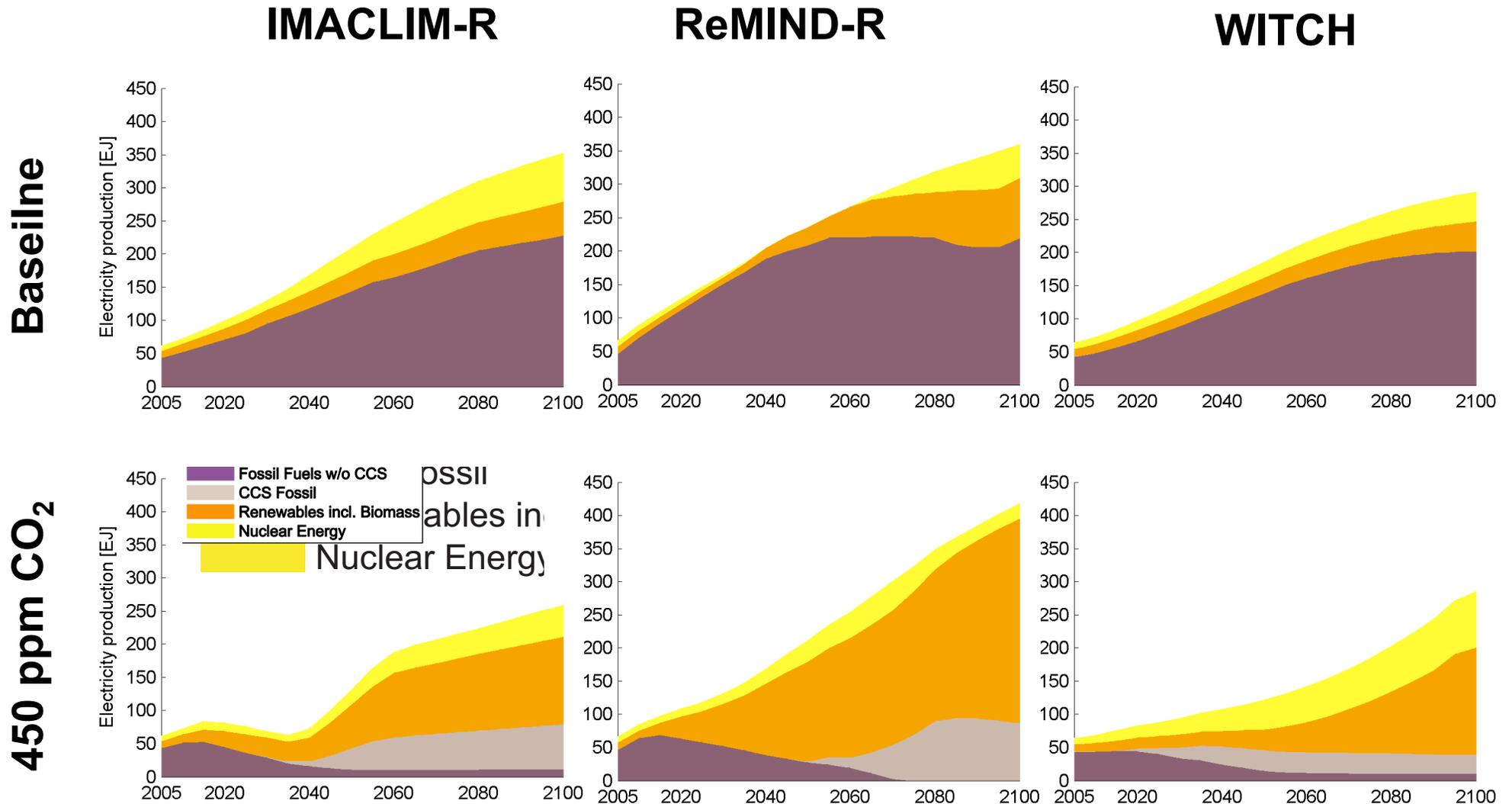


- Fossil Fuels w/o CCS
- CCS Fossil
- Renewables w/o Biomass
- Biomass w/o CCS
- CCS Biomass
- Nuclear

Luderer et al., 2009



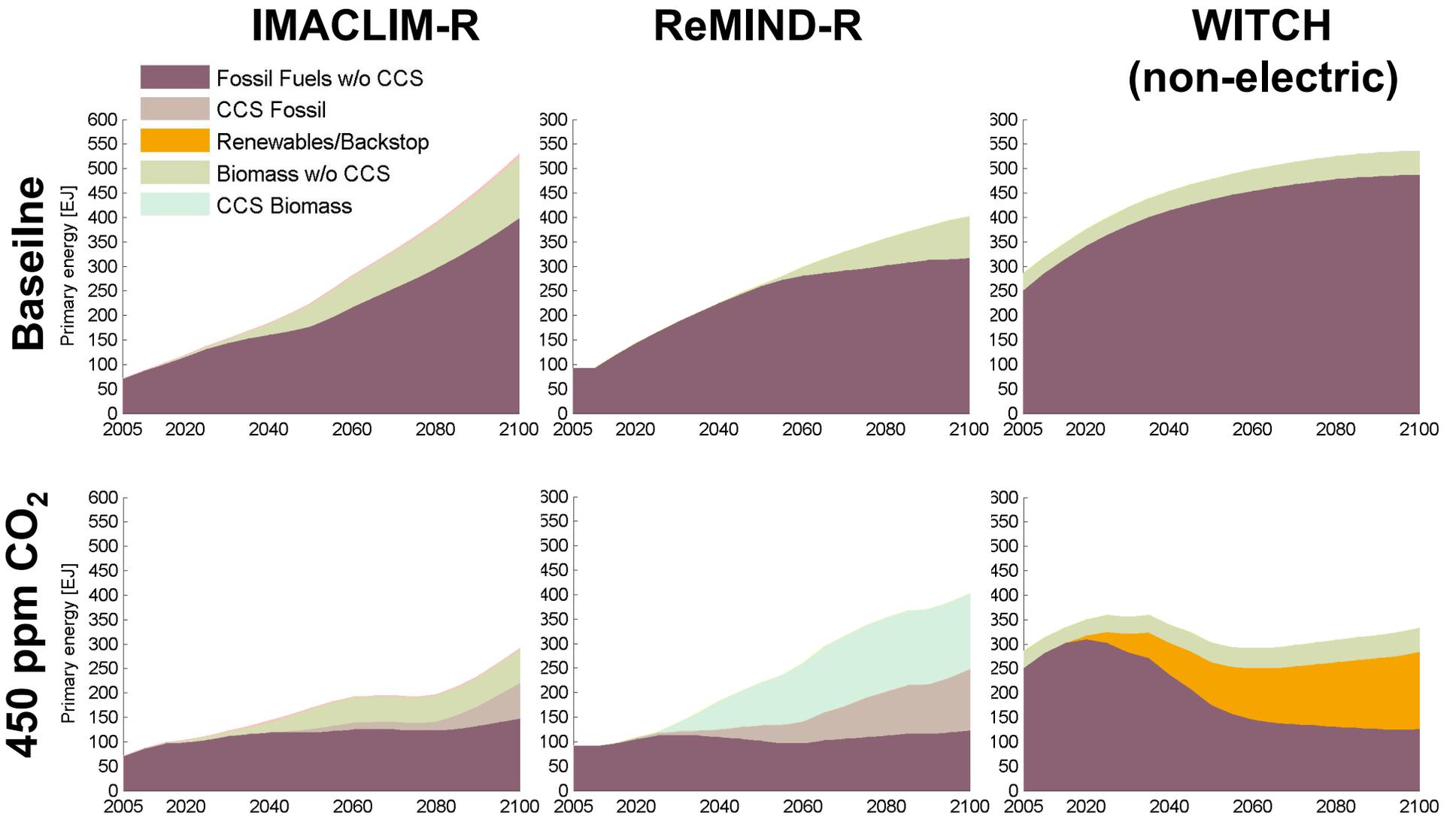
Sectoral results: Electricity production



Luderer et al., 2009



Sectoral results: Transport



Luderer et al., 2009



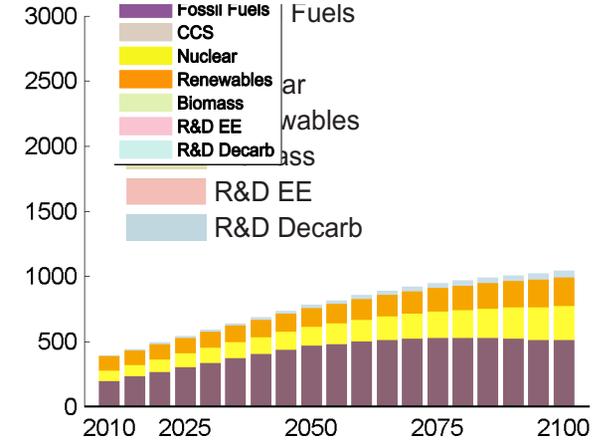
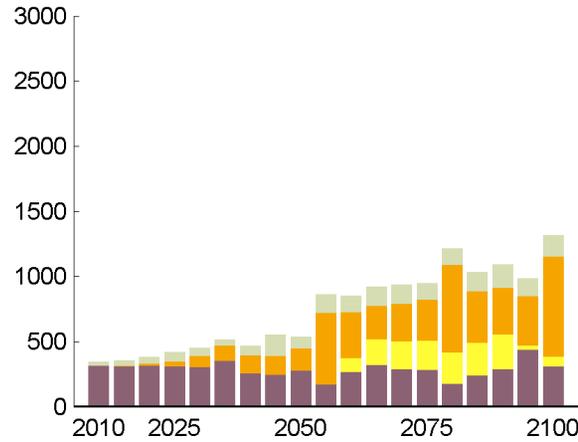
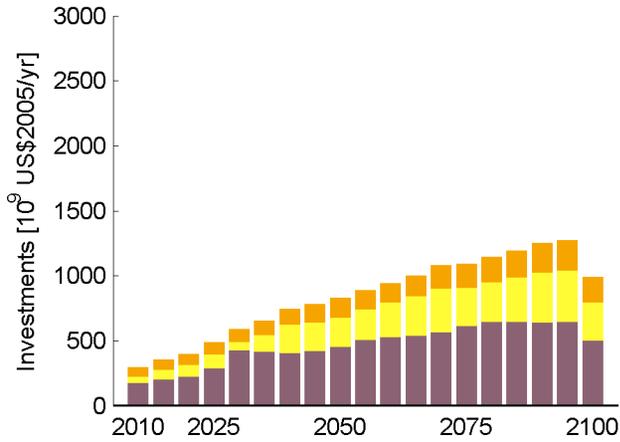
Energy system investments

Baseline

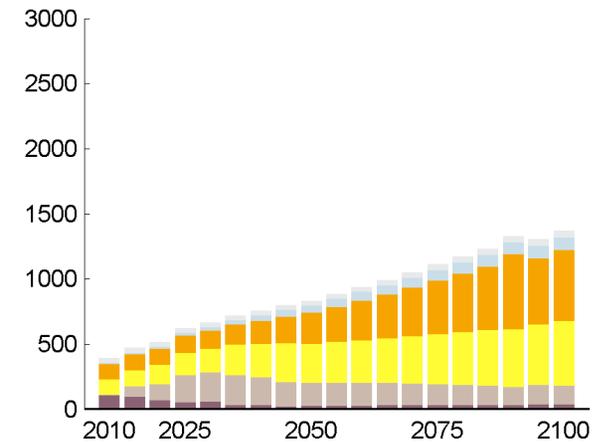
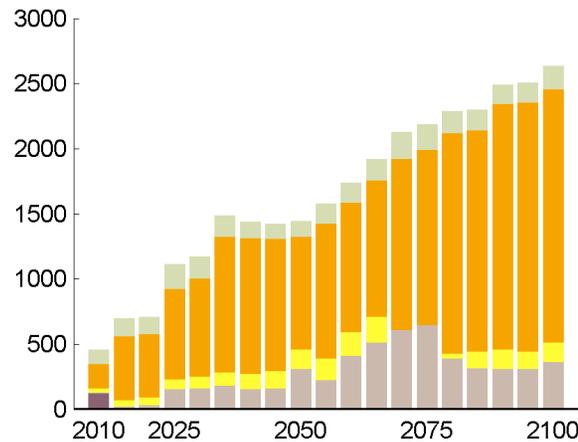
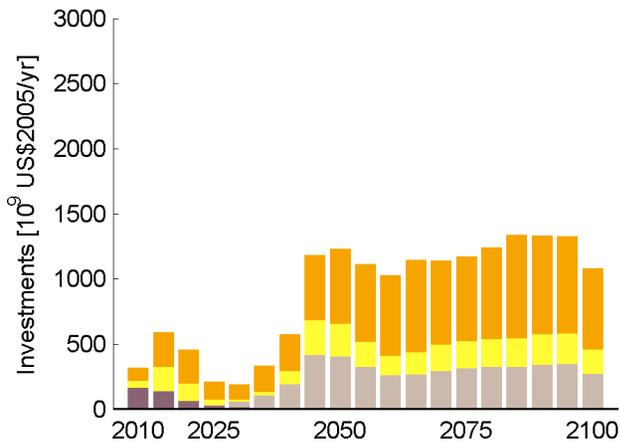
IMACLIM-R

ReMIND-R

WITCH



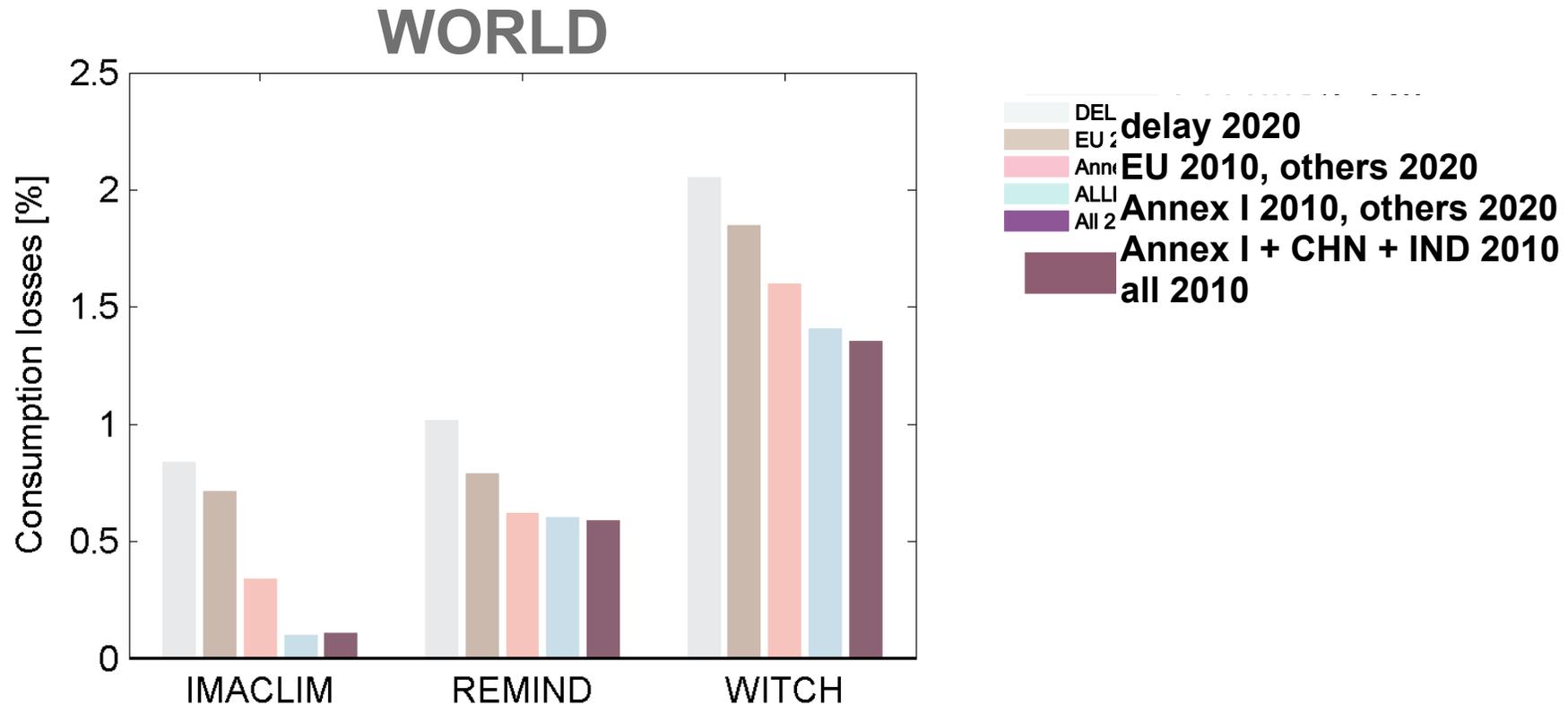
450 ppm CO₂



Luderer et al., 2009



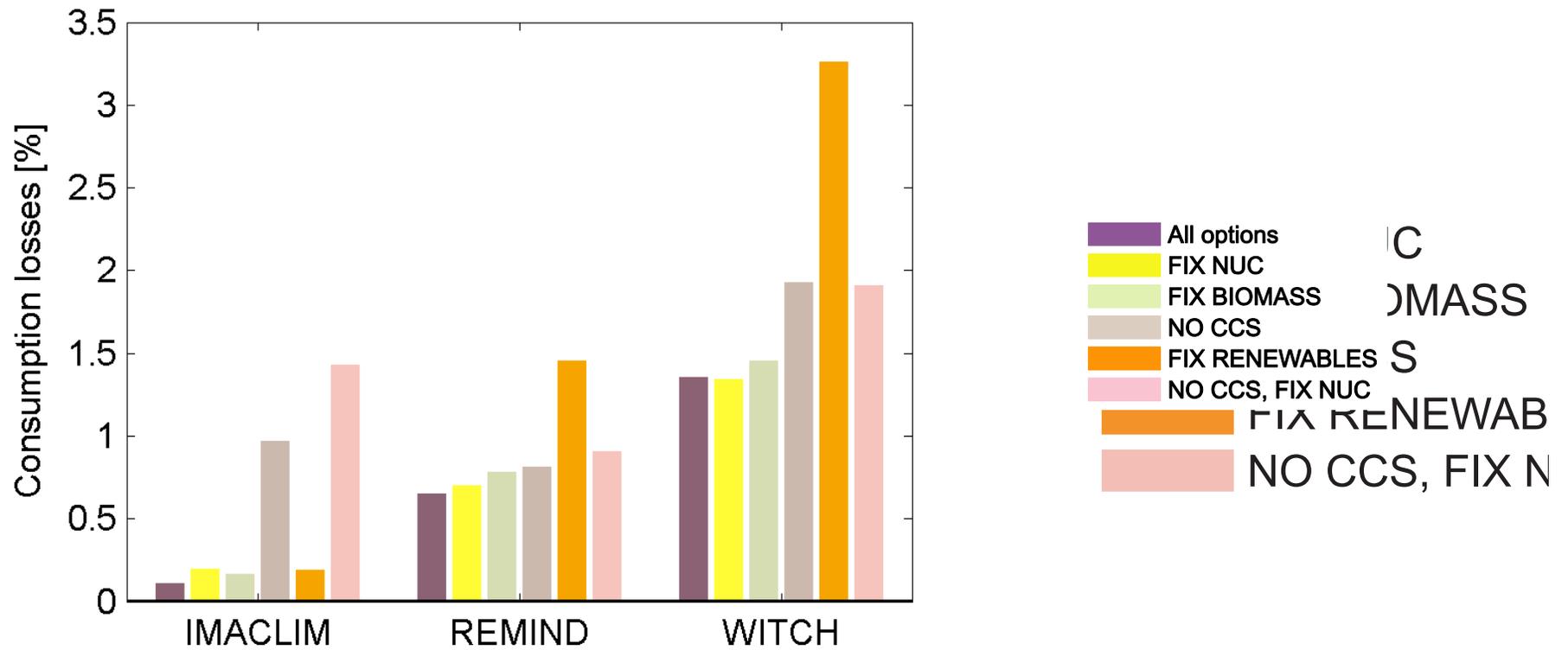
The cost of delay



Luderer et al., 2009;
Jakob et al., in prep.

- ➔ delay of action beyond 2020 makes climate target unachievable
- ➔ decreasing costs with increasing participation in climate coalition

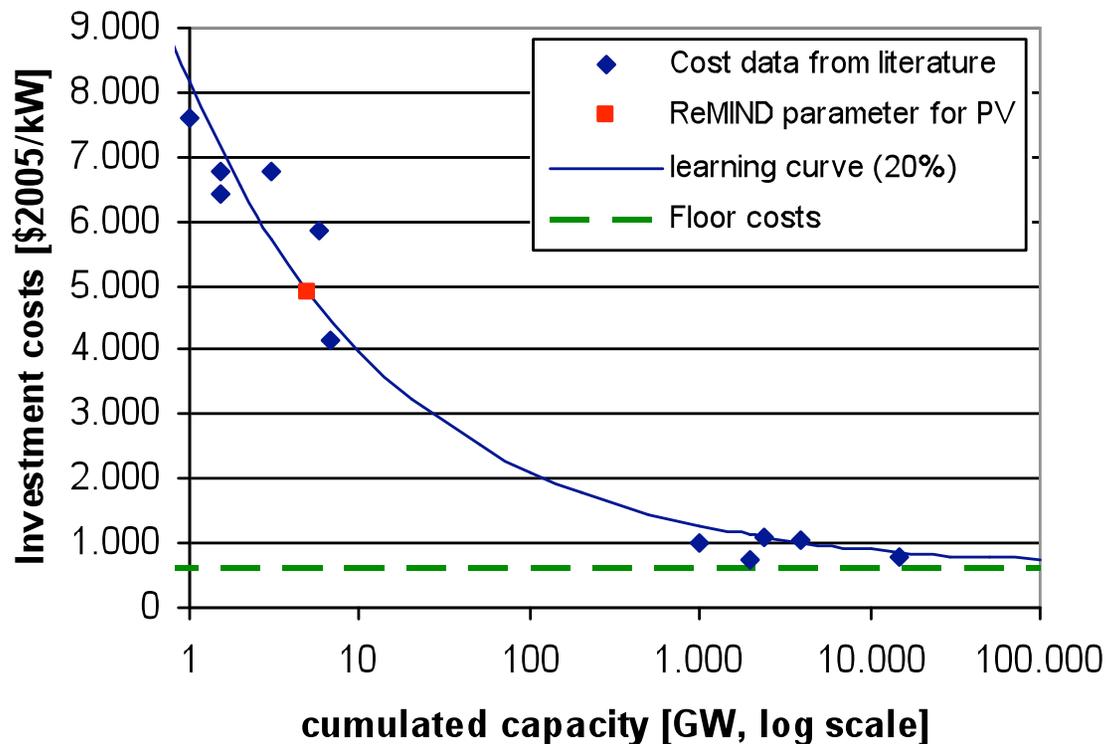
Technology option values (RECIPE)



Luderer et al., 2009

Renewables in REMIND-R

Technology	Unit	Scenario			
		BAU	POL ⁴⁹⁰	POL ⁴⁵⁰	POL ⁴¹⁰
Wind	\$US/kW	1144	960	917	901
Solar PV	\$US/kW	4900	3823	2548	1543



- Storage requirement per installed capacity for each technology depends on the share of generation
- Storage parameterized for three time scales (daily, weekly, seasonal). Flow batteries and H₂-electrolysis are used for daily and weekly fluctuations.
- Resulting average cost penalties due to investment into storage capacities and storage losses:

in 2050

PV: 830\$/kWp → 1140-1360\$/kWp
 Wind: 890\$/kWp → 1000-1270\$/kWp

in 2075

PV: 760\$/kWp → 1030-1340\$/kWp
 Wind: 890\$/kWp → 970-1210\$/kWp

Renewable Potentials

