Mitigation Strategies and Costs

The Effects of Endogenous Technological Change – Lessons from IMCP

Environmental and Resource Economics 3rd World Congress

Kyoto, 5 July 2006

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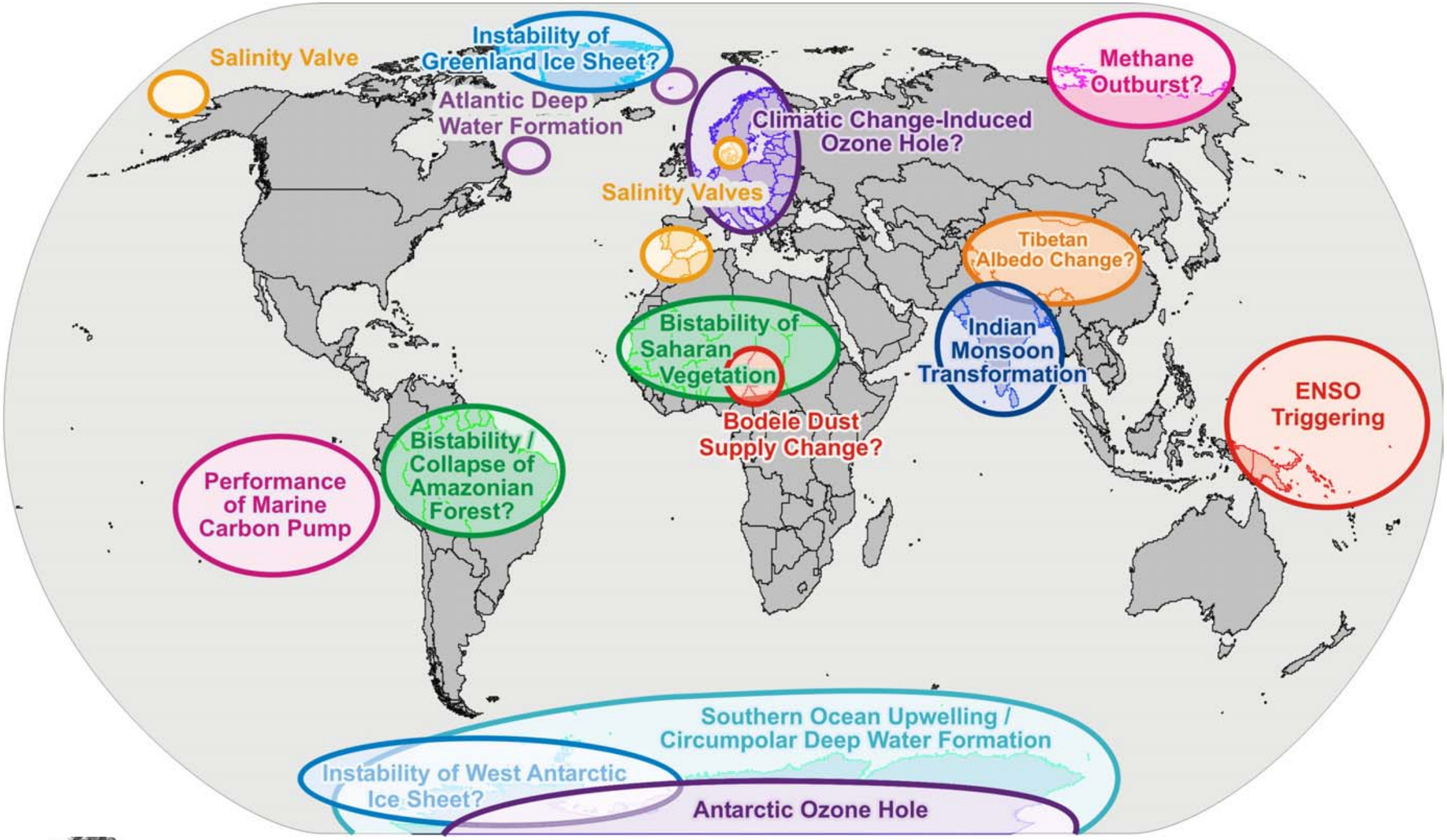
Dr. Ottmar Edenhofer / Kai Lessmann

Cost-Benefit Approach to Climate Change Management:

Climate Protection Benefits = Avoided Damages – Adaptation Costs – Mitigation Costs

Tipping Points in the Earth System



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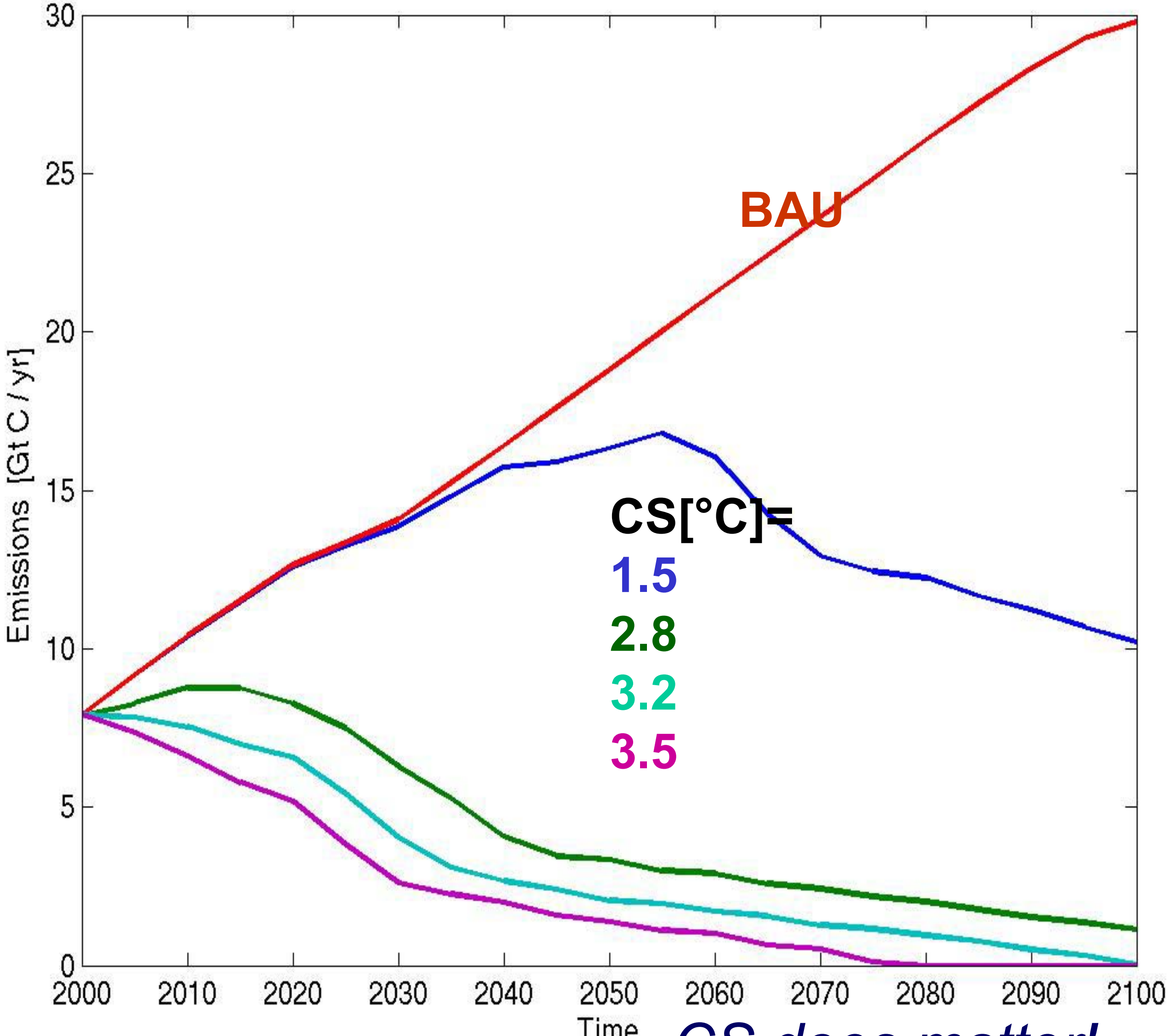
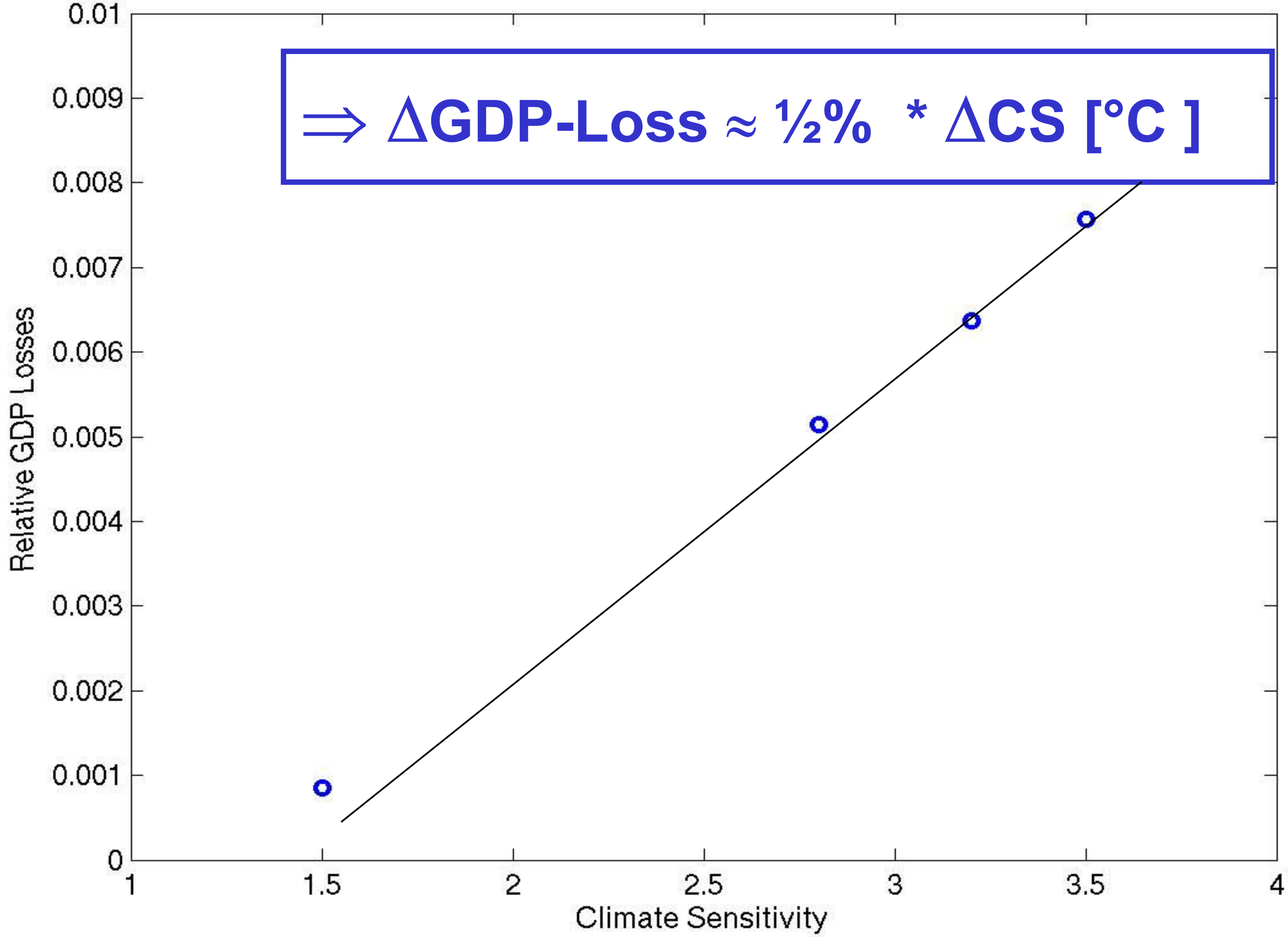
Optimal Emissions vs Climate Sensitivity



CS does matter!

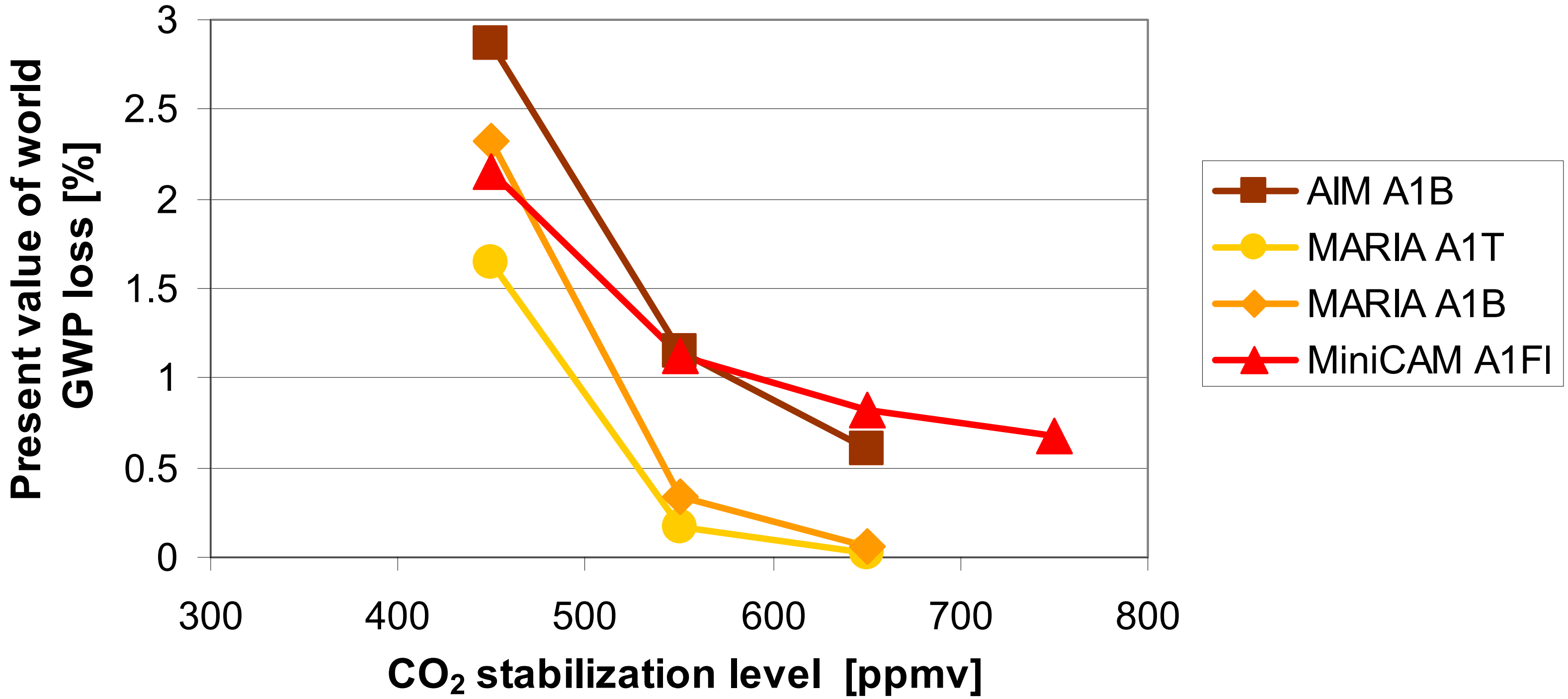
Does Climate Uncertainty matter for the State-of-the-Art Economic Model MIND?



Are there limits to adaptation?

Dutch cow ready for sea level rise?

Mitigation costs



Conventional wisdom

- ITC reduces mitigation costs only in partial equilibrium models.
- Technological change is not a free lunch, it has its own opportunity costs.

SPECIAL REPORT

The costs of global warming

Efforts to forecast how Earth's future climate will affect us must consider the economic growth of both rich and poor nations. But there are doubts over the theories being used, as **Quirin Schiermeier** explains.

Discussions of climate change tend to involve uncertainties, and most climate researchers have come to accept the inherent unknowns of their business. After all, the climate models they use to project the course of global warming are generally seen as the best that science can offer. But there is a growing feeling that the economic assumptions on which their work is based are outdated and unreliable. And this could have serious implications for assessments of climate change.

The Intergovernmental Panel on Climate Change (IPCC), which coordinates efforts to predict the effects of global warming, is currently finalizing its fourth assessment report. It has asked 15 climate groups to run their models using output from a range of different 'scenarios', representing various assumptions about energy use, economic development reflect how lifestyle and energy demand in both rich and poor countries are likely to change.

Climate researchers are familiar with the problem. "Some emissions scenarios are perhaps already demonstrably wrong," says Erich Roeckner, a climate modeller at the Max Planck Institute for Meteorology in Hamburg, Germany, who has modelled three of them for the IPCC (see "Early results"). "It is possible that all of them are wrong." But most feel that economics is a field they are not qualified to assess.

Ridiculous assumption?

One key criticism is the assumption that the economies of poor countries will quickly catch up with those of rich nations. "It is ridiculous to assume, as the IPCC does, that rich and poor countries will economically converge as rapidly as the European Union has done over the past

Translating temperature changes into impacts on society is beset with unknowns.

Models in the IMCP

	Technological detail	
Calculus	*Top Down*	*Bottom Up*
Welfare maximization	Optimal growth models ENTICE-BR FEEM-RICE DEMETER-1CCS AIM/Dynamic-Global MIND 1.1	
Cost minimization		Energy system models MESSAGE-MACRO GET-LFL DNE21+
Initial value problems	Simulation models E3MG	
Static equilibrium + recursive dynamics	Computational general equilibrium models (CGE) IMACLIM-R	

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ENDOGENOUS TECHNOLOGICAL CHANGE AND THE ECONOMICS OF ATMOSPHERIC STABILISATION

Special Issue **IAEE**
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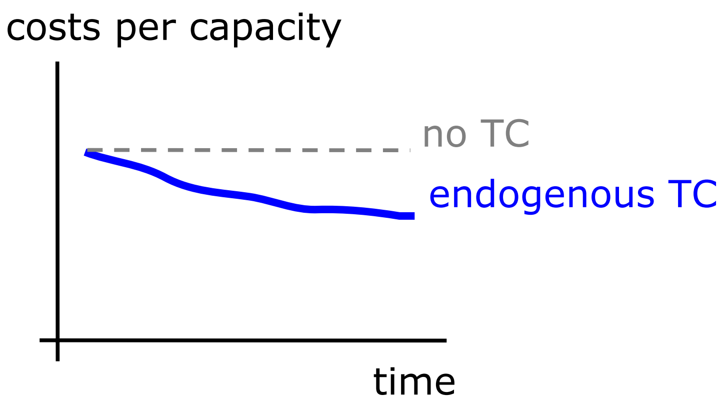
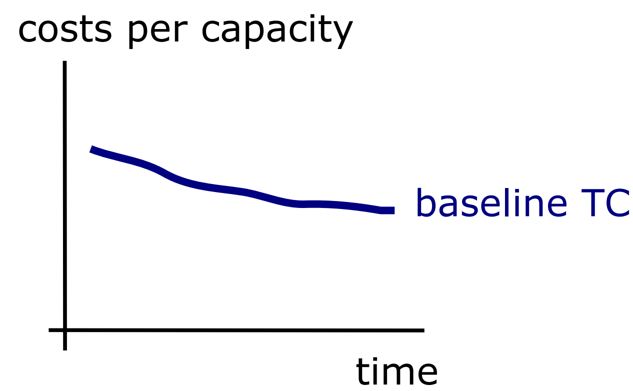
IMCP Scenario Definitions

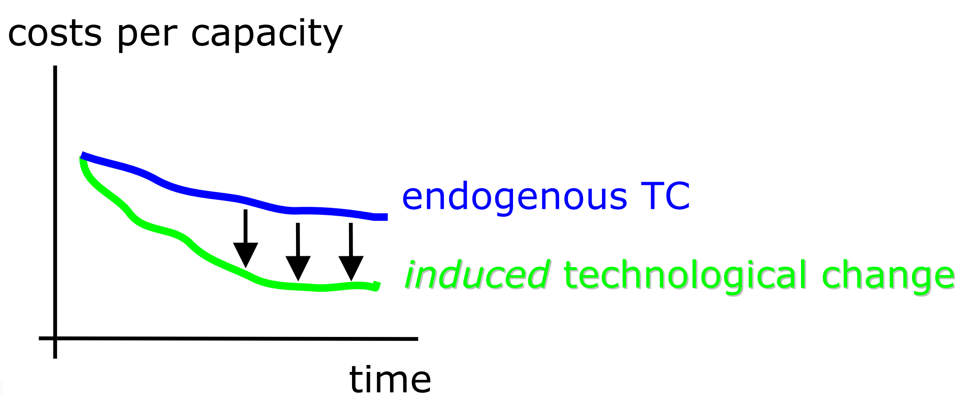
Baseline



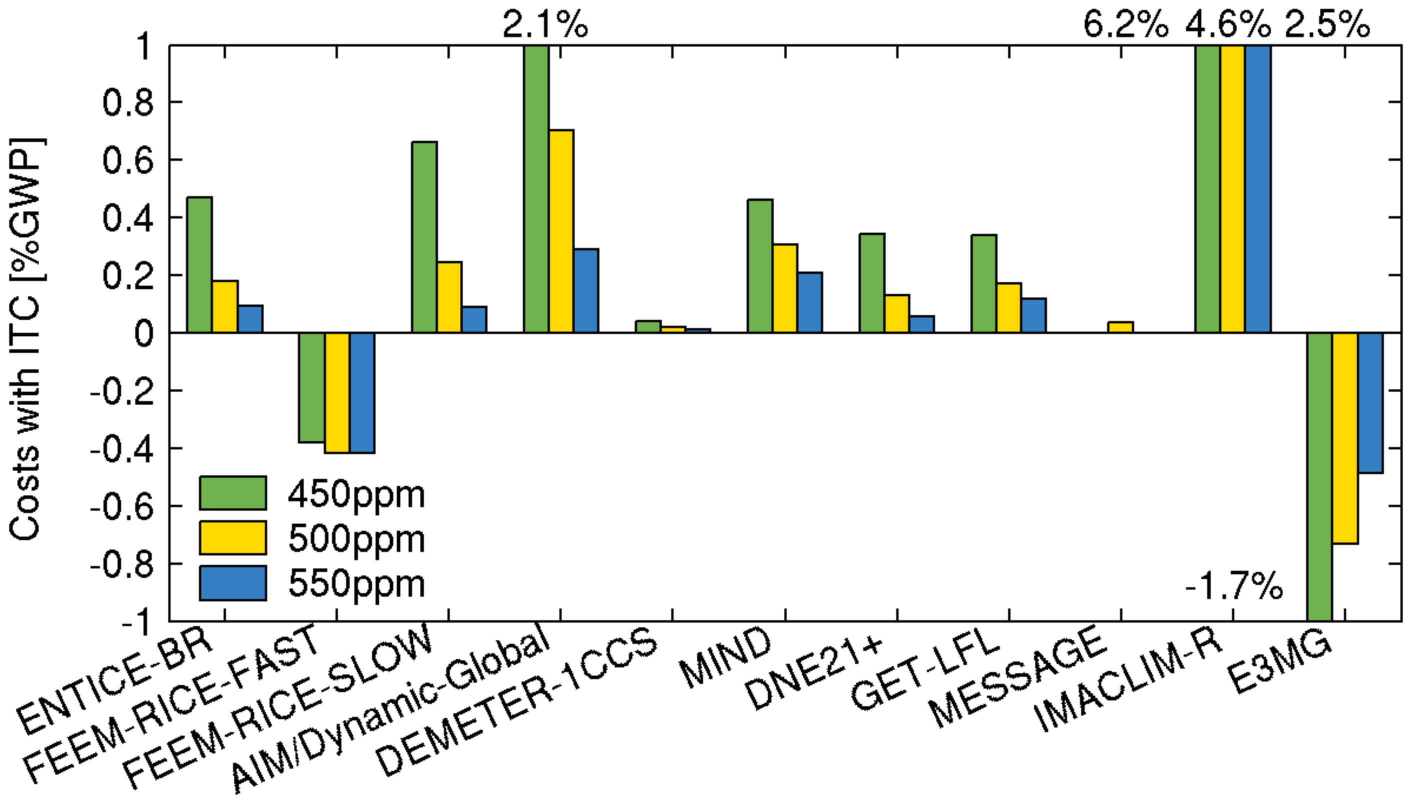
Policy Scenario without ITC



Policy Scenario with ITC

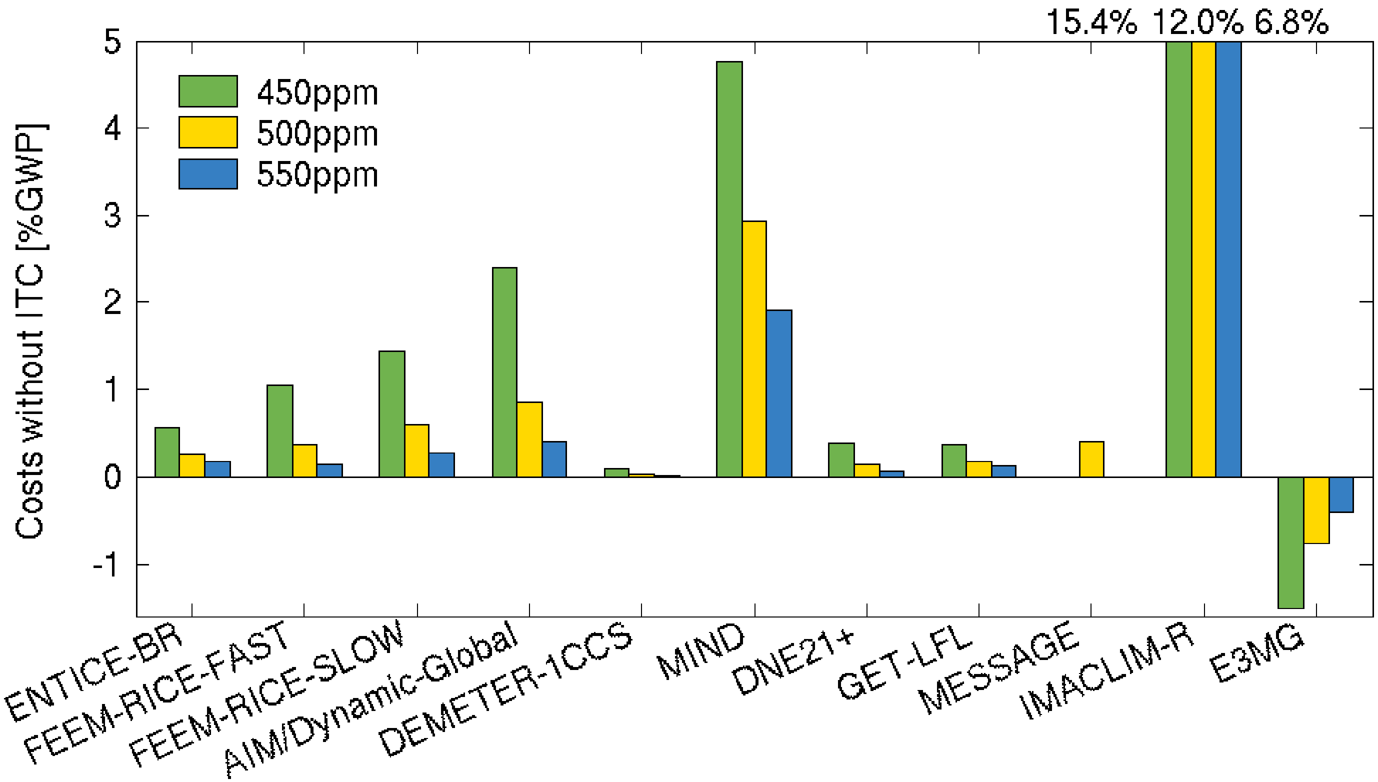


Mitigation Costs with ITC



Source: Edenhofer, Lessmann et al. 2006

Mitigation Costs without ITC



Source: Edenhofer et al. 2006

Mitigation Costs – Result

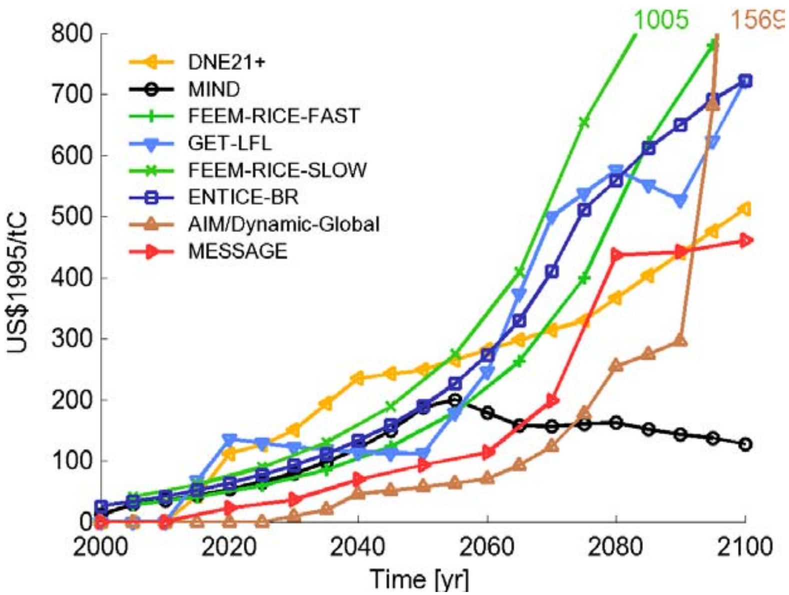
- Induced Technological Change reduces the mitigation costs

- Mitigation costs increase with stabilisation levels despite ITC

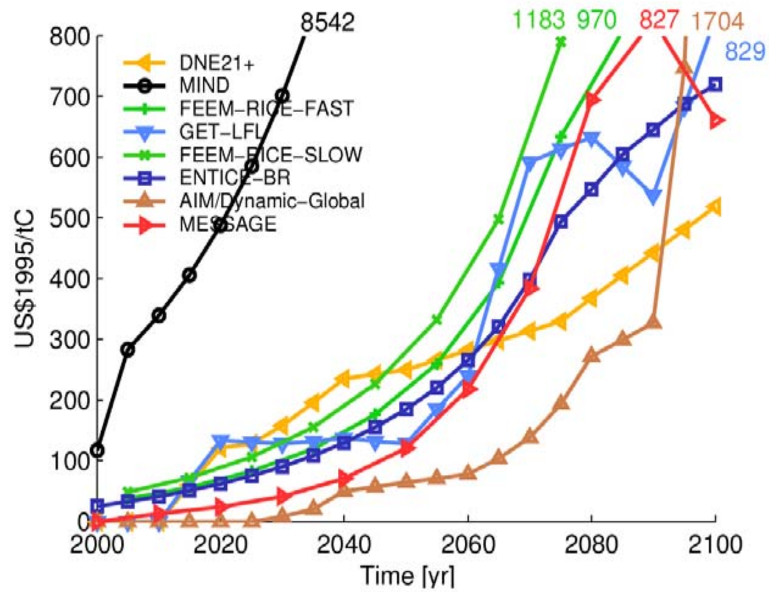
- The “typical” IMCP model derives mitigation costs below 1 % of gross world product for stabilisation scenarios of 450 - 550ppm CO_2.

Shadow prices

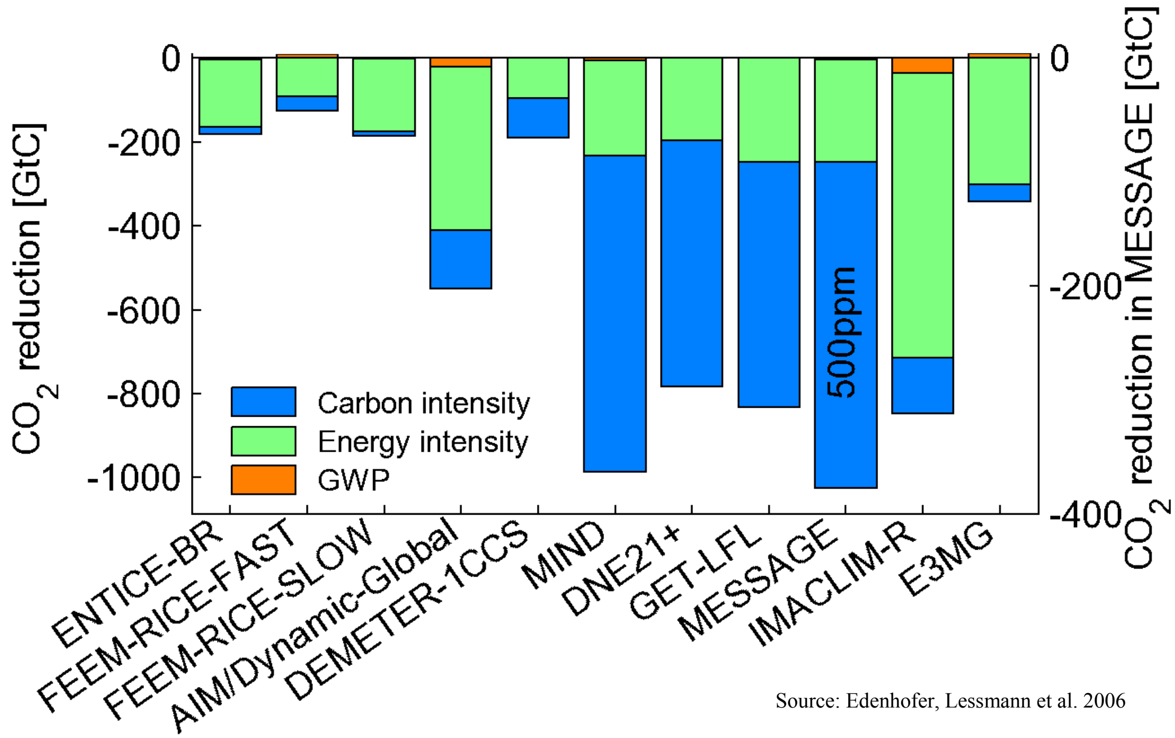
With ITC



Without ITC

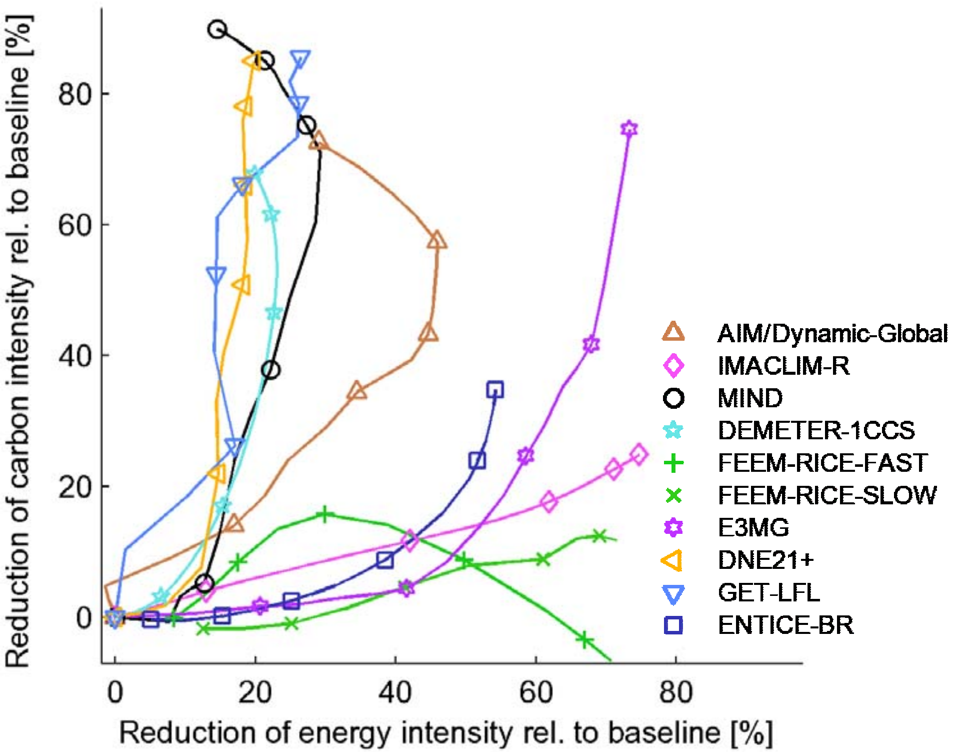


Cumulative CO_2 Reduction for 550ppm Stabilization Scenario



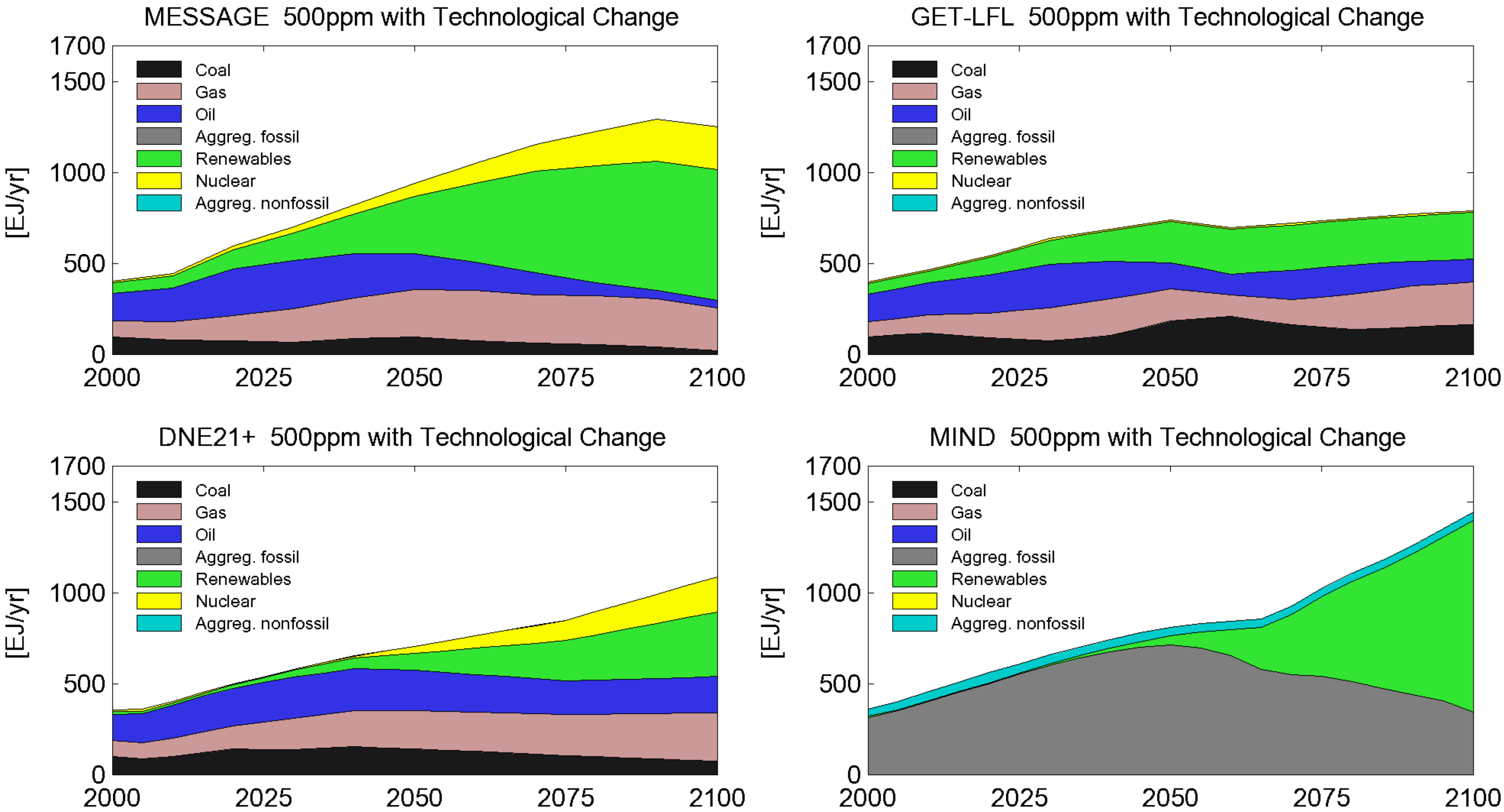
Source: Edenhofer, Lessmann et al. 2006

Energy Intensity/Carbon Intensity with ITC



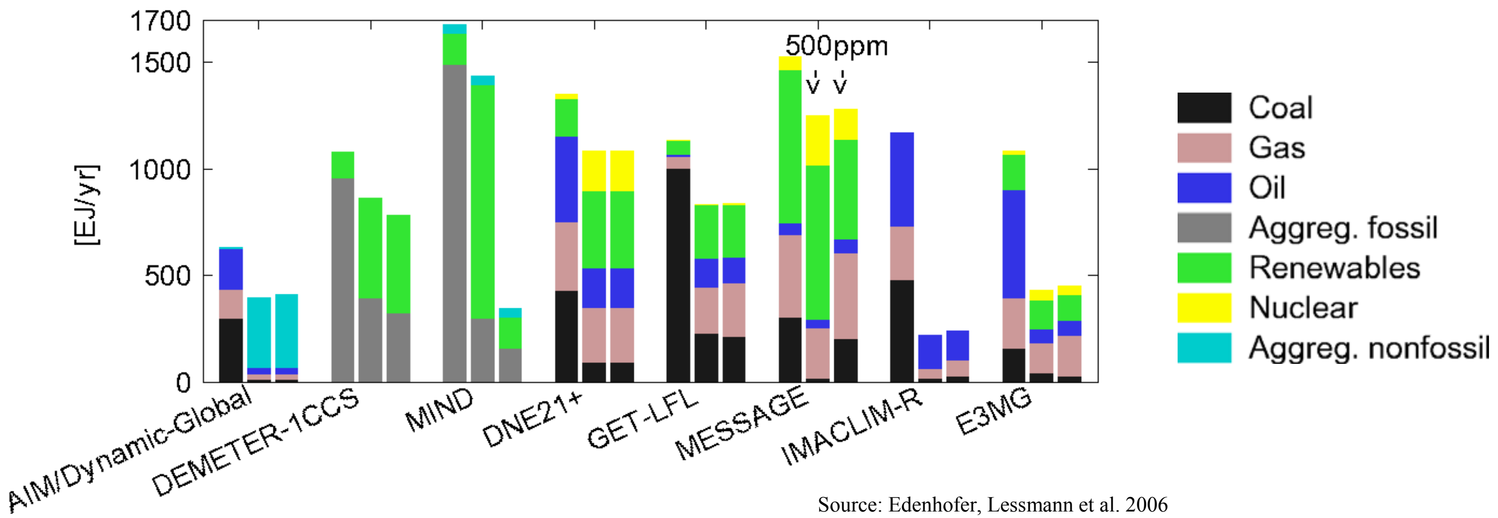
Source: Edenhofer, Lessmann et al. 2006

Energy System and Hybrid Models



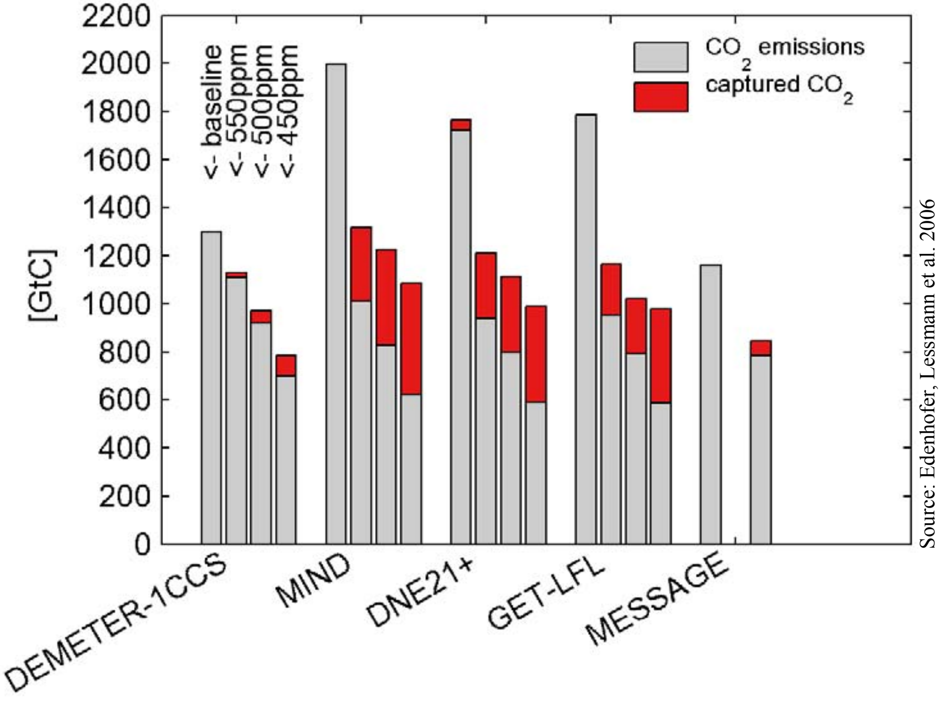
Energy System

2100



Source: Edenhofer, Lessmann et al. 2006

Captured CO_2 and Total CO_2 Emissions



Source: Edenhofer, Lessmann et al. 2006

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Economists claim carbon cuts won't break the world's bank

Panel beaters: could low-carbon energy be surprisingly affordable?

Transforming the world's energy industry to stop the flood of greenhouse gases into the atmosphere might actually be quite cheap.

Figures of tens of trillions of dollars are often cited, and used to question whether measures such as the Kyoto Protocol, which attempts to limit carbon emissions, are too expensive. But according to a suite of economic models released late last month, the costs of stabilizing carbon dioxide levels could be tiny — equivalent to setting back the growth of global GDP (gross domestic product) by less than 1% over 100 years; global GDP generally grows 2–3% each year. In some cases, the right policies for limiting carbon emissions could even create a surprising win–win situation, leading

> "Reducing greenhouse gases will be relatively cheap — but only if we do the right things."

London. "But only if we do the right things."

The models simulate a complex issue in economics: how government climate policies such as research investment or greenhouse-gas regulation can bring about technological development. It is obvious that technologies evolve, but the processes involved have been factored into economic models only since the late 1990s, in part because it is difficult to untangle how advances occur. The Innovation Modelling Comparison Project, published in a special issue of *The Energy Journal,* is a two-year effort involving eleven different models that represent the latest thinking on the problem.

The results are striking. Nine of the models predict that stabilizing carbon dioxide levels at 450 parts per million, widely seen as the most

Why are hybrid models important for modelling ETC and ITC?

- ITC is channelled at different levels of the economic system
- Important aspects are:
  - Sector and region specific channels
  - Expectations about future investments (time-consistency)
  - Backstop technologies, end-of-pipe and ETC in the fossil fuel sector

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What are hybrid models?

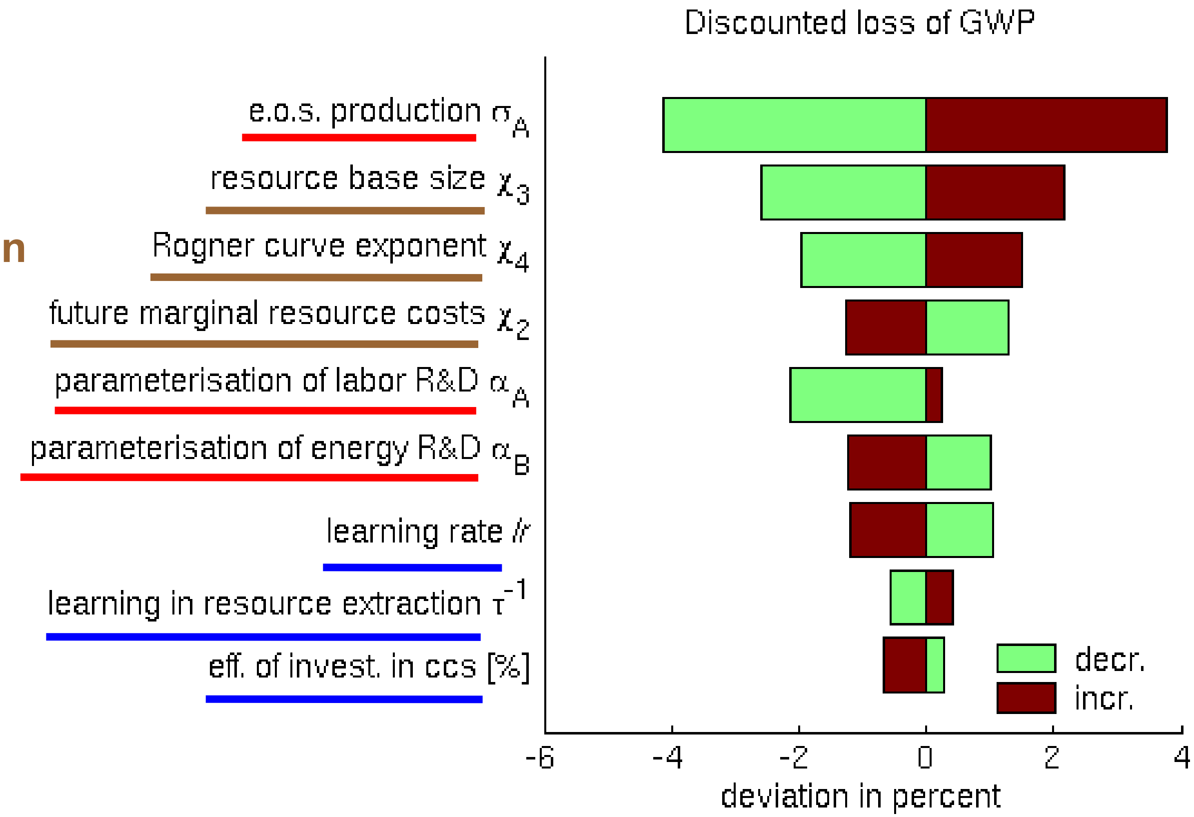
- Hybrid models combine features or modules from different conceptual frameworks in a consistent way
- The different features or modules can be coupled either online or offline

Sensitivity Analysis in MIND – GWP

Macro-economy

Resource extraction

Energy sector



ITC in Extraction

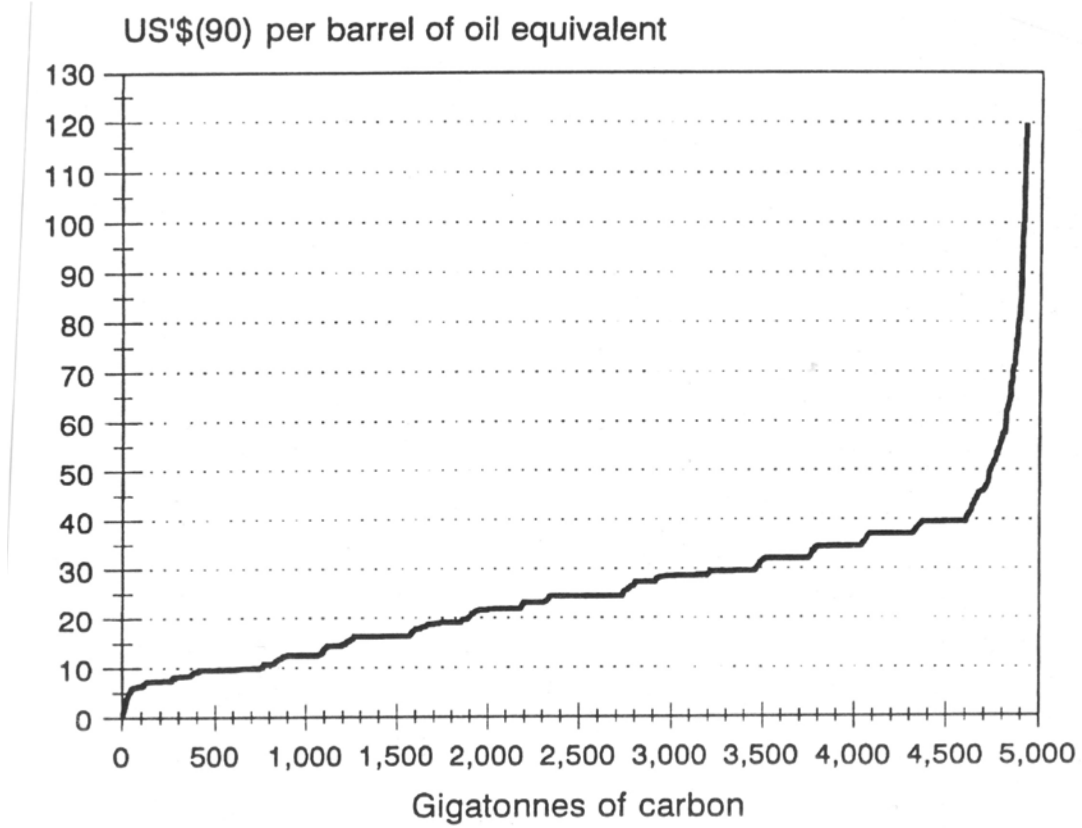
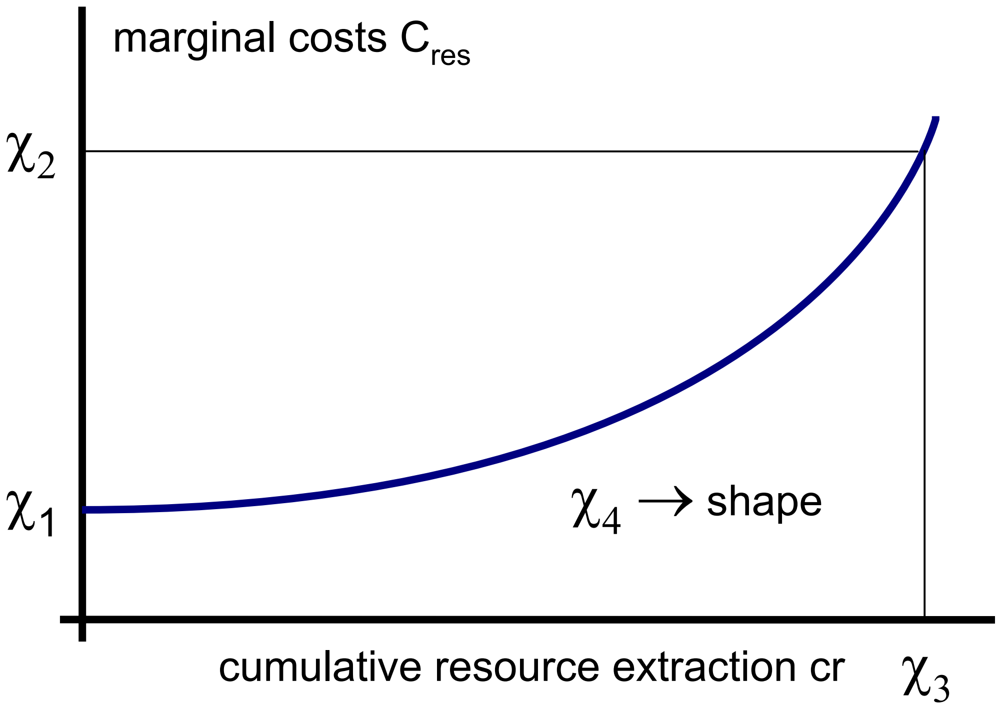


Figure 8 Aggregate quantity-cost curve for carbon contained in the global fossil resource base.

Source: H.-H. Rogner, An Assessment of World Hydrocarbon Resources, International Institute for Applied Systems Analysis (IIASA), May 1998

Marginal Extraction Costs

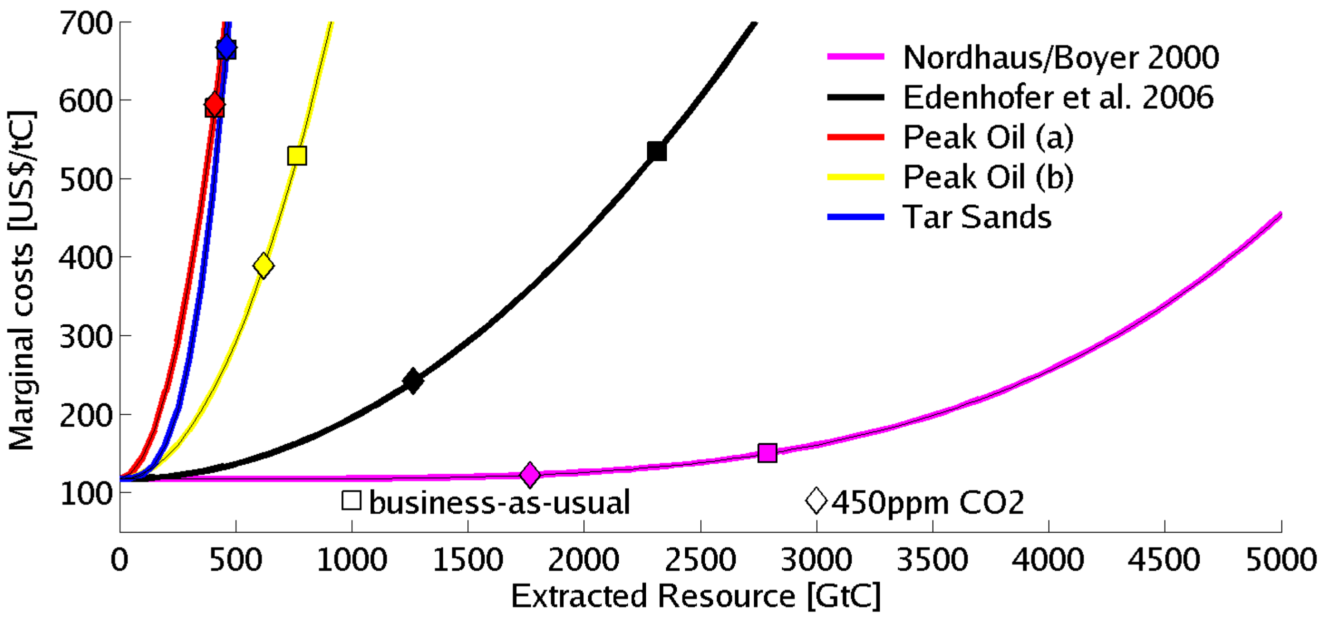


$$cr(t) = \int_{t_0}^{t} R(t')dt'$$

$$C_{res}^{mar} = \chi_1 + \chi_2 \left(\frac{cr}{\chi_3}\right)^{\chi_4}$$

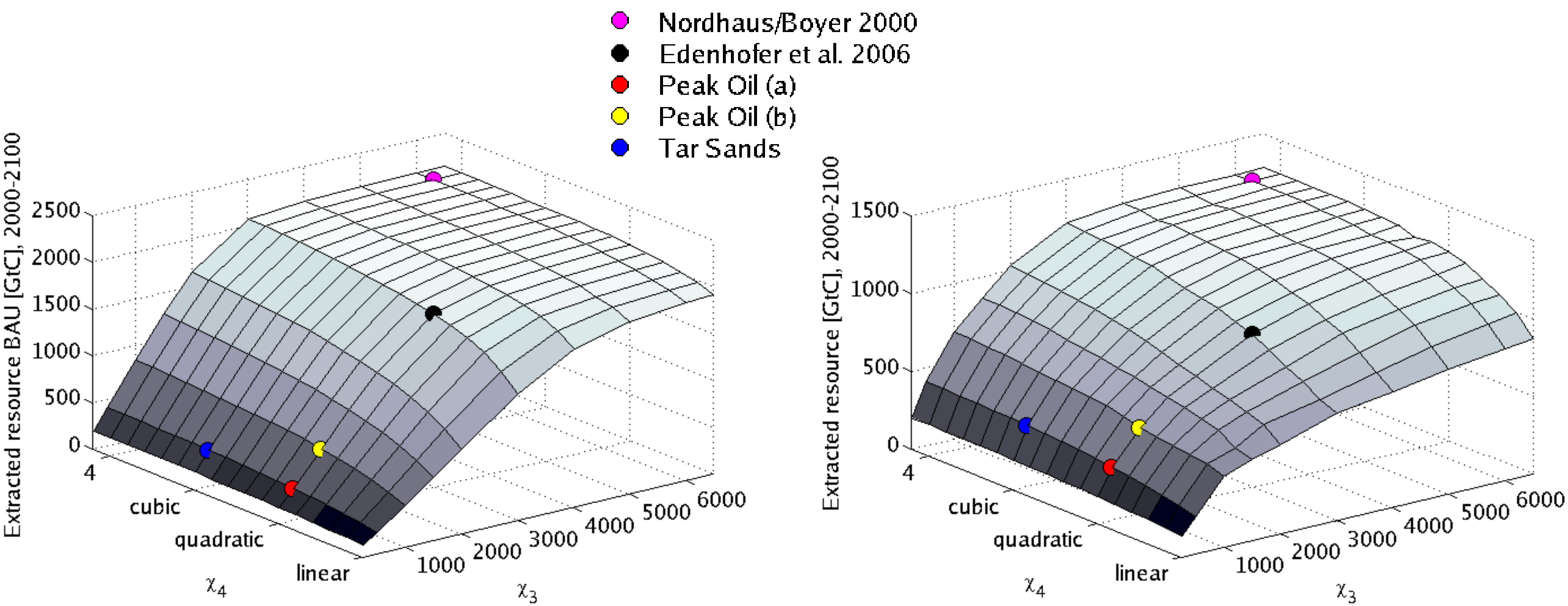
adapted from Nordhaus/Boyer (2000)

Scenario Definitions



	χ_3	χ_4
Nordhaus/Boyer 2000	4	6000
Edenhofer et al. 2006	2	3500
Peak Oil (a)	2	500
Peak Oil (b)	2	1000
"Tar sands"	3	500

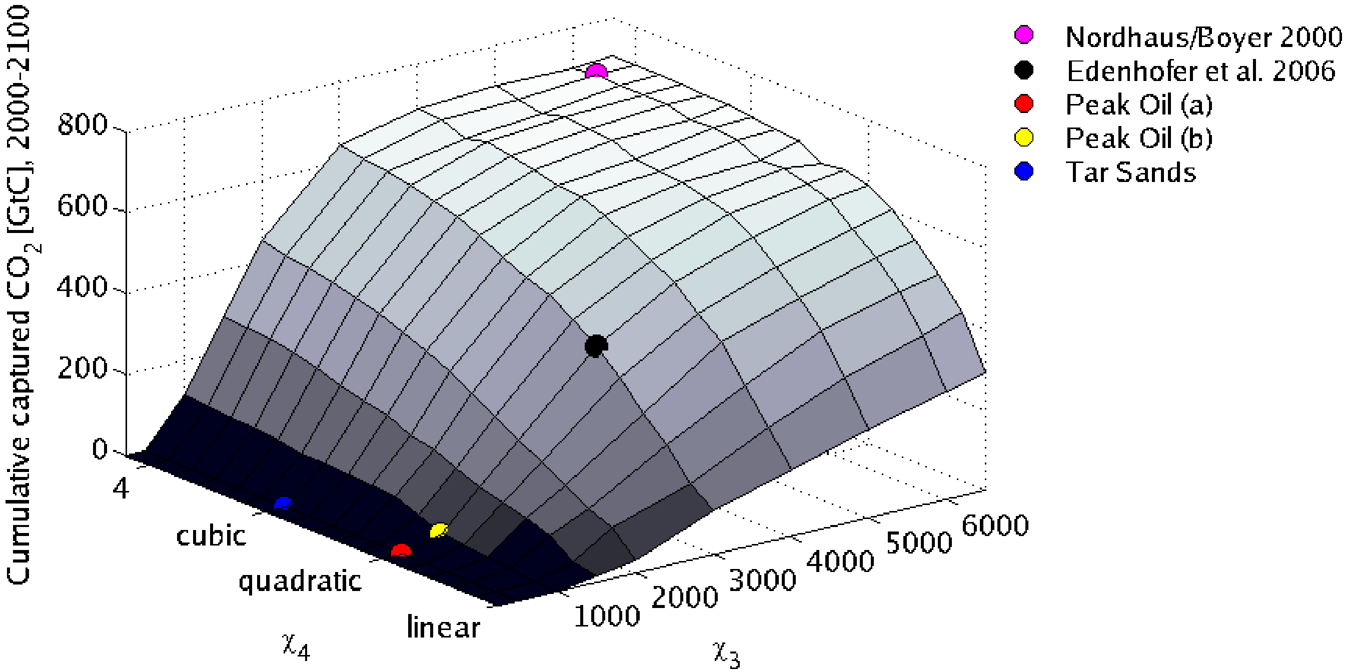
Resource Extraction



business as usual

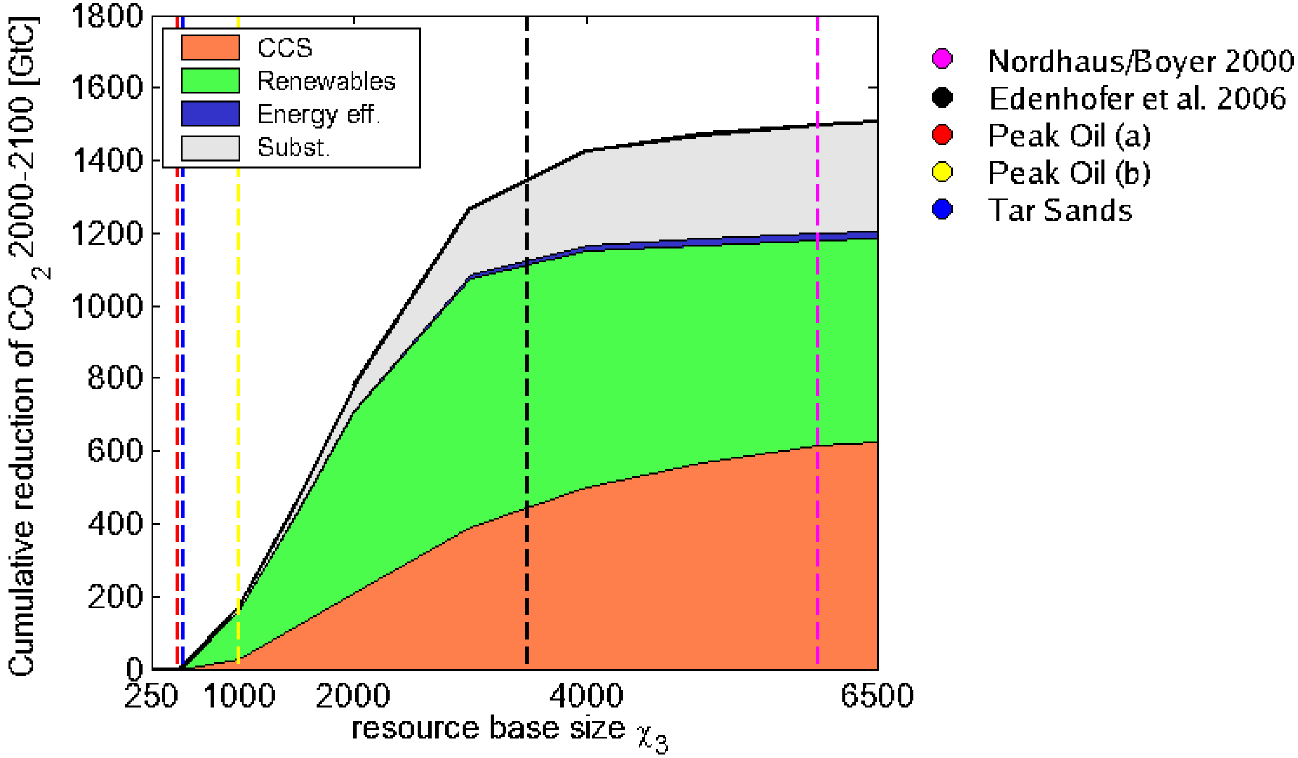
450ppm CO_2 concentration stabilization

Carbon Capturing and Sequestration

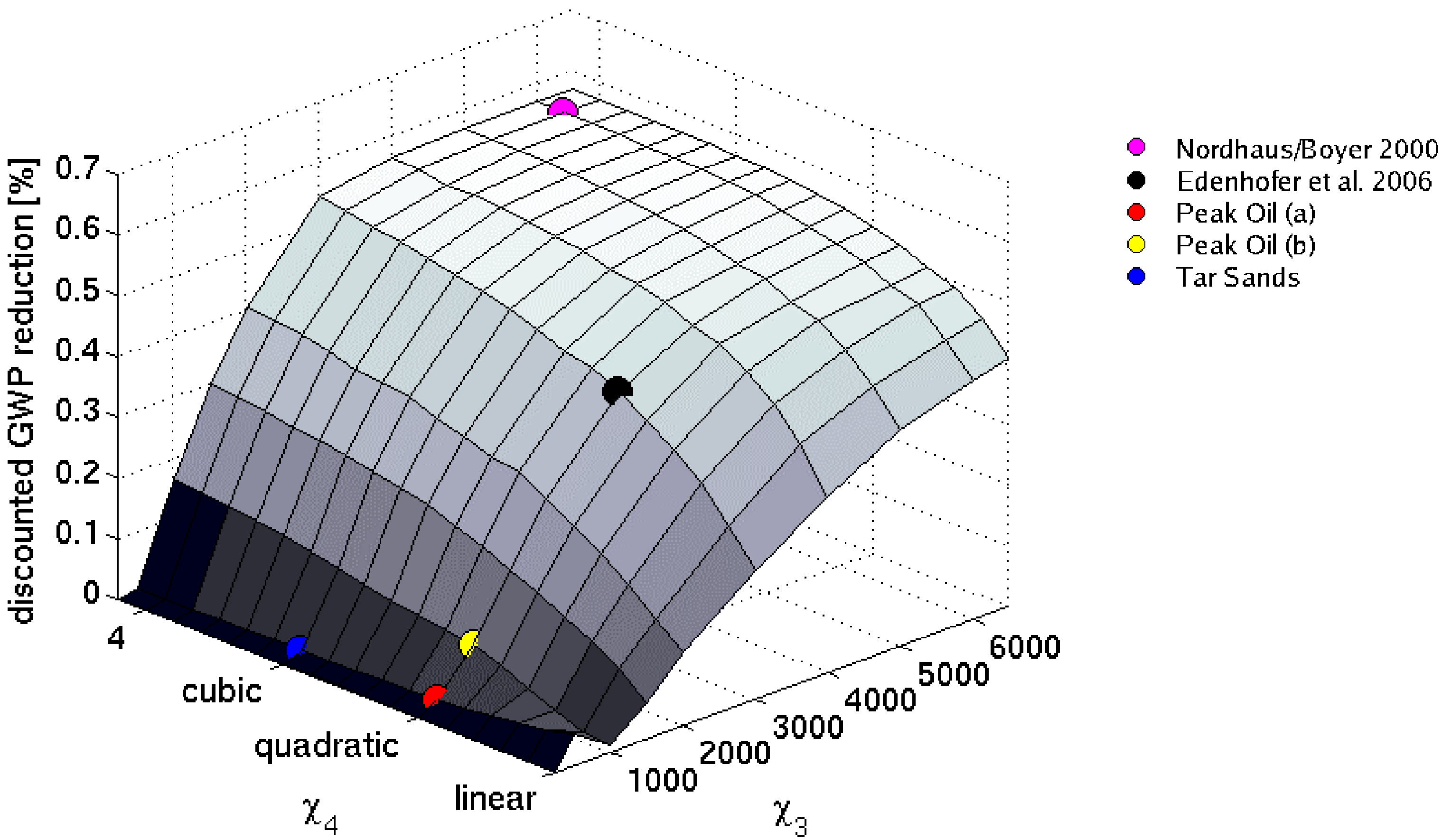


Mitigation Options

CO_2 reduction, attributed to mitigation options



GDP Losses



discounted GWP reduction [%]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4
cubic
quadratic
linear
χ_4
1000
2000
3000
4000
5000
6000
χ_3
Nordhaus/Boyer 2000
Edenhofer et al. 2006
Peak Oil (a)
Peak Oil (b)
Tar Sands

MIND – A Case for Hybrid Modelling

- Technological Change in the fossil fuel sector is crucial in determining the opportunity costs of climate protection.

- For a realistic estimations of costs and strategies, TC in the following sectors is crucial:
  - Backstop technologies
  - End-of-pipe technologies
  - Extraction and exploration sector