How to incorporate endogenous technological change in climate economy models

Lessons from the Innovation Modelling Comparison Project (IMCP)

3rd International Workshop on
INTEGRATED CLIMATE MODELS:
AN INTERDISCIPLINARY ASSESSMENT OF
CLIMATE IMPACTS AND POLICIES
12-13 January 2006
Trieste, Italy

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1. The IMCP Project
2. Mitigation Costs
3. Mitigation Strategies
4. A Case for Hybrid Models - MIND
5. Conclusion

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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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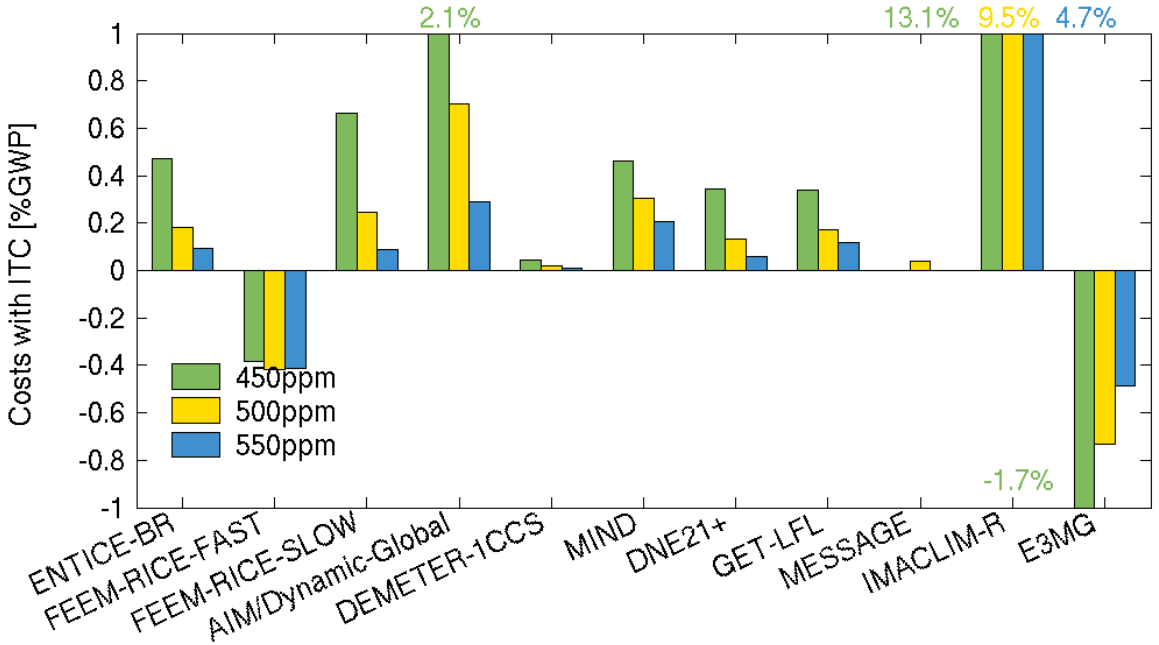
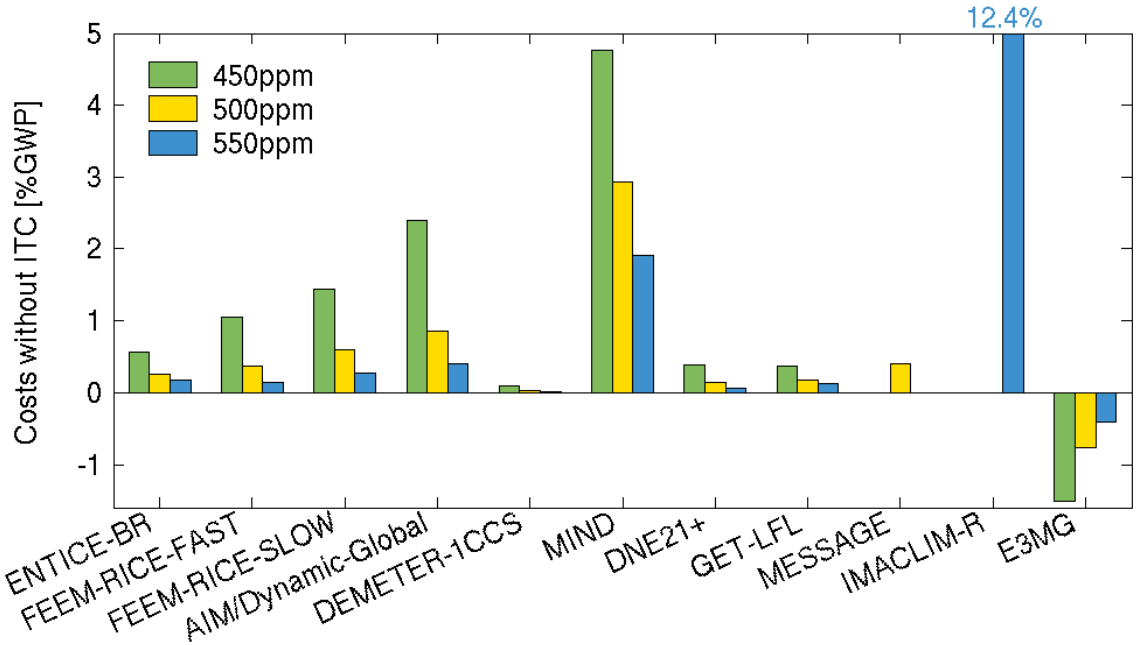
Mitigation Costs – Result I

- 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.

Abatement costs with ITC

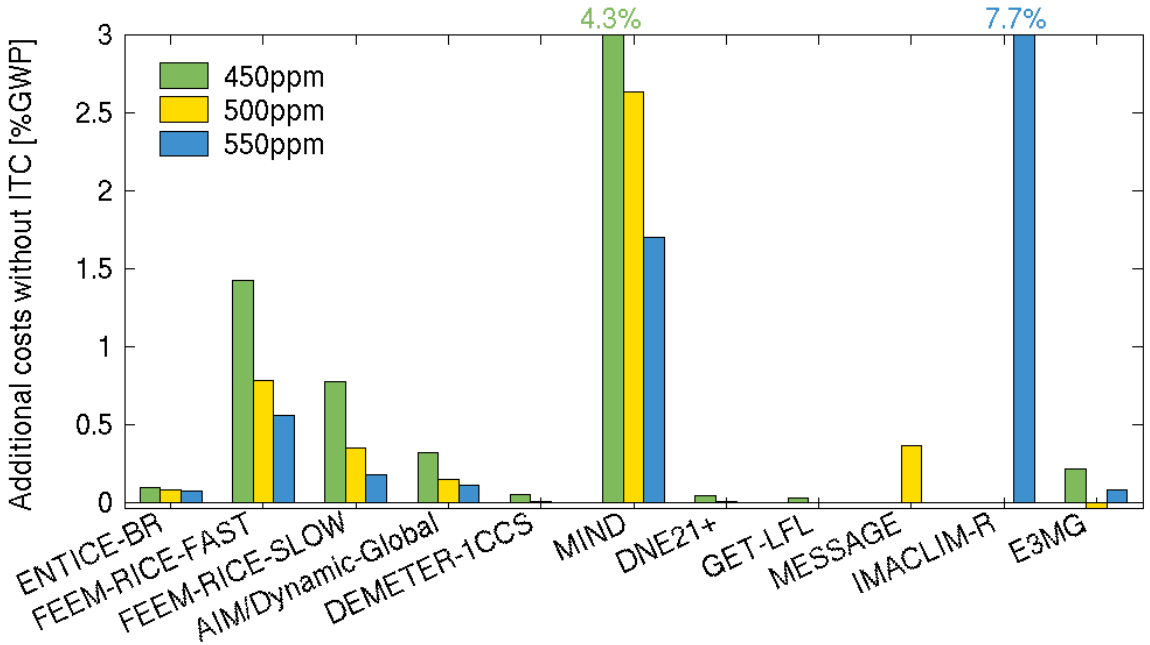


Abatement costs without ITC

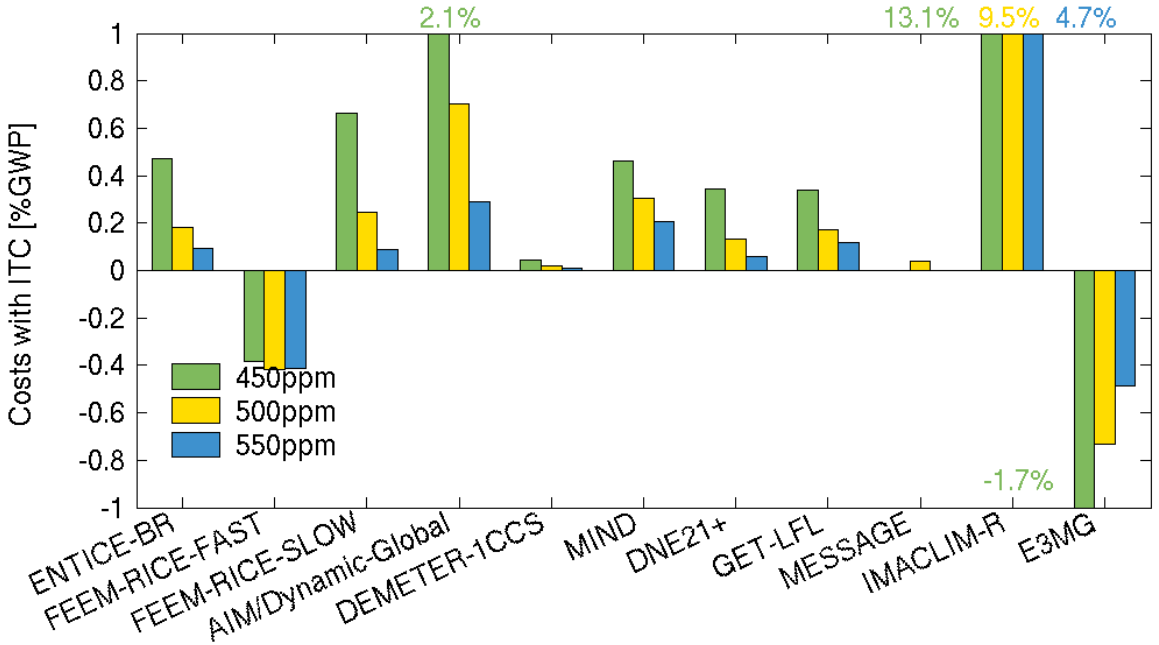


Additional abatement when ITC options are disabled

i.e. the difference of the precending slides



Abatement costs with ITC



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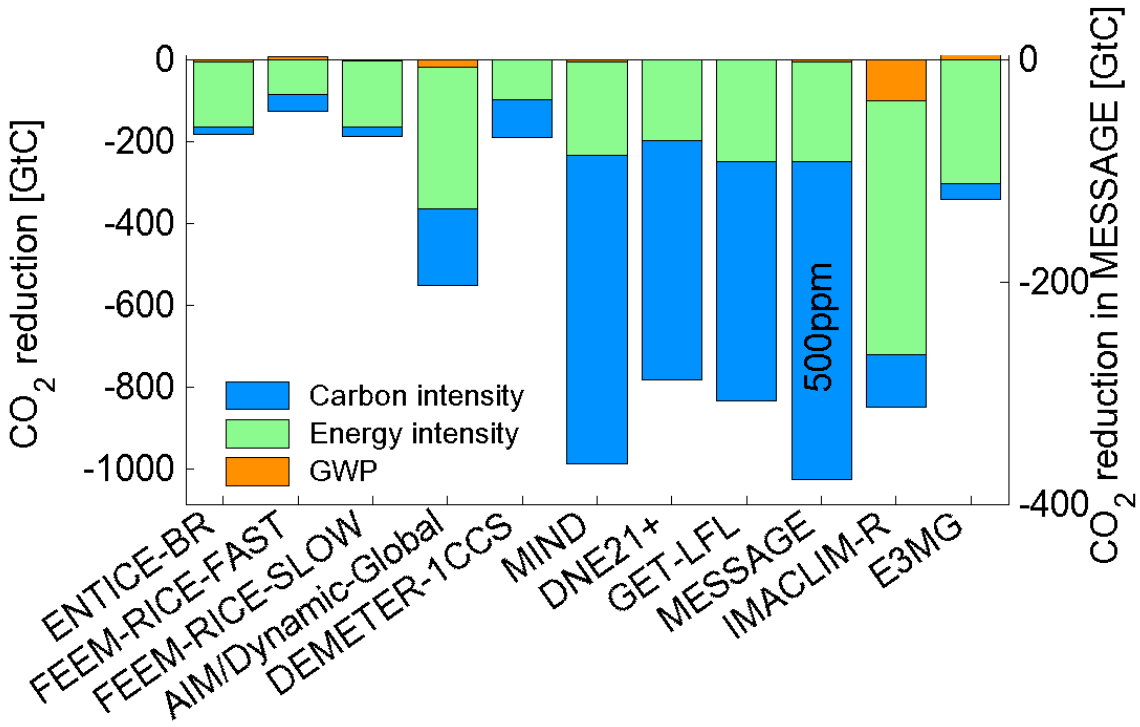
Mitigation Strategies – Result II

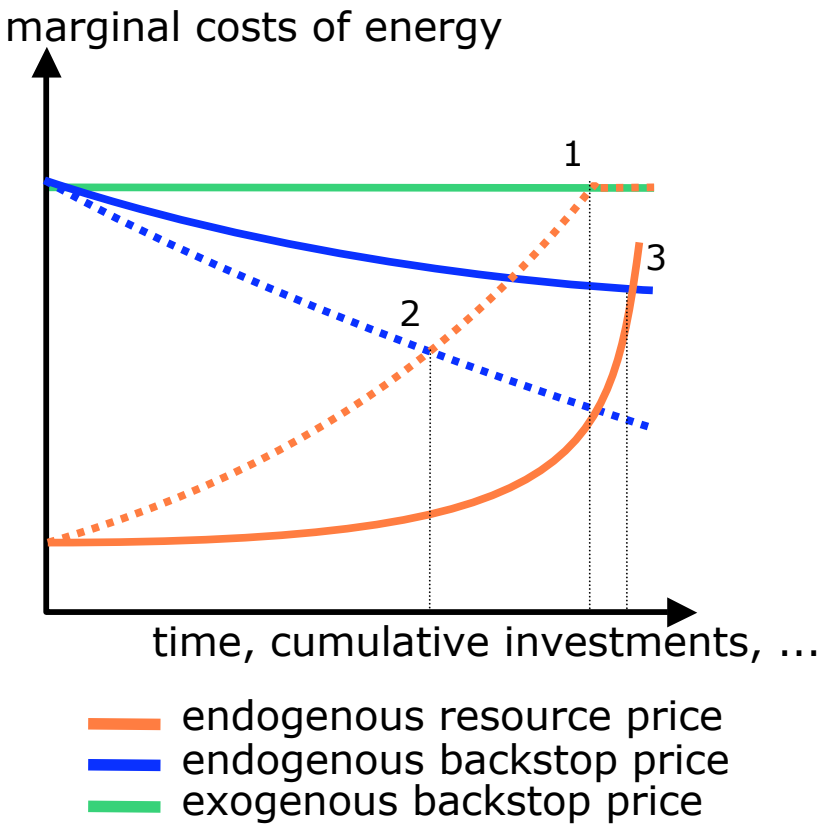
- Induced technological change works more towards decarbonisation of energy rather than reducing energy intensity of output.
- Backstop Technologies (mostly modelled as renewable energy technologies) are crucial for achieving low emissions at low costs.
- Some models show extensive use of Carbon Capturing and Sequestration (CCS) as temporary solution. CCS as an end-of-pipe technology allows postponing the introduction of the backstop technology in some models.
- Some models with backstop technologies and CCS show path dependent behaviour.

Decomposition of CO_2 reductions along Kaya's indentity

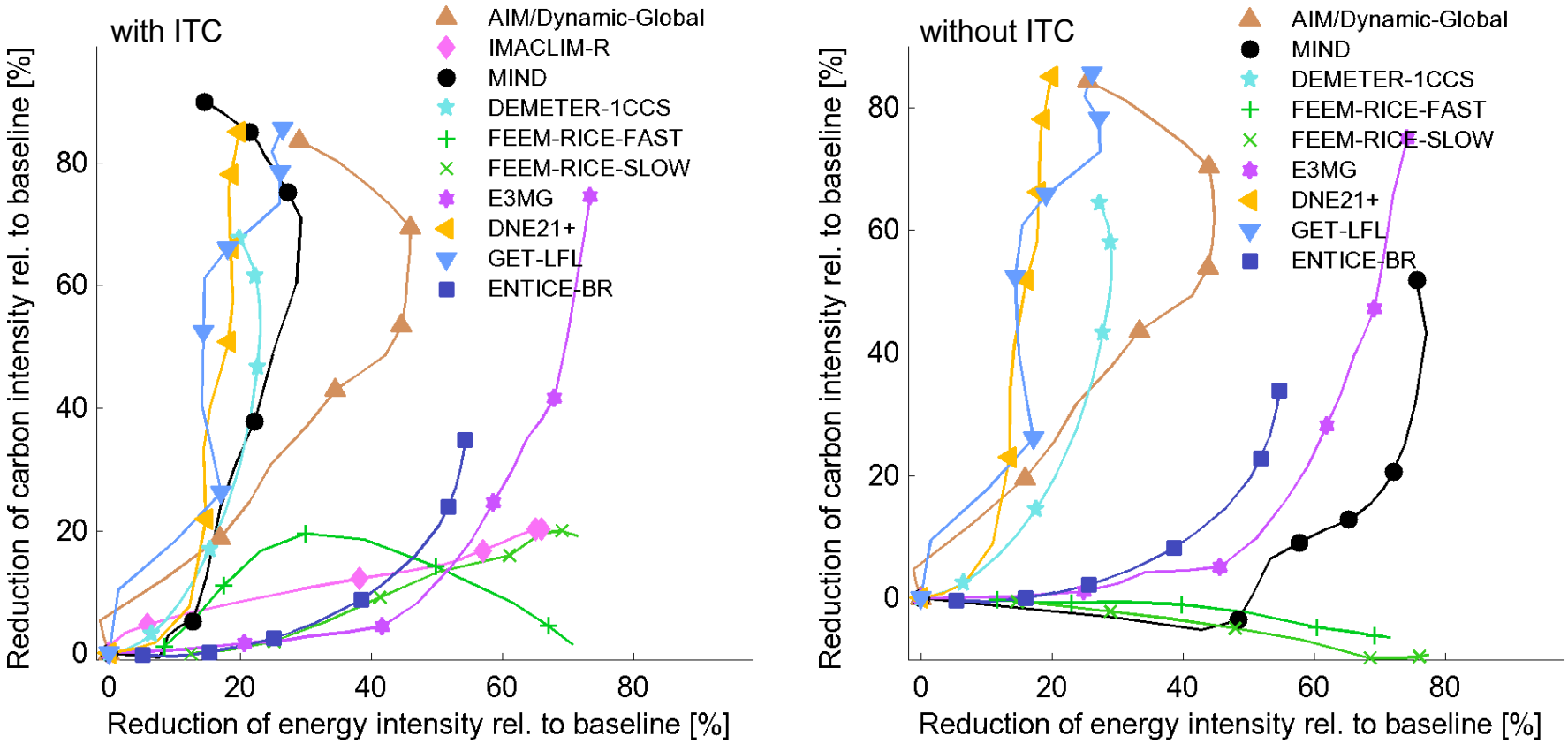


The figure shows data from the 550ppm scenario.

Different formulatios of backstop technology



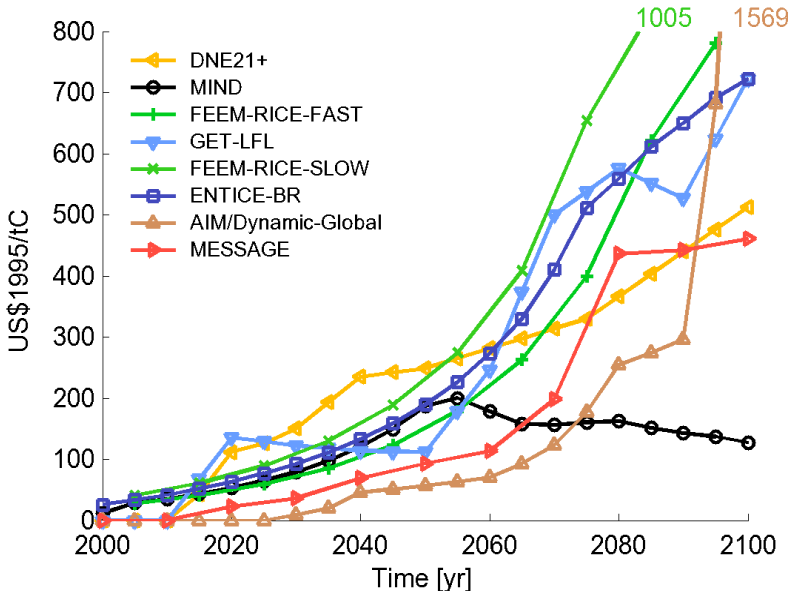
Timing of mitigation options



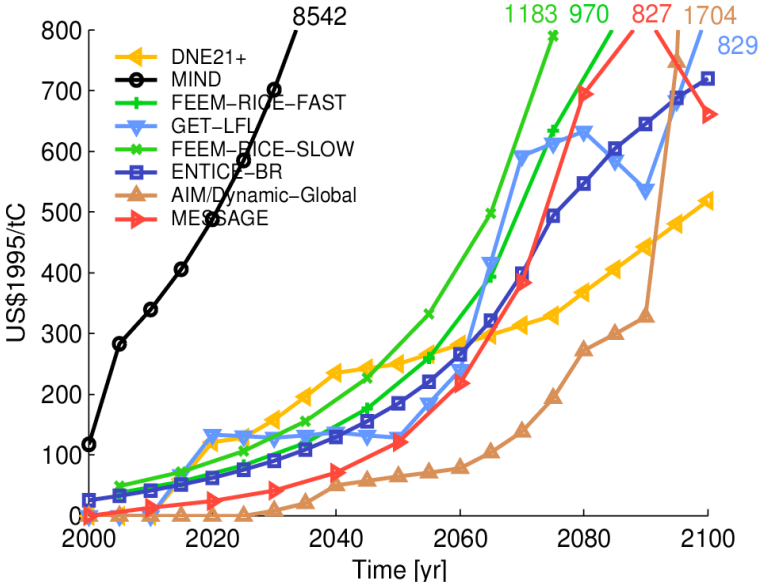
Bullets are set 20 years apart.

Shadow prices

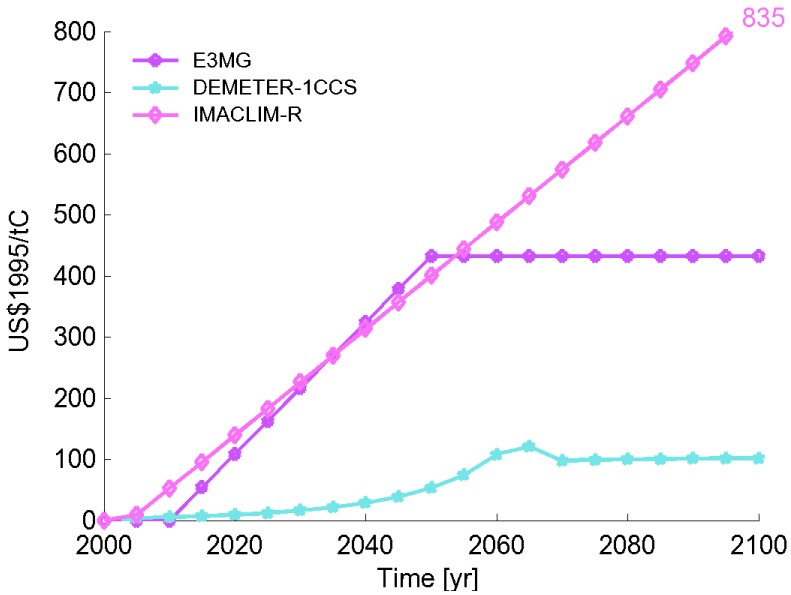
With ITC



Without ITC



Carbon tax


835
800
700
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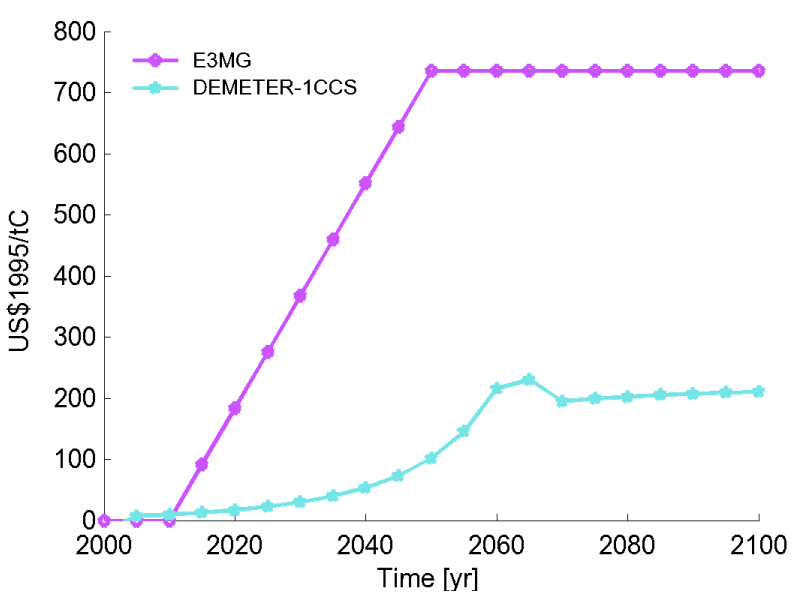
200
100
0
E3MG
DEMETER-1CCS
IMACLIM-R
US$1995/tC
2000
2020
2040
2060
2080
2100
Time [yr]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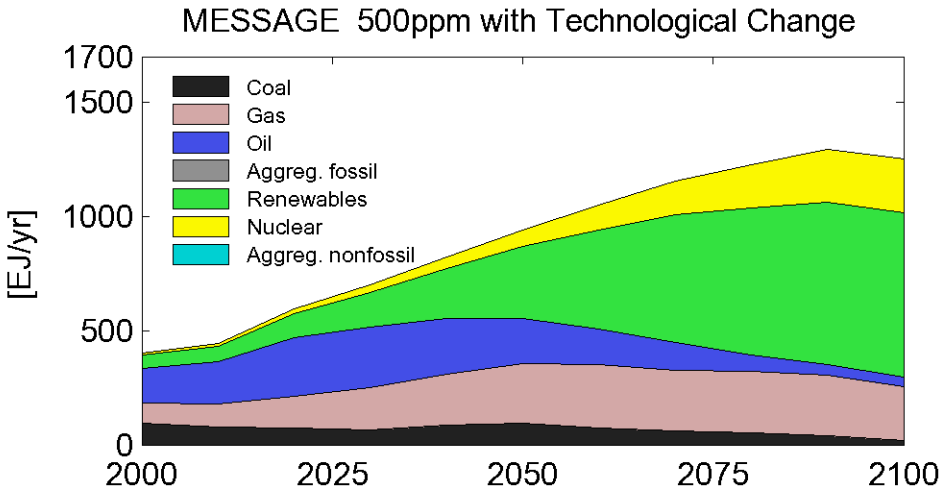
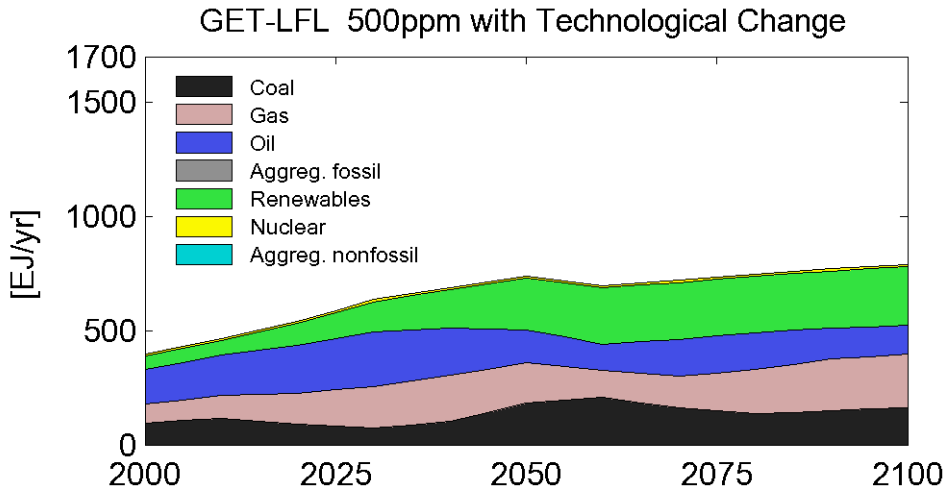
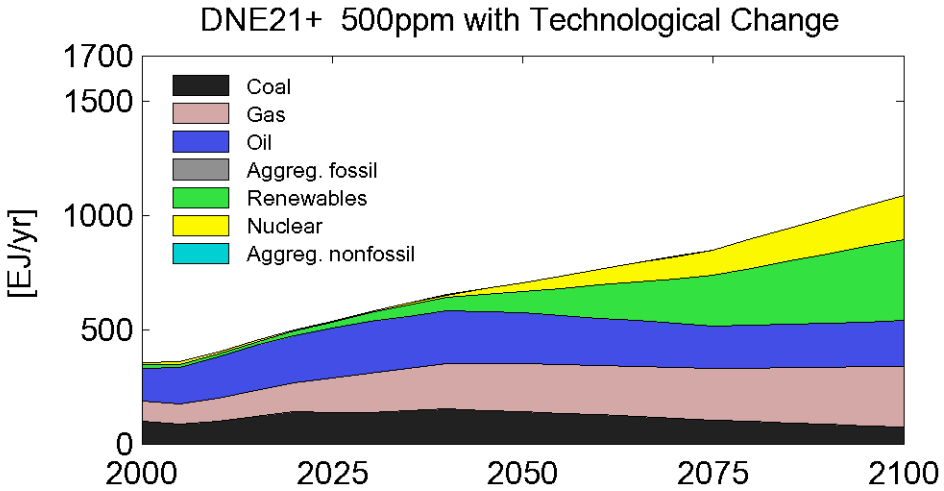
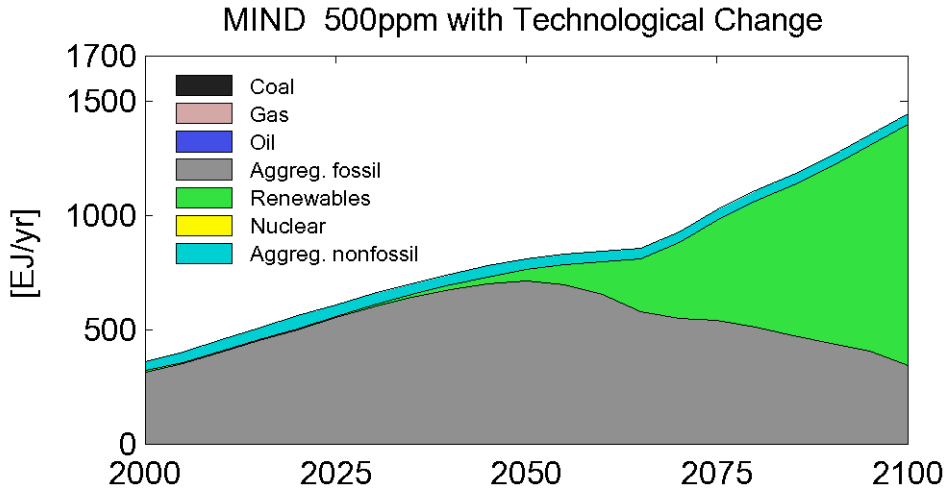
Energy System and Hybrid Models

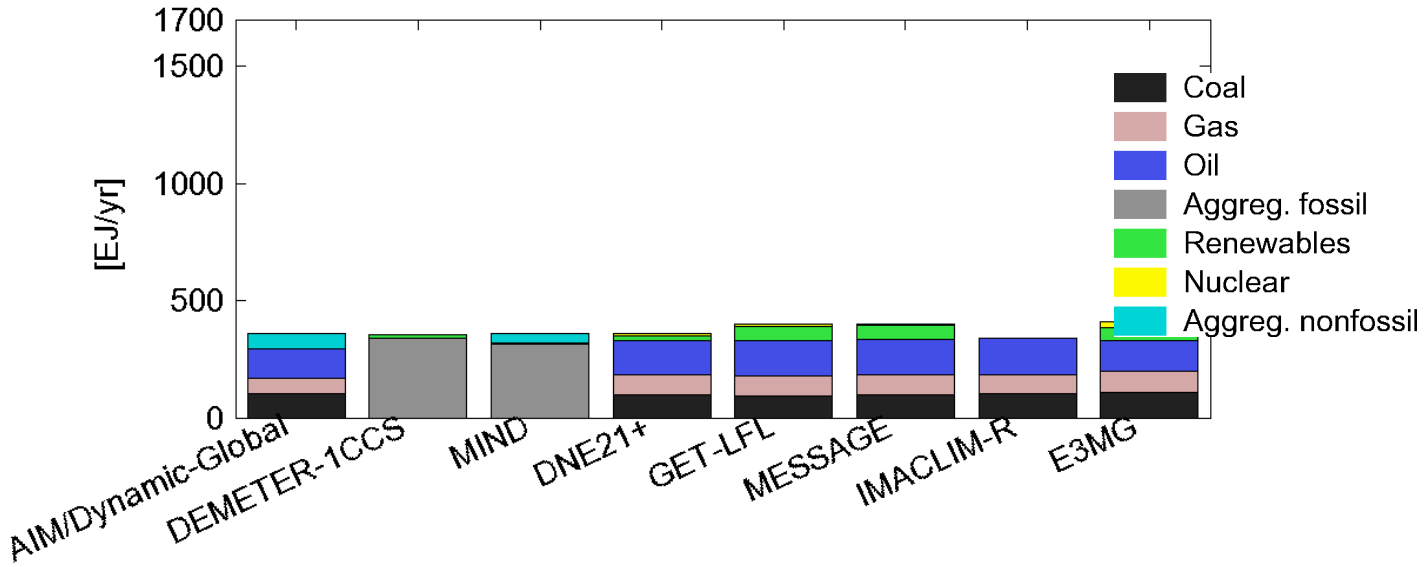




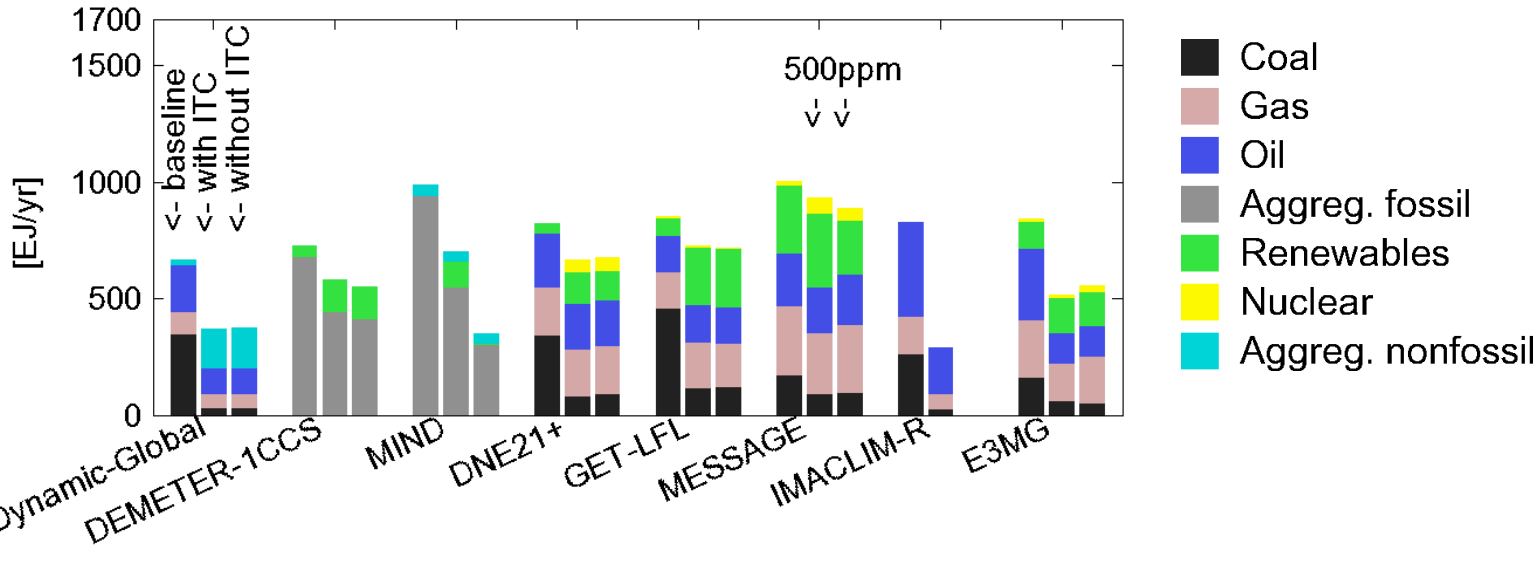




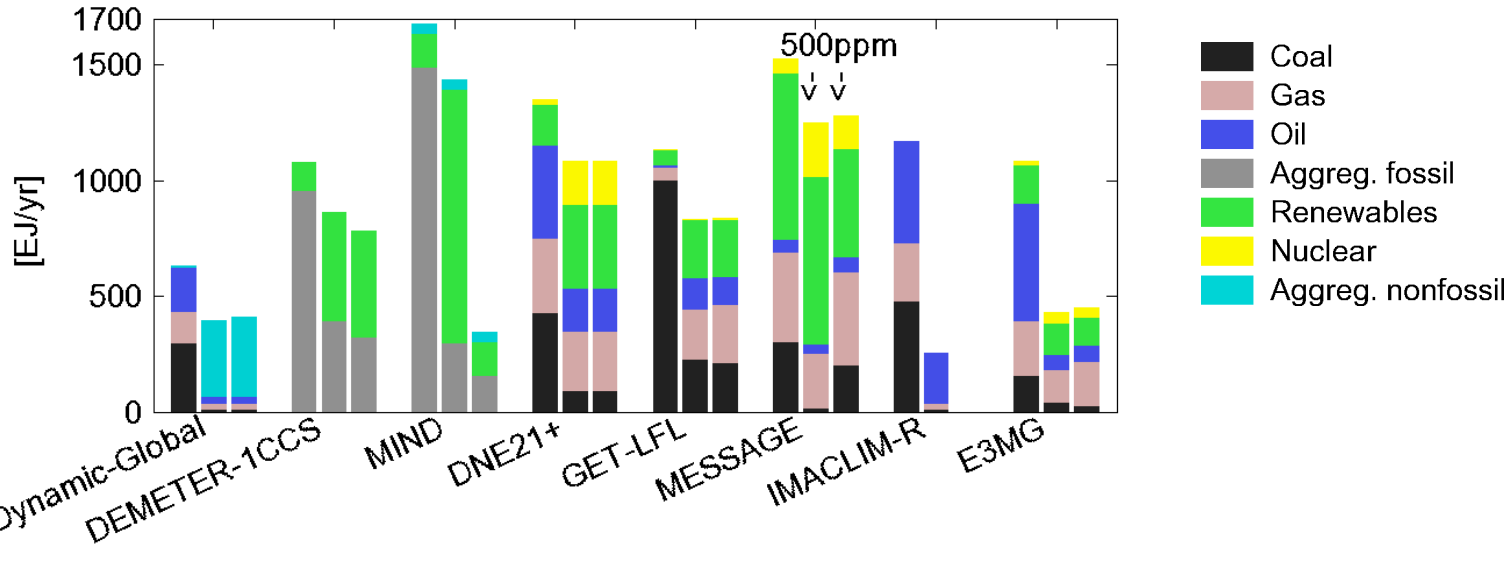
Energy sources in 2000



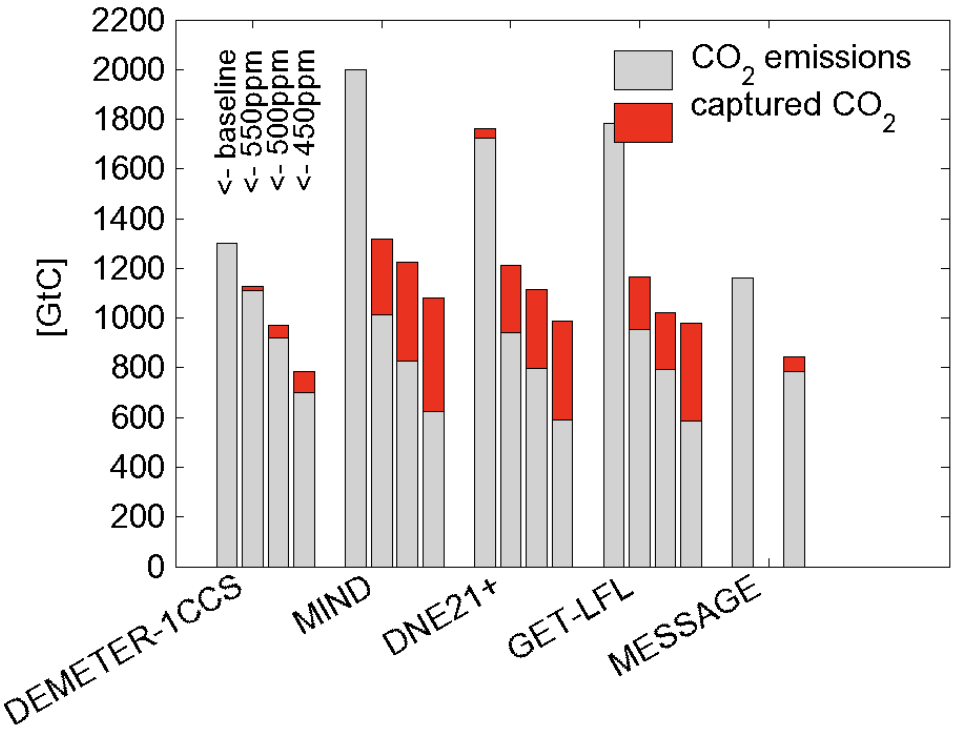
Energy sources in 2050



Energy sources in 2100



Carbon capturing and sequestration (CCS)



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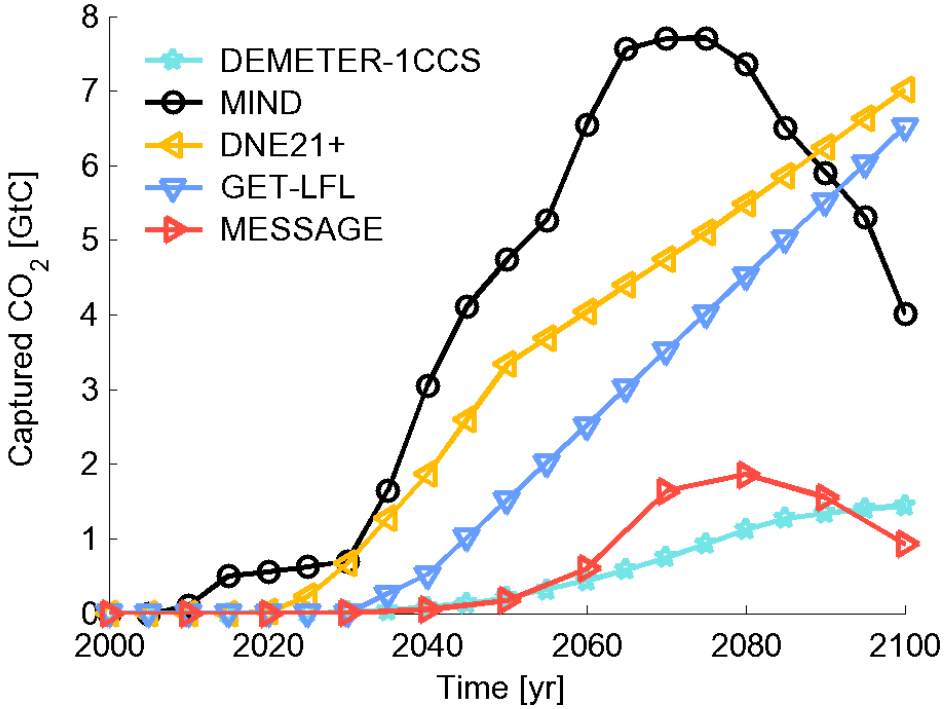

The Case for Hybrid Modelling

- Long-term investment decisions
- Backstop technologies / ETC in the fossil fuel sector
- End-of-the-pipe technologies

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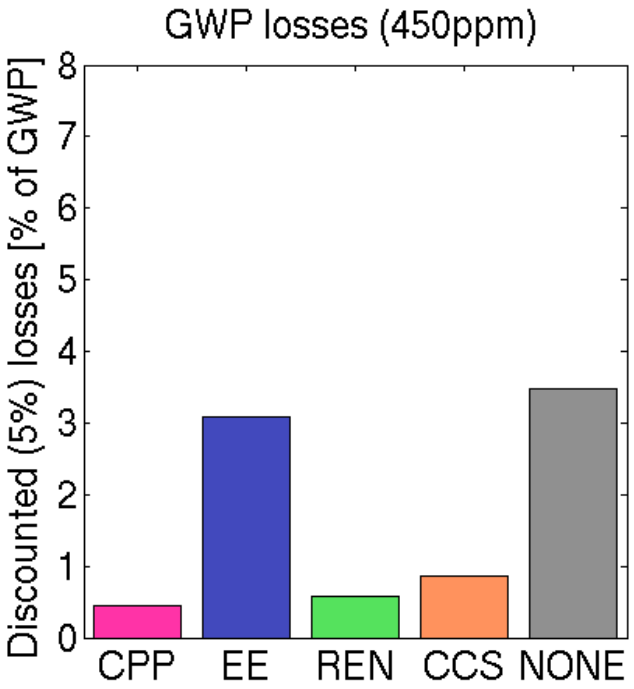
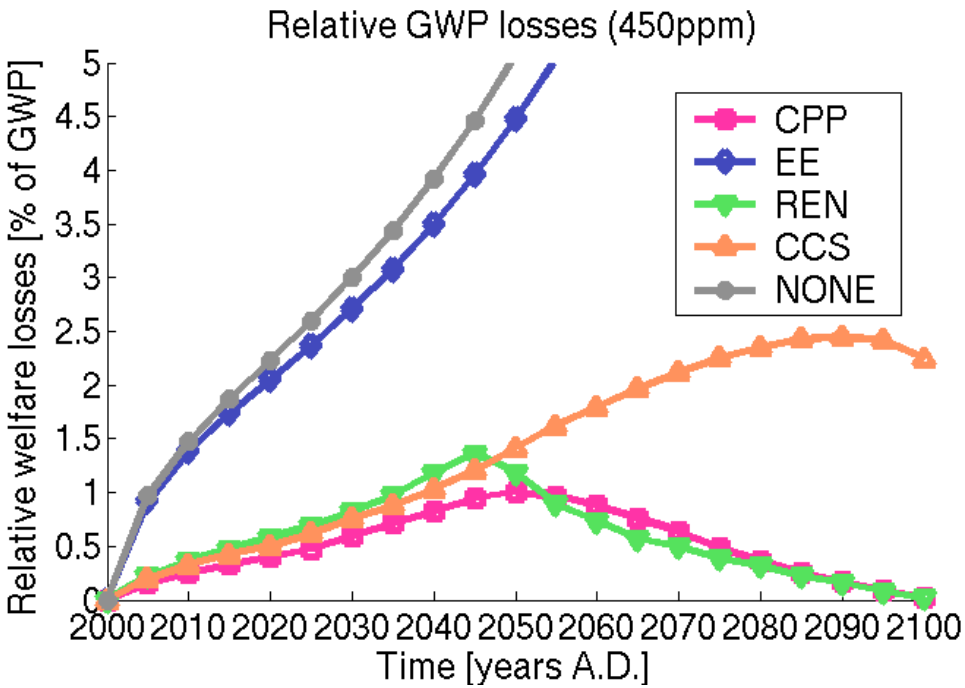
Influence of backstop/end-of-pipe





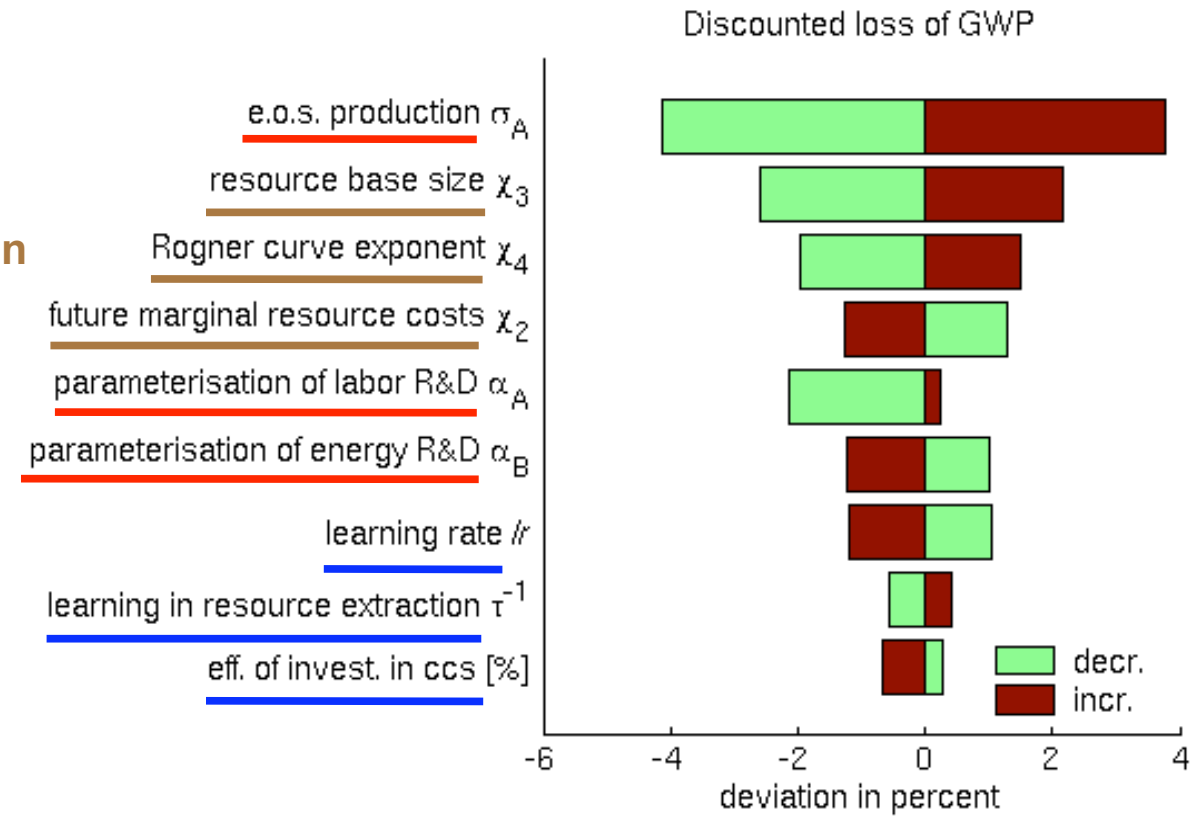
CPP: All options (climate protection path)
EE: Only energy efficiency improvements
REN: Only renewable energy sources
CCS: Only CCS
NONE: Neither EE nor REN nor CCS

Sensitivity Analysis – GWP

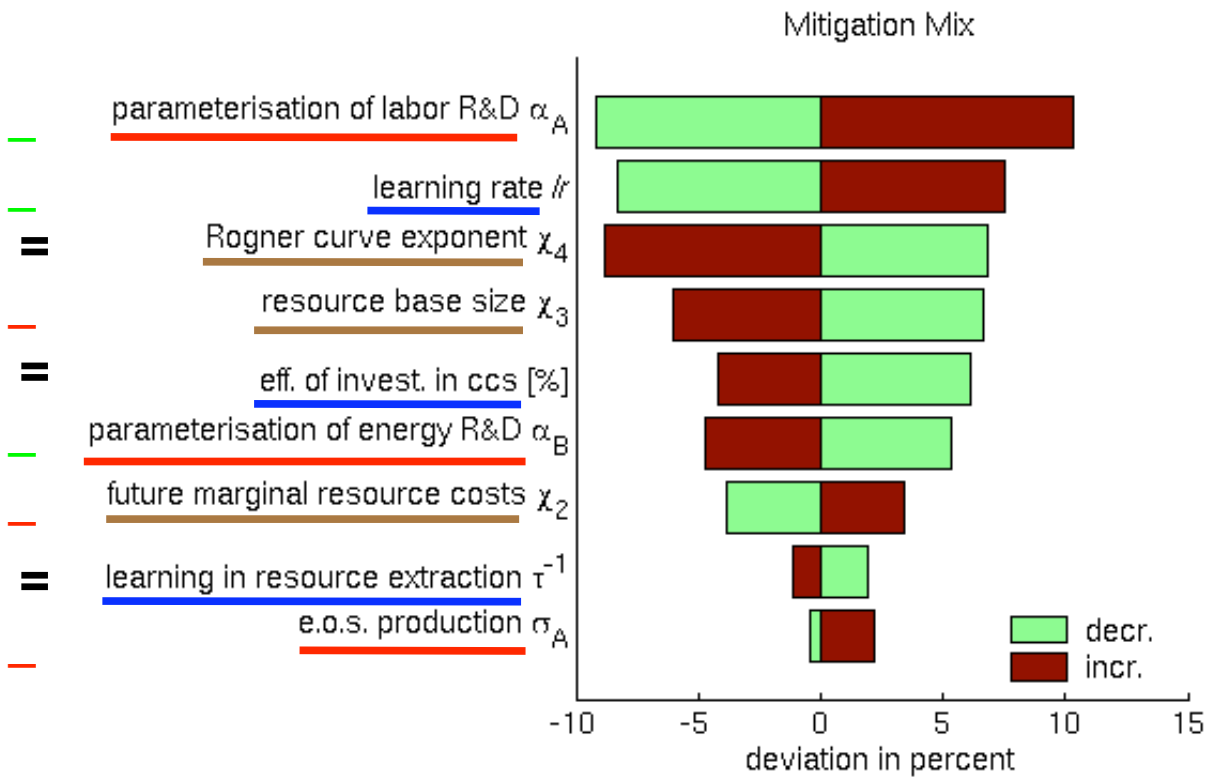
Macro-economy

Resource extraction

Energy sector

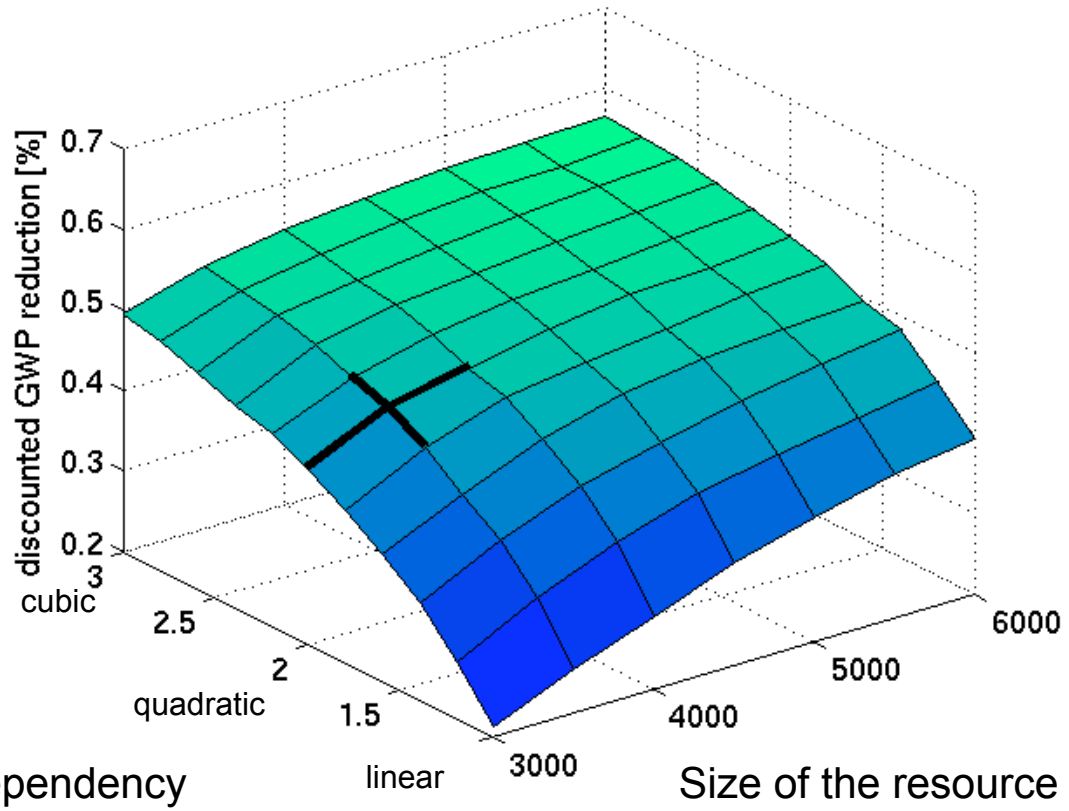


Sensitivity Analysis – Mitigation mix



Macro-economy
Resource extraction
Energy sector

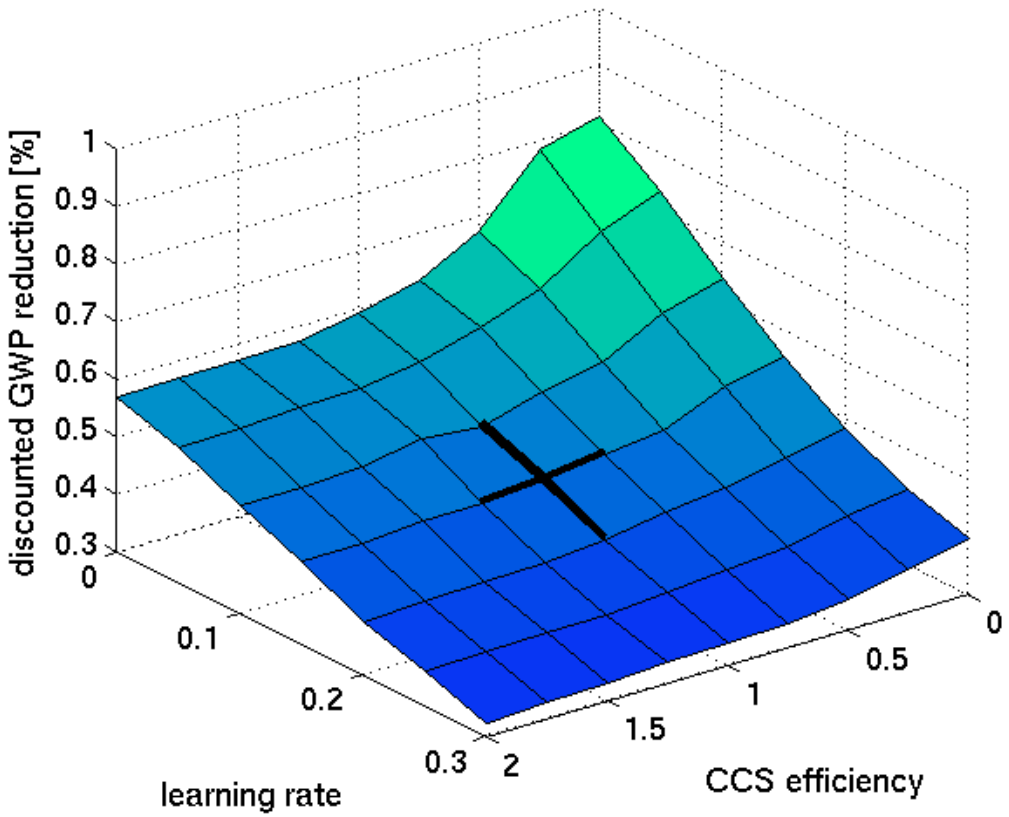
The Role of TC in the Extraction Sector



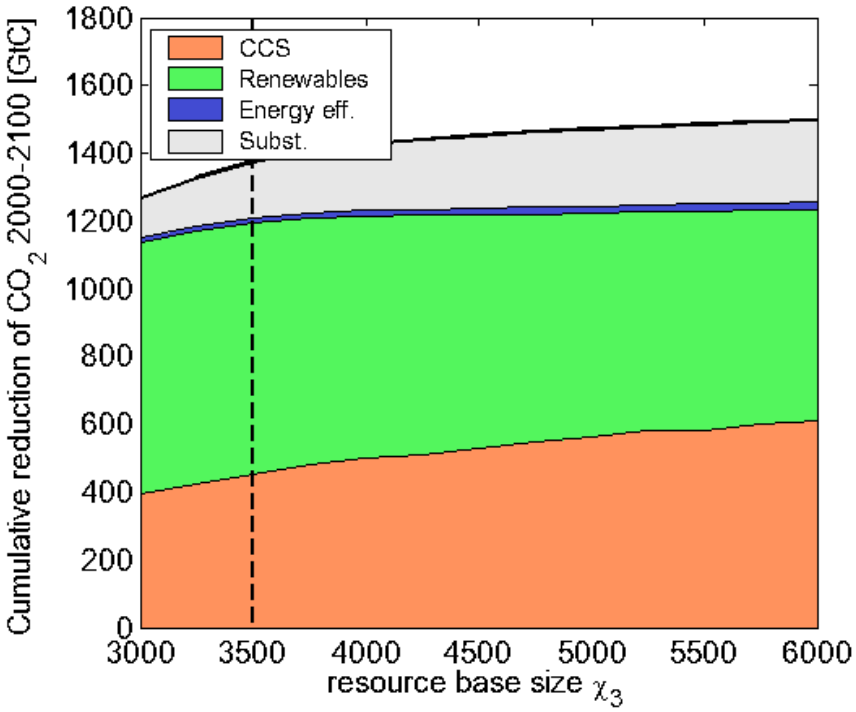
Functional dependency of cumulative extraction and their costs

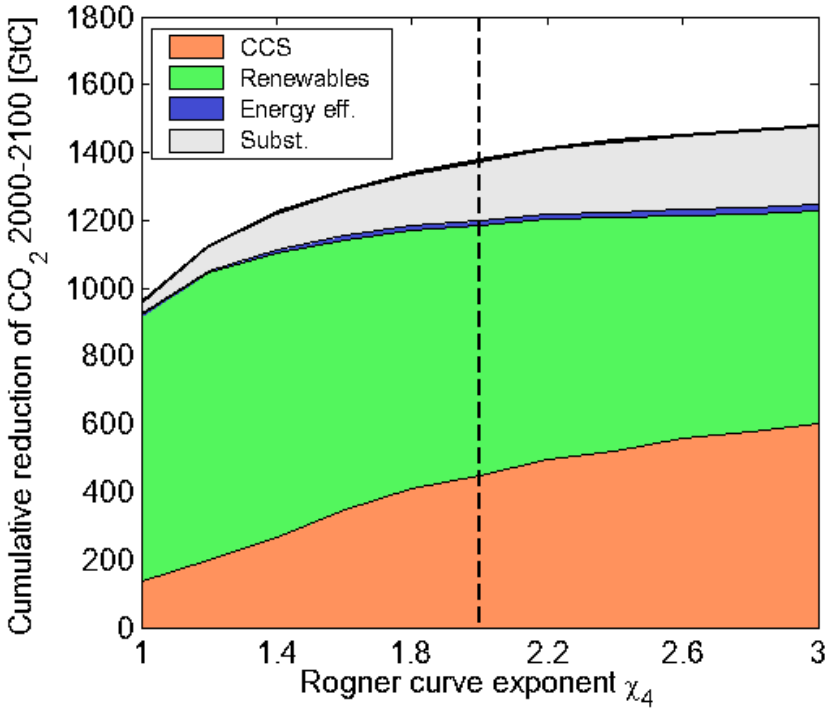
Size of the resource base [GtC]

End-of-pipe and backstop

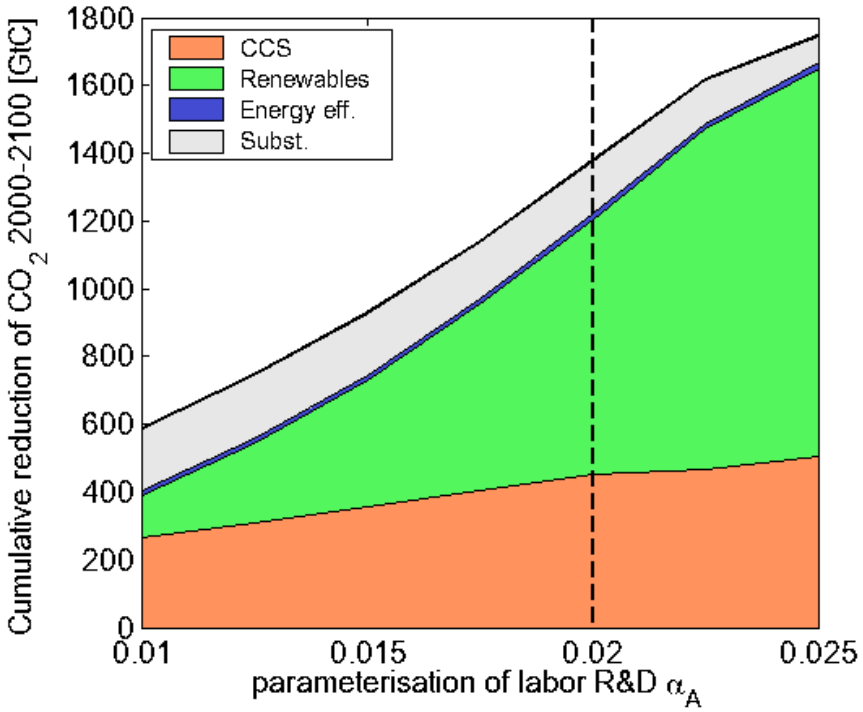


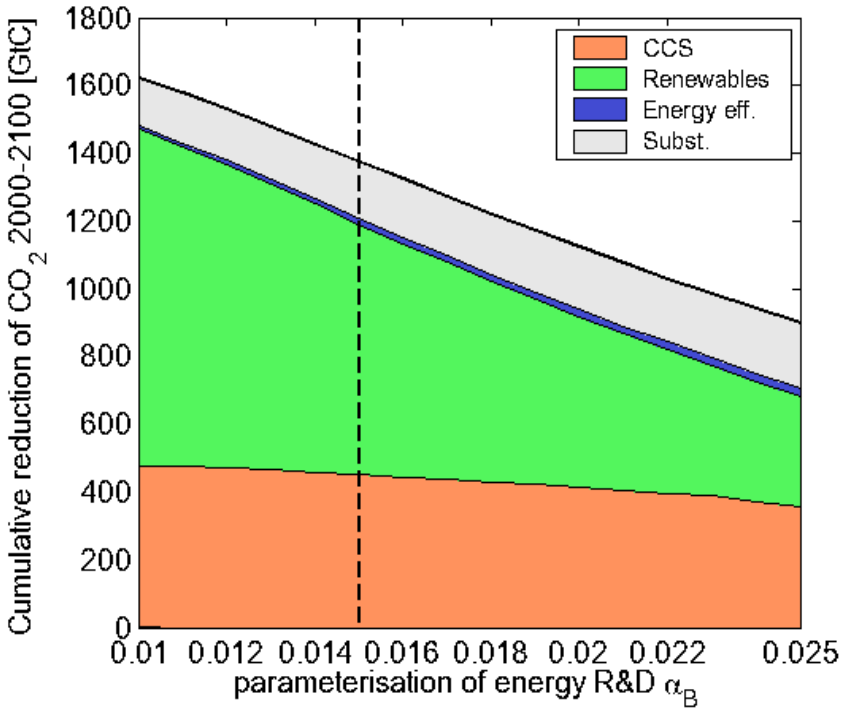
Impact of Resource Extraction



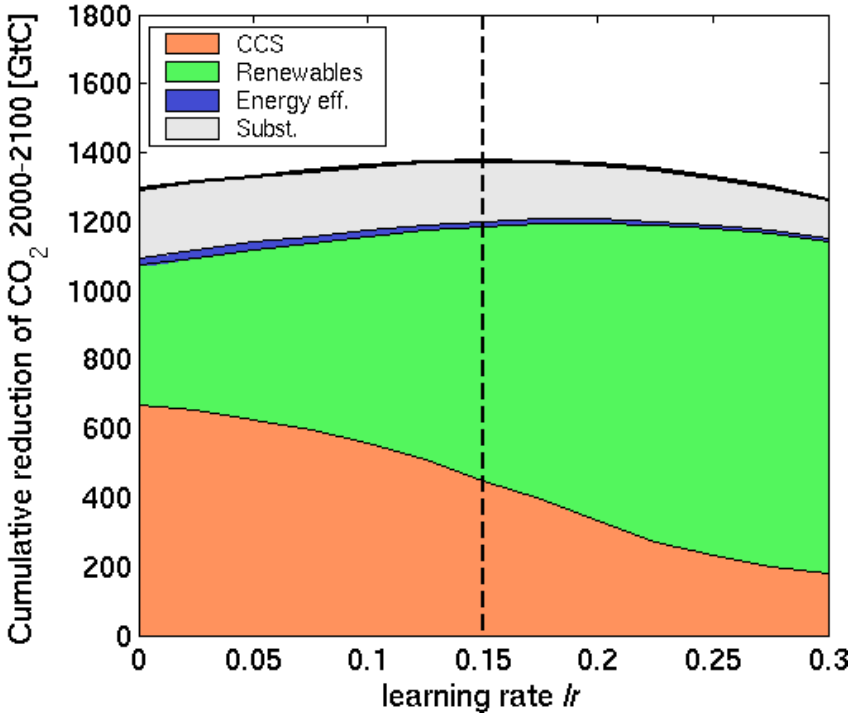


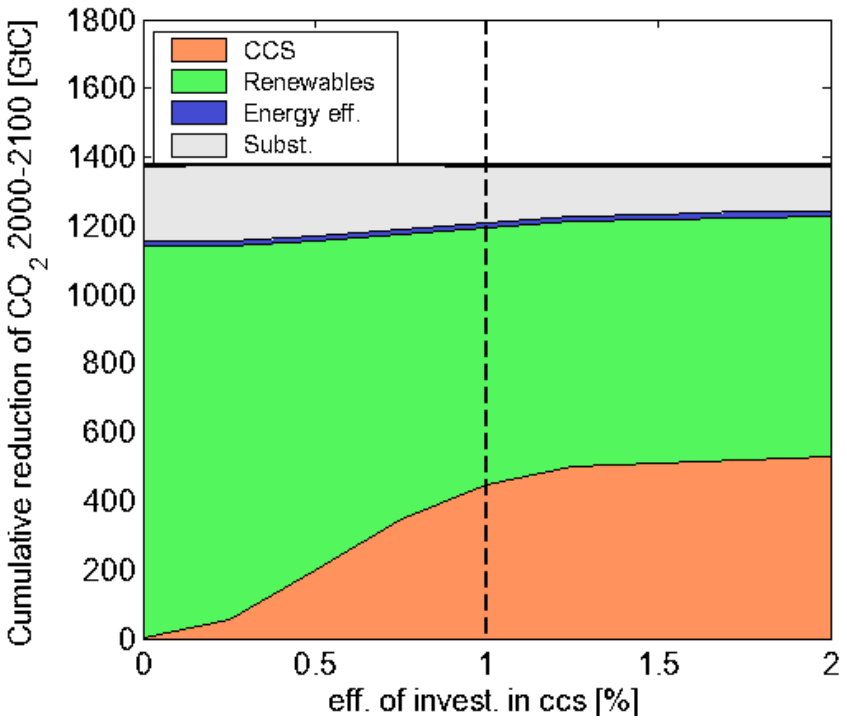
Impact of Macroeconomic efficiency





Impact of Energy Sector





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

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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

Good Candidates for Coupling Exercises

- Sectoral/regional resolution:
  CGE – Energy-System-Models
- Expectations and backstop:
  Energy System – Optimal Growth
- Long-term prediction and sectoral resolution:
  Optimal Growth – CGE models

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