Cost-Efficient CO_2 Emission Cuts through Induced Technological Change & Risk Management for CO_2 Sequestration Options

ESF Strategic Workshop on Ocean Acidification
28 Jan 2008
Meloneras, Gran Canaria

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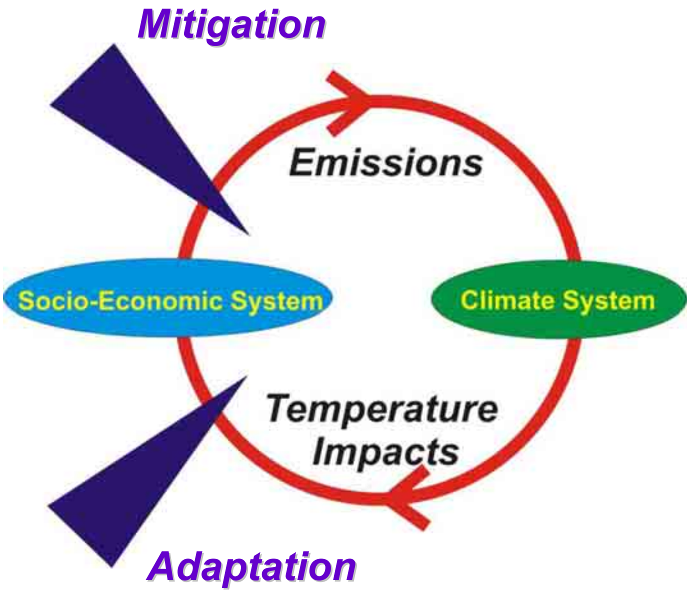
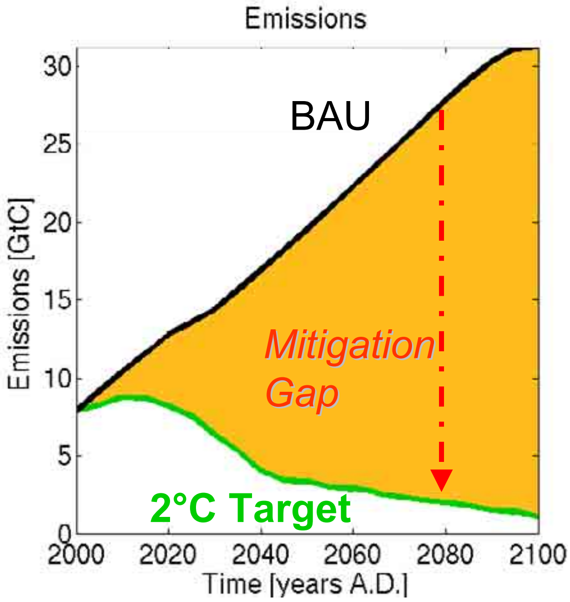
Climate Policies



Limits of Adaptation?

CO_2-Emissions
Business as Usual (BAU)
vs EU´s 2°C-Target



Climate-Economists until 2006:

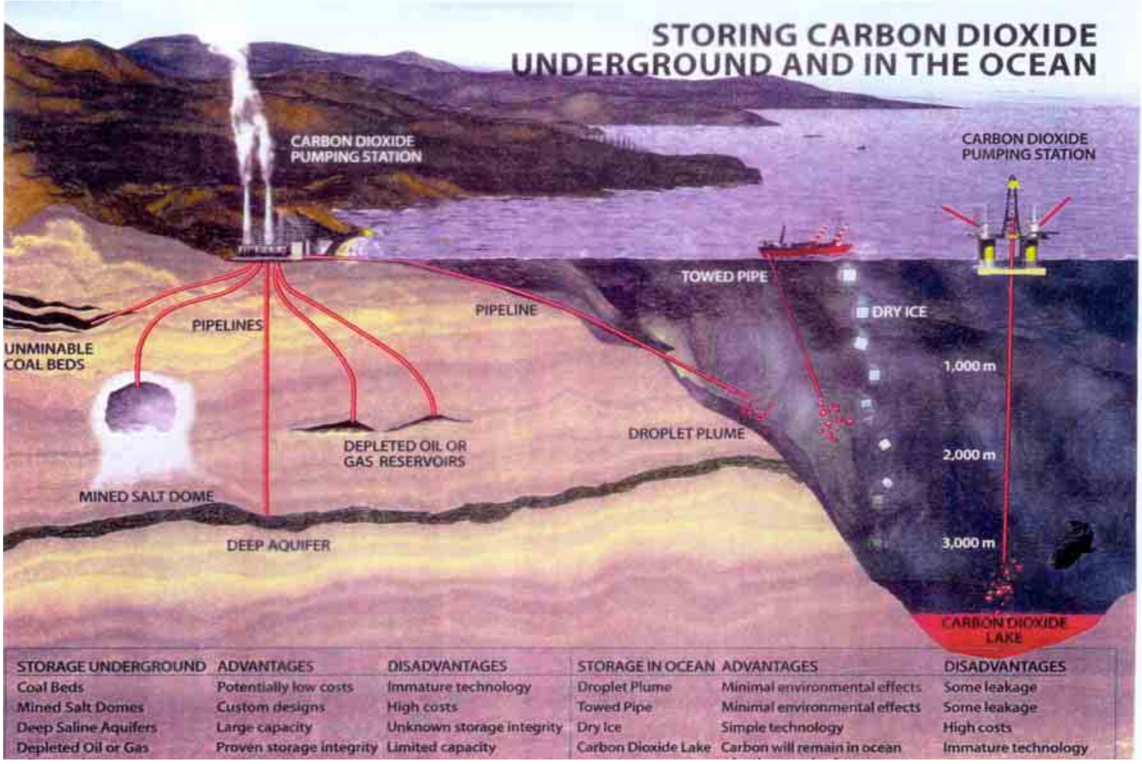
„2° target costs 5..20% GWP

Too expensive!!
Too dangerous!!“

Our Research Question

- **When** to invest **how much** into **what energy** technology, given the 2°C target?
- Options:
  - Renewable sources
  - Energy efficiency
  - Carbon capture & „sequestration“ (CCS)
- ⇒ coupled economy – climate modules.
- *Project Edenhofer/Held 2003-2007 funded by VolkswagenFoundation, then EC funded ADAM-Pr.*

Carbon Capture & Sequestration

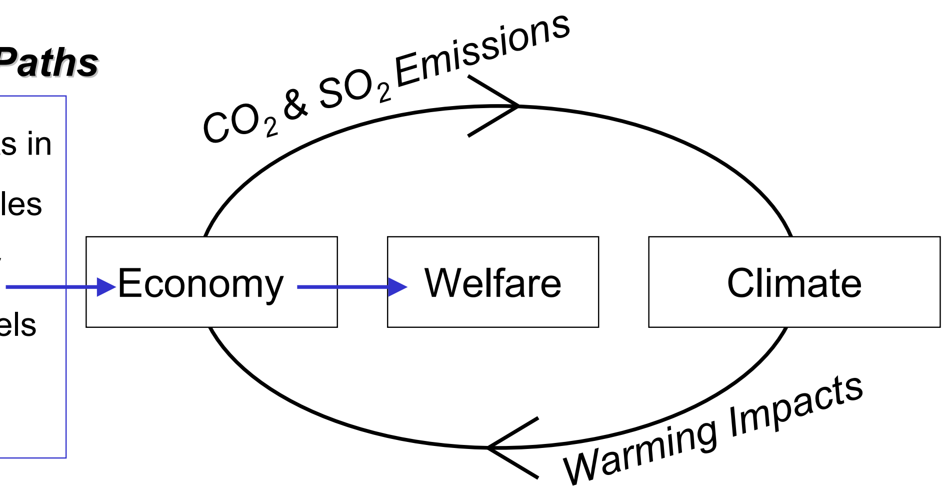


Standard Approach: Cost Benefit Analysis of the Climate Problem

Control Paths

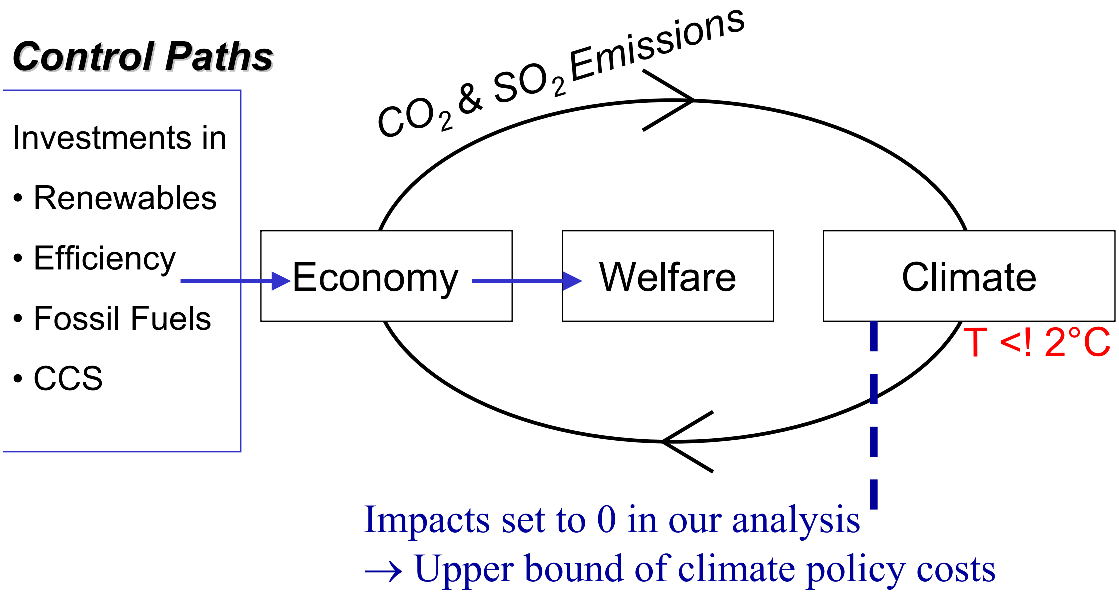
Investments in

- Renewables
- Efficiency
- Fossil Fuels
- CCS



Max ! ∫dt Utility(t) [control Paths] **exp(- *r t*);**

Our approach: Cost Effectiveness Analysis of the 2°C Target



Model of Endogenous Economic Growth MIND

- Optimisation until 2300
- Discounting 1% / year
- Cost reduction due to
  - ‚learning-by-doing' &
  - R&D

(Edenhofer et al., Ecol. Econ. 2005)

Archetypical Economic Growth Model
(after F. Ramsey)

- Increase in capital (factories, ...)

  $$dK/dt = \sqrt{K} - C$$

- In each period, production $\sqrt{K}$ may either
  - be invested in dK/dt or
  - consumed C
- Optimise time-aggr. welfare

  $$\int dt \quad \log(C(t)) \quad \exp(-r\,t)$$

Costs of Fossil Resources Extraction

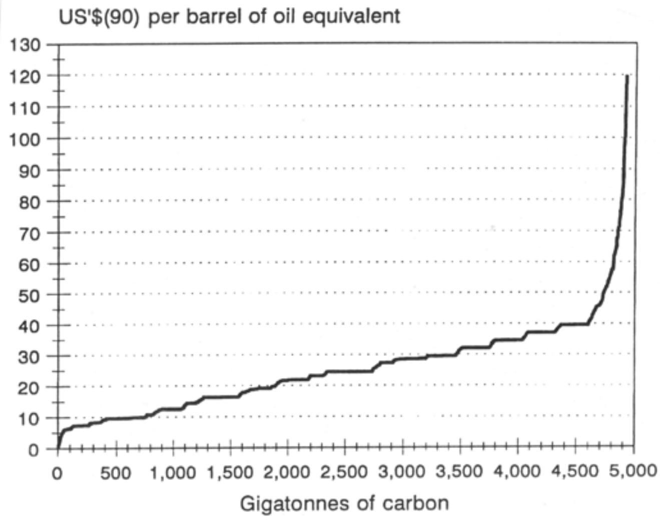
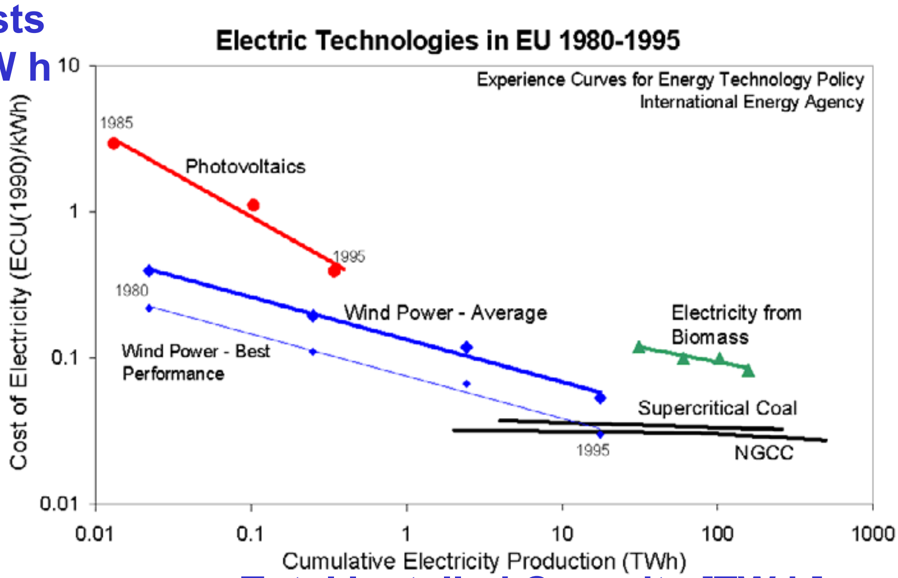


Figure 8 Aggregate quantity-cost curve for carbon contained in the global fossil resource base.

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

Mass Production lowers Costs

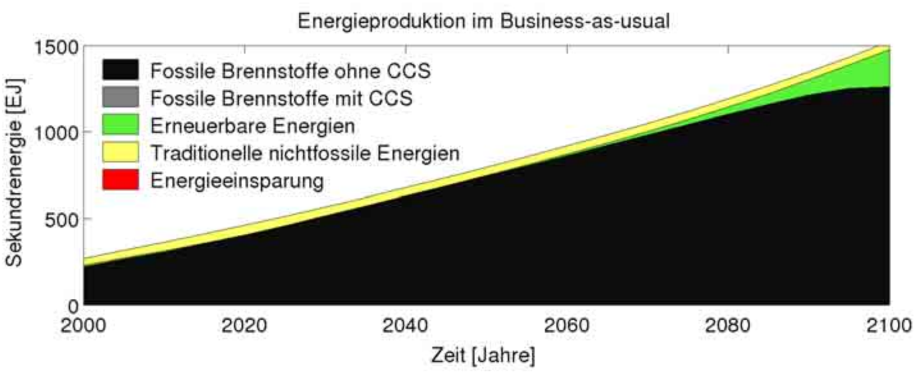
Costs / kW h



Total Installed Capacity [TW h]

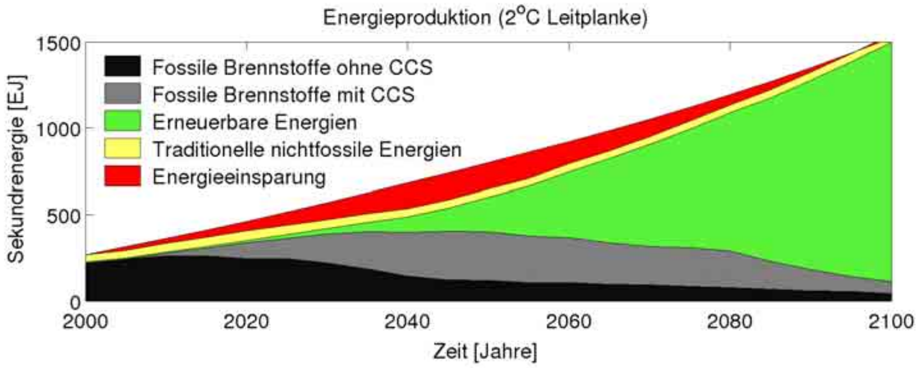
Source: IEA (2000): Experience Curves for Energy Technology Policy; p. 21

Energy Production under BAU



Traditional nonfossil
Renewable
Fossil without CCS

~2° Scenario



Energy Efficiency
Traditional nonfossil
Renewable
Fossil with CCS
Fossil without CCS

Source: Edenhofer, Bauer, Kriegler (2005): Ecological Economics.

Economic Costs of Climate Protection

- **Stabilisation @450ppm**
  ≙ 0.5...1% GWP loss

- **Induces momentum in climate policy:**
  – Environmentalists may be satisfied as the 2° target gets a chance
  – Economists are satisfied as costs are low.

- Society can act...
- ...in spite of ongoing normative discrepancies

NEWS NATURE|Vol 441|18 May 2006

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

"Reducing greenhouse gases will be relatively cheap — 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


THE ENERGY JOURNAL

IAEE INTERNATIONAL ASSOCIATION for ENERGY ECONOMICS

WWW.IAEE.ORG

ENDOGENOUS TECHNOLOGICAL CHANGE AND THE ECONOMICS OF ATMOSPHERIC STABILISATION

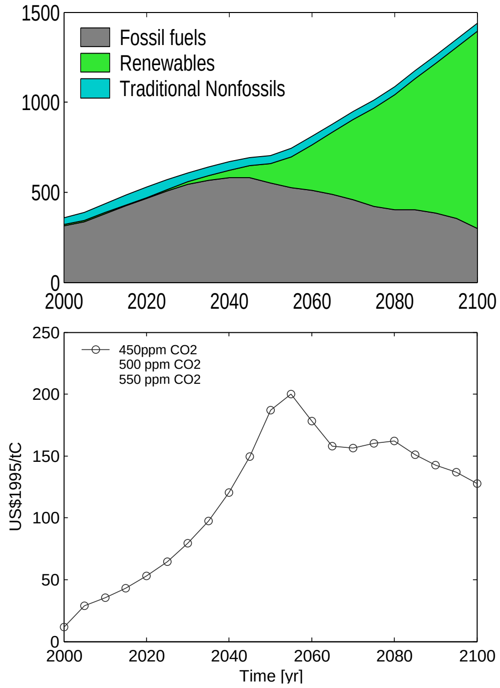
Special Issue **IAEE**
International Association for Energy Economics

Guest Eds.: Edenhofer et al., 2006

CO_2 will have a Price

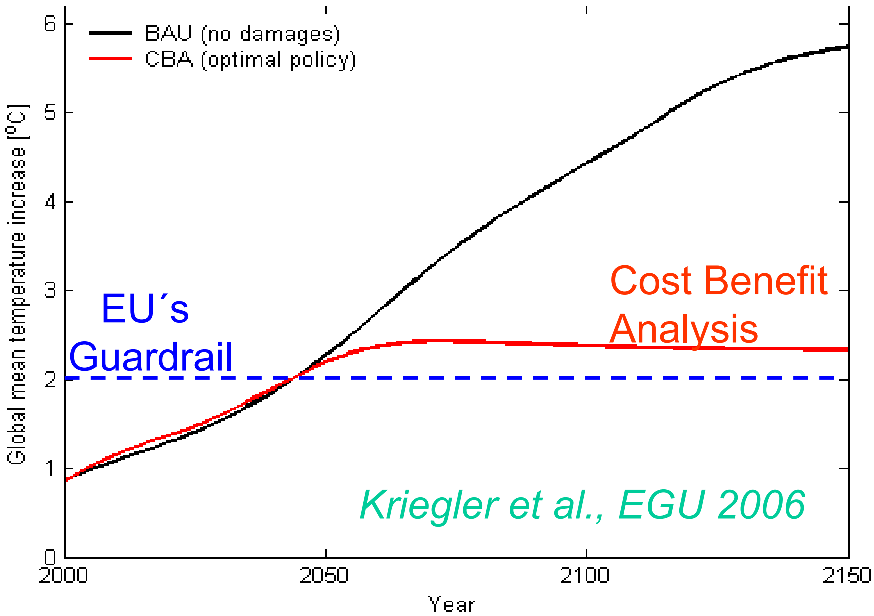
Energy Mix

CO_2-Certificate-Price [$US(1995) / tC]



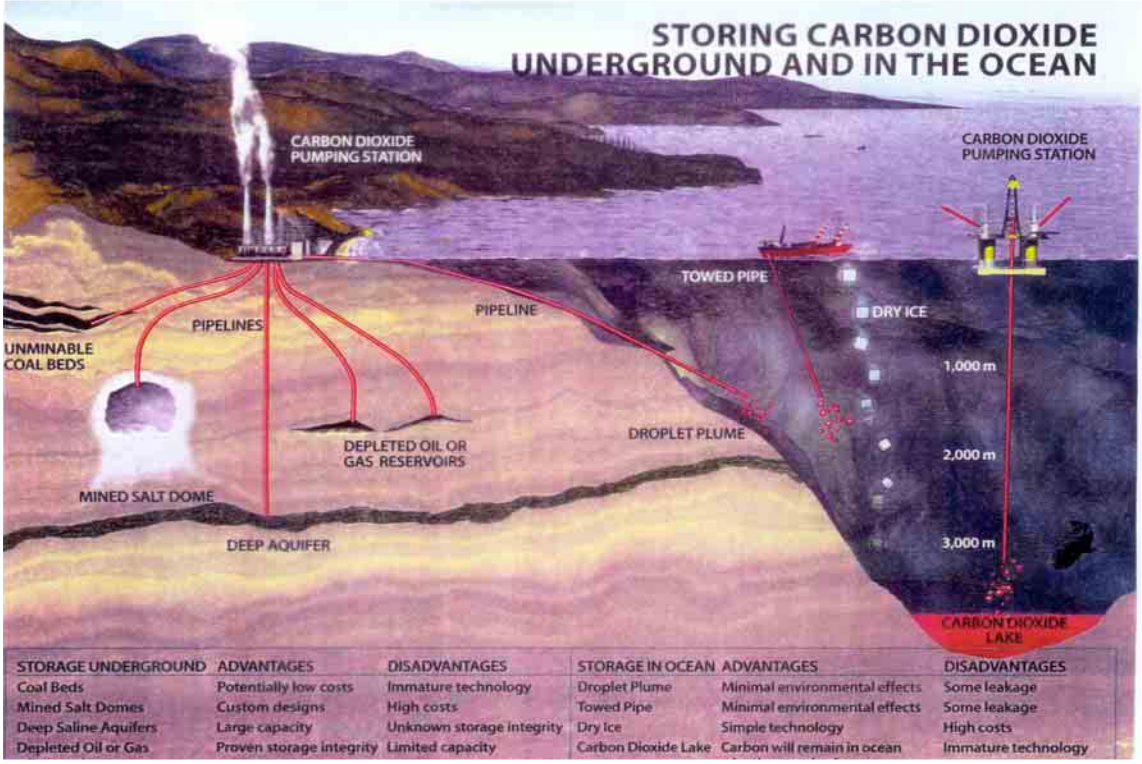
(Edenhofer et al., 2005)

Results for Nordhaus / Boyer damage fct.



Traditional Cost Benefit Analysis, BUT with Learning by Doing / R&D in the Energy Sector

Carbon Capture & Sequestration

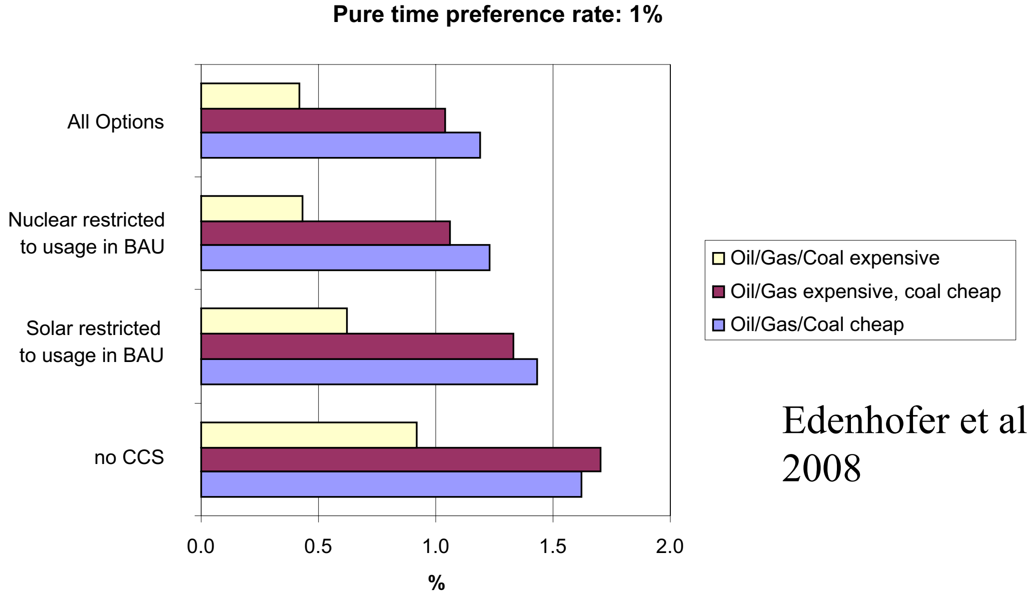


No CCS without aggressive Warming Mitigation Policy

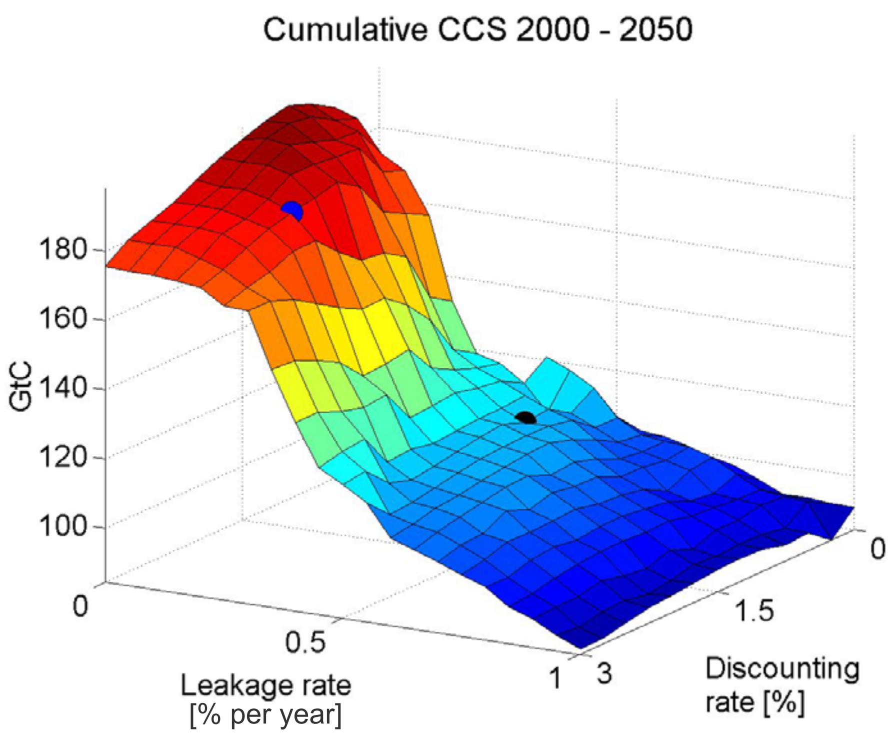
- 2°C target ~ 450ppm CO_2
  ~ 0.5..1% GWP loss

- @450ppm target: ~500 GtC for CCS
- @550ppm target: ~250 GtC for CCS
- @650ppm target: CCS marginal
- *(according to our MIND model)*

Mitigation costs
(Consumption losses from CO_2 stabilization)

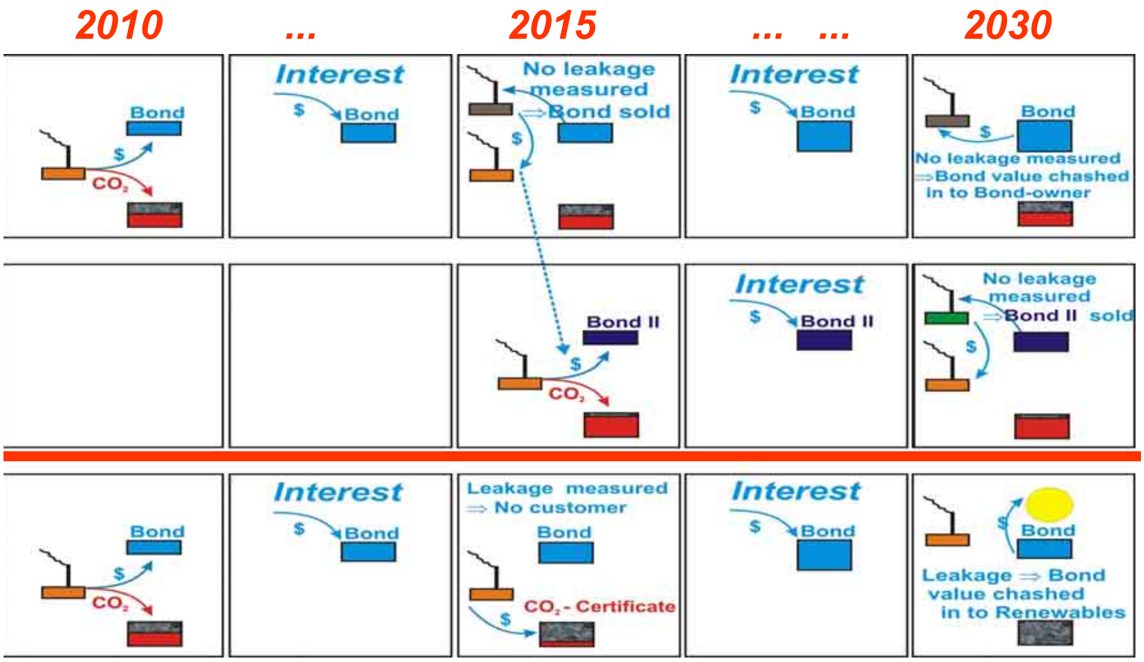


Edenhofer et al., 2008



Bauer et al.

CCS Bonds as Incentive for Secure Formations



Edenhofer, Held, Bauer 2005; Held, Edenhofer, Bauer 2006

Ocean vs. Geol. Sequestration

- Pro of OS:
  - Abundant
  - Remote
- Cons of OS
  - Less efficient
  - Unclear impacts + large spatial range (wrt natural variability)
  - Correlated risk with global warming via uncertain diffusivity parameter
  - Bonds schemes harder to design

Potential for {HH-> Workshop}

- Economically feasible low CO2 conc paths
- Extra costs of ‚strangelove ocean‘ (shut down of carbon pump) – ‚within 2h‘
- Effects of economic acididification damages on optimal CO2 paths
- Early warning system for system thresholds

Potential for {Workshop -> HH}

- Potential for acidification thresholds?
- Holocene to present day deep sea *p*H fluctuations?
- Seabed leakage CO_2 observation limit?
- Assessment of Ocean mineralisation?

My Research – Further Topics

- Extra investment to insure against system response uncertainty (Held et al., subm. En. Econ.)
- Early warning systems for Tipping Points (Held&Kleinen 2004; Dakos et al.,..Held, to be resubm.)
- Expected economic value of observation systems (climate sensitivity, ...)
- Imprecise Bayesian learning & insurance for situations of deep uncertainty (Held 2007)

Summary

- GWP-loss of „2° target“ minor: ½..1%
  - due to learning by doing & R&D investments
  - assuming average climate & econonmic parameters
- Bond schemes for distributed environmental risk (such as CCS) promising instrument – BUT: detection limit for leakage?
- Pre-‘System Dynamics‘ Assessment of CO_2 release into the ocean by reference to natural variability?