Laboratoire
des Sciences du Climat
et de l'Environnement

C.I.R.E.D.
Centre
International
de Recherche
sur l'Environnement
et le Développement

Is there an optimal timing for sequestration to stabilize future climate?

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(in collaboration with Philippe AMBROSI and Philippe CIAIS)

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A mitigation portfolio to stabilise climate under uncertainty

Four mitigation options, with **very different costs** and **mitigation potentials**, **timescales** and **environmental concerns**:

- **emissions reductions**
- **biological carbon sequestration** (BCS)
- **carbon capture and storage** in **geological** formations (GCS)
- **carbon capture and storage** in **oceanic** reservoirs (OCS)

A mitigation portfolio to stabilise climate under uncertainty : questions asked

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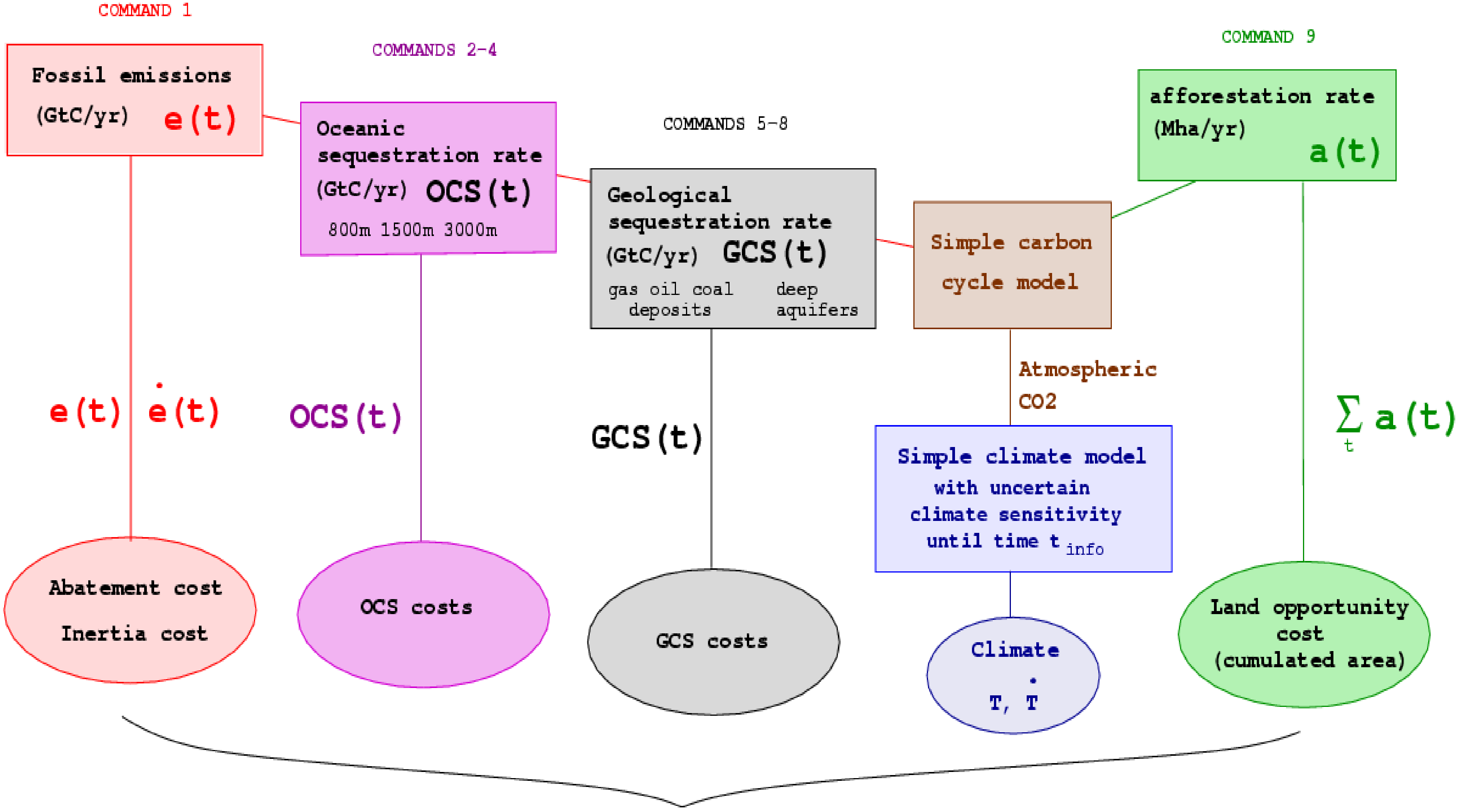
1. Role and importance of sequestration versus emission reductions in stabilizing climate (both at short and longer term): <u>Can we really **“buy time” through sequestration**</u> **?**
   - **delay abatement efforts, amounts of C?**
   - **contribution to lower overall climate policy costs?**
2. **Are seq. options competitive or do they complement** each other?
3. **Existence of unaccounted drawbacks** to scenarios that include massive resort to carbon sequestration (role of leakage and climate sensitivity)?
4. **Do uncertainties about future climate sensitivity matter in choosing seq. options**? How portfolios are suited to anticipate :
   - uncertainties about climate sensitivity,
   - future emission trajectories (high CO2 scenarios)?

Outline

- A compact, integrated, parameter-scarce, climate policy optimisation model: **Response-sq**.
- Physical effects of storage on atmospheric CO2 and temperature.
- Least-cost stabilization policies with and without sequestration portfolio: the role of sequestration in climate policies.

RESPONSE
– An optimal control integrated assessment model



COMMAND 1

Fossil emissions
(GtC/yr) $e(t)$

COMMANDS 2-4

Oceanic sequestration rate
(GtC/yr) $OCS(t)$
800m 1500m 3000m

COMMANDS 5-8

Geological sequestration rate
(GtC/yr) $GCS(t)$
gas oil coal deposits
deep aquifers

Simple carbon cycle model

COMMAND 9

afforestation rate
(Mha/yr) $a(t)$

$e(t)$ $\dot{e}(t)$

$OCS(t)$

$GCS(t)$

Atmospheric CO2

$\sum_t a(t)$

Simple climate model with uncertain climate sensitivity until time t_{info}

Abatement cost
Inertia cost

OCS costs

GCS costs

Climate
T, $\dot{T}$

Land opportunity cost (cumulated area)

Total expected cost is minimized to meet climatic constraints (do not exceed T max and $\dot{T}$ max)

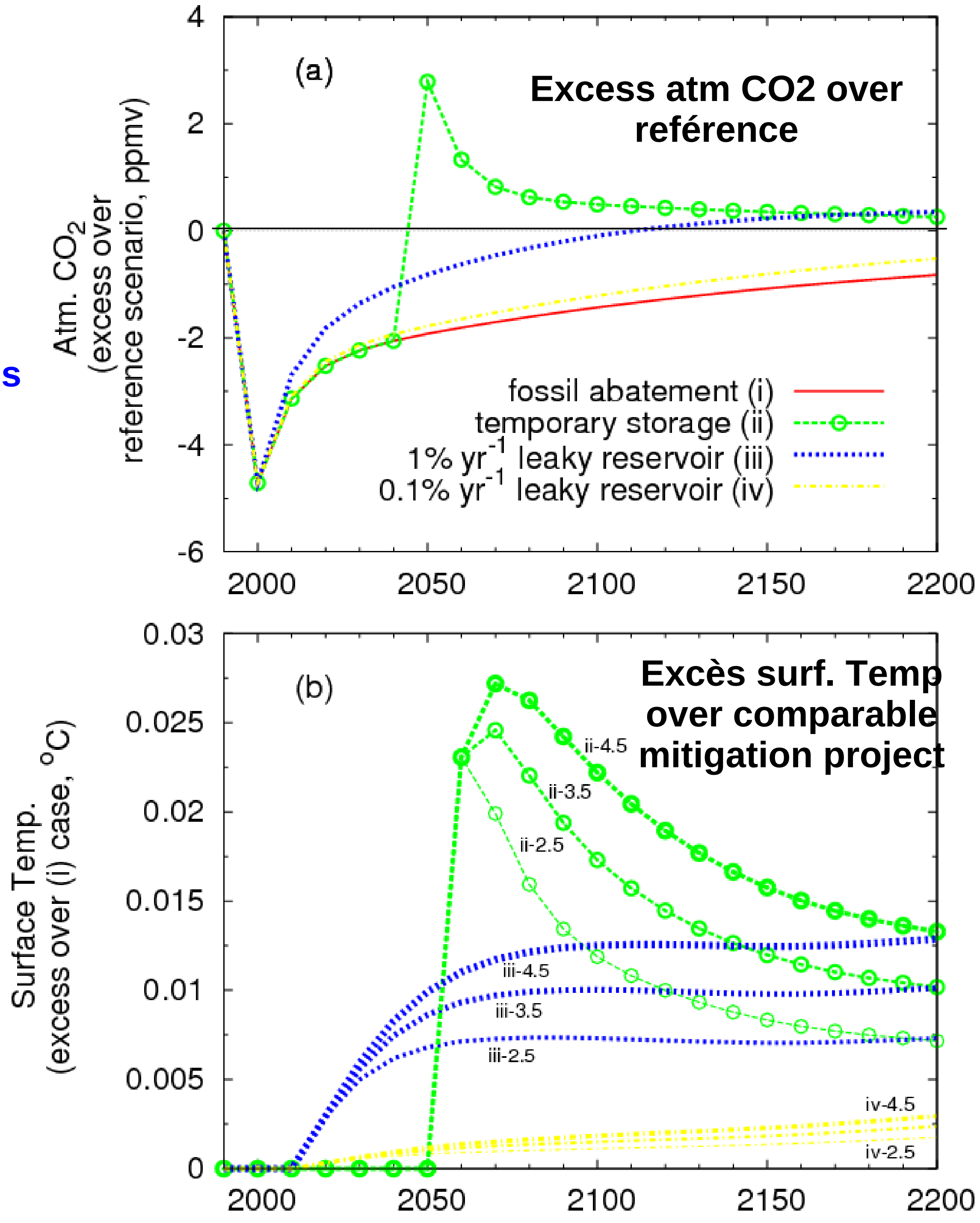
Climatic effects of 10GtC projects

>> MITIGATION
>> BIOLOGICAL SEQUESTRATION
 for 50 years
>> OCEANIC SEQUESTRATION
With 0.1%/yr and 1%/yr leakage rates

Even weak leakage question the use of CCS

>> CCS might be useless ... In scenarios
In which we would need it the most
(high climate sensitivity,
 high emissions)

High climate sensitivity penalizes the use of leaky sequestration
>> the orientation of the technological portfolio is not independent of climatic parameters



Excess atm CO2 over reférence

Excès surf. Temp over comparable mitigation project

Drawbacks?

- Because of delayed effects, a lower value might be attached to sequestration measures if they are leaky.
- The magnitude of this discount will be higher if climate sensibility happens to be high.
- Do these implications automatically preclude the use of sequestration policies? let’s see…

RESPONSE
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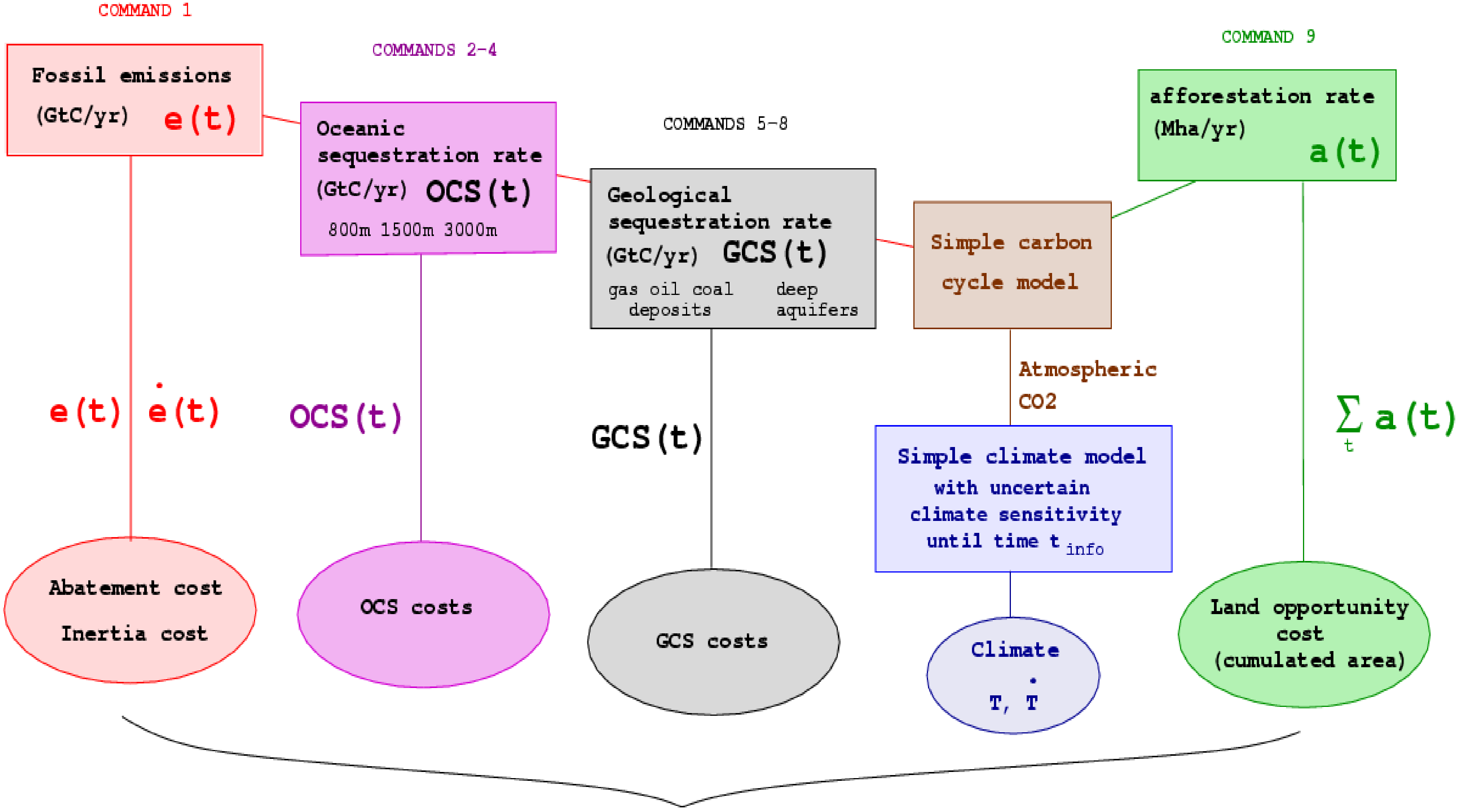

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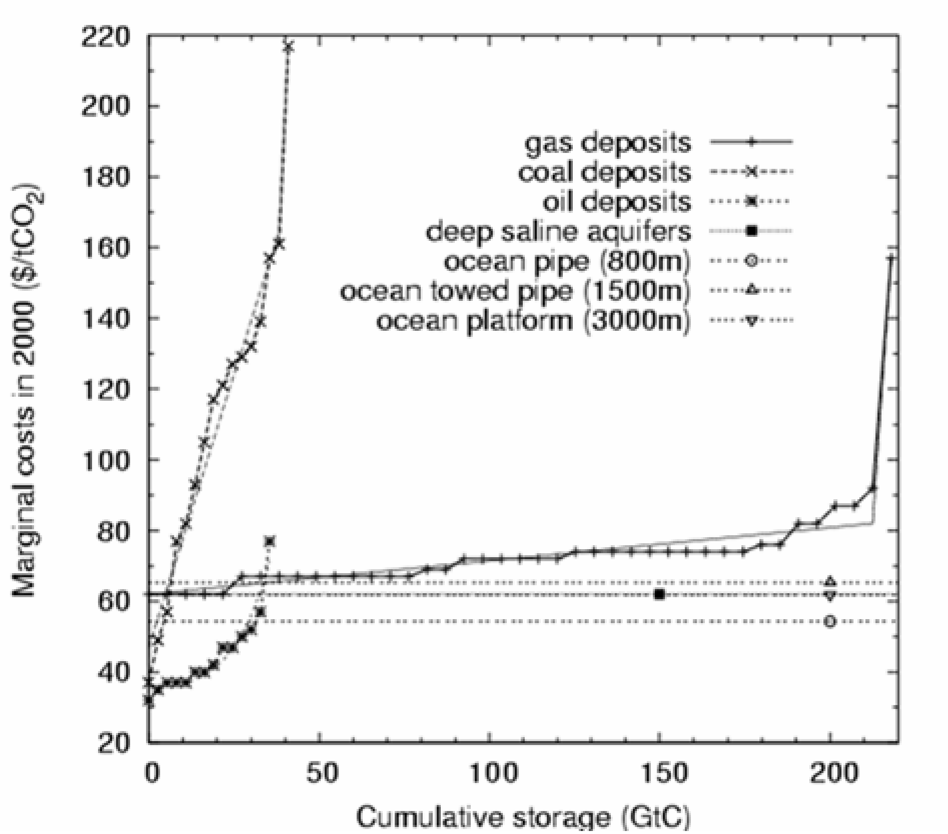
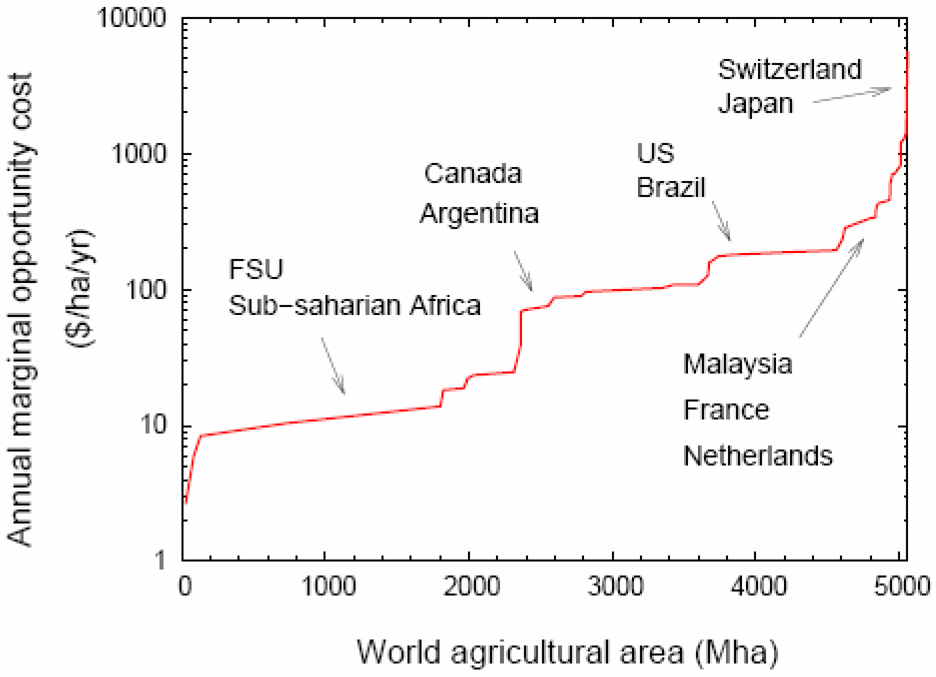
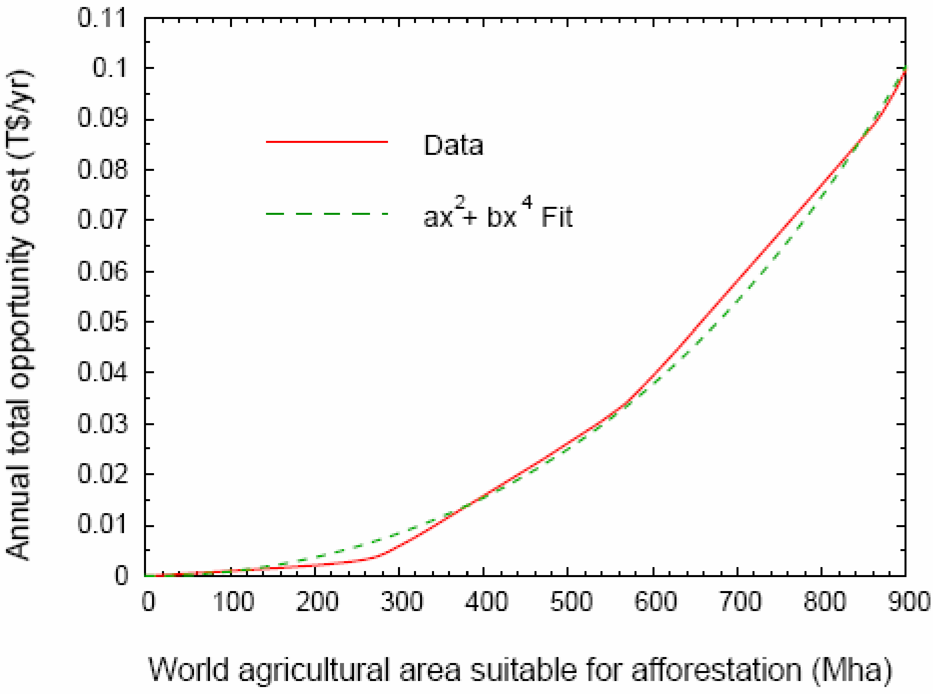
CC&S cost curves



maximum potential of reservoirs (except the ocean): **~ 1 400 GtC**

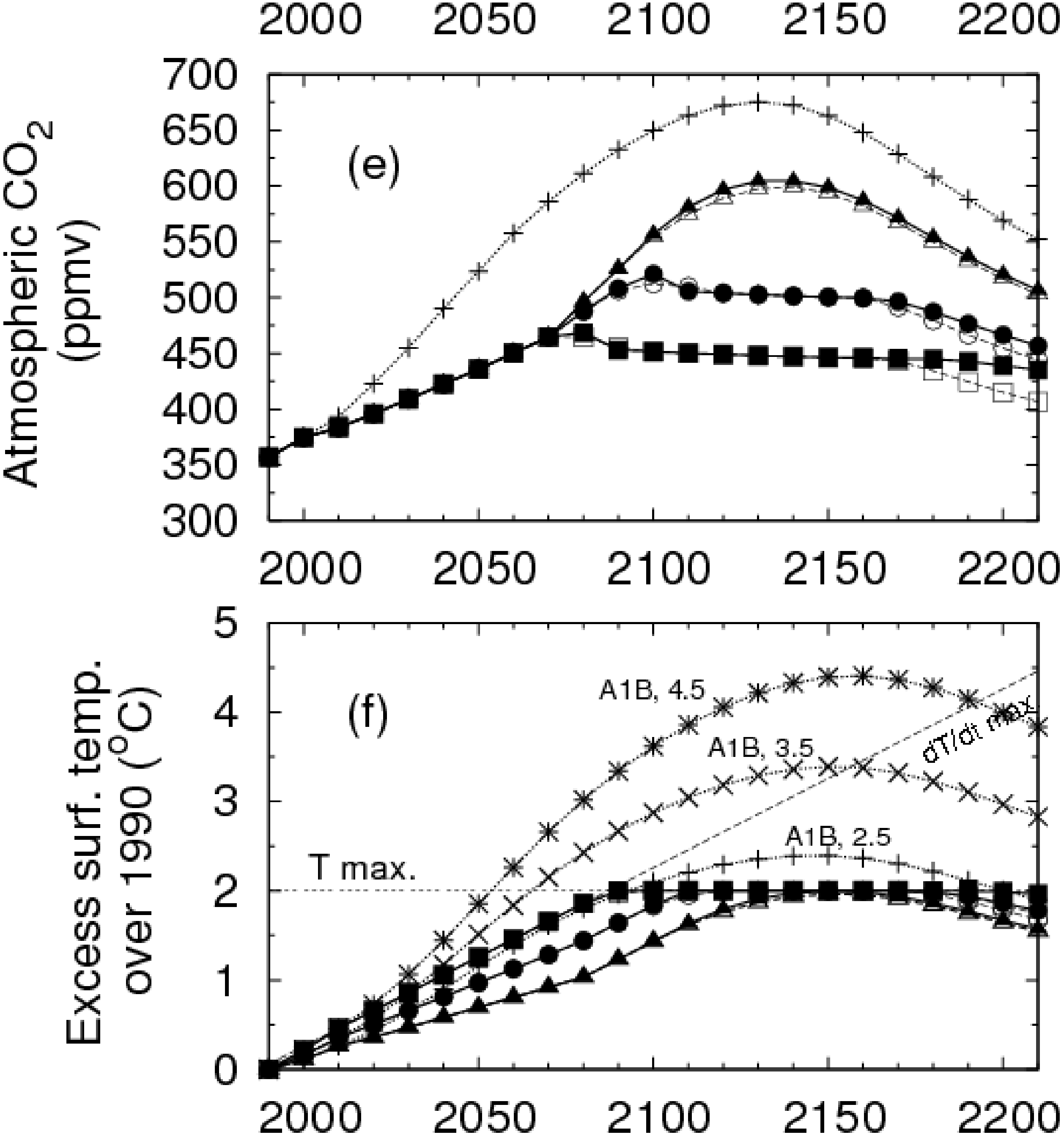
Opportunity cost
of immobilizing lands (base year 1997)





Source: FAO 1997 for agricultural area per country
GTAP 1997 for annual net agricultural revenue per country
land-cover maps by Ramankutty and Foley for areas suitable for afforestation

- average Carbon gained afforested over 50 years: **0.1 GtC/Mha**
- **maximum potential** of BCS reservoir: **100 GtC**

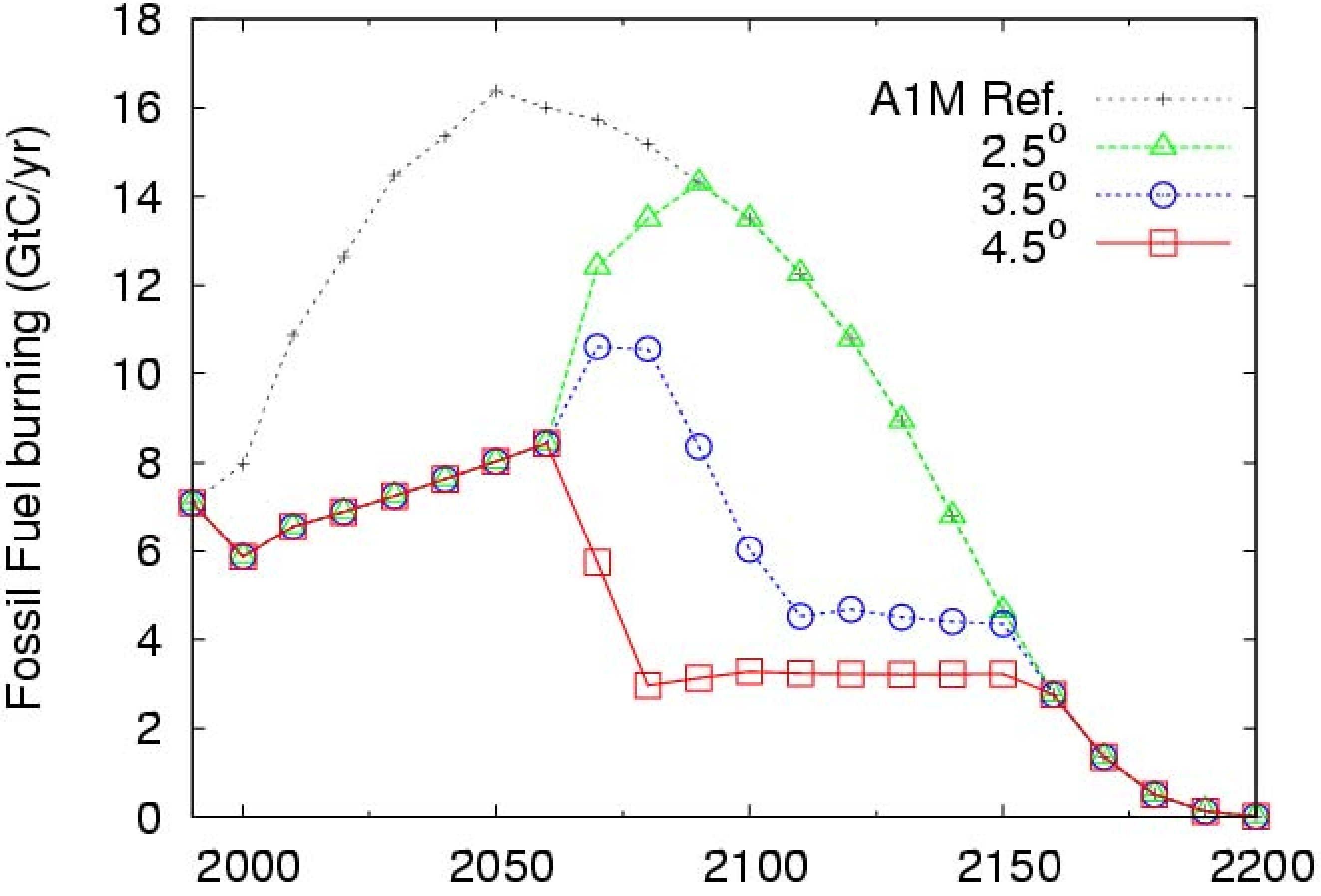


Atmospheric CO2

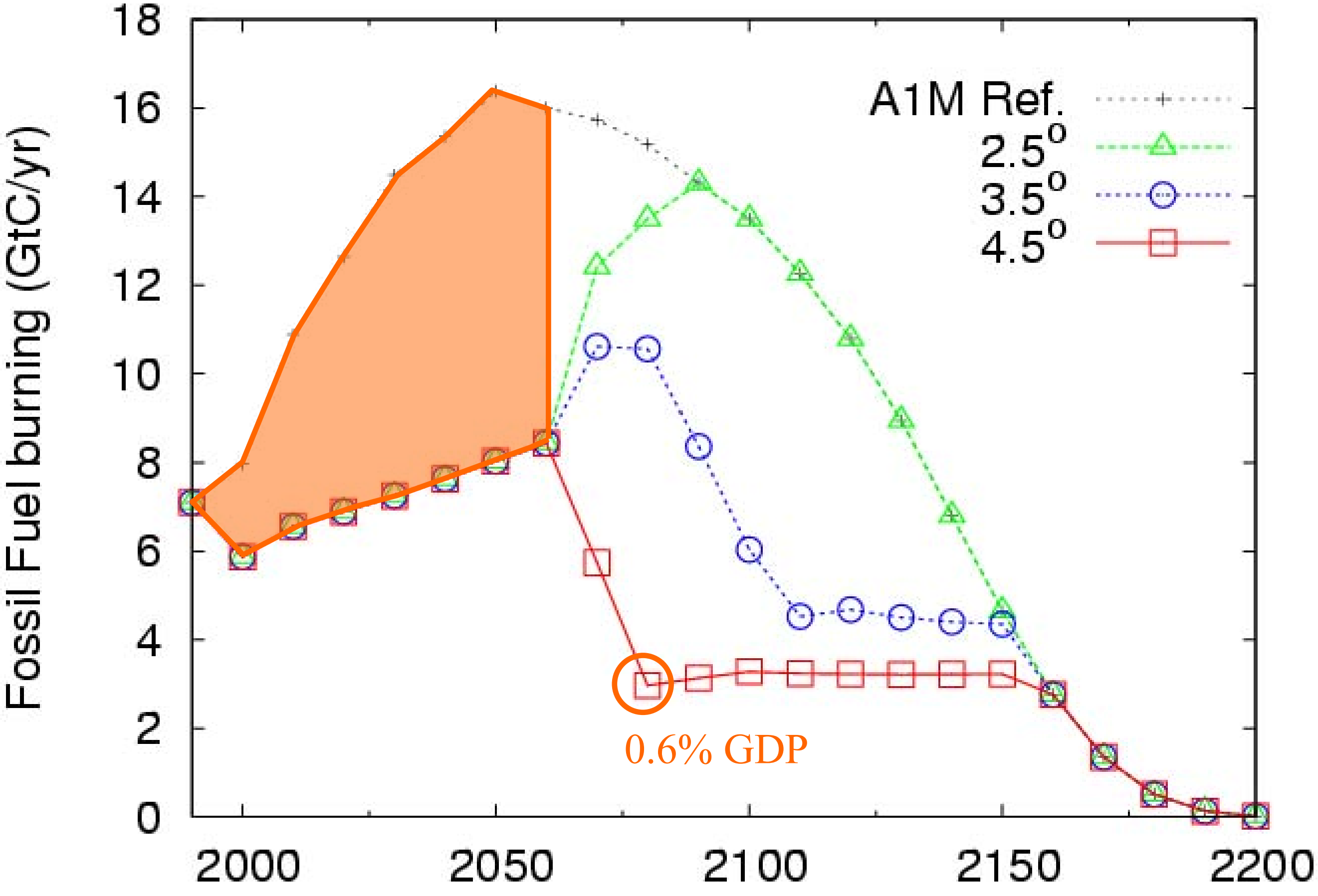
and

Excess surface temperature in optimal scenarios (**envelope Constraint**)

Optimal trajectories: abatement, BCS, G&OCS



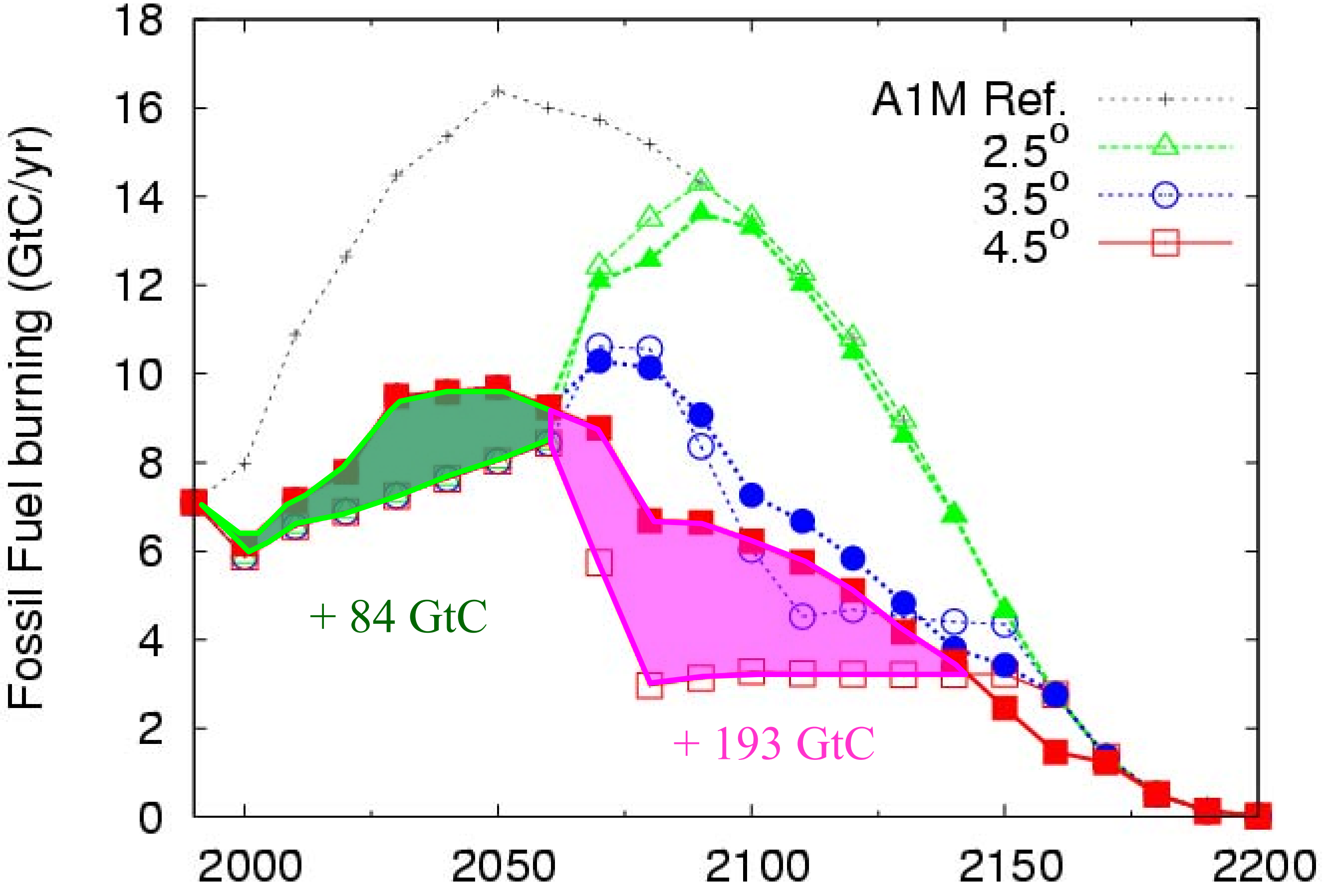
Optimal trajectories: effect on fossil abatement



0.6% GDP

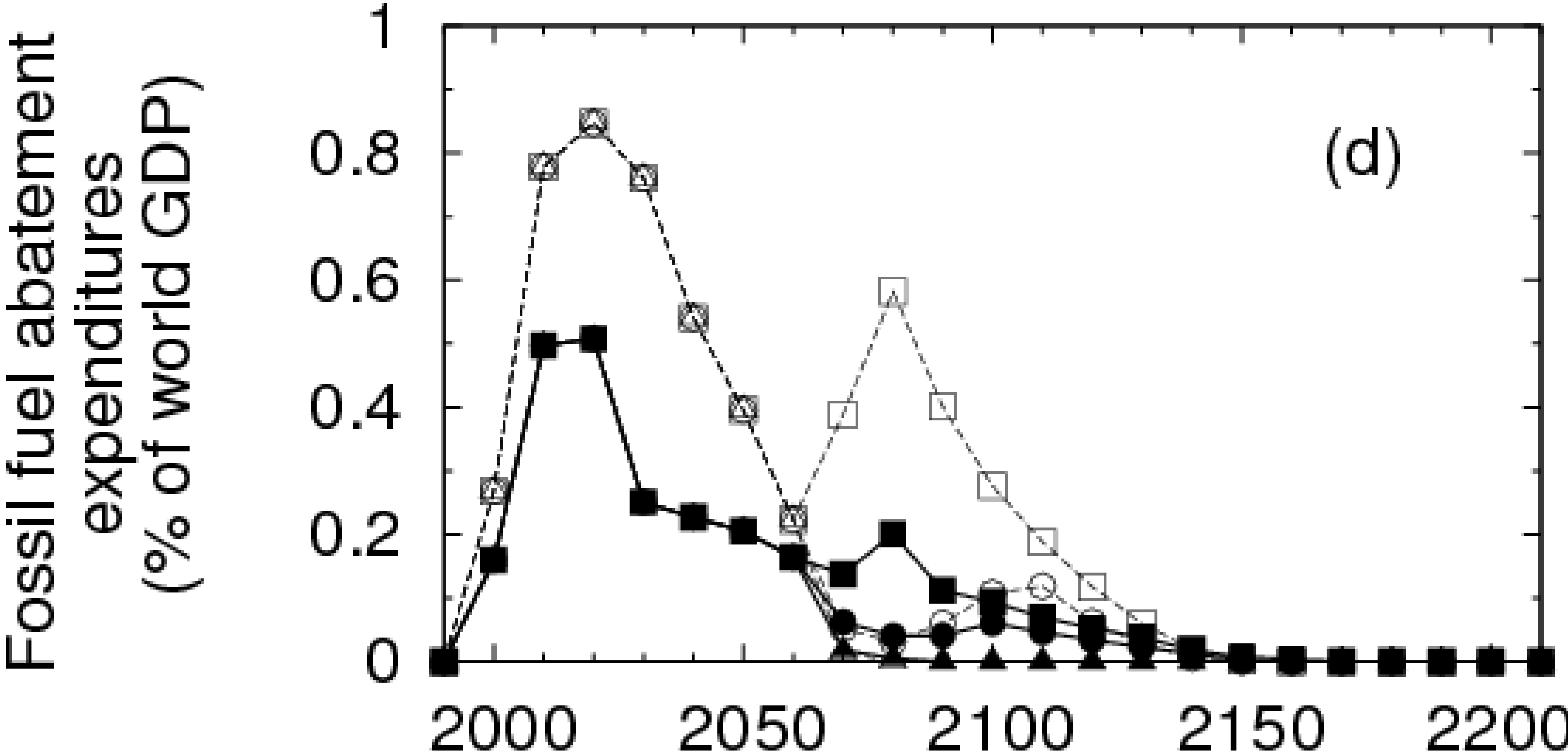
42% of baseline emissions

Optimal trajectories: abatement, BCS, G&OCS



BCS: a **brake** on emissions G&OCS: a **safety valve** on emissions

Reduction of fossil fuel abatement expenditures
Due to sequestration options



A2		Cumulative C fluxes (GtC)			Economic Cost (T$)	
		REF	Abatement only	Seq. Policy	Abatement only	Seq. policy
Fossil fuels	ST	**1043**	**578**	**682**	4.45	2.13
	LT 2.5	5146	1975	2358	0.35	0.30
	LT 4.5		797	1812	1.95	0.62
BCS	ST			-55		0.29
	LT 2.5			41		0.05
	LT 4.5			43		0.07
GCS	ST			-30		0.30
	LT 2.5			-85		0.00
	LT 4.5			-991		0.10
OCS	ST			-19 (0)		0.10
	LT 2.5			-1097 (670)		0.06
	LT 4.5			-616 (452)		0.48
NET	ST	1043	578	578	4.45	2.82
	LT 2.5	5146	1975	1888	0.35	0.41
	LT 4.5		797	700	1.95	1.28

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Leakage tends to penalise OCS

Future (irreversible) leakage has to be compensated by **additional mitigation efforts**

⇨ **a bias in favour of GCS**

High climate sensitivity case	Low-emissions scenario (A1)	High-emissions scenario (A2)
OCS (GtC)	308	616
G&OCS (GtC)	338	1664
Share of OCS in G&OCS (%)	**52**	**37**
Cumulative leakage (GtC)	211	406

Conclusion

- **Sequestration** options can help to **cut down costs** as a **substitute to abatement** : up to 35%
- **Complementarity** of BCS (short-term) and G&OCS (long-term)
- **Rate of deployment** of these options proves **binding**
- **Leakage from the ocean** (not to speak of local risks of OCS) penalises ocean sequestration; **OCS may not be compatible with high emissions scenarios and high climate sensitivity**
- **Climate-carbon feedbaks imply additional necessary reduction in emissions of 10% to 15%**