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for the Middle East and North Africa

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Climate Change, Climate-Change Economics and Policy

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ecological and environmental economics

Climate Change, Climate-Change Economics and Policy

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the abdus salam international centre for theoretical physics

united nations educational, scientific and cultural organization

international atomic energy agency

Fondazione Eni Enrico Mattei

The Beijer International Institute of Ecological Economics - The Royal Swedish Academy of Sciences

Structure of the lecture

1. Climate change

2. Climate-change impact assessment

3. Climate-change policies
   3.1. Mitigation
   3.2. Adaptation

Climate Change

Global Warming
& Climate Change

↓

Often used as synonyms

↓

Refer to the *likely* increase in the global mean temperature of the Earth

Greenhouse Effect

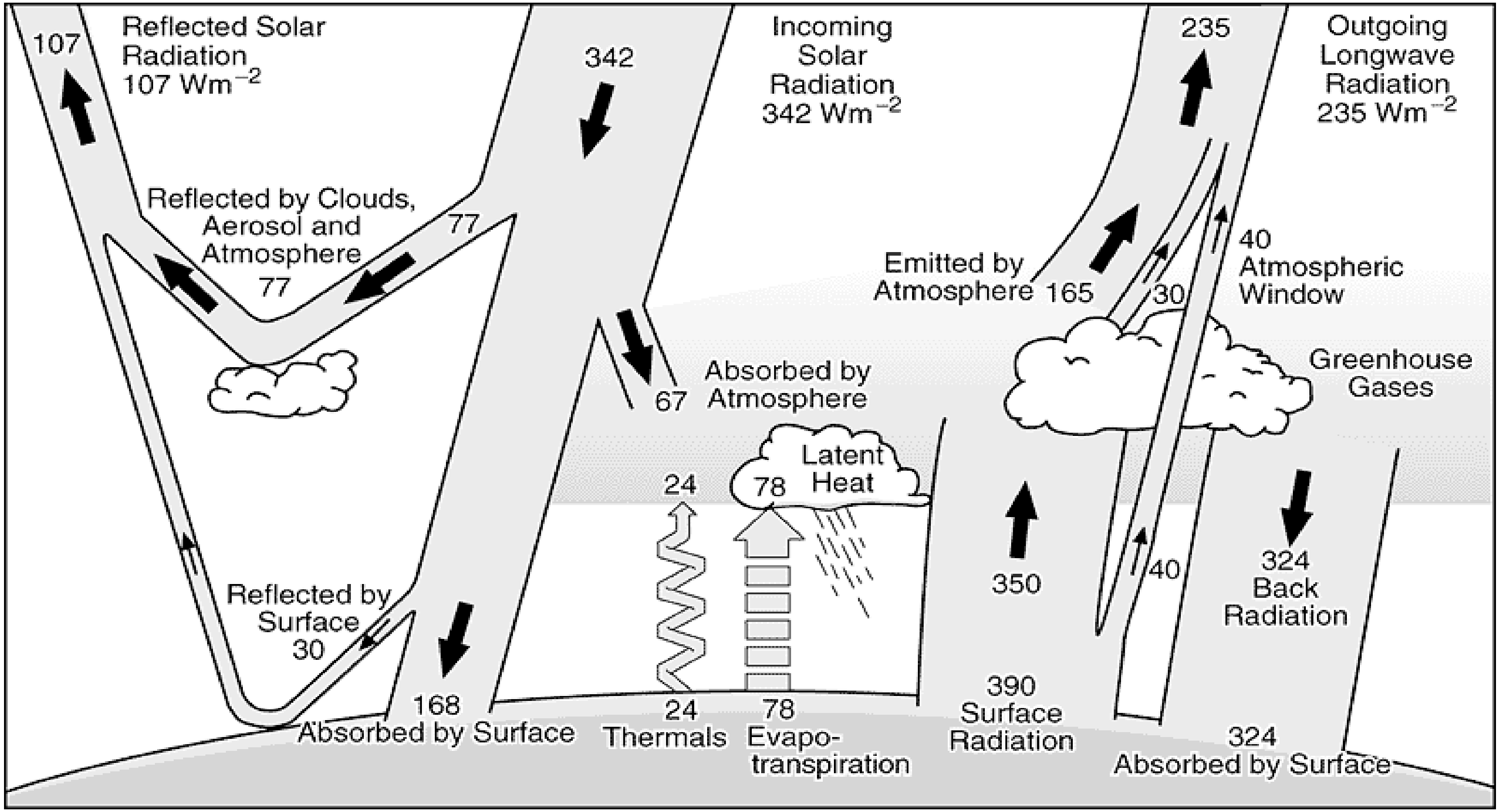
↓

ONE of the causes of Climate Change

↓

- The atmosphere *and* the Sun heat the Earth's surface.
- The Earth radiates this energy back into space.
- The atmosphere, absorbing some of the outgoing energy, retains heat.

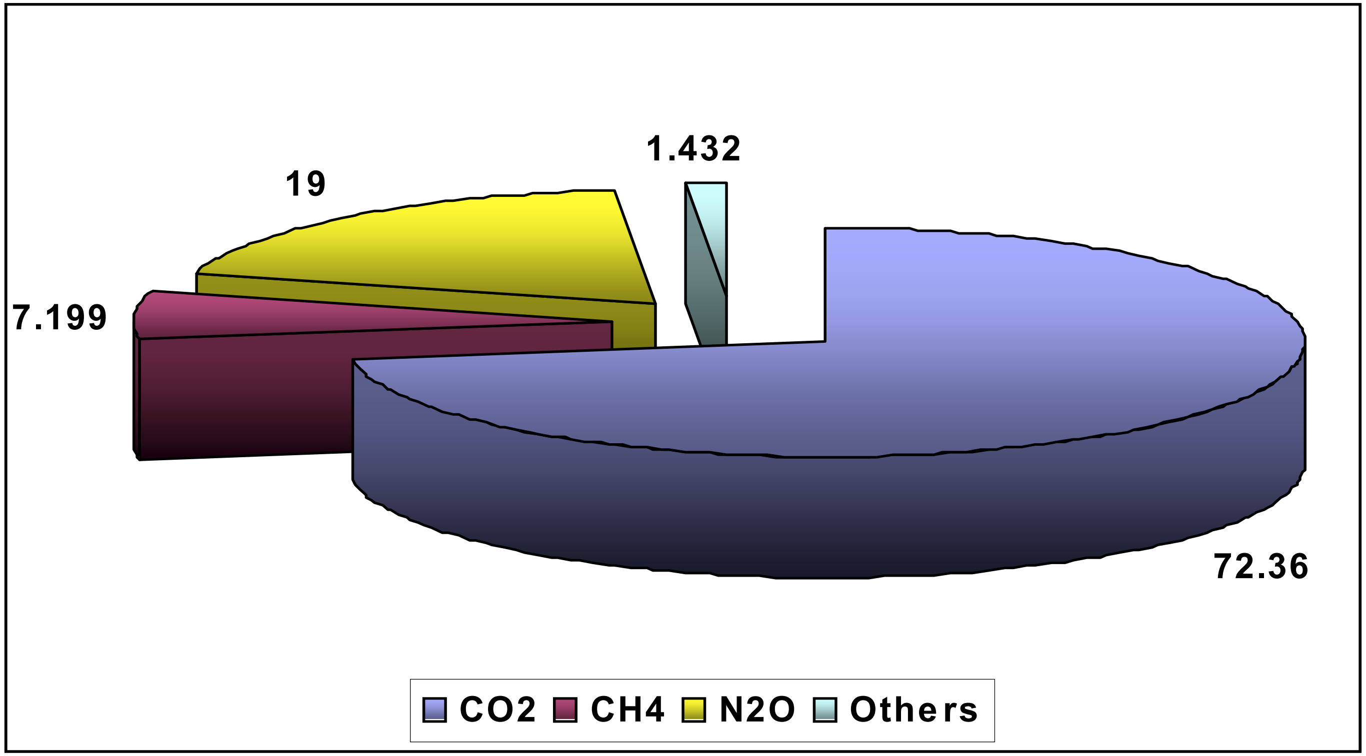
Greenhouse effect and Earth annual and global mean energy balance



Source: IPCC 2001 Climate Change 2001 "The Scientific Basis"

GAS	Origin	Atm. lifetime	GWP
CO_2	Natural + m-made Use of Fossil fuels + deforestation	5-200	1
CH_4	Natural + m-made Livestock + Wetland cultivation (rice)	12	23
N_2O	Natural + m-made Coal burning + Fertilisers	114	296
CFC	M-made Refrigerants + foam plastic, elect. comp.	45	1320 - 9300
HFC	M-made	0.3 - 260	12 - 12000
Fluor.ed	M-made	3200 - 50000	5700 - 22200

Relative "warming" contribution of different GHGs (%)



Source: US Dept. of Energy 2000

Keep in mind: ***Water vapour - 95% of all GHGs in the atmosphere - is not in the picture!!***

Studying Climate-Change: A Brief Historical Overview

1986 - "Detection" of the CC phenomenon (Arrhenius)

1955-65 - First modelling efforts (first satellite data). 1967 "first" GCM Manabe & Wetherald.

1988 - IPCC created by WMO and UNEP

1990 - First IPCC report: anthropogenic influence + possible negative impacts.

1990 - Beginning of climate negotiations

1992 - UNFCC – 240 signatories. Limit CO2 emissions to 1990 levels by year 2000 + Agenda 21

1995 - Second IPCC report: social-economic dimension of CC:

1997 - Kyoto Protocol

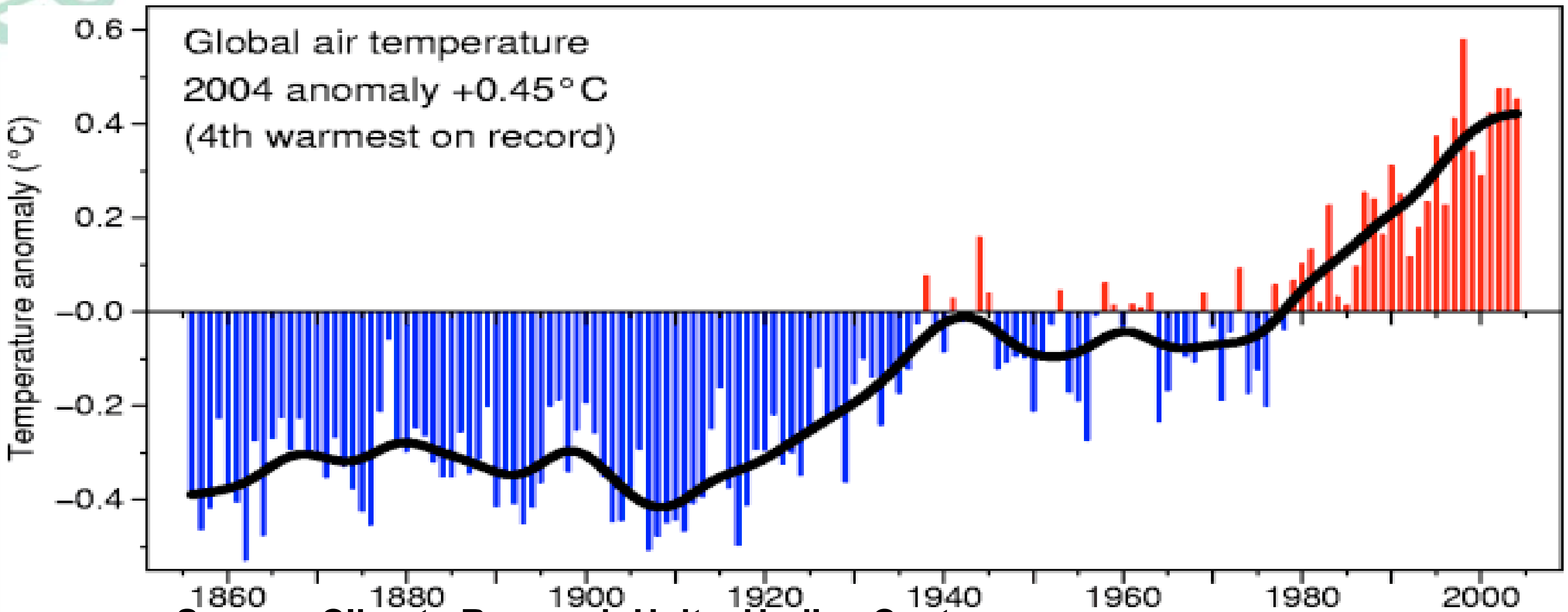
2001 - Third IPCC report: Impacts, adaptation and vulnerability.

2004 - Kyoto Protocol into force.

- Is global mean temperature really increasing?
- How much of the change in temperature is due to the Greenhouse Effect (i.e. to GHGs)?
- How much of the change in temperature is due to human influence?

Note: - Data are often the same but interpreted differently.
- Knowledge is continuously increasing.
- Still large uncertainties.

A look into the recent past

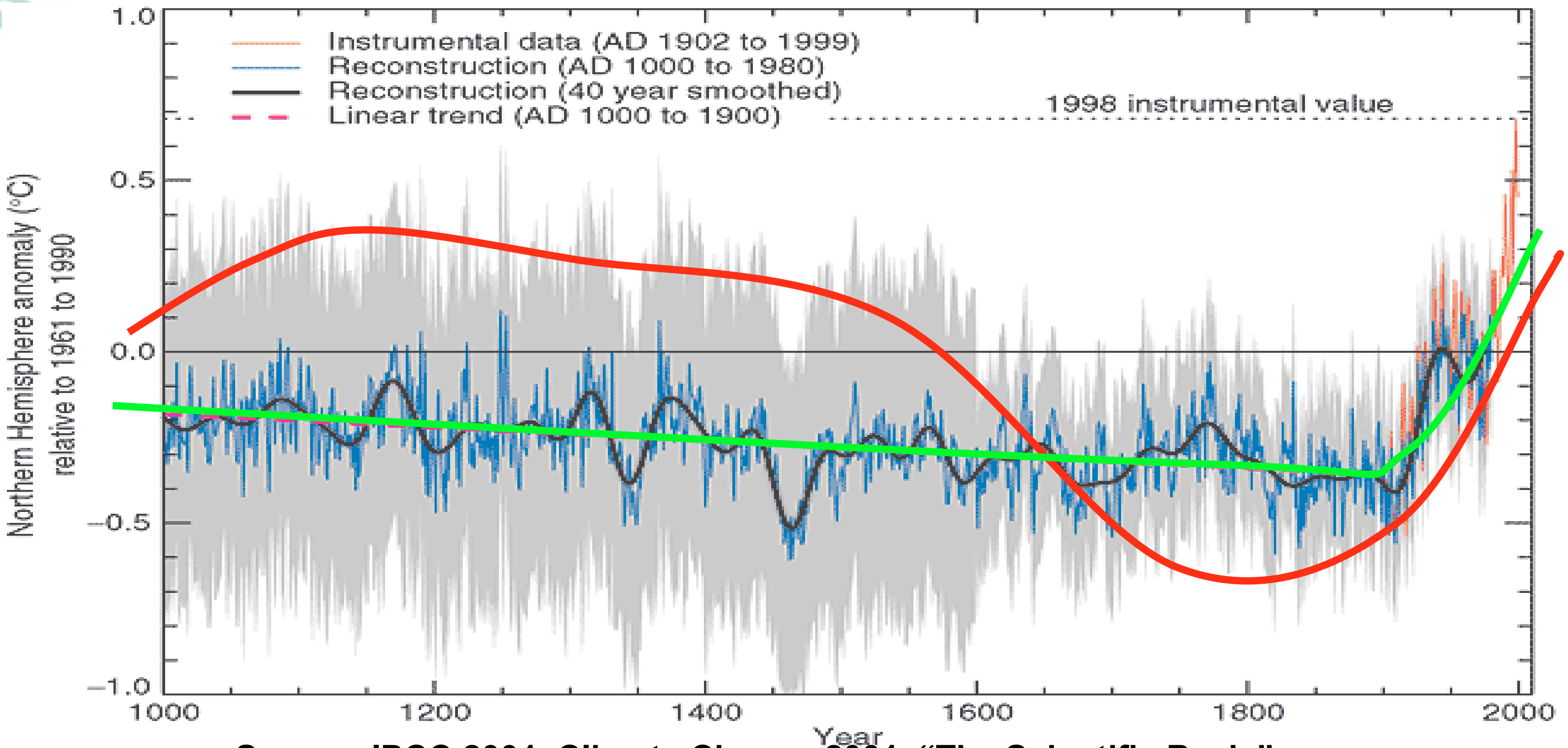


Source: Climate Research Units, Hadley Centre

Surface **temperature: warming ≃ 0.1°C per decade**

Lower troposphere **temperature: no warming 1979 -1997**

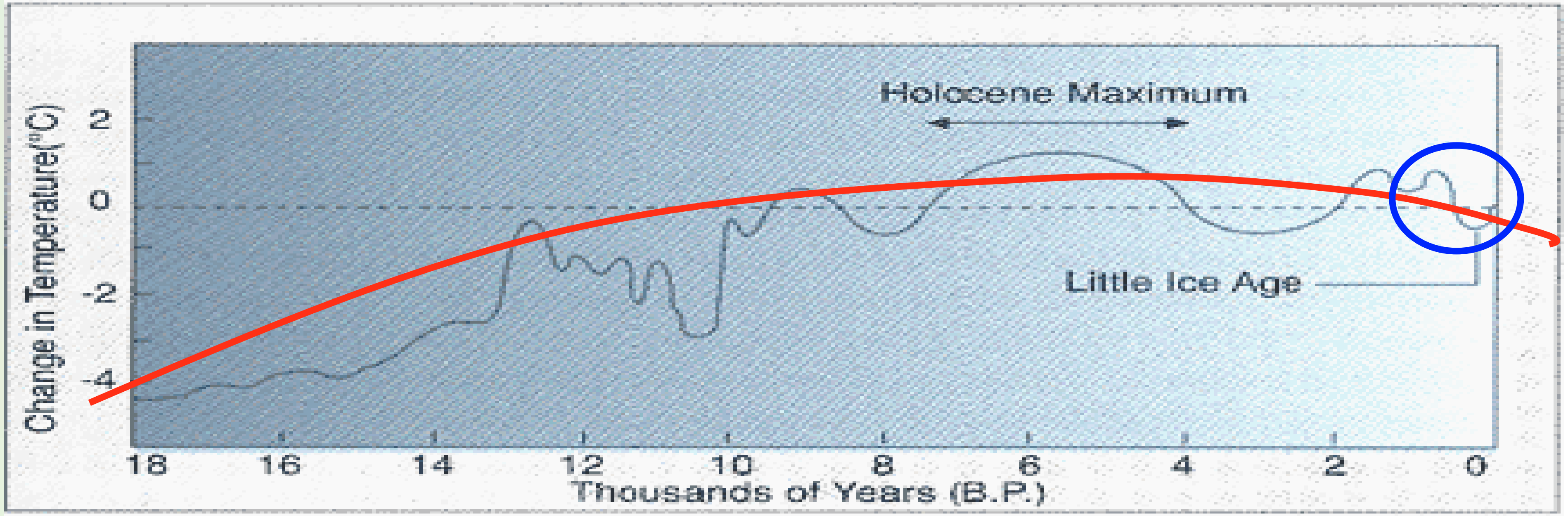
A bit further into the past



Source: IPCC 2001, Climate Change 2001, "The Scientific Basis"

It is likely that the rate and duration of the warming of the 20th century is larger than any other time during the last 1,000 years with 1990s warmest decade of the millennium in the Northern Hemisphere, and 1998 the warmest year (IPCC, 2001).

A look into the "far" past



Source: IPCC

Earth climate has never been steady

There may have been "recent" hotter phases than today

There have been larger and more rapid variations than those predicted by climate models for 2100

Key Messages # 1

We are living in a "warming phase"

Likely of unprecedented amplitude

Likely of unprecedented duration

BUT

We are "conveniently" considering the past 1000 years horizon

There are still large uncertainties

How much of the change in temperature is due to the Greenhouse Effect (i.e. to GHGs)?

Any factor that alters the radiation received from the Sun or lost to space or the redistribution of energy between atmosphere, land and ocean can affect climate.

The influence of GHGs on Earth climate is undisputed.

That they contribute to determine climatic changes over the time scale of centuries is also undisputed.

For the sake of completeness…

Ice ages of the last million years linked to changes in absorbed solar radiation affected by orbit changes.

Even longer-term climate changes linked to tectonic events.

Shorter-term climate changes (decadal cycles) linked to atmosphere/ocean interactions and changes in ocean circulation.

How much of the change in temperature is due to the Greenhouse Effect (i.e. to GHGs)?

What is being discussed is the effective contribution of GHG to Climate Change

According to the IPCC

(IPCC, Climate Change 2001, "The Scientific Basis")

"In the light of new evidence and taking into account the remaining uncertainties, **most of** [(>50%, 70%?)] *the observed warming over the last 50 years is* ***likely*** *to have been due to the increase in greenhouse gas concentrations".*

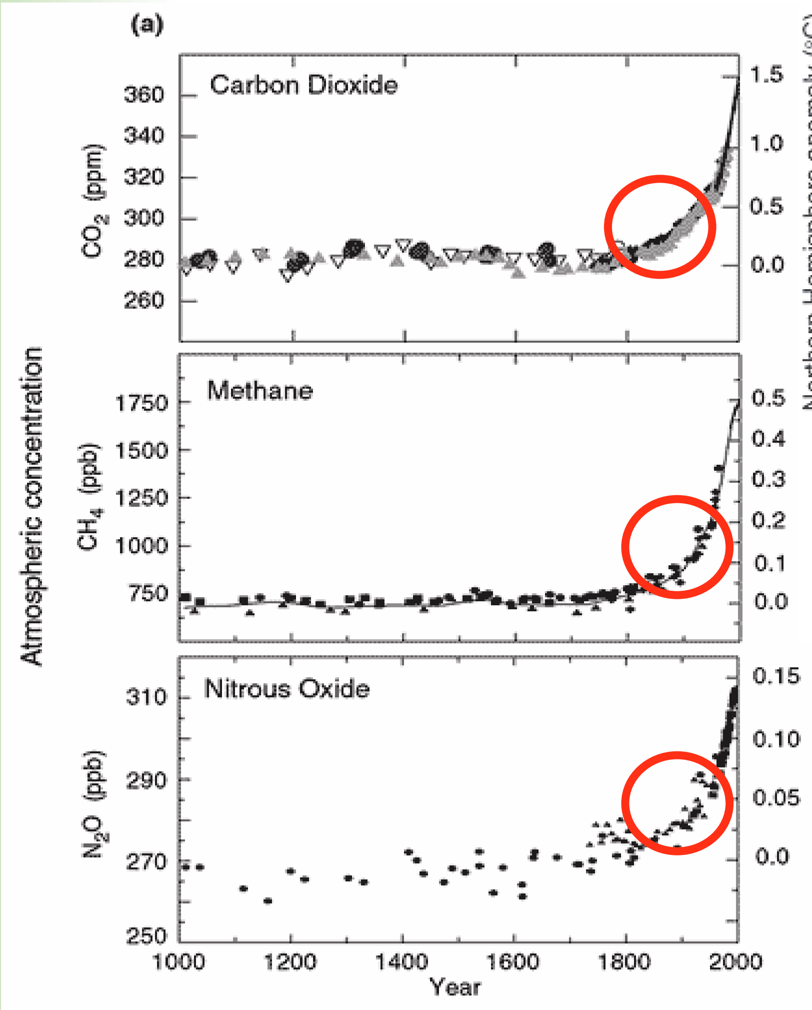
According to others

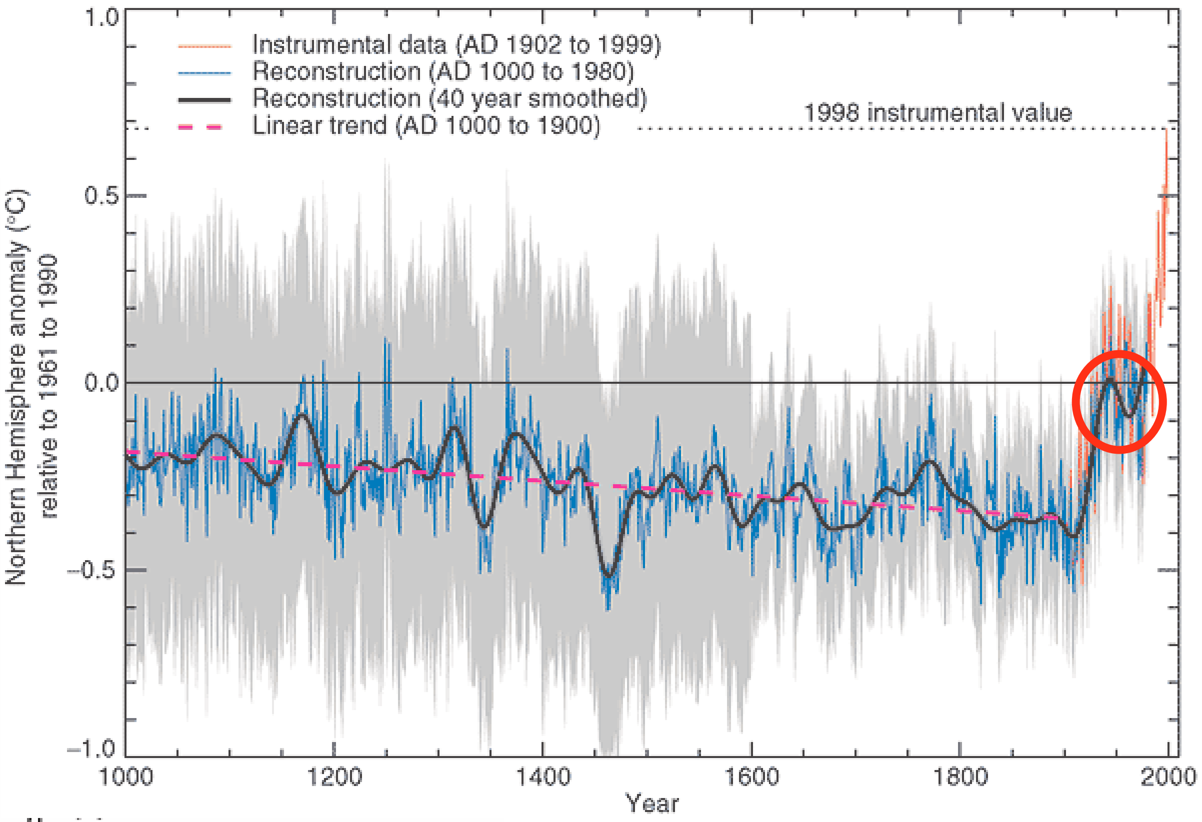
(e.g. Singer,1999)

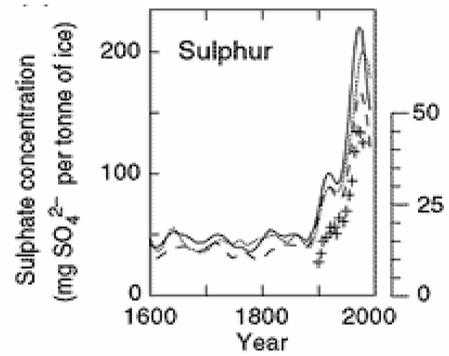
"Yet the causal connection [between GHG and climate] *is not at all clear."*

An example of the controversy and (my personal understanding) of the different positions.

How much of the change in temperature is due to the Greenhouse Effect (i.e. to GHGs)?







Source: IPCC, Climate Change 2001, "The Scientific Basis"

Key Messages # 2

GHGs do influence Earth climate

The relevant time scale is centuries

This influence *could be* negligible (sceptics), but also very important (IPCC)

IF GHGs determine MOST OF Earth climate

Human contribution to CC is *roughly* represented by human contribution to GHG concentration

How much of the change in temperature is due to the anthropogenic Influence?

GHG concentration from pre-industrial period to present (PpB converted in CO2 eq. via GWP)

	Multiplier (GWP)	Pre-industrial	Natural additions	M-made additions	Tot. Relative Contr.n	Percent of Total
CO2	1	288,000	68,520	11,880	368,400	72.369
CH4	21	17,808	12,117	6,720	36,645	7.199
N2O	310	88,350	3,599	4,771	96,720	19.000
CFCs and oth.	many	2,500	0	4,791	7,291	1.432
Total		396,658	84,236	28,162	509,056	100.000

Source: adapted from U.S. Department of Energy, 2000

Human Contribution $= \frac{28{,}162}{509{,}056} * 100 = 5.5322\ \%$

Considering that m-made emissions are concentrated in this century the IPCC concludes:

"Anthropogenic GHGs are likely to have made a significant and substantial contribution to the warming observed during the second half of the 20th century" **(IPCC: CC 2001 "The scientific basis)**

How much of the change in temperature is due to the anthropogenic Influence?

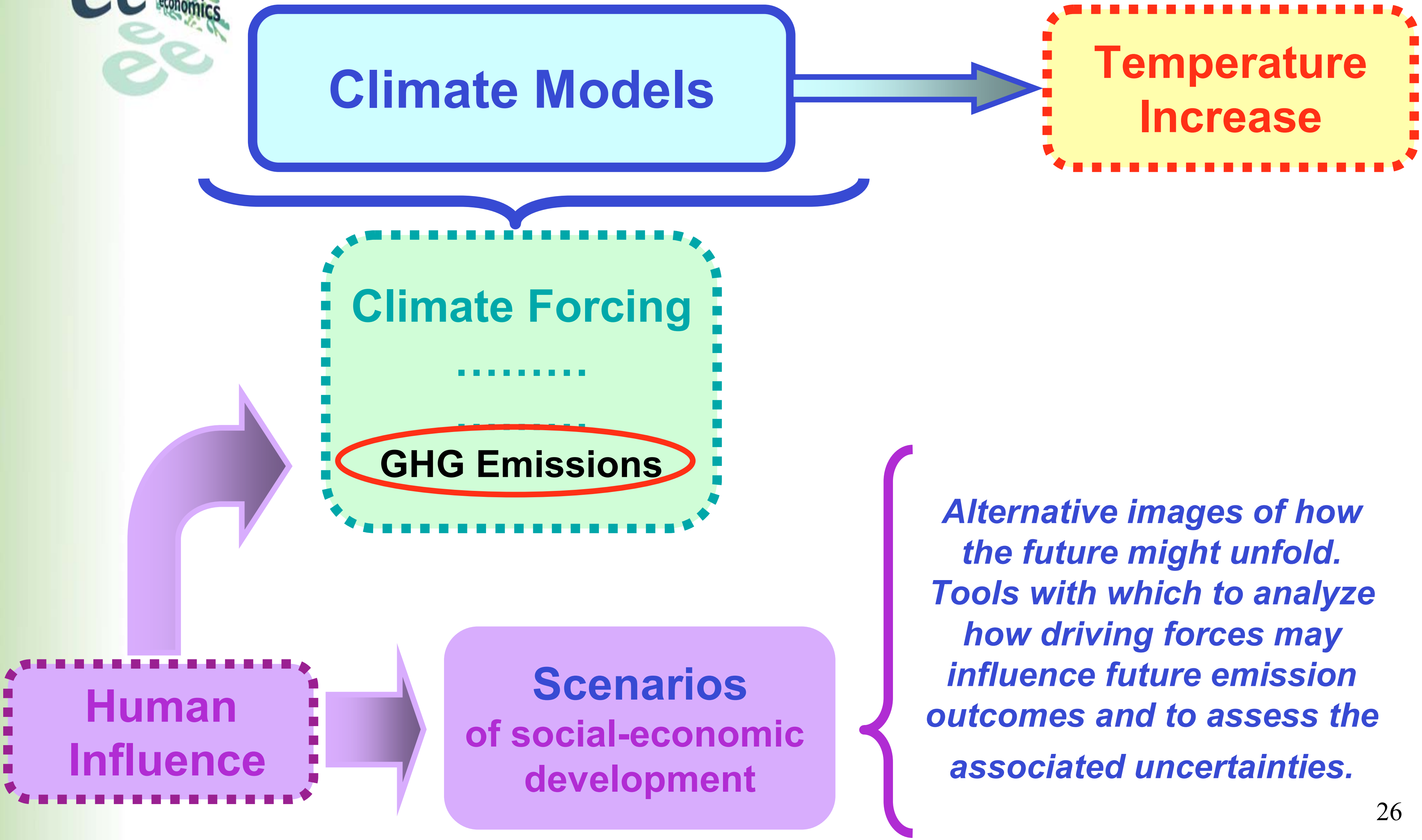
BUT !

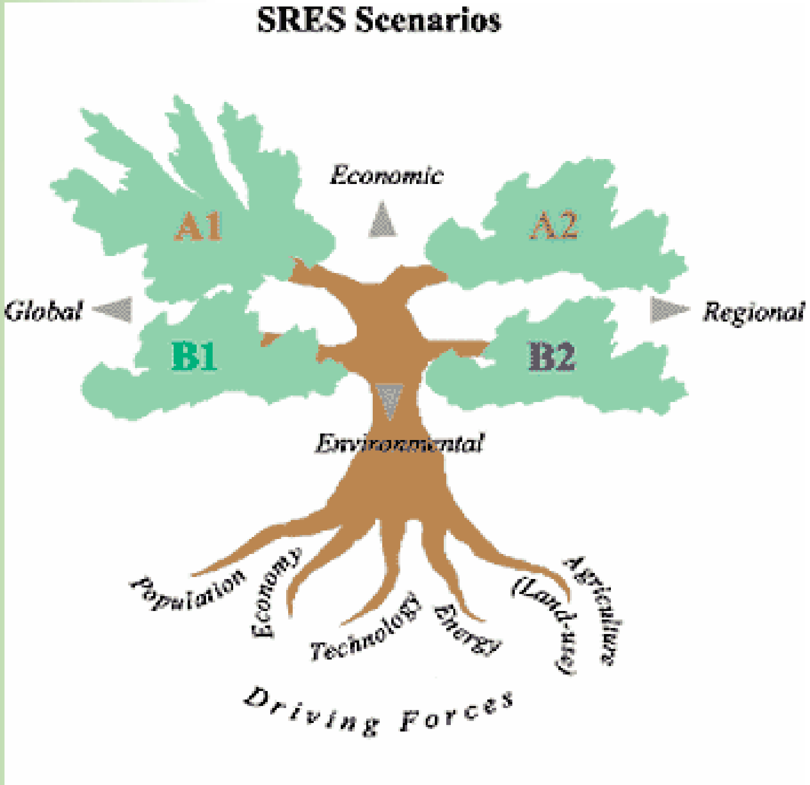
GHG concentration from pre-industrial period to present (PpB converted in CO2 eq. via GWP) considering Water Vapour

	% of All Greenhouse Gases	*% Natural*	*% Man-made*
Water vapor	**95.000%**	**94.999%**	**0.001%**
CO2	3.618%	3.502%	**0.117%**
CH4	0.360%	0.294%	**0.066%**
N2O	0.950%	0.903%	**0.047%**
CFC's, and others	0.072%	0.025%	**0.047%**
Total	**100.00%**	**99.72**	**0.28%**

Key Messages # 3

Over the last century human contribution to climate change ranged from the 0.28% (with WV) to the 5.53% (w/o WV)


Climate Models
Temperature Increase
Climate Forcing
……….
……….
GHG Emissions
Human Influence
Scenarios
of social-economic development
Alternative images of how the future might unfold. Tools with which to analyze how driving forces may influence future emission outcomes and to assess the associated uncertainties.



Source: IPCC, Climate Change 2001, "The Scientific Basis"

A1: rapid economic growth and technological dev.pm. Low population growth.

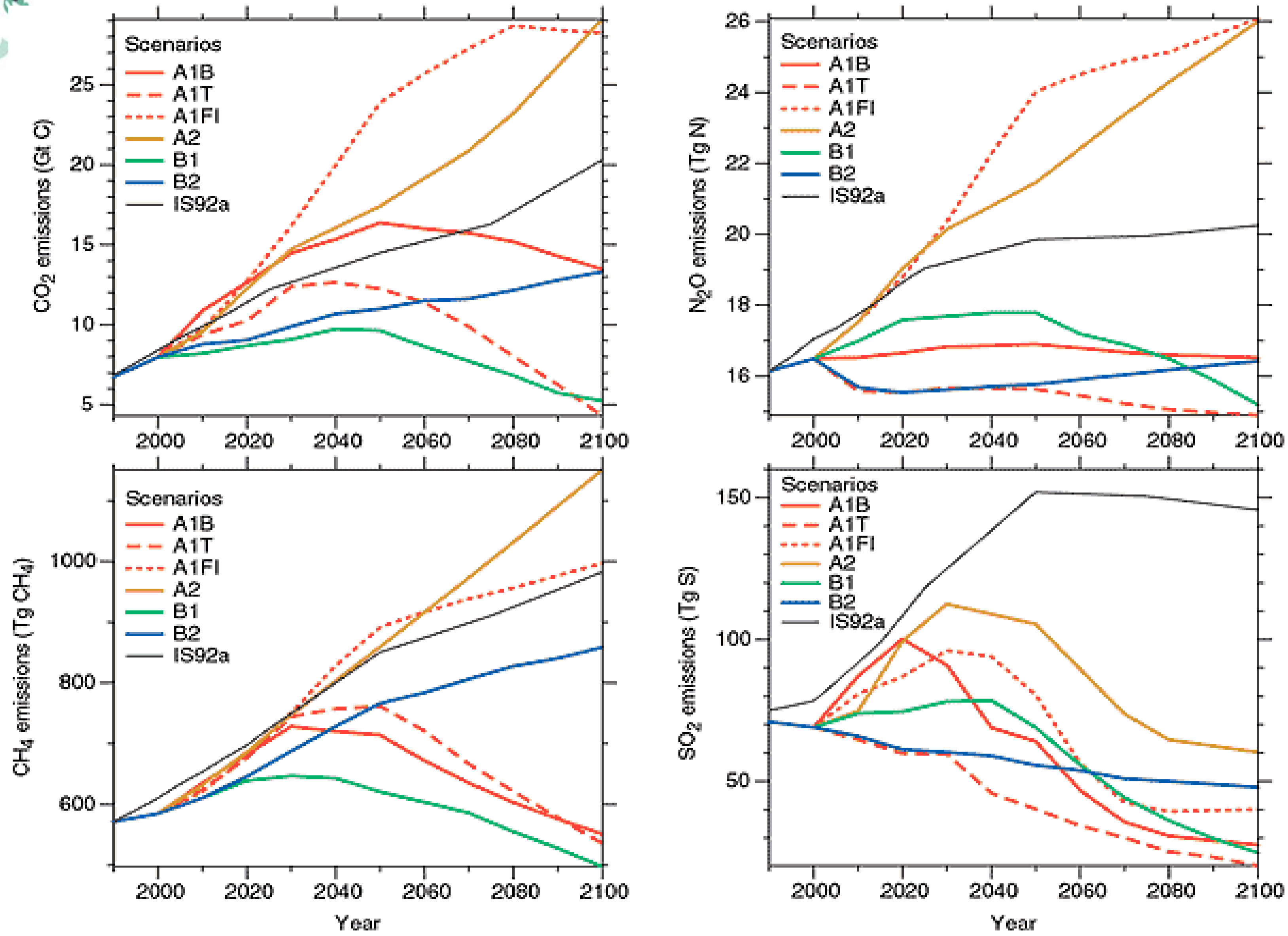
A2: heterogeneous world, preservation of local id, economic growth but more fragmented technological progr. High population growth.

B1: convergent world, low population growth, development towards a high tech and service society. Emphasis on sustainability.

B2: like B1, but with more emphasis on local solution.

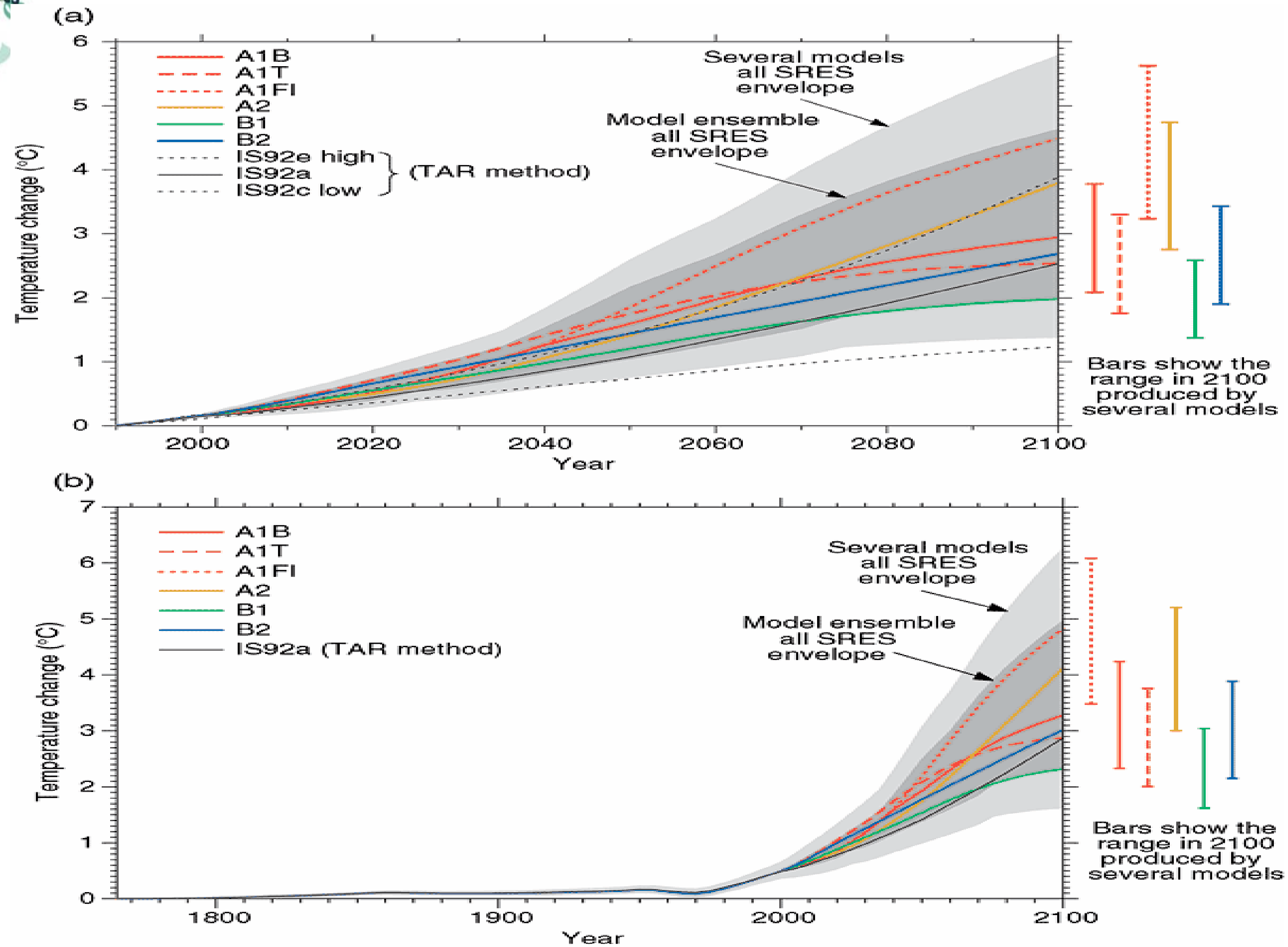
Anthropogenic emissions of major GHGs

Source: IPCC, Climate Change 2001, “The Scientific Basis”



A look into the future

Temperature Increase



Source: IPCC, Climate Change 2001, "The Scientific Basis"

Key Messages # 4

According to all IPCC scenarios anthropogenic influence is a main determinant of FUTURE climate change

Uncertainty remains !!!!!

Let’s Start With Economics

Is CC a problem?

Yes if even though independently upon human contribution some negative consequences may arise

Is this an economic problem?

Yes if we may want to intervene to alleviating adverse consequences given scarce resources → *Cost and benefit of ADAPTATION strategies*

In addition in the presence of a human contribution

We may want to intervene to reduce CC causes given scarce resources → *Cost and benefit of MITIGATION strategies*

Harmoniz. MITIGATION ADAPTATION

This originated two strands of “research” families

“Climate-change impact assessment”

Climate-change costs are representative of climate-change policy benefits in term of avoided damage

“Climate-change policy assessment”

Costs of climate change policies to be compared with benefits, but also in the presence of sub - optimal targets in term of effectiveness, efficiency, equity => sustainability

Climate-Change Impact Assessment

Exemplifying a climate-change impact (Integrated) assessment exercise

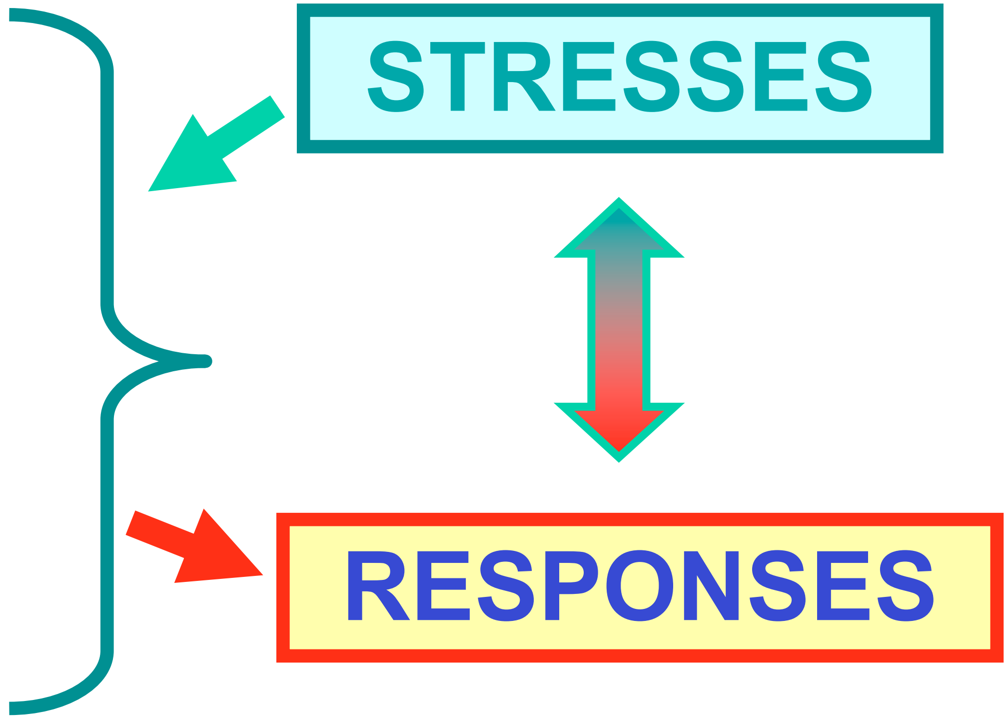
(Reduced form of) Global Circulation Model(s)
→ **Info.** on Climate Change and Variability
- Temp. increase
- Temp. rate of change
- Precipitation
- Sea level rise

Environmental Impact Models
→ **Disentangle** Climate Change in (some) Physical Impacts
- Loss of land (sq. Km.)
- Health (mort./morb.)
- Changes in crop yields
- …………………

Economic Model
→ **Provides** Welfare Evaluation of Physical Impacts + **Feedback** on the environment (CO_2 emissions)

What has to be evaluated: a tentative classification of C-C impacts

- ✓ Water resources
- ✓ Agricultural and food security
- ✓ Terrestrial and freshwater ecosystems
- ✓ Coastal zones and marine ecosystems
- ✓ Human settlements
- ✓ Energy and industry
- ✓ Insurance and other financial services
- ✓ Human health



Peculiarities of C-C Impact Assessment #1

✓**UNCERTAINTY:** *the knowledge of environmental and socio-economic dynamics, and of the feedback between the two is still affected by a large amount of uncertainty*.

✓**GEOGRAPHICAL SCALE:** *climate change is a global phenomenon affecting the whole world, at the same time environmental and socio-economic impulses and responses are highly differentiated across regions.*

✓**TIME SCALE:** *climate change is a long-term phenomenon. Assessing impacts on environmental and socio-economic systems requires a long-run perspective.*

Peculiarities of C-C Impact Assessment #2

- ✓ **EFFECTS INVOLVING INTERACTING SYSTEMS** ***characterized by:***
  - ***Non linearity*** *(in environmental and economic systems)*
  - ***Discontinuity*** *("Jumps", abrupt changes of state e.g. extreme events, catastrophes, new technologies),*
  - ***Irreversibility*** *(non-return point e.g. species extinction, irreversible investments high sunk costs).*

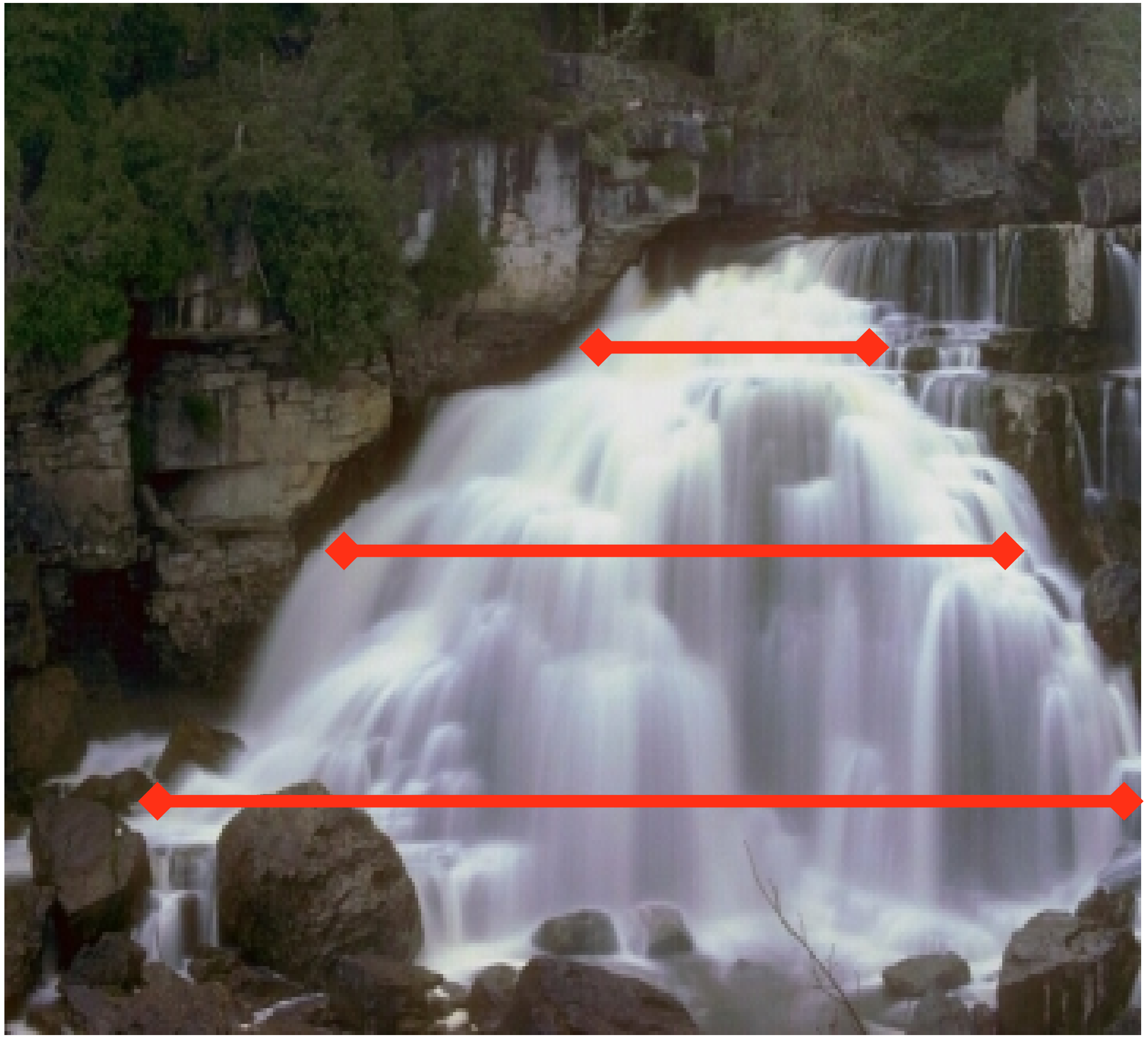
- ✓ **WELFARE MEASUREMENT (ethical judgements):**
  - ***Interpersonal utility comparison*** *(is it possible to compare and aggregate utility?)*
  - ***Inter-temporal utility comparison*** *(is it legitimate to discount and what discount rate has to be used?)*
  - ***Choice of a metric*** *(NON market values - money, loss of human life, multi-criteria approach?)*

Summarizing: a cascade of uncertainty!

Uncertainty on climate change

Uncertainty on its "physical" impacts

Uncertainty on social-economic evaluation



Let's try anyway the exercise!

ecological and environmental economics

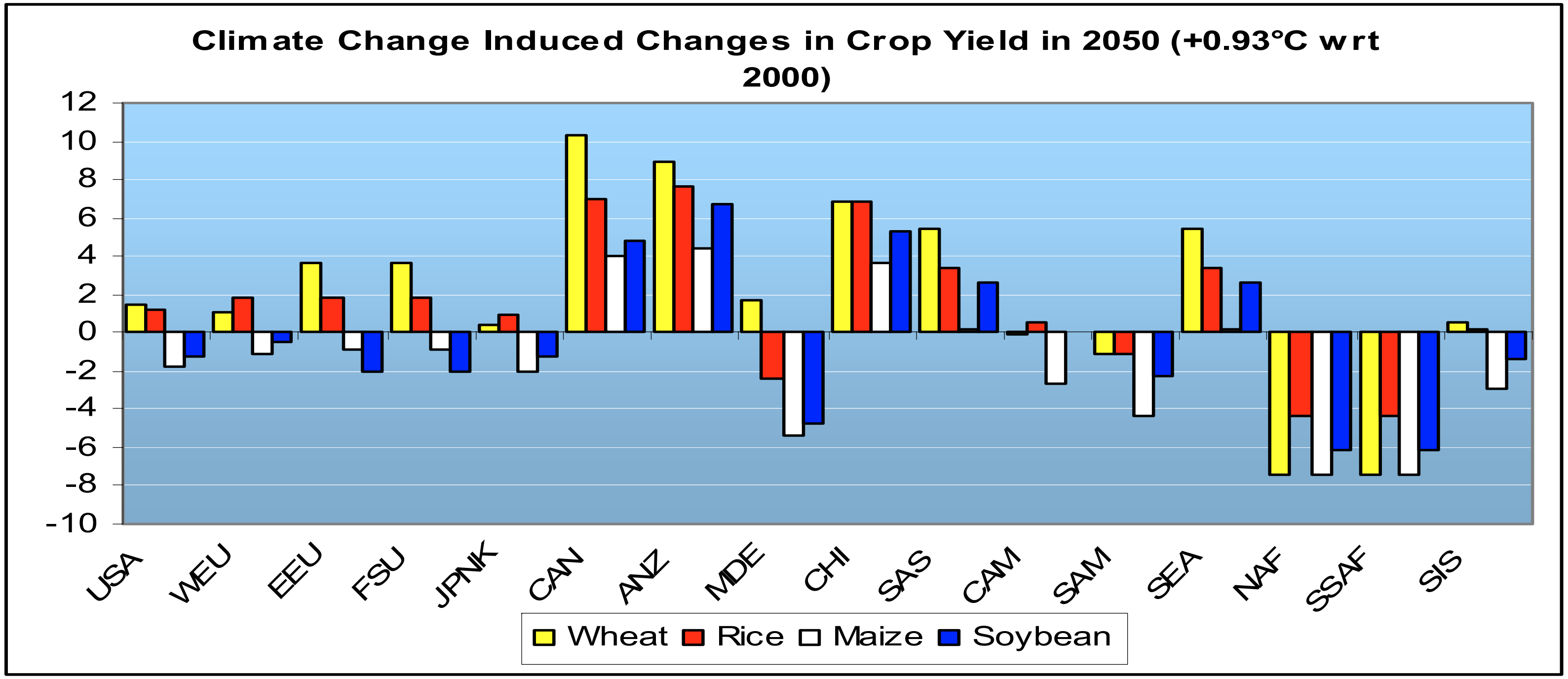
Damages in physical units: 2.5° C temperature increase scenario

Type of Damage	INDICATOR	EU	USA	FSU	CHINA	Non OECD	OECD	World
Agriculture	*Welfare loss (%GDP)*	0,21	0,16	0,24	2,1	0,28	0,17	0,23
Forestry	*Area lost (Km2)*	52	282	908	121	334	901	1235
Fishery	*Reduced Catch (1000 t)*	558	452	814	464	4326	2503	6829
Energy	*Incr. El. Dem. (TWh)*	54,2	92	54,6	17,1	142,7	211,2	353,9
Water	*Reduced Avail. (Km3)*	15,3	32,7	24,7	32,2	168,5	62,2	230,7
Coastal Prot.	*Annual Cost (m$/yr)*	133	176	51	24	514	493	1007
Dryland loss	*Area lost (Km2)*	1,6	10,7	23,9	0	99,5	40,4	139,9
Wetland loss	*Area lost (Km2)*	9,9	11,1	9,8	11,9	219,1	33,9	253
Ecosystem loss	*Nr. of Habitats Lost*	16	8	n.a.	4	53	53	106
Health	*Nr. of Deaths (1000)*	8,8	6,6	7,7	29,4	114,8	22,9	137,7
Migration	*Nr. Of Migrants (1000)*	229	100	153	583	2279	455	2734
Hurricanes								
Casualties	*Nr. of Deaths (1000)*	0	72	44	779	7687	313	8000
Damages	*m$*	0	115	1	13	124	506	630

Source: adapted from IPCC, 1996 SAR

But consider for instance

Climate Change Mortality 2050 by Region and Disease (additional deaths)							
	Malaria	**Schisto**	**Dengue**	**Cardio-Vascular**	**Respiratory**	**Diarrhea**	**Total**
USA	0	0	0	-174158	2540	2006	-169613
EU	0	0	0	-178895	2389	590	-175916
EEFSU	0	0	0	-289210	3970	1074	-284166
JPN	0	0	0	-68009	3784	15	-64211
RoA1	0	0	0	-47070	1267	31	-45772
Eex	753	-62	53	-50088	82341	31244	64241
CHIND	632	0	626	-813307	92732	28709	-690608
RoW	63090	-568	535	-143466	175516	421683	516791
WORLD	64475	-630	1215	-1764202	364538	485352	-849252



Key Messages # 5

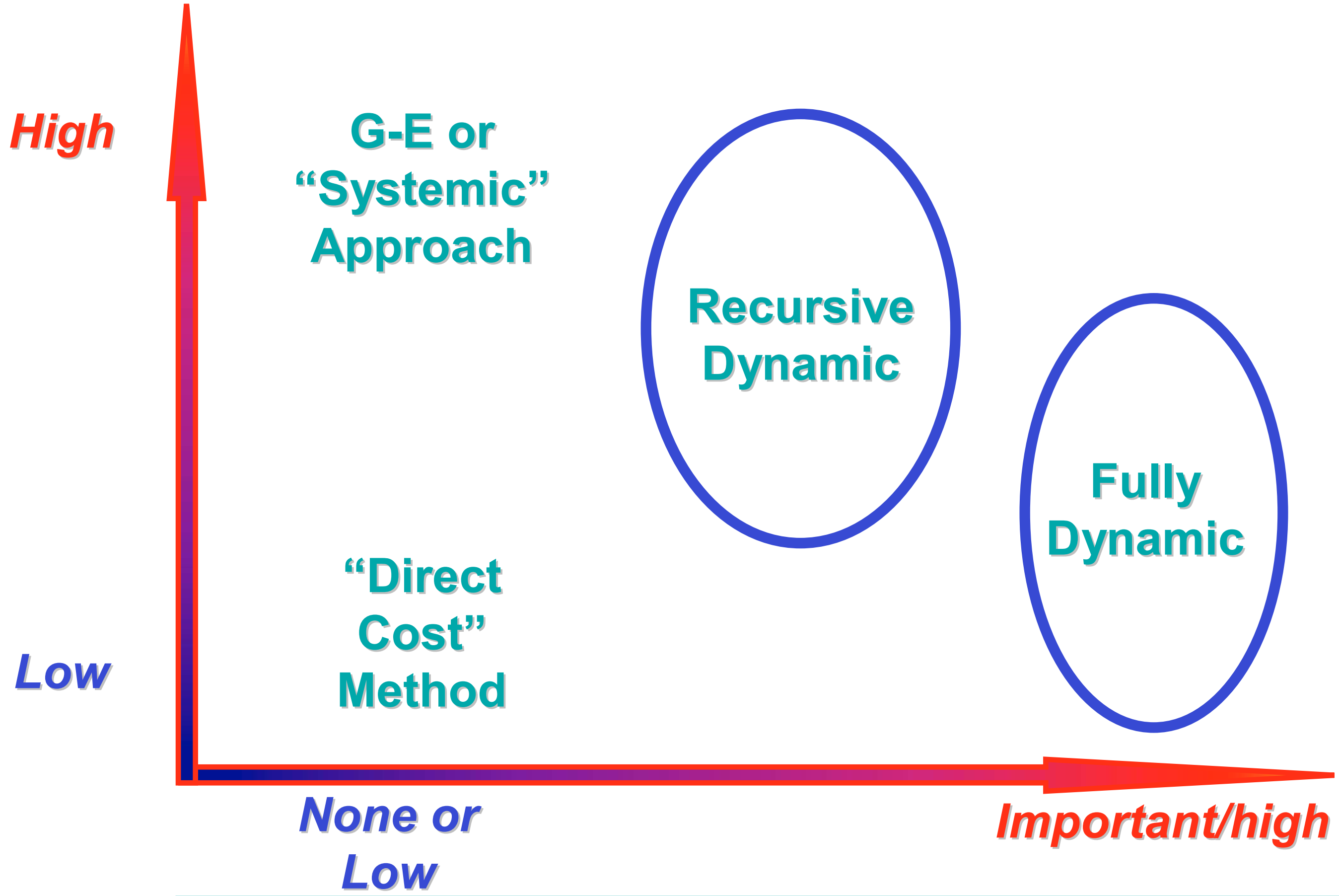
Climate Change impacts are highly differentiated at the geographical scale

There can be also positive consequences

Even though sticking to the “hard” physical facts, climate change is a matter of scale but also of redistribution

Costing Methodologies

Degree of "comprehensiveness" of the economic picture



Role of time and accuracy of its description

The “direct cost” methodology

(Total Cost) = (Price) x (Quantity)

e.g.:

Health Cost of CC = (Number of deaths) x (value of life)

Cost of Sea-Level rise = (Land lost) x (value of land)

etc.

Purely static exercise: either because it refers to points in time or because it does not consider adaptation of the social-economic system

Example

Monetized Damage: 2.5° C temperature increase scenario

	Fankhauser (1995)		Tol (1995)	
Region	*bn$*	*% GDP*	*bn$*	*% GDP*
EU	63.6	1.4		
USA	61.0	1.3		
Other OECD	55.9	1.4		
OECD Americs			74.2	1.5
OECD Europe			56.5	1.3
OECD Pacific			59.0	2.8
Total OECD	180.5	1.3	189.5	1.6
E.Europe/FSU	18.2	0.7	-7.9	-0.3
Centrally Planned Asia	16.7	4.7	18.0	5.2
South & South-East Asia			53.5	8.6
Africa			30.3	8.7
Latin America			31.0	4.3
Middle East			1.3	4.1
Total Non-OECD	89.1	1.6	126.2	2.7

Source: Adapted from IPCC 1996 SAR

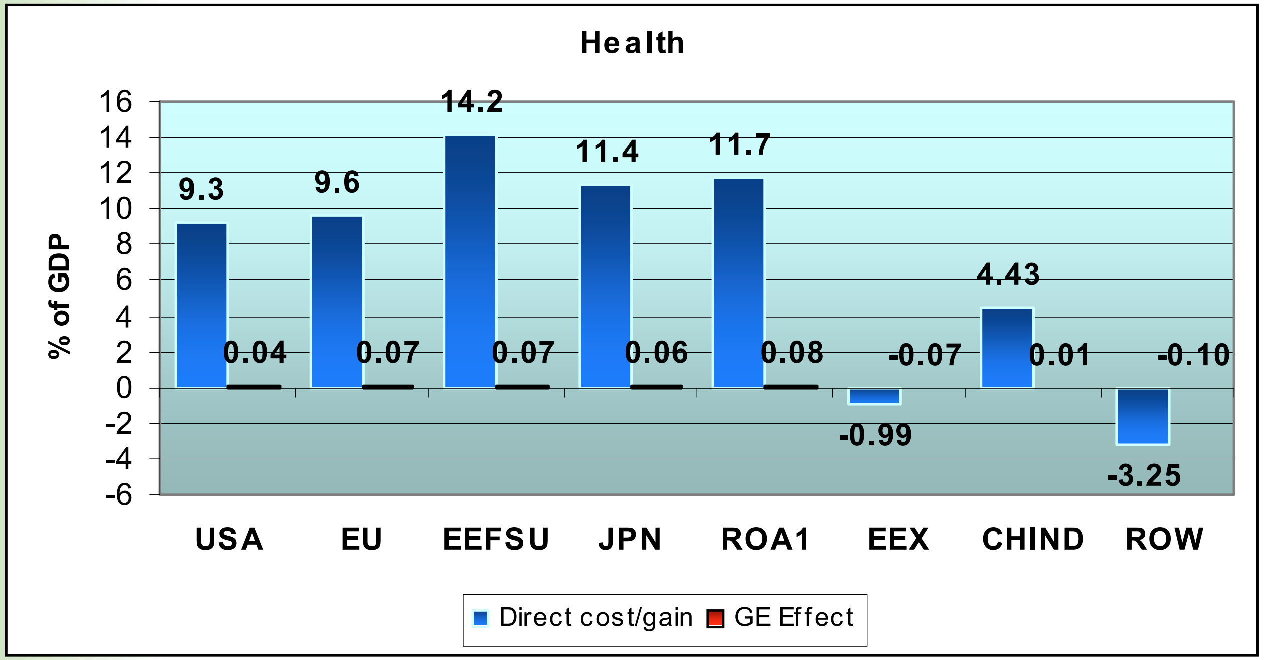
A step further: the "G-E, Systemic" Approach

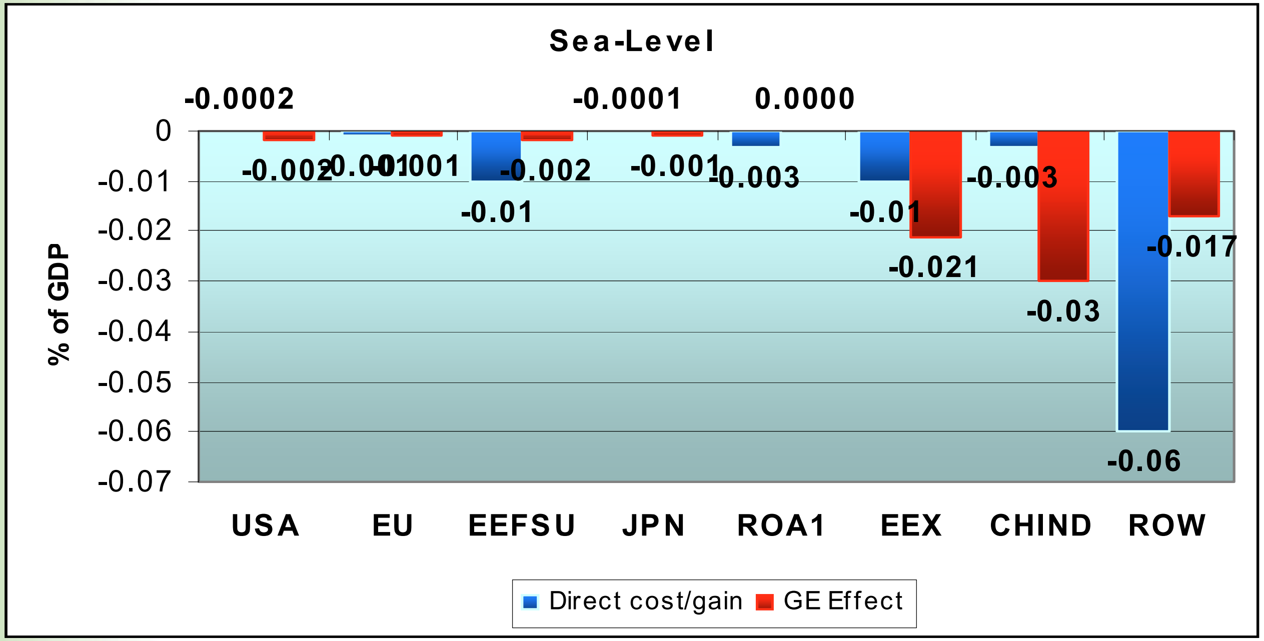
- ✓ The world is divided into economic areas (regions, countries).
- ✓ Each area is divided into economic sectors.
- ✓ All these "cells" *communicate* through economic (and environmental) mechanisms.

The main economic linkages and propagation mechanisms can be highlighted (domestic and international substitution between factors and goods). Direct *and* indirect consequences are taken into account.

Examples

C-C Impact Assessment





Health

C-C Impact on GDP: direct vs G-E effects *(2050)*

Sea-level rise

Source: Bosello et al. 2004, 2005

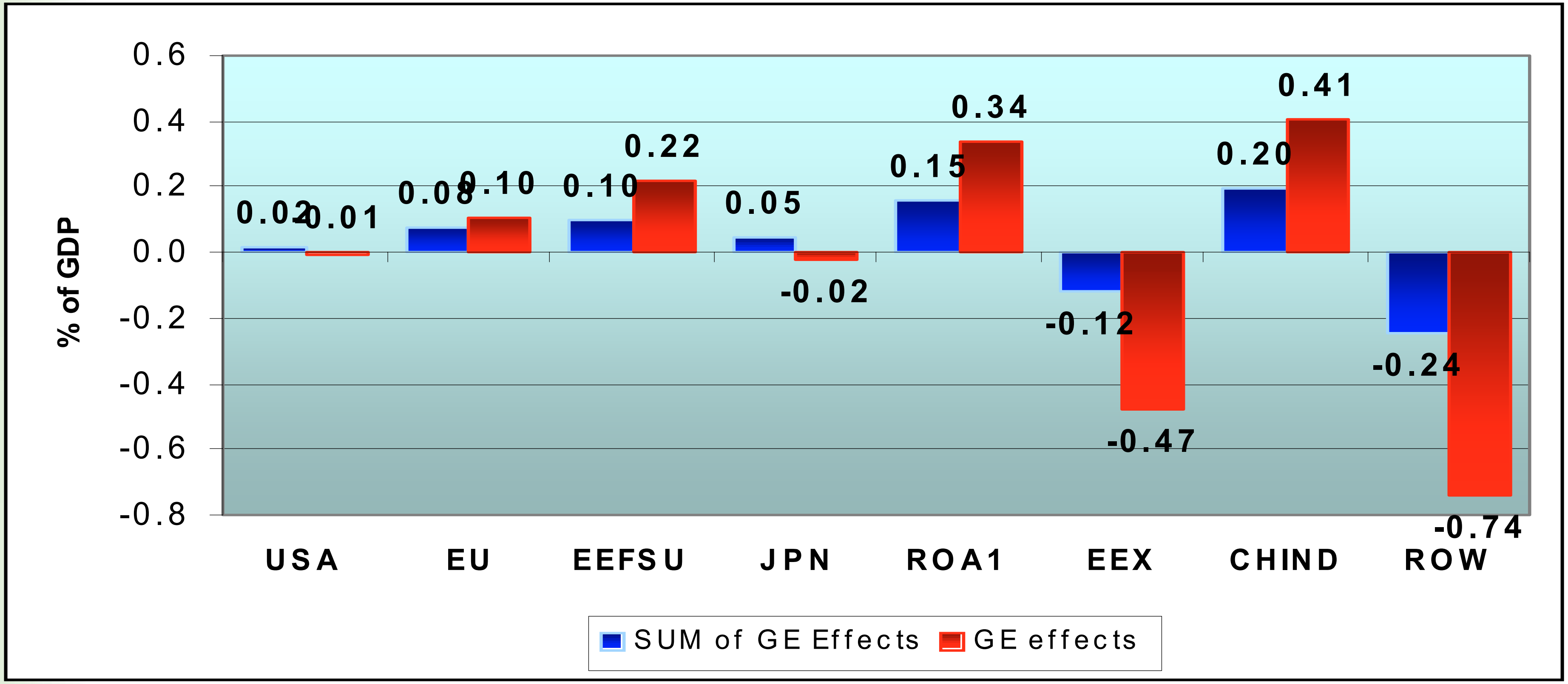
Impact interactions

C-C impacts on GDP:

- health
- sea-level
- tourism
- agriculture

Summing GE effects

Compounding GE effects



A "Dynamic" Approach

It has to be considered that climate and economic systems **interact dynamically over time** and that **damages are a continuous flow over time** associated to each ton of greenhouse gas emitted.

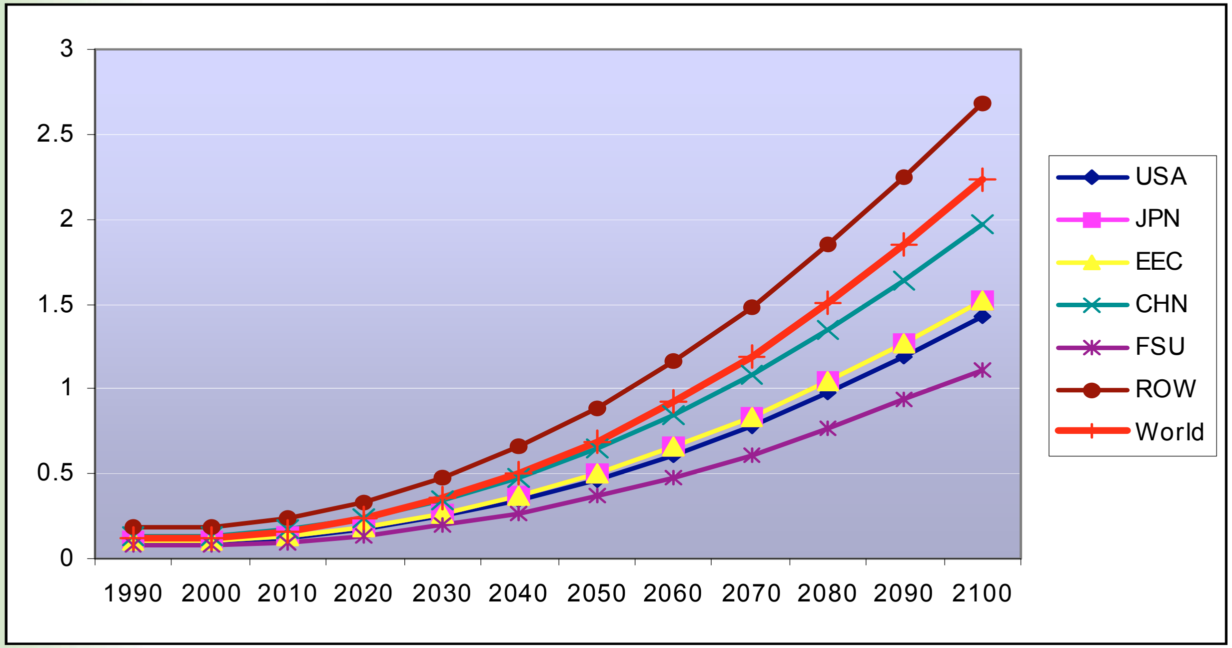
Only a rough indication can be provided by point estimates like damages stemming from 2.5°C of temperature increase.

	1991-2000	2001-2010	2011-2020	2021-2030
Nordhaus (1994)	5.3	6.8	8.6	10
Cline (1992,1993)	5.8-124	7.6-154	9.8-186	11.8-221
Peck and Teisberg (1992)	10-12	12-14	14-18	18-22
Fankhauser (1994)	20.3	22.8	25.3	27.8
Maddison (1994)	5.9-6.1	8.1-8.4	11.1-11.5	14.7-15.2

Source: as in table

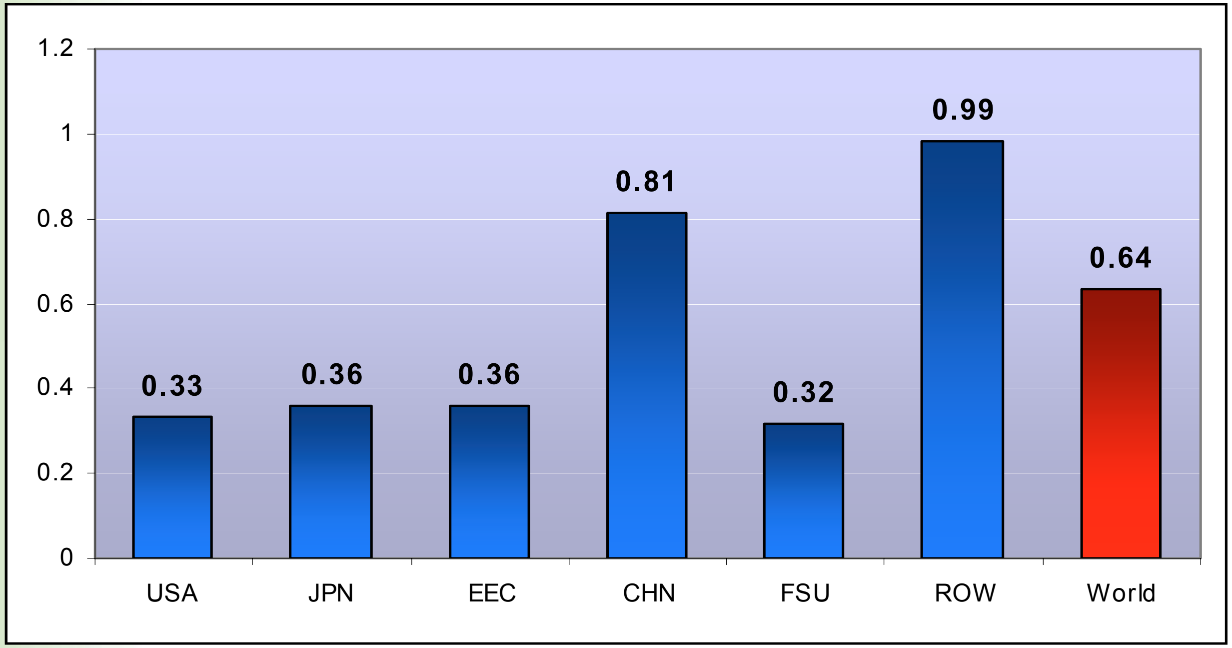
C-C Impact Assessment

Climate change damages as % of GDP



Source: our computation running the FEEM-RICE model

Discounted Climate change damages as % of discounted GDP 1990-2100



Source: our computation running the FEEM-RICE model

Key Messages # 6

Climate Change impacts are highly differentiated at the geographical scale

Considering large aggregations they are far from catastrophic, but they increase as the detail increases

There is an unambiguous penalization of developing countries

Note the role of time dimension

Climate-Change Policies

In the previous steps we "determined" climate-change ***costs***

Amounting to determining ***benefits*** of climate-change policies

then

If we determine climate-change policy ***costs + effectiveness***

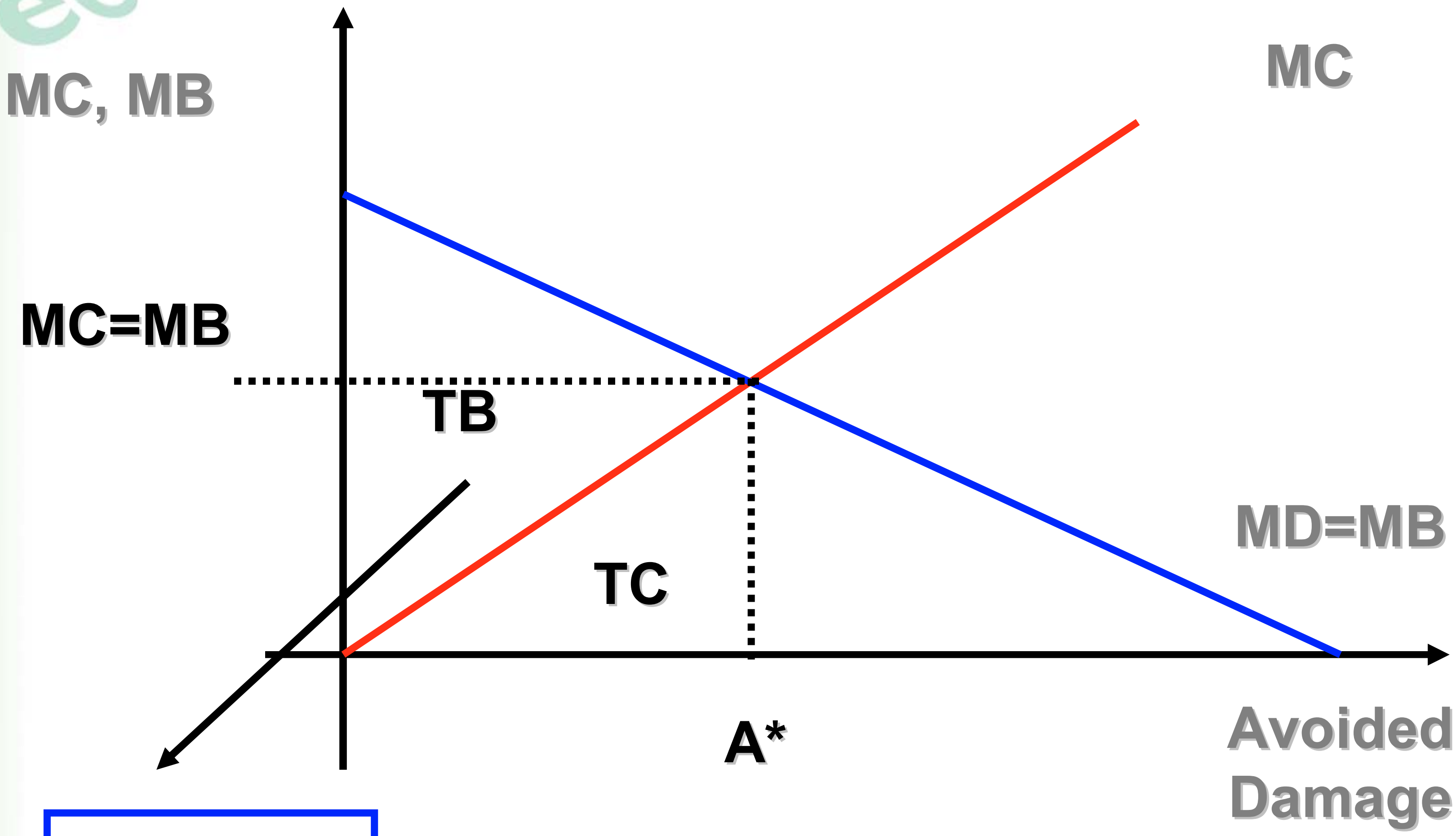
And compare

We can determine the optimal balance between benefits and costs of climate change policies

i.e.

We can find the optimal (utility maximising) level intervention.

Graphically: optimal internalization of the externality



≃ 0.6% to 2% of GDP

Mitigation (abatement)

Framing the problem

(IF there is anthropogenic influence on climate change)

Emissions originate/are an externality

Negative CC consequences imposed to others different from polluters, benefits appropriated by polluters only

These negative consequences are non priced (external to the market)

Overprovision of the "bad", too much CC respect to social optimum

Negative externality is a "public bad", its reduction is a public good

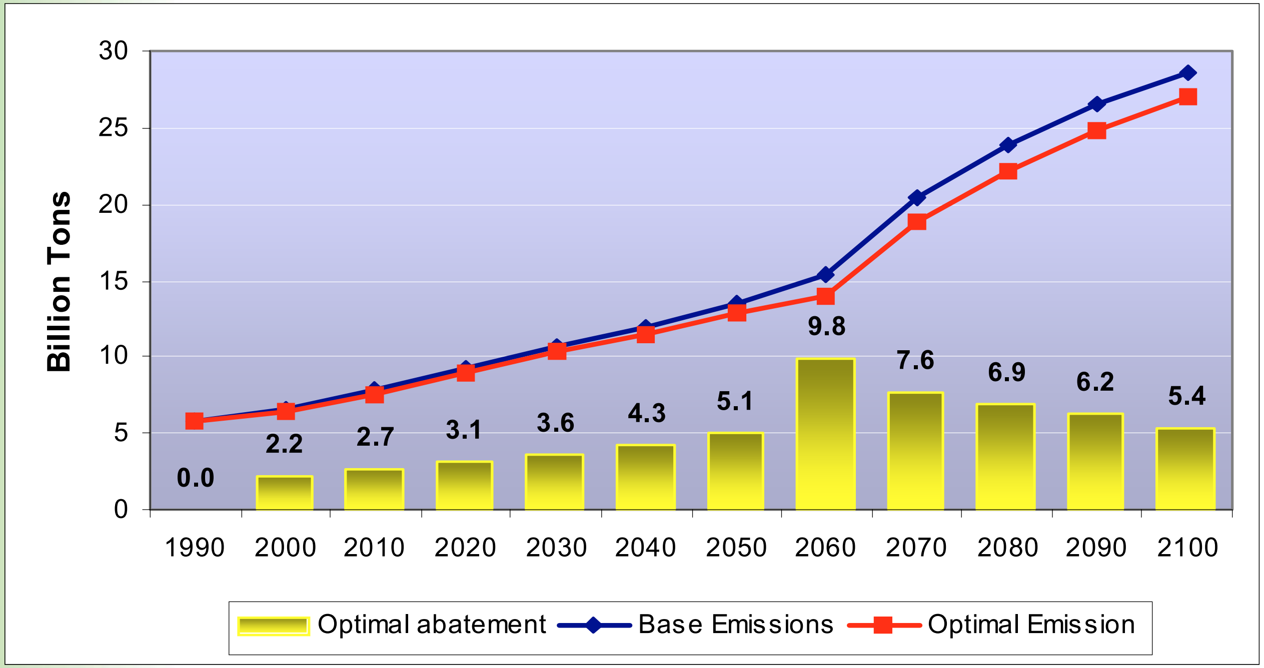
Non rivalry

Non excludability

Free riding + "leakage"

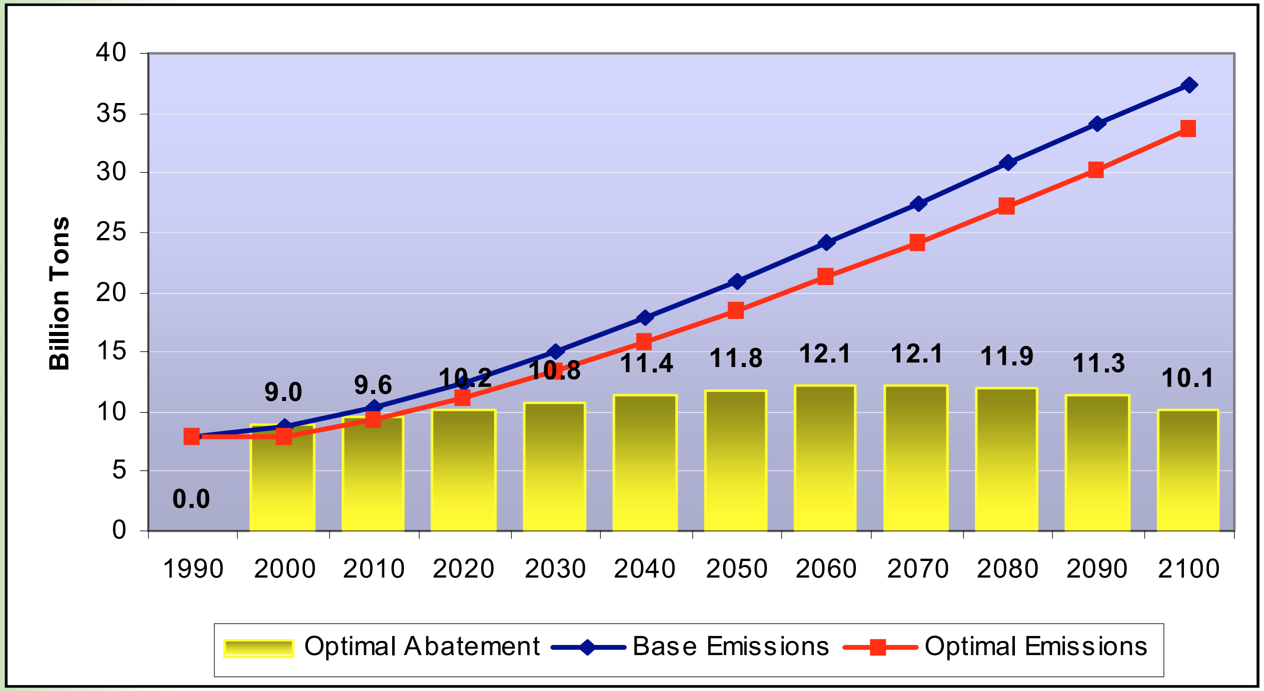
Now, back to mitigation costs: What are they?

Direct costs of mitigation activities →	These are "good" costs to internalise the externality
Competitiveness costs for sectors and countries →	If decision to mitigate concerns some actors only
Social costs: who and in which form bears the costs. →	Lower growth → higher unemployment (?); higher prices to final consumers



Source: our computation running the Peck-Teisberg model (1992)

Optimal abatement (mitigation) considering direct costs and benefits of policies



Source: our computation running the FEEM-RICE model

Which in our case amounts to spending in the entire period 1990-2100 roughly the:

0.03% of world GDP

To reduce environmental damage roughly of the:

7%

Giving a gain in terms of avoided damage roughly of the:

0.04% of world GDP

What can influence these outcomes and thus climate change mitigation policies?

Higher damages and catastrophic irreversible events

The role of uncertainty

The perception of time

The role of ancillary benefits

Higher damages and catastrophic irreversible events

It is trivial to demonstrate that in the presence of higher environmental damages all models suggest higher abatement

(Indeed I am not showing this just believe me)!

But this simple and intuitive result depends on the absence of uncertainty

In other words: we would be willing to abate more if we were sure that damages were higher

But

true damages are uncertain

One can claim that uncertainty should induce higher conservation anyway

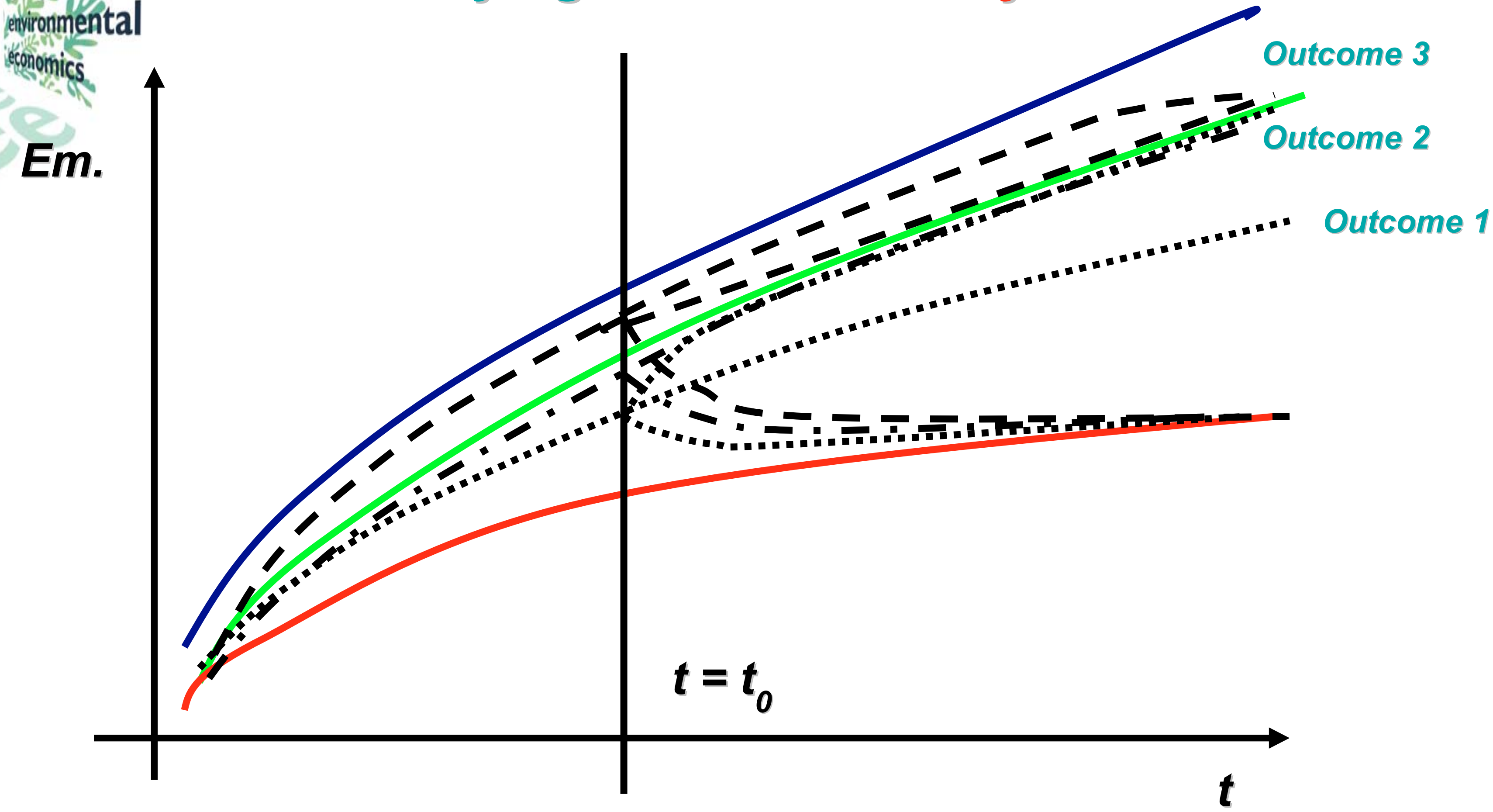
Unfortunately uncertainty works in many directions

Damages(costs) can be higher (lower), but also lower (higher) than expected

Different "uncertainty areas" can compensate each other e.g. higher damage by a lower climate sensitivity

We can incur in losses being too risky, but also too cautious (irreversibility)

Playing with uncertainty



- *Base emission path*
- *Emission path consistent with a low environmental damage*
- *Emission path consistent with a high environmental damage*

Possible emission paths consistent with uncertainty

The perception of time

As said: deciding about a policy is a matter of balancing costs and benefits *inter-temporally*

Climate-change damages, and thus possible benefits of mitigation policies, are experienced in the (far) future. Costs are sustained in the present

Our perception of future and our balance between present and future determine our decisions today

Given That

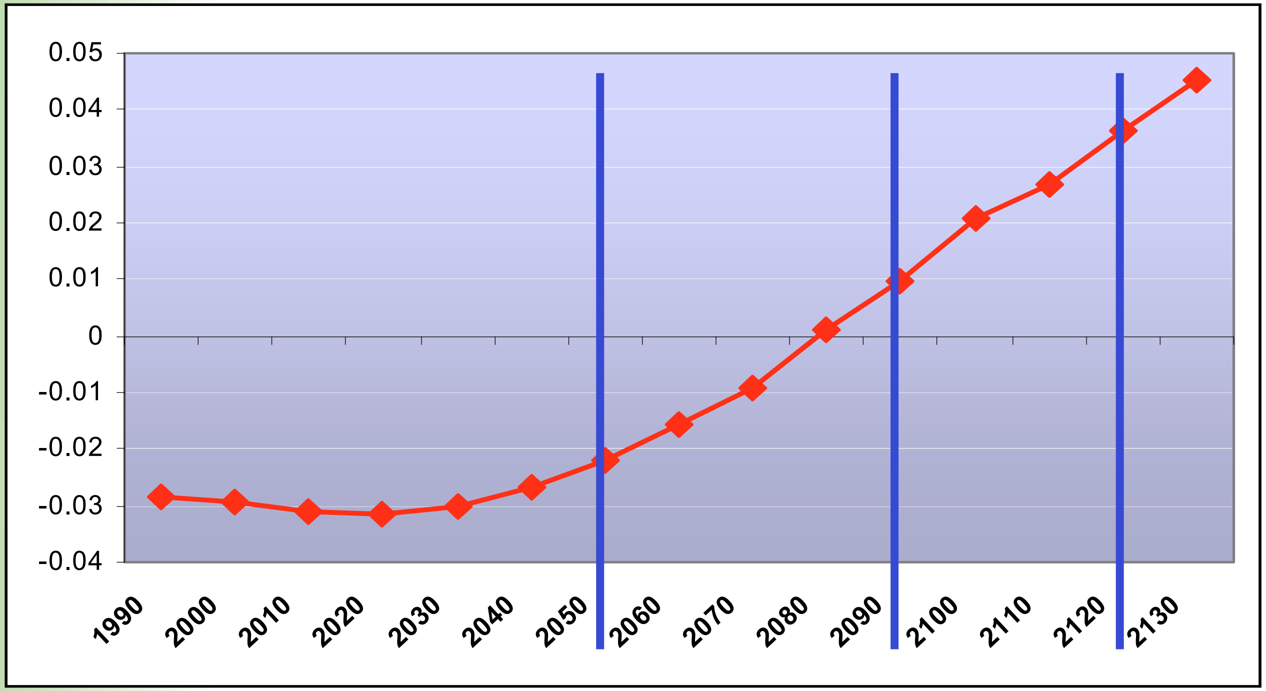
Benefits of abatement are a stream increasing over time according to the slope of the damage function...

…the longer-term the perspective, the higher the benefits from a possible mitigation strategy.

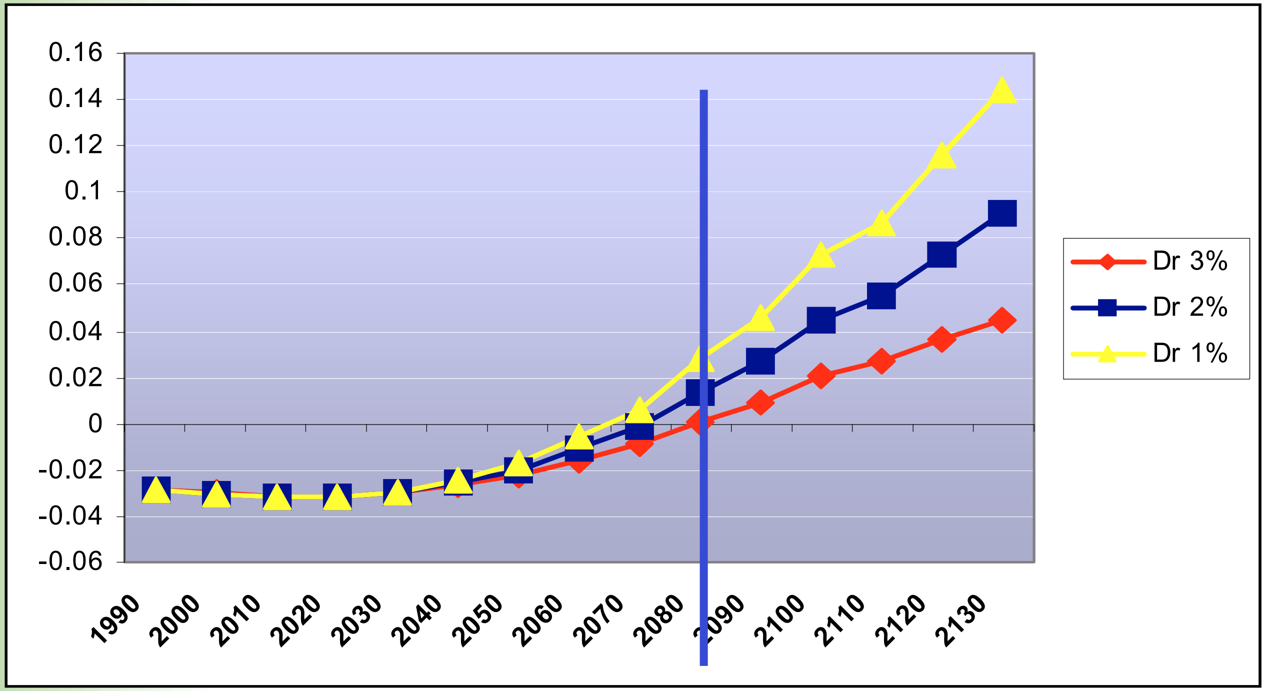
Moreover

The higher the "weight" of the future, (an economist would say the less we discount the future), the higher the incentive to mitigate.

C-C Policies



The "perspective"



The role of time: welfare gains of a mitigation policy wrt no policy

Discounting

Source: our computation running the FEEM-RICE model

The role of ancillary benefits

Ancillary effects: *incidental side effects of policies aimed exclusively at greenhouse gas mitigation*

Ancillary benefits:

- Heath effects
- Ecological effects
- Economics effects
- Social effects

Ancillary costs

Key Messages # 7

Benefits deriving from abatement can overcome its costs and (strong) mitigation policies can be justified but it is necessary at least:

To adopt a long-run perspective

To consider all benefits (also ancillary)

To behave according to the precautionary principle respect to environmental irreversibility and discontinuity

And remember:

Given the uncertainty of climate-change damages, targets for mitigation policies cannot be defined *optimally* (costs perfectly balancing benefits at the margin), but *“reasonably”* or *“prudentially”* in environmental and economic terms.

e.g.

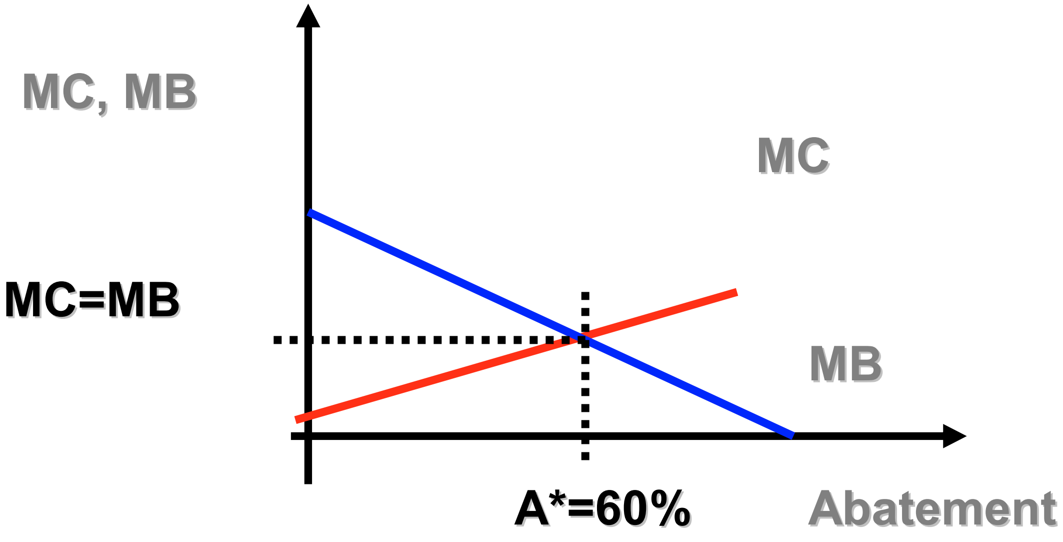
Reduce GHG emissions to the 1990 level in year 2000 (1992 Rio “Earth Summit”)

Reduce GHG emissions the 5.2% respect to 1990 level within the period 2008-20012 (Kyoto Protocol)

Stabilize carbon concentration at 550, 450 ppm.

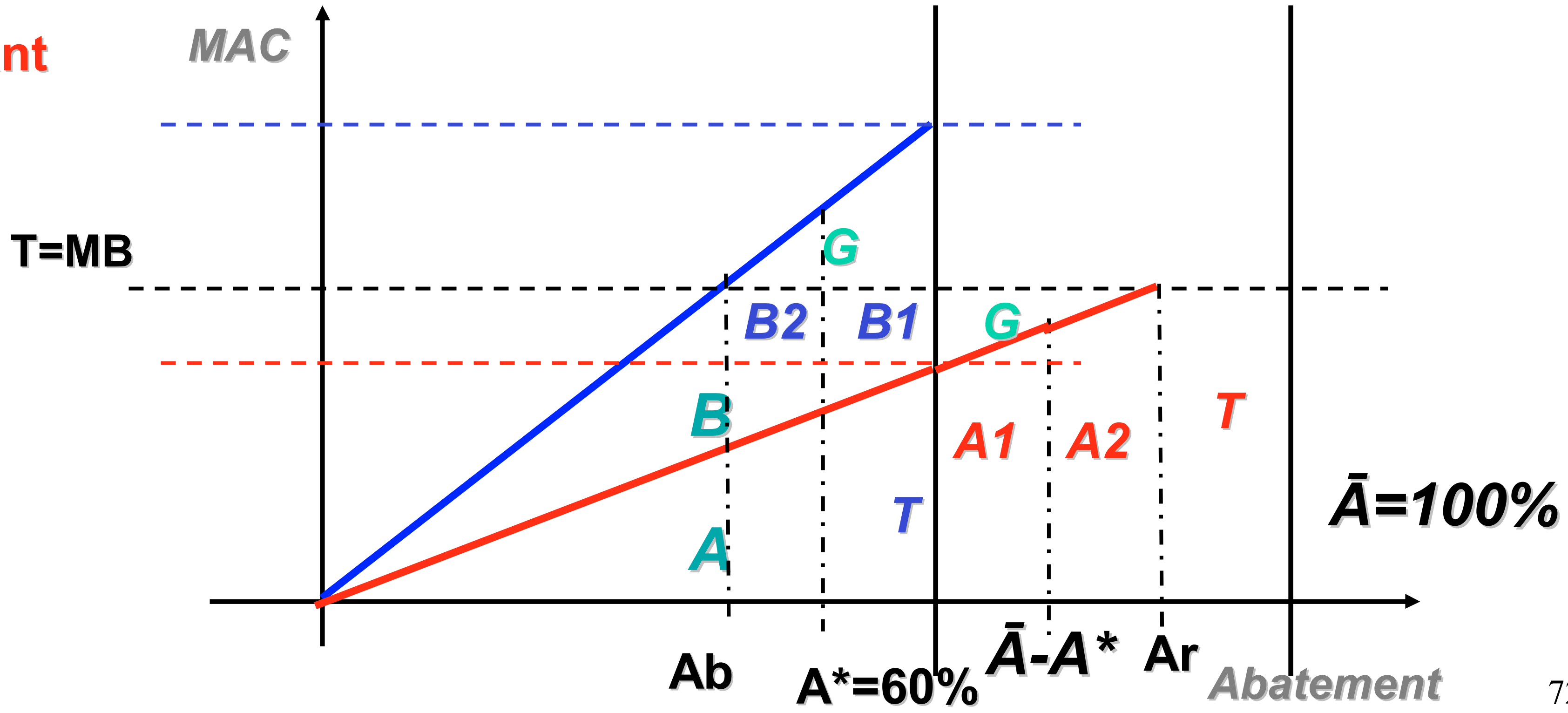
The "standard" tools in climate-change policies

	Public interv.	Adm. costs	Eff.ness	Eff. cy	Rev. Raising
Command and Control	High	Low	High	Low	None
Emission taxes	Medium	High	Low	High	High
Property/Emission rights	Low	Low - High	High	High	None - High



Blue plant

Red plant



Further issues: *international negotiations* and climate-change mitigation policies

GHGs emissions are a "public bad" →	Environmental effectiveness => "large" participation
→	Free-riding incentive
No super-national enforcing authority exists →	Agreement based on "voluntary" participation => Benefits > Costs to participants
Countries are different →	Uneven distribution of gains among winners and winners and losers

All this condensates in two key concepts

An IEA can be ***signed*** if and only if it is ***profitable*** to all parties

Each participant is better off with than without the agreement

An IEA can be ***sustained over time*** if and only if it is ***stable*** to all parties

- No incentive to free-ride: each participant is better off inside the agreement than outside the agreement with other parties committed to the agreement
- Outsiders no incentive to join in

In principle both issues can be accommodated with transfers from winners to losers or to potential free-riders

According to the theory this can be very difficult

indeed

The higher the benefits the, higher the incentive to free ride that cannot be possibly offset by any transfer scheme

(Carraro Siniscalco, 1992; Heal 1994; Barrett, 1997)

EXIT 1

An IEA with binding content can be signed only by a small number of countries (max 3)

EXIT 2

An IEA is signed by a large number of participants => it is empty of environmental commitment

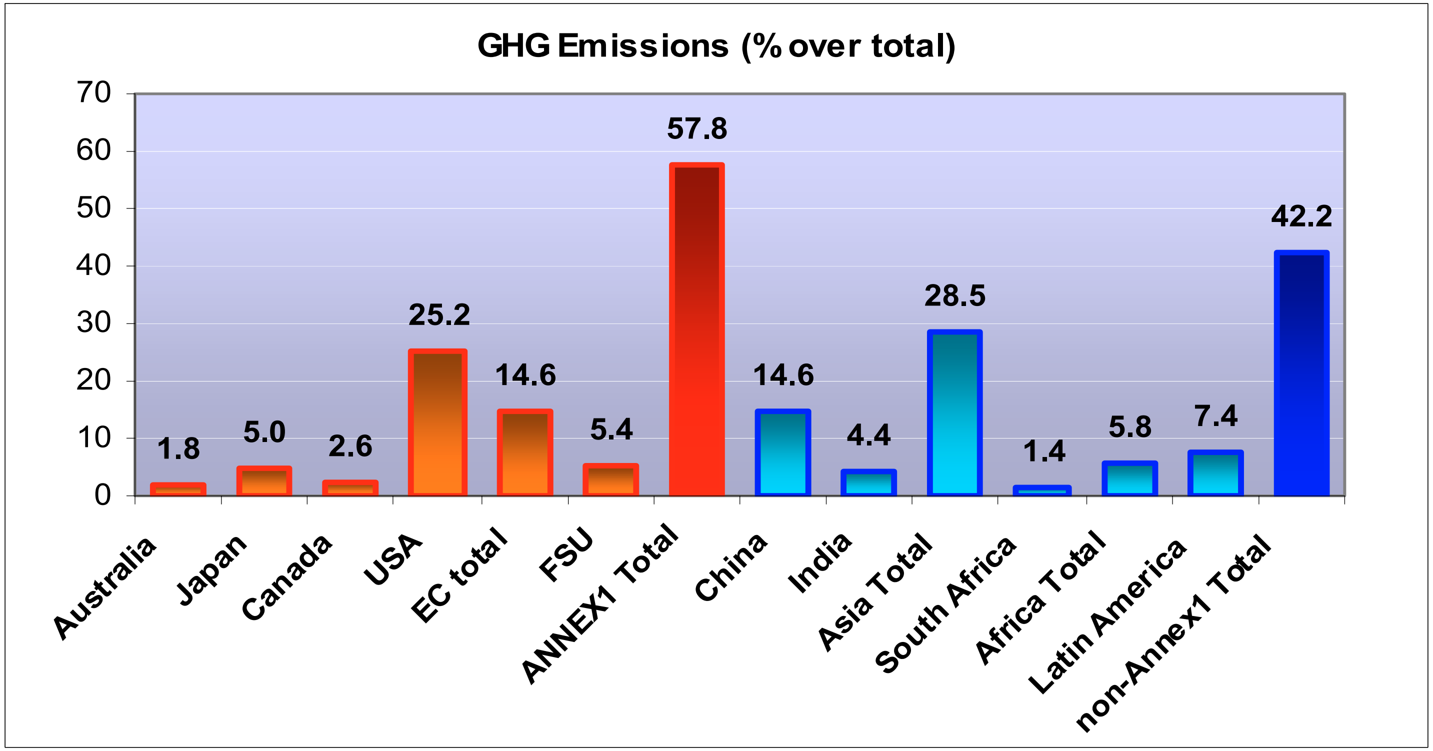
An example: an interpretation of the Kyoto Protocol negotiation process

USA + Australia non-ratification	The agreement is perceived as excessively costly = **non profitable**. Requiring "meaningful participation" of LDCs = requiring a **transfer** from LDCs
Russia ratification	Required reduction low and possibility to sell hot-air => agreement very **profitable + no incentive to free ride**
EU ratification	Possibility to buy hot air lowers costs + wrong estimates of costs?
In general, attempts to widening the agreement	Indirect relaxation of the commitment see carbon sinks => approaching status quo ante

In addition, regarding negotiations:

the effectiveness/efficiency/equity puzzle

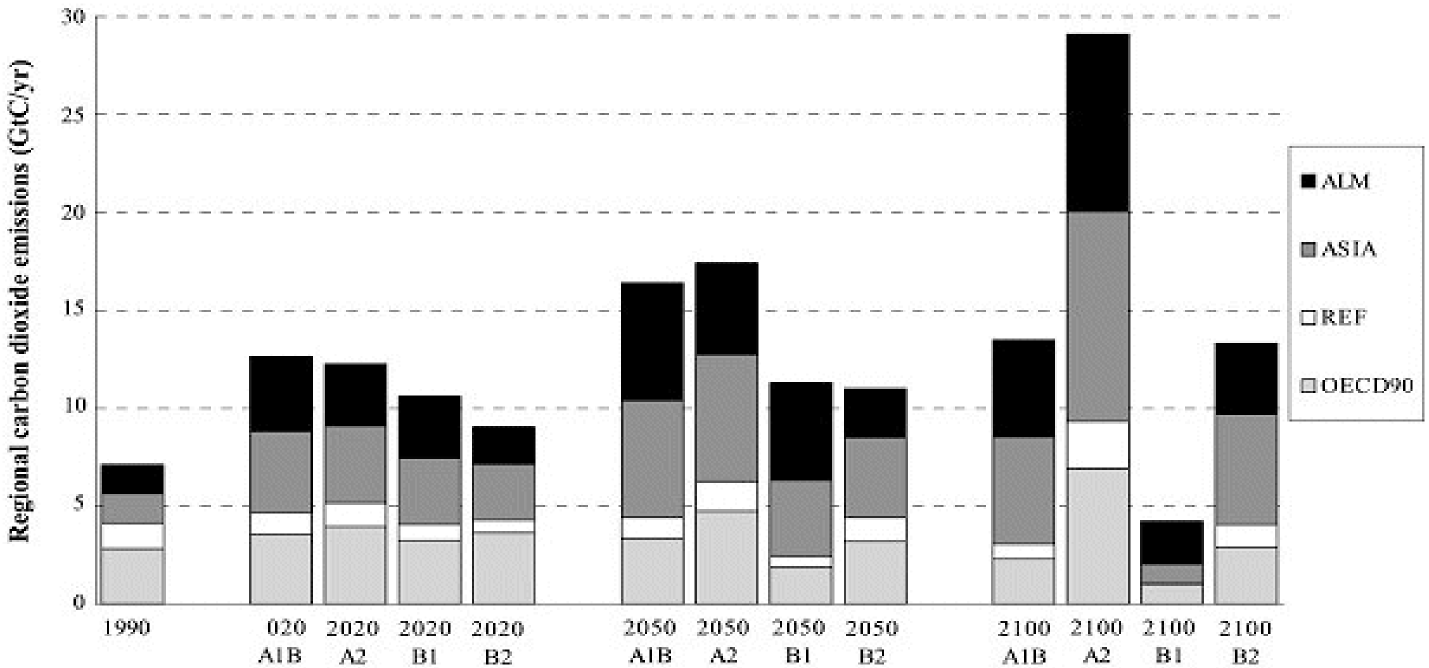
C-C Policies



Source: UNFCCC, 3rd National Communications

Today

Effectiveness does require a meaningful involvement of developing countries



Tomorrow

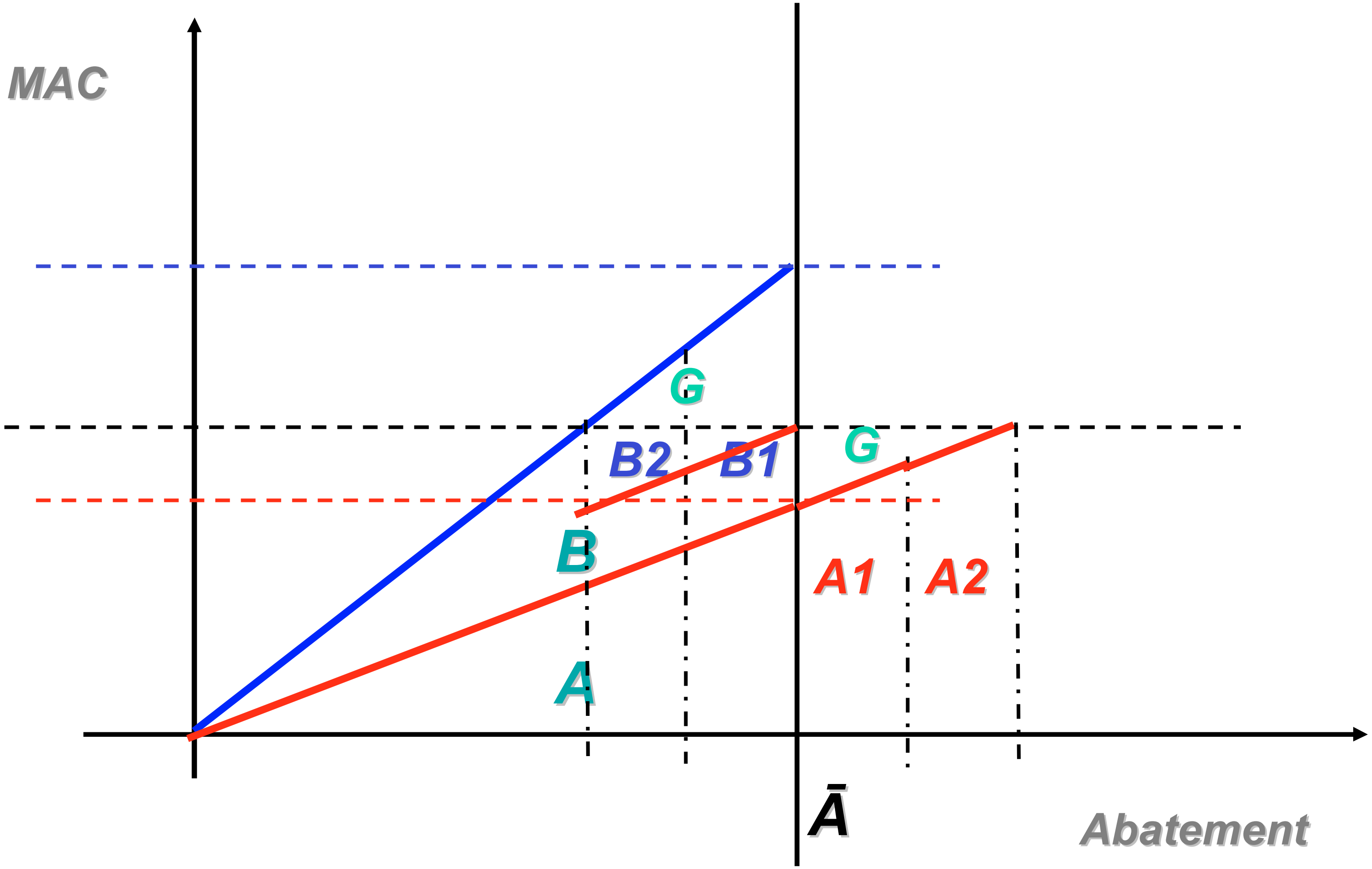
Source: IPCC SRES 2001

But also efficiency

The general argument

Blue Country

Red Country



Cost reduction (efficiency gain) is possible when effort is concentrated where it is "cheaper"

Of course a transfer is necessary

Where is it cheaper to abate?

Abatement in Developing Countries is usually cheaper than abatement in Developed Countries

?

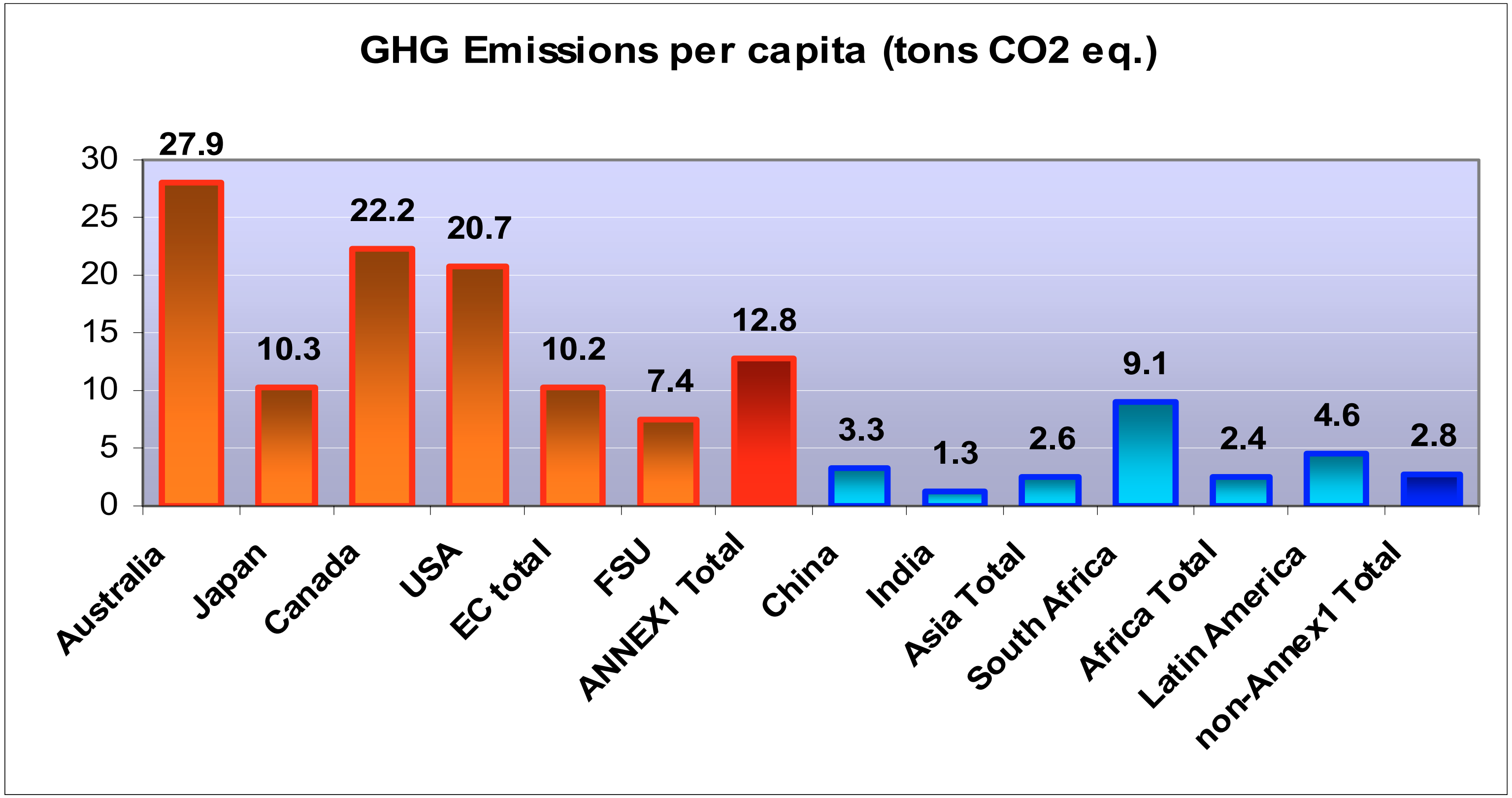
In Developed Countries technological development and taxation systems have already pushed production systems to lower energy and emission intensity

Cheaper abatement options already exploited => additional reductions very costly. Marginal abatement costs higher

But equity?

On the one hand there are the legitimate instances of development of Developing Countries

On the other, also considering the contribution to GHG emissions from a more “balanced” perspective:



What can be done?

Careful design of country commitments (emission reduction targets) in order to reach equitable burden sharing

↓

Surely does not provide cost minimization

↓

Very difficult, but outcome politically feasible

Design an "efficient" agreement and then use transfers to compensate heavily abating countries

↓

Note: efficiency => cost minimization => maximum gain => largest amount to be transferred

↓

"Easier", but politically unfeasible

In both cases

It can be attempted to enlarge the gain from cooperation

↓

ISSUE LINKAGE

↓

Joint negotiations on multiple agreements

Key Messages # 8

Optimal (cost-effective) abatement seems to be low → This notwithstanding (because of?) uncertainty on costs and benefits. Role of time dimension.

Implementing this albeit low abatement effort is difficult: Costs/gains unevenly distributed among countries; incentive to free-ride; effectiveness/efficiency/equity seem to work in opposite directions.

This is true also for tools: the most effective instruments are also the most costly.

Crucial role of compensating mechanisms.

ADAPTATION

A shift in emphasis in the second half of the '90s

Until mid '90s main focus on mitigation (1995 SAR)

→ *Prudential and reasonable*

→ *"Easy" to investigate*

↓

Standard tools for economic policy (command and control and/or market based mech.s) & standard analysis.

Then

Awareness of climate inertias

Difficulty of effective implementation of mitigation policies (Kyoto)

→ Interest on adaptation (2001 TAR)

Adaptation: ***any adjustment in ecological-social-economic system in response to actual or expected climatic stimuli, impacts or effects*** (Smit et. al 1999).

Several criteria can be used to identify the different adaptation processes (see e.g. Smit et al. 1999; Klein and Tol, 1997; Fankhauser et al., 1999; IPCC, 2001).

Concept or Attribute	
Purposefulness	*Autonomous → Planned*
Timing	*Anticipatory → Responsive*
Temporal Scope	*Short term → Long term*
Spatial Scope	*Localised → Widespread*
Function/Effects	*Retreat – accommodate – protect – prevent*
Form	*Structural – legal – institutional*
Valuation of performance	*Effectiveness-efficiency-equity-feasibility*

Source: adapted from Smit et al. 1999

Autonomous Adaptation: **natural automatic response to a "shock". Also socio-economic systems react partly autonomously. There are substitution possibilities triggered by price (scarcity) signals.**

Planned Adaptation: **strategies apt to alleviating the damage once it is (or will be) materialized via proper modifications of the impacted socio-economic-environmental system. Undertaken by public agencies – agents.**

Objectives of planned adaptation (Klein and Tol, 1997):

- ✓ **increasing the robustness of infrastructural design and long term investment,**
- ✓ **increasing the flexibility of vulnerable managed system,**
- ✓ **enhancing the adaptability of vulnerable natural systems,**
- ✓ **reversing trends that increase vulnerability ("maladaptation"),**
- ✓ **improving societal awareness and preparedness.**

Apart from definitions and classifications the literature on adaptation is very narrow and incomplete indeed IPCC TAR states:

[p. 779] ***"…Adaptation to climate change has the potential to substantively reduce many of the adverse impacts of climate change and enhance beneficial impacts - though neither without cost nor without leaving residual damages…"***

nevertheless [p. 880]: ***"…Current knowledge of adaptation and adaptive capacity is insufficient for reliable predictions of adaptations; it also is insufficient for rigorous evaluation of planned adaptation options, measures and policies of governments"***

Some tentative quantifications of adaptation costs

	M. US$ 1997	% of GDP in 2050	Study
Full Coastal Protection	207458	0.29	(a) From Bosello et al. (2004a)
Space Heating and Cooling	23065	0.00048	(b) From Fankhauser (1995)
Resettlement and Migration Costs	4327	0.0022	(c) From Fankhauser (1995)
	13800	0.0072	(d) From Tol (1995)
Health	214949	0.11	(e) From Bosello et al. (2004b)
TOTAL	449789	0.39	(a)+(b)+(c)+(e)
TOTAL	459262	0.4	(a)+(b)+(d)+(e)

Source: adapted from studies in table

Adaptation seems to be able to offset climate change damages at a low cost!

BUT

- Quantitative evidence on adaptation still needed.
- More importantly, a framework is still needed, clarifying the different mechanisms through which adaptation and mitigation operate, highlighting respective cost-efficiency and effectiveness.

Some research questions

If we can adapt, is it still worth to mitigate? If yes what are the main drivers of the choices to mitigate and adapt? What would characterise an "optimal" mix between the two strategies?

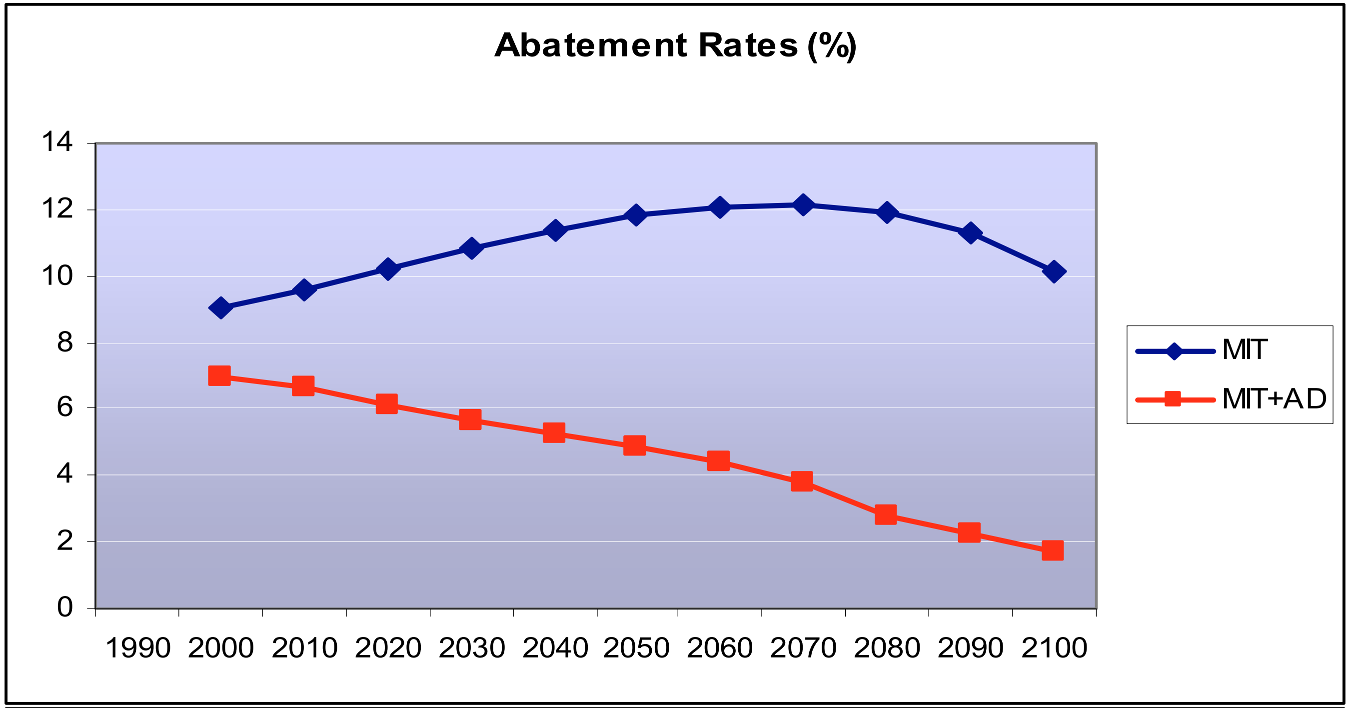
An Example:

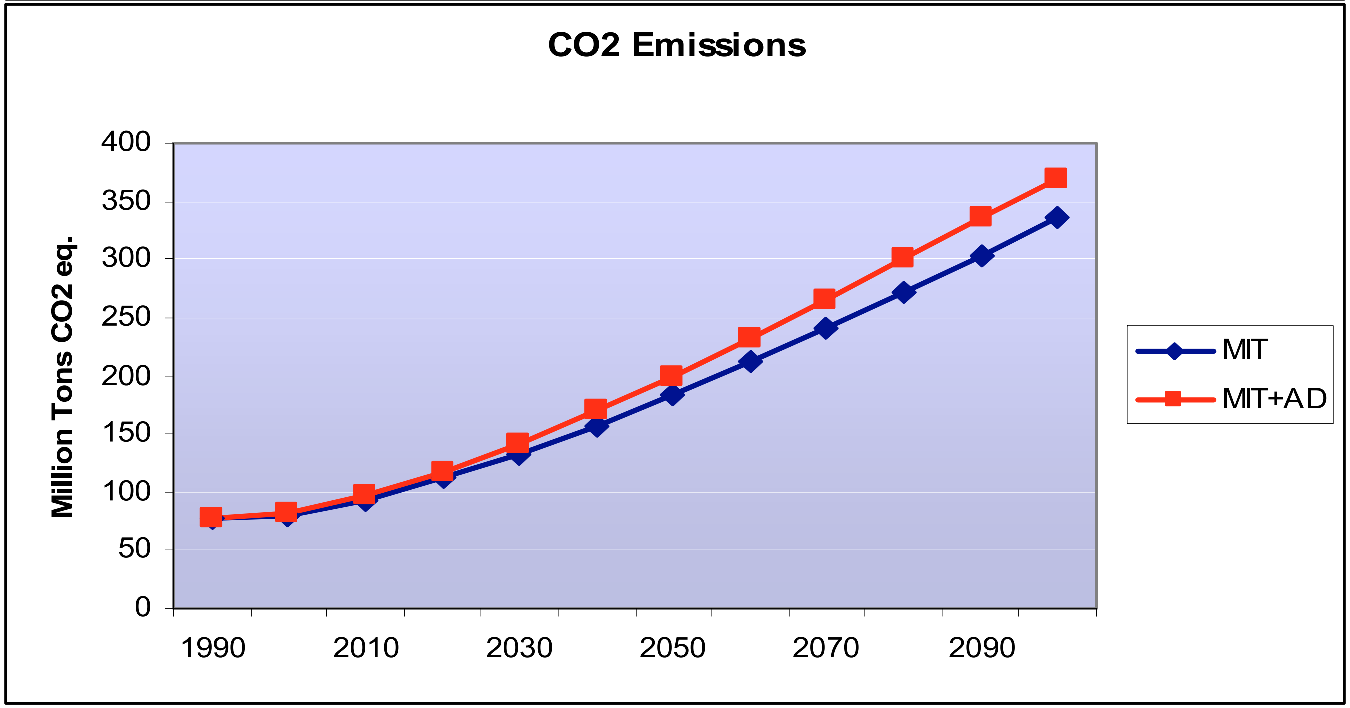
Possible results from a "simple" model where a central planner can decide not only how much to abate (mitigate), but also how much to invest in protection from climate change damages (adapt).

To clarify:

Mitigation = Abatement → Filters end of chimneys

Adaptation = Protection → Building dikes





C-C Policies

Abatement is lower

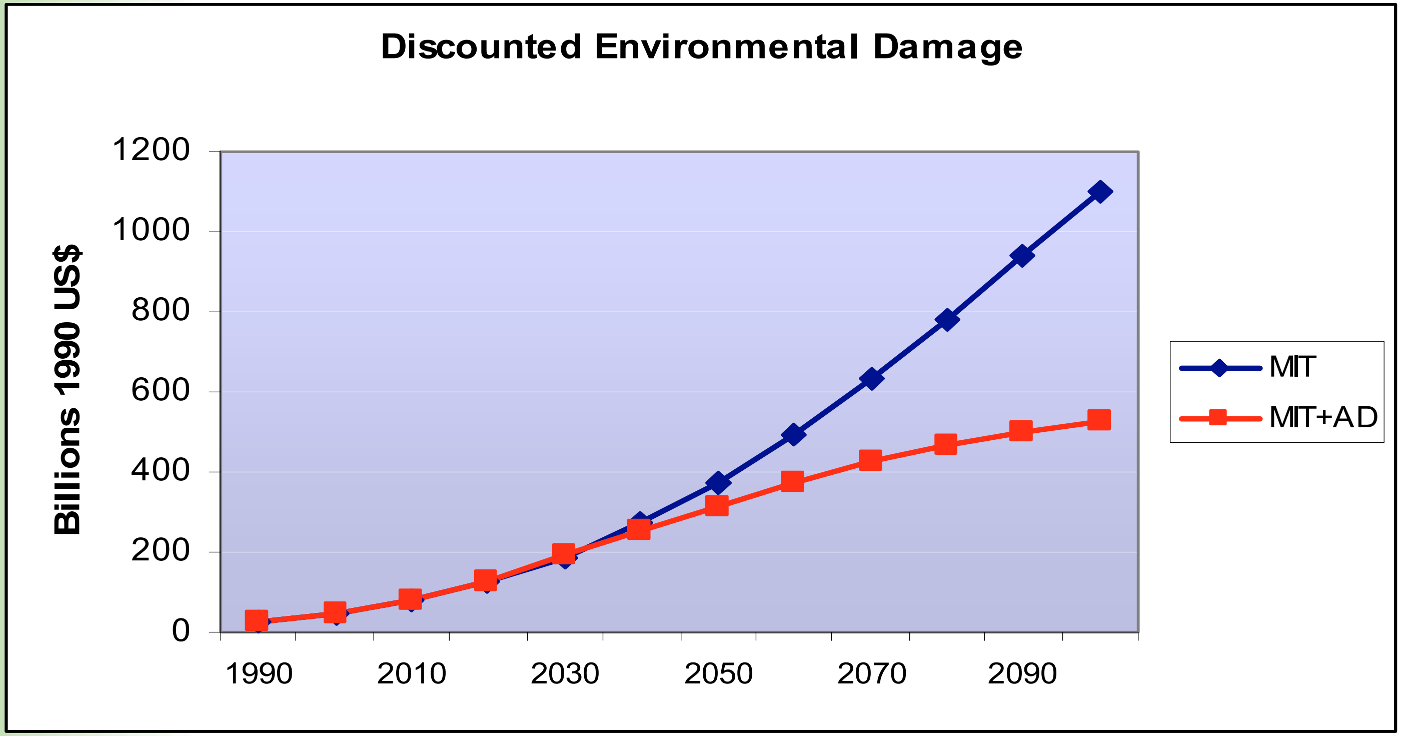
Resources are shared between the two strategies

and

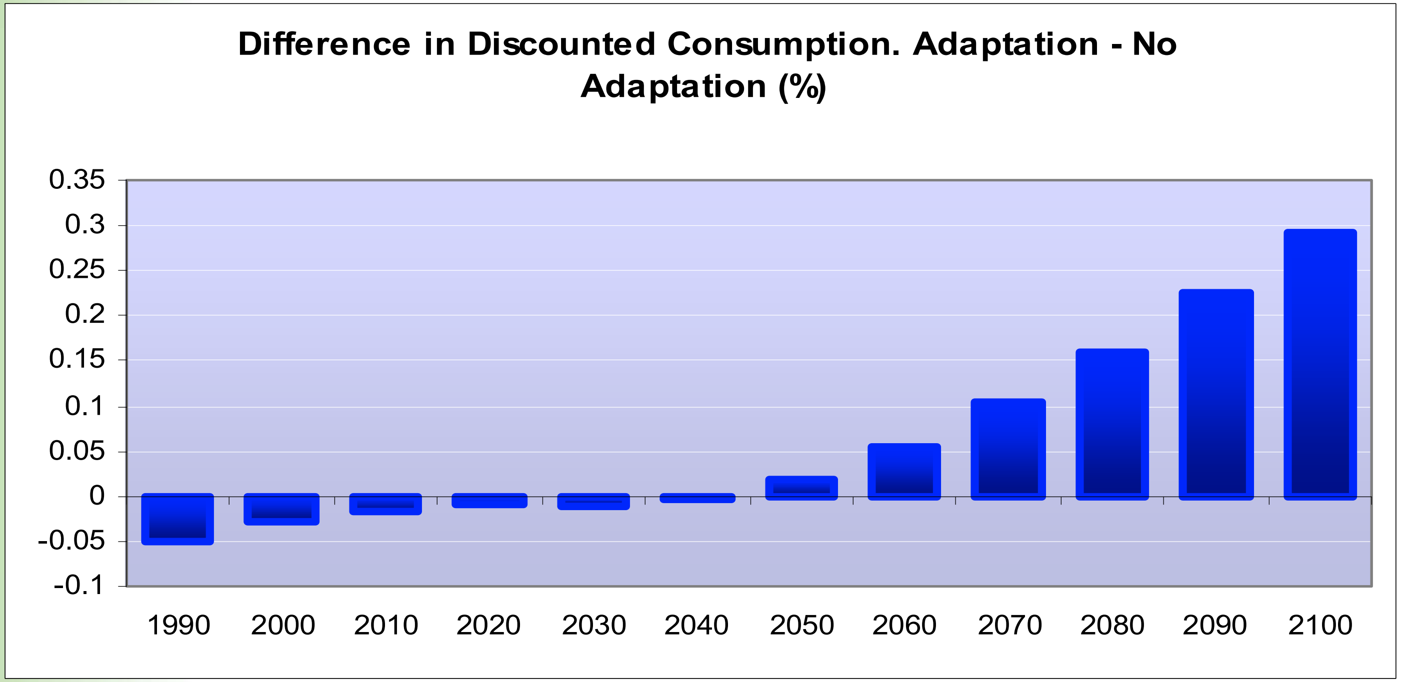
Emissions are higher

but...

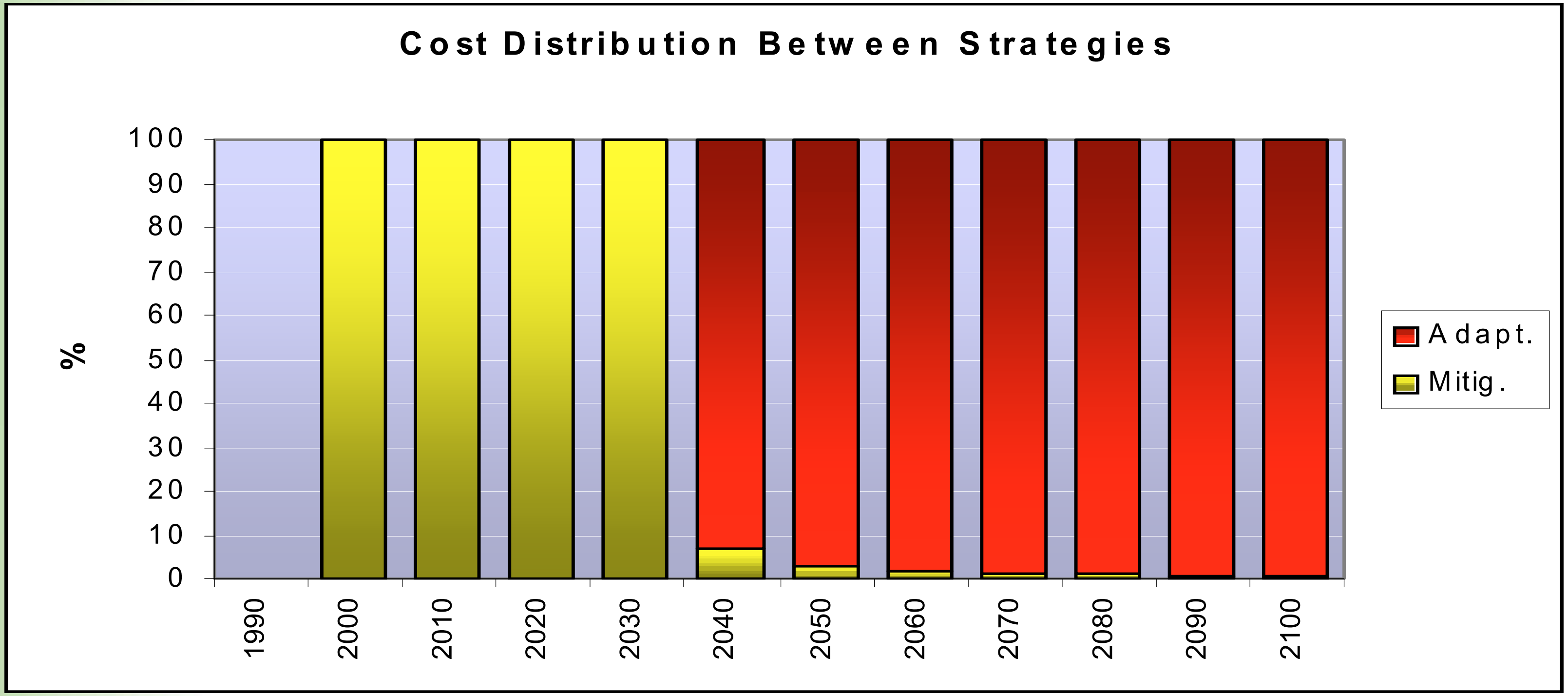
C-C Policies



The damage suffered is lower



Welfare is higher



Mitigation prevails in earlier phases, adaptation in the latter.

Benefit side: benefits from adaptation sooner (economic inertia 10 ys), benefits from mitigation later (environmental inertia 50 ys) => need to mitigate in advance.

Environmental side: weaker inertia => adaptation is a better response to *current* damage => need to adapt only when damage materializes (i.e. after 2040).

Cost side: mitigation penalises current output, adaptation penalises present *and* future output (effects on capital stock). Initially damage and capital stocks low => penalizing capital stock (adapt) less cost effective than penalizing current output (mitigate). Then the situation reverses => adapting more cost effective than mitigate.

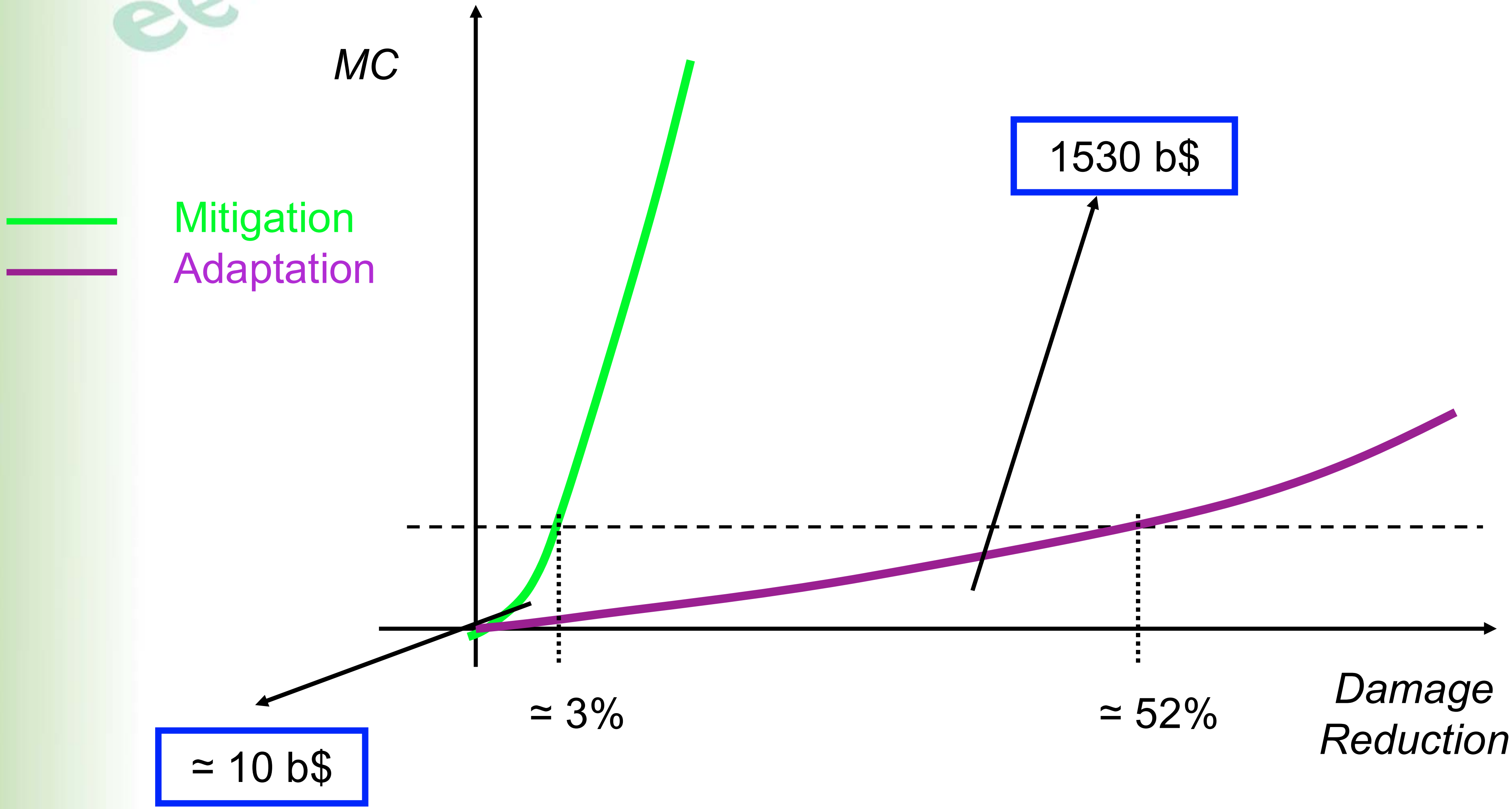
XTP	(Discounted) Effectiveness of policies: (% reduction of damage wrt no policy)			(Discounted) Expenditures on policies		
	Total	Mitigation (% on total)	Adaptation (% on total)	Total (% of GDP)	Mitigation US b. $	Adaptat. US b. $
2020	**-0.42**	**100**	**0**	**0.01**	**6.54**	**0**
2030	**-1.13**	**100**	**0**	**0.01**	**7.55**	**0**
2040	**-8.68**	**21**	**79**	**0.12**	**8.25**	**110**
2050	**-18.76**	**13**	**87**	**0.2**	**8.72**	**290**
2100	**-55**	**6**	**94**	**0.8**	**9.26**	**1530**

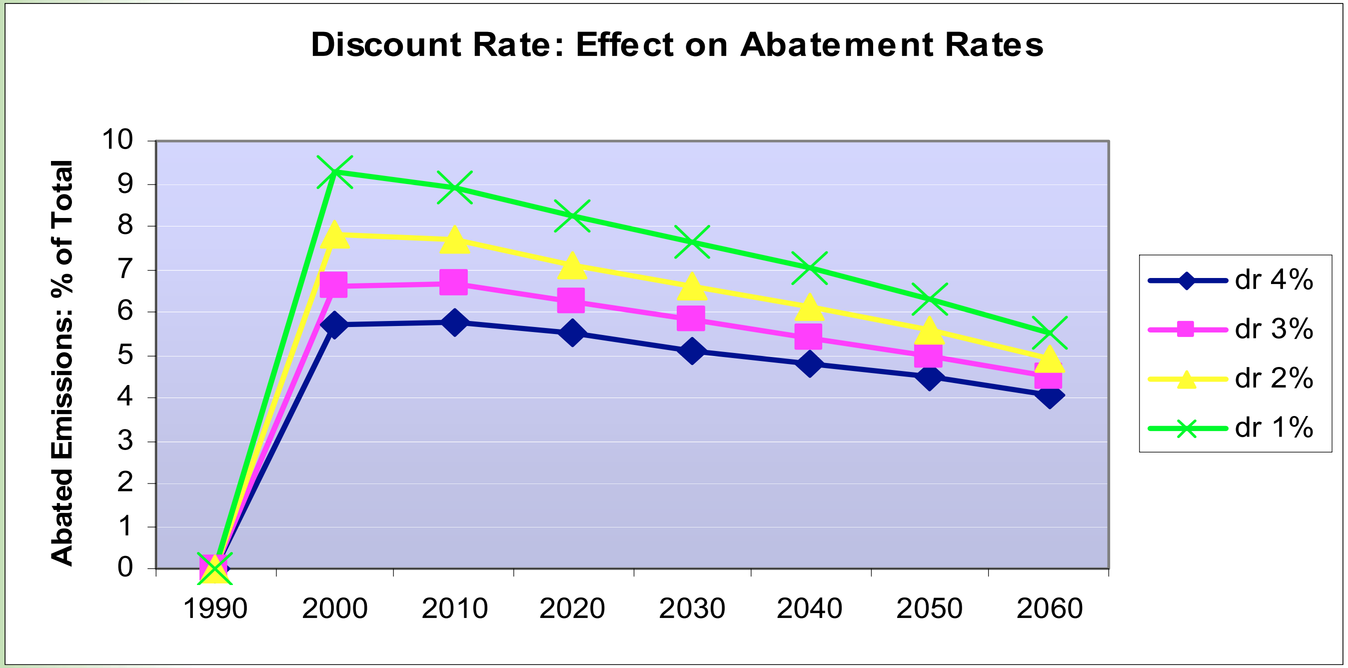
In 2100, 160 times more resources devoted to adaptation, but adaptation only 15 times more damage reducing. Mitigation seems more cost-effective. So why the unbalance?

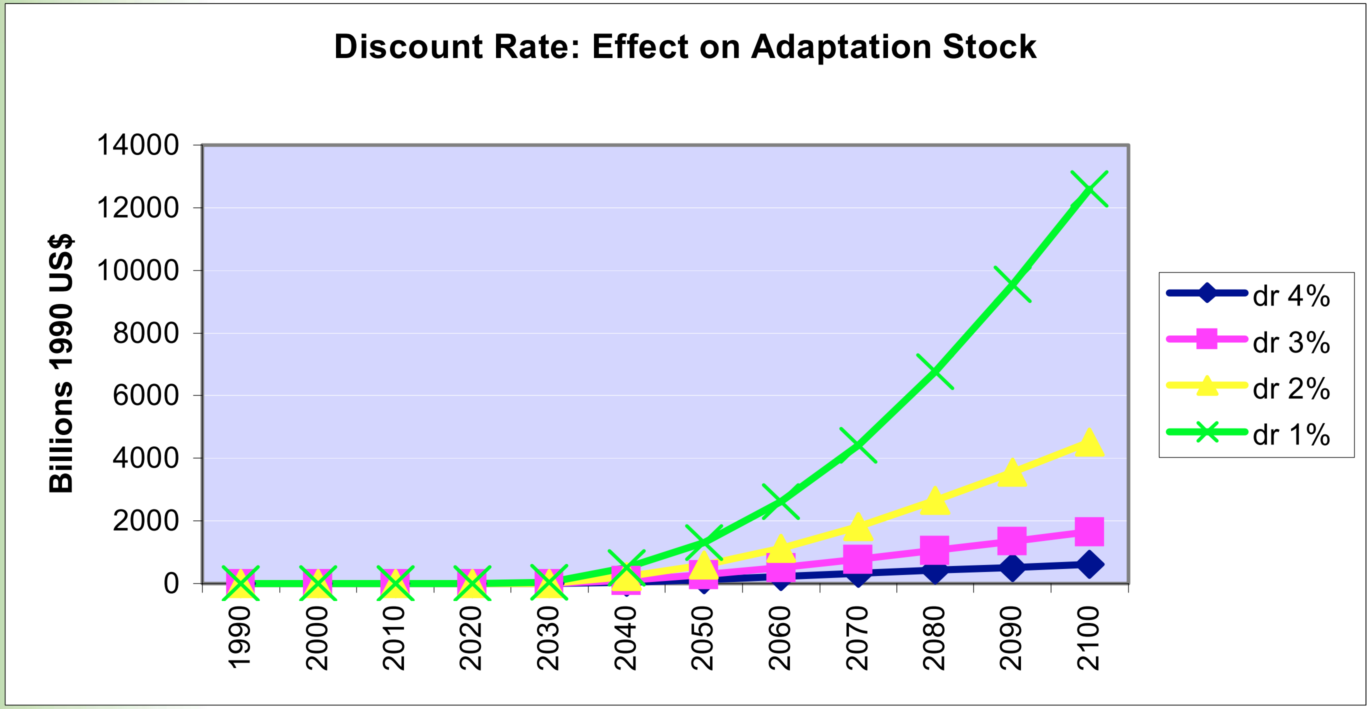
Policies must be considered in relative and not absolute terms.

Structure of abatement costs: abatement costs exponential. Steeply increasing beyond a 10% abatement rate. (6% abatement costs 9 US billions $, 50% abatement costs 2112 US billions $).

Adding the benefit side: a 50% abatement rate costs 2112 bs $ and reduce the damage the 29%, 1530 billions $ invested in adaptation reduce the damage the 52%.

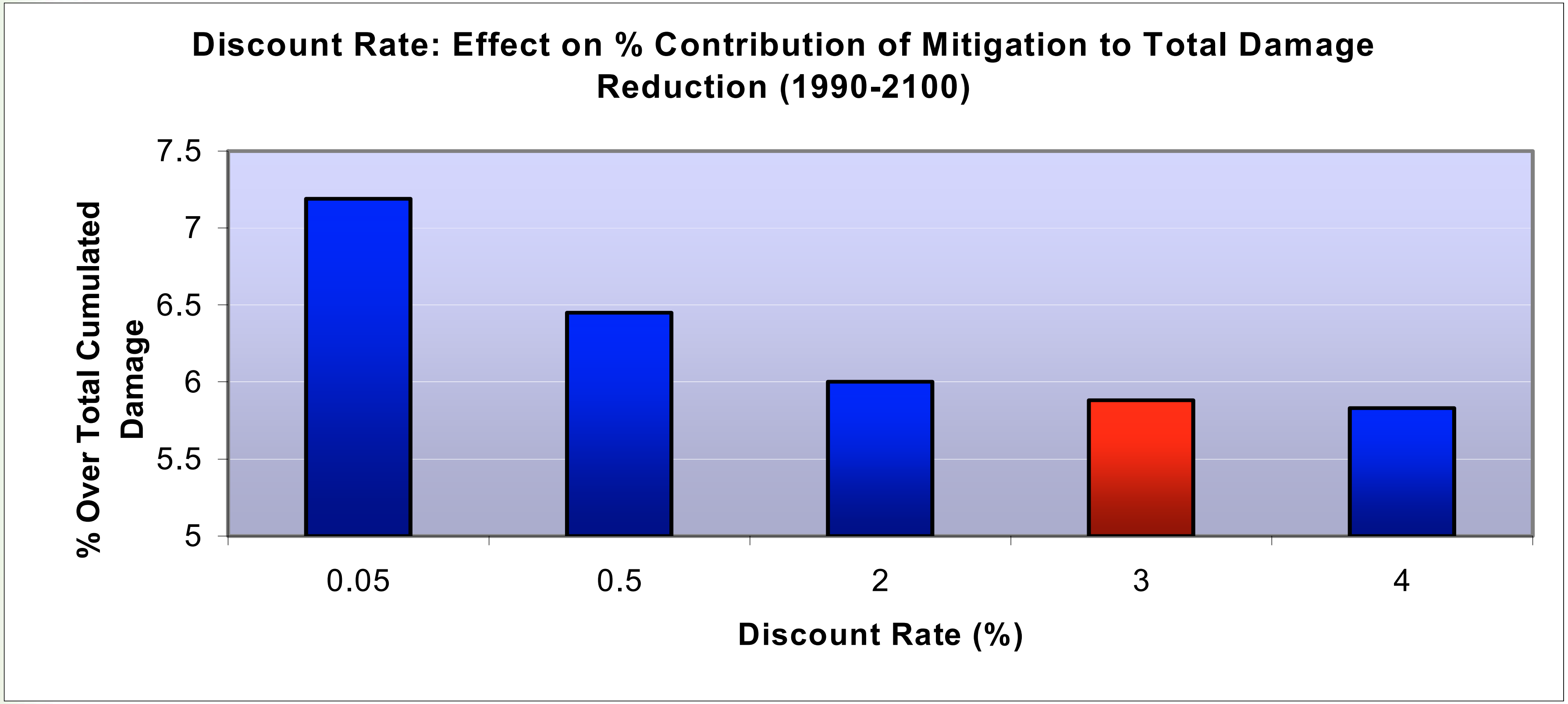

MC
1530 b$
Mitigation
Adaptation
≃ 3%
≃ 52%
Damage
Reduction
≃ 10 b$





Effect of the discount rate

Lowering discount rates increases both abatement and investment in adaptation



But in relative terms mitigation increases more: Lower dr => future “more important” => “environmental inertia” reduced => mitigation relatively more convenient.

Key Messages # 9

Mitigation and adaptation are strategic complements. Both contribute to the solution of the climate change problem.

It is dynamically optimal to mitigate first and adapt then. No "wait and see" mood for mitigation even though adapting is possible.

The possibility of higher future environmental damage or higher preferences for the future increase the weight of mitigation wrt adaptation.

When, in latter phases, adaptation becomes convenient, the large majority of resources are absorbed by adaptation. It is more cost-effective.

THANK YOU!

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