Netherlands Environmental Assessment Agency

Quantitative comparisons of RCPs

Detlef van Vuuren (with contributions from Tom Kram, Jae Edmonds, Nebojsa Nakicenovic Richard Moss, Keywan Riahi, Steve Rose, Allison Thompson)
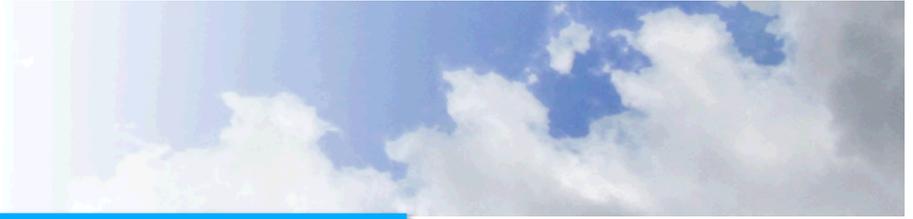
Scenarios in climate reseach

➢Scenarios are important in climate research:
  ➢Consistent, quantified, stories of the future / 'drivers' that help answering a certain question
  ➢More specifically: information flows between research communities
  ➢Language about possible trends

Use of scenarios

➢ Scenarios are used for different purposes:
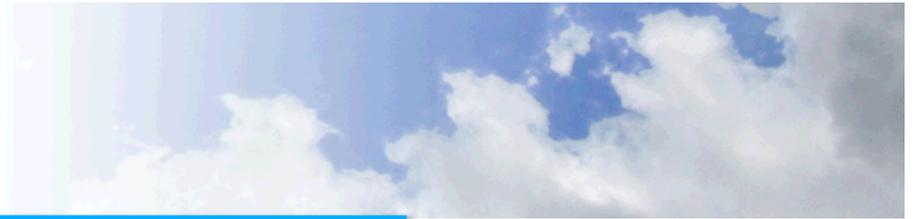 ➢ Basis for climate calculations
  ➢ Basis for impact assessment
  ➢ Basis for mitigation analysis

RCPs
(Special Issue in Climatic Change!)

Use of scenarios

➢Scenarios are used for different purposes :
    ➢Basis for climate calculations
    ➢Basis for impact assessment
    ➢Basis for mitigation analysis

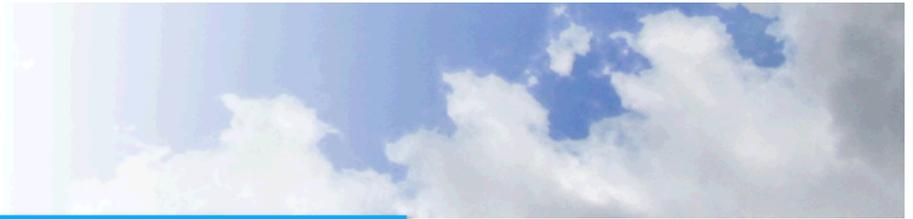What is needed?
Climate impacts depend on:
- Exposure (climate change)
- The subject at risk (f (population, income etc)
- Adaptive capacity (f (technology, income, governance etc))

Use of scenarios

➢ Scenarios are used for different purposes:

   ➢ Basis for climate calculations

   ➢ Basis for impact assessment

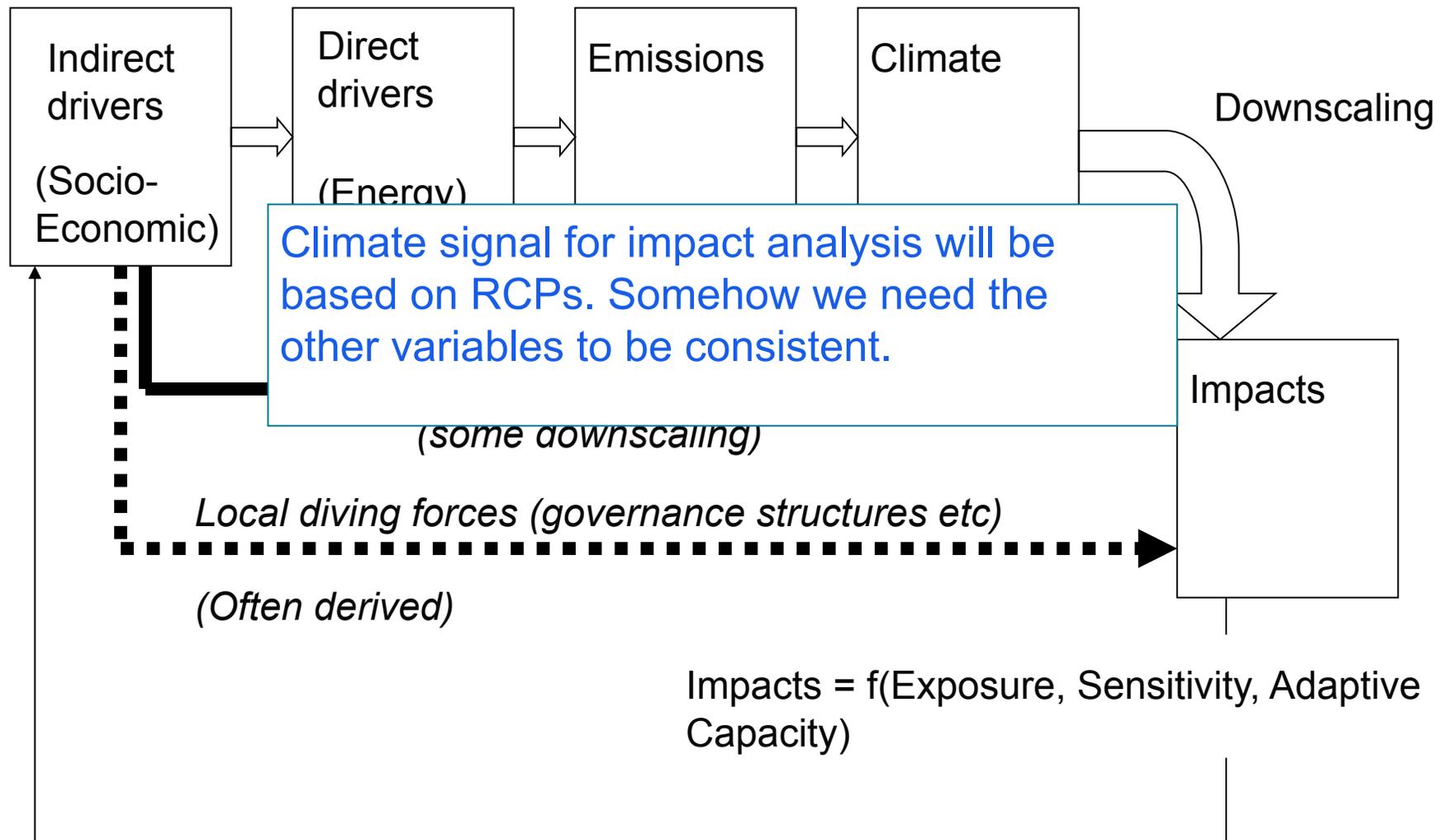   ➢ Basis for mitigation analysis

What is needed?

Mitigation depends on:

- Baseline + target
- Assumptions on technology etc.
- Assumptions on climate governance (global cooperation etc)

Scenarios for impact analysis

Indirect drivers

(Socio-Economic)

Direct drivers

(Energy)

Emissions

Climate

Downscaling

Climate signal for impact analysis will be based on RCPs. Somehow we need the other variables to be consistent.

Impacts

(some downscaling)

Local diving forces (governance structures etc)

(Often derived)

Impacts = f(Exposure, Sensitivity, Adaptive Capacity)

RCPs as first step in scenario process

➢ RCPs have been selected from the available literature to span the climate range, in order to facilitate climate modelling

➢ They all have been peer reviewed (2x), and each provides a consistent description of socio-economics, emissions, radiative forcing and land use
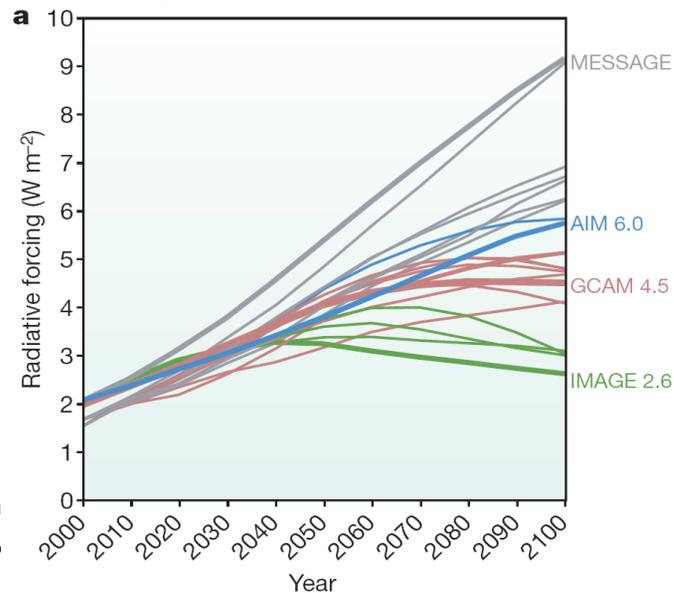
Span RF scenarios   Represent 10-90th emissions
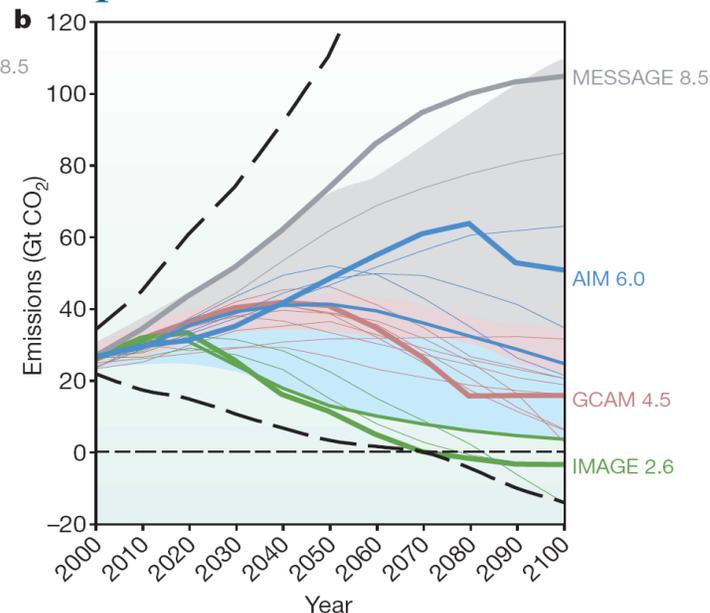
What do the RCPs provide?

Crucial questions:

➢ Can information of the *RCPs be directly* used as input for socio-economic storylines?

➢ how strong is the *correlation* between assumptions on socio-economics and the RF/ emission outcomes used for RCPs !

➢ Can we based on this come up with *proposals*?

sistent set of
mptions and
omes, based on:

e target set
odel run
ition)

climate
model run

Climate

Information
mitigation studies

Explore relationship between socio-economic assumptions and RF

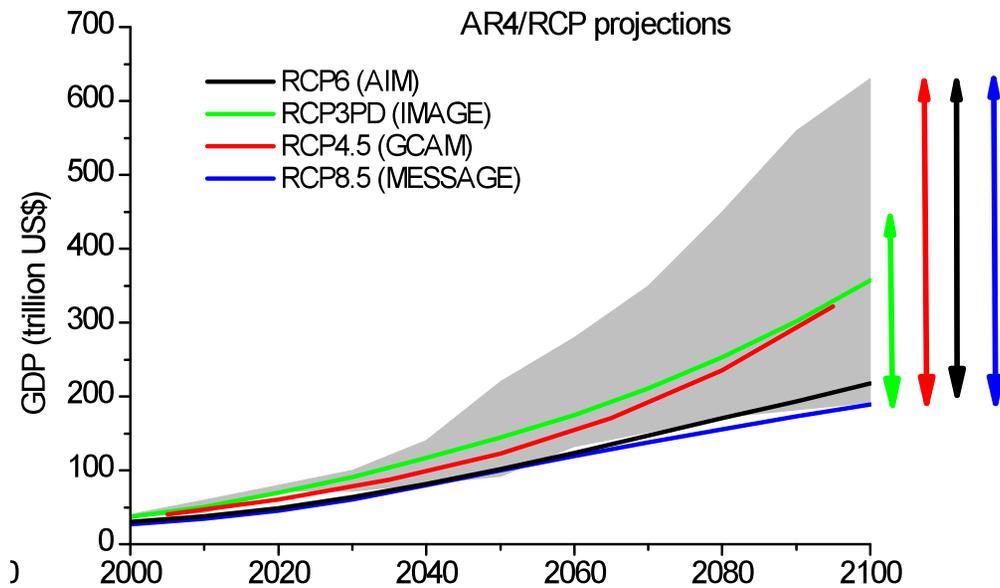For the questions, we use available data from:
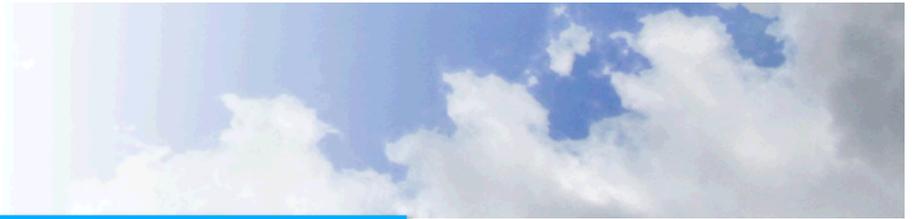
➤ AR4 Scenario database (a large number of scenarios categorised for RCP RF levels)
➤ More recent published material (EMF-22) (Clarke et al., 2009)
➤ Material provided by RCP groups

➤ For simplicity, we will only look at the global data;
➤ We look into population; income; energy use; land use;
➤ We look into these factors in isolation!
➤ Note that we use available information; mostly based "full participation"; but not all (don't think it will influence results much).

Population

EMF-22

AR4-database + RCP

RCP6 (AIM)
RCP4.5 (GCAM)
RCP3PD (IMAGE)
RCP8.5 (MESSAGE)
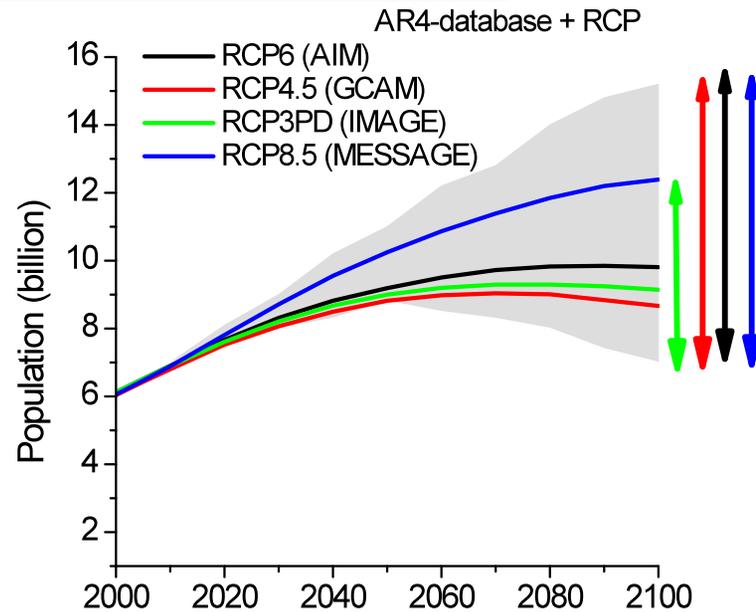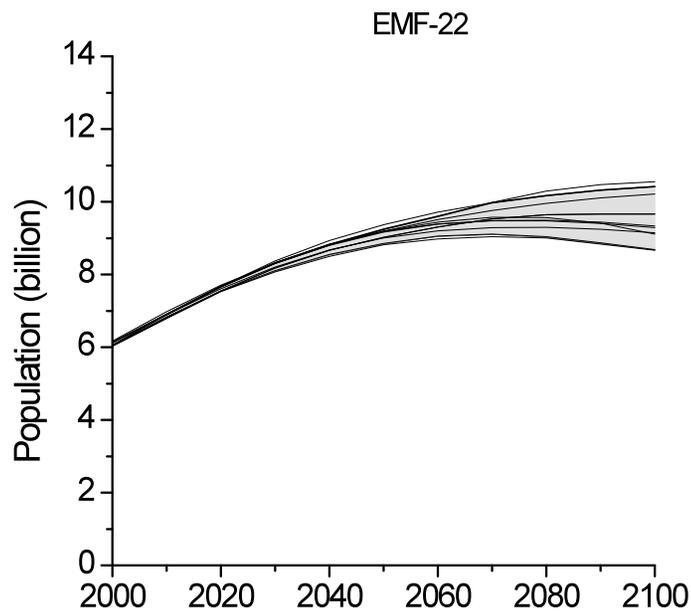
- ➢ There seems to be no correlation between pop. assumptions and radiative forcing levels (scenarios exists with high and low population for each level)
- ➢ Rather narrow population range considered in current scenario studies
- ➢ Most RCPs cluster within the range of intermediate assumptions (with no logical order), except for RCP8.5

GDP

AR4/RCP projections

Legend:
- RCP6 (AIM)
- RCP3PD (IMAGE)
- RCP4.5 (GCAM)
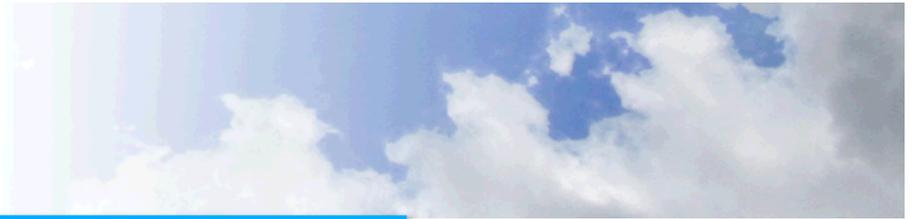- RCP8.5 (MESSAGE)

GDP (trillion US$) vs year (2000–2100)

➢ Range of GDP assumptions in literature for low RF-scenarios is slightly more constrained than for the other levels (but only few studies)
➢ Order of GDP assumptions in RCPs is for a set somewhat counterintuitive (RCP3 highest)

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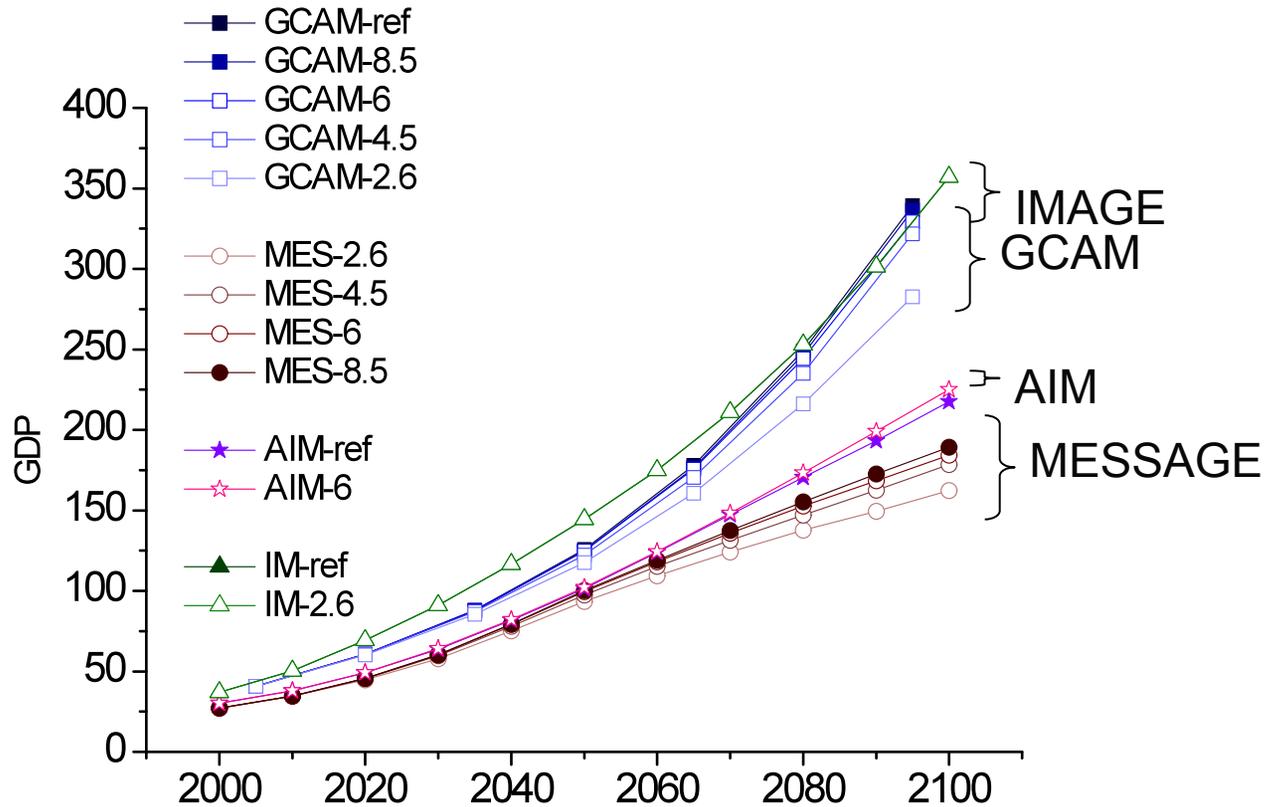
GDP (EMF-22)
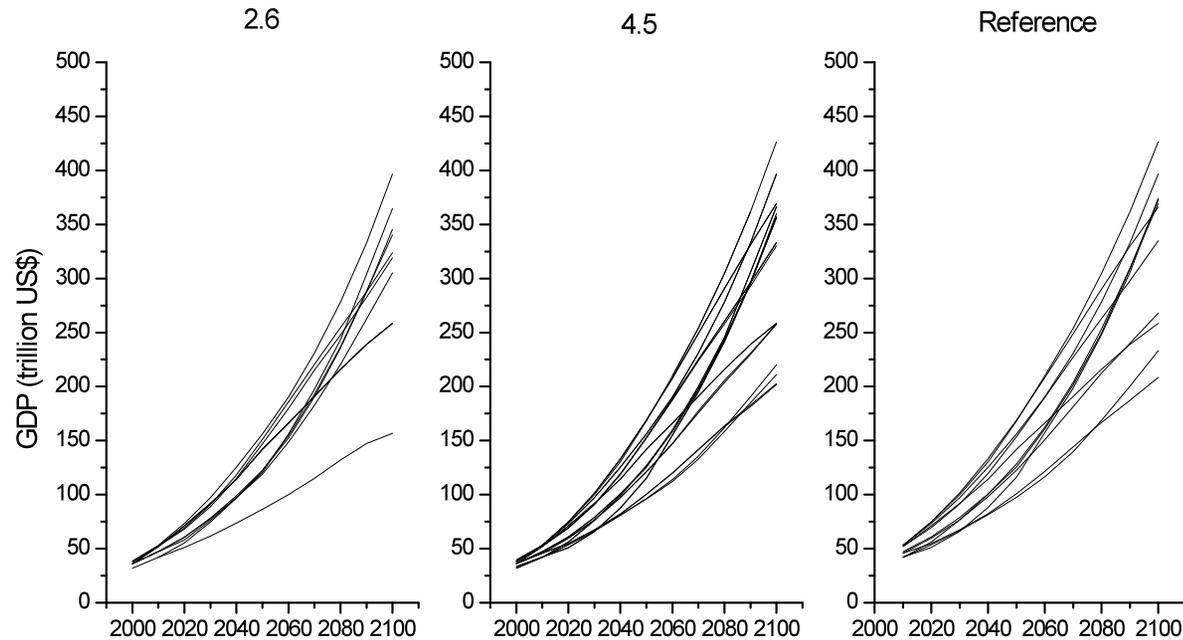
For nearly all individual models, lower GDP for lower RF levels (impact of mitigation of GDP)

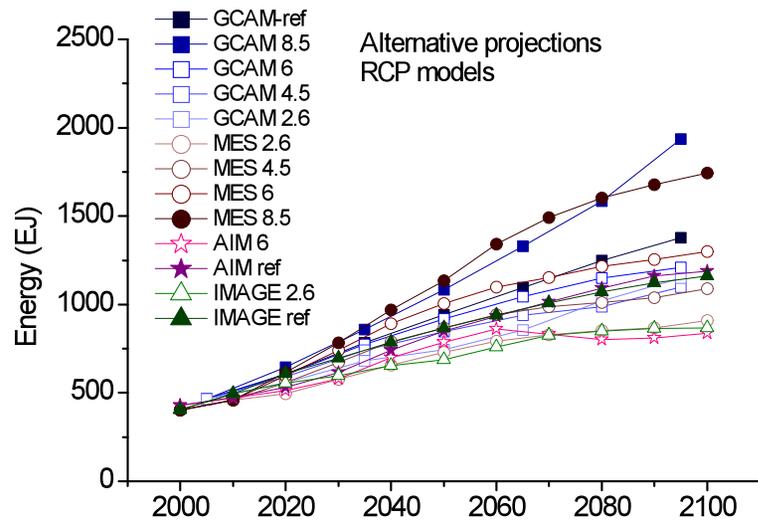As other assumptions influence GDP more than climate policy, results for basically the same GDP range for every level.

GDP (consistent sets from the RCP teams)

Position is determined by scenario assumptions – not by the RF level (2.6 can have a high – GCAM, IMAGE; or low GDP)

Primary energy (EJ)

EMF-22

Median values
▲ Baseline (range light grey)
◄ 4.5 (range medium grey)
▼ 2.6 (range dark grey)

AR4/RCP projections

RCP6 (AIM)
RCP3PD (IMAGE)
RCP4.5 (GCAM)
RCP8.5 (MESSAGE)

Alternative projections
RCP models

GCAM-ref
GCAM 8.5
GCAM 6
GCAM 4.5
GCAM 2.6
MES 2.6
MES 4.5
MES 6
MES 8.5
AIM 6
AIM ref
IMAGE 2.6
IMAGE ref
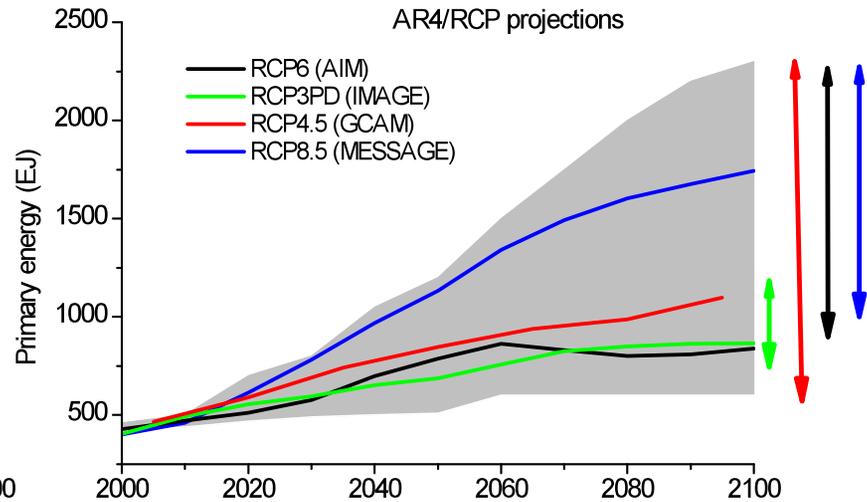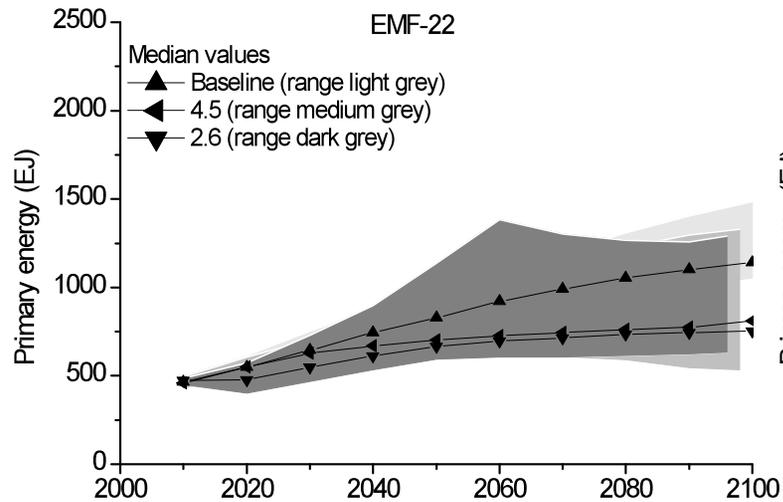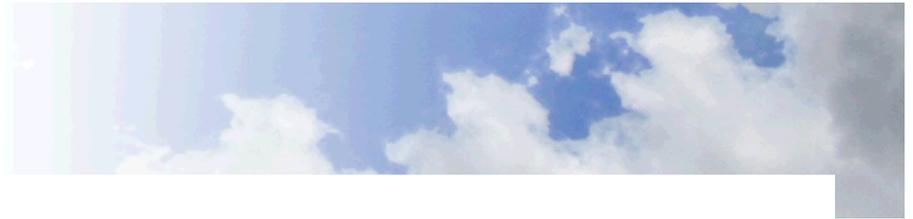
There is some relationship between energy consumption and radiative forcing level.

CO₂ emissions
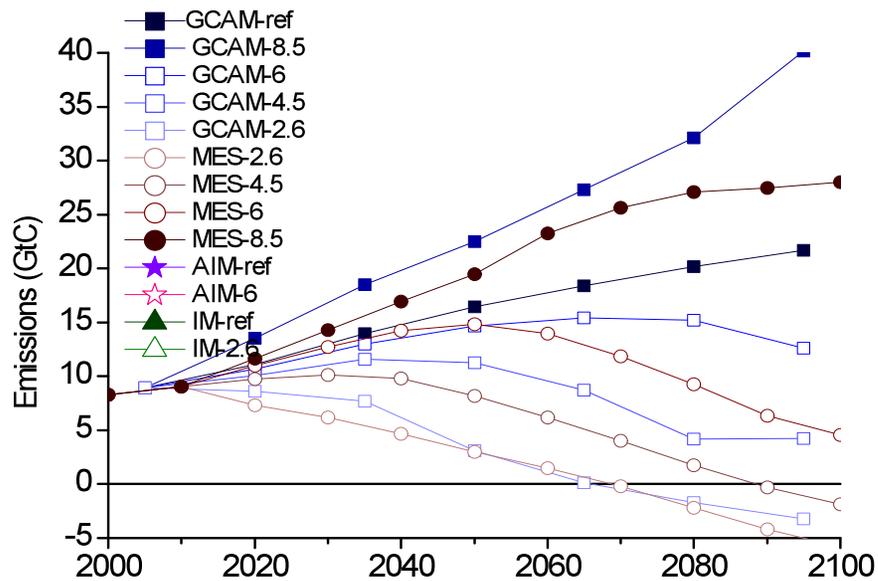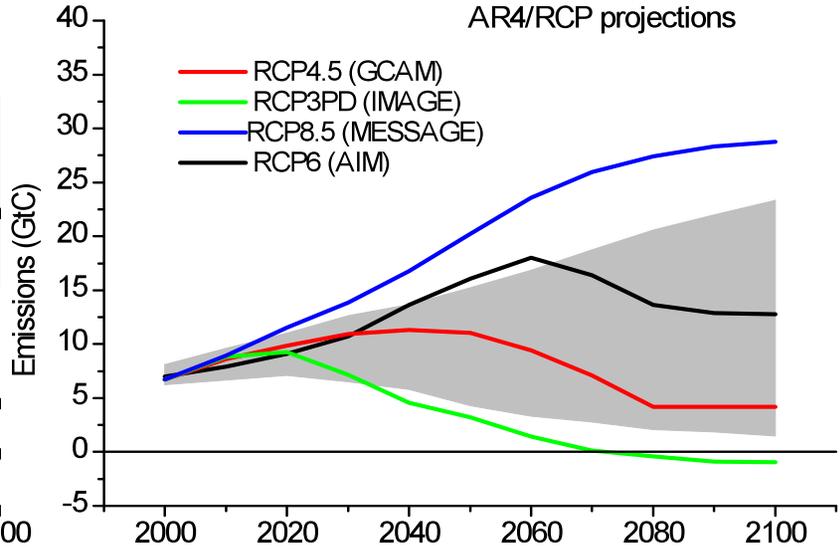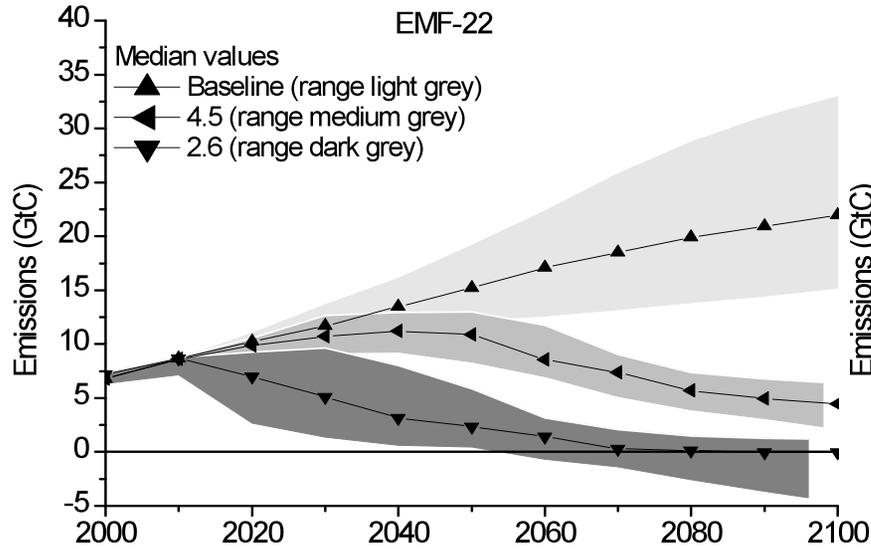
As expected, position is determined by RF level (climate policy) much less by model specific assumptions!

Forest area
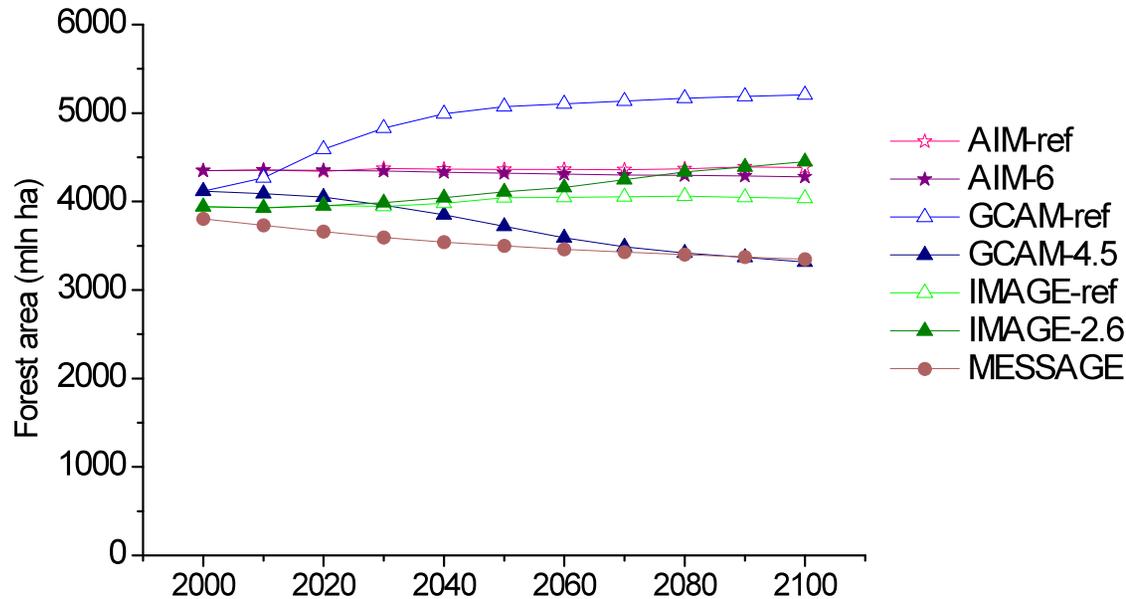
MESSAGE: major expansion of agriculture area (high population scenario)

GCAM-4.5: major reforestation programme as result of consistent C-price

IMAGE-2.6: some loss of forest to bio-energy

AIM: More-or-less stable forest area

4 interesting stories, that are mostly model dependent, not RF level dependent

Overall conclusions of analysis

- There are scenarios reaching each RF level
    - *independent of population assumption*
    - *independent of income assumption*
- Each scenario underlying the RCPs provides consistent combination of population, GDP, energy, RF; however as a set they provide no logic ordering (not selected for that) nor do they always cover the full range of possible outcomes

What else is new?
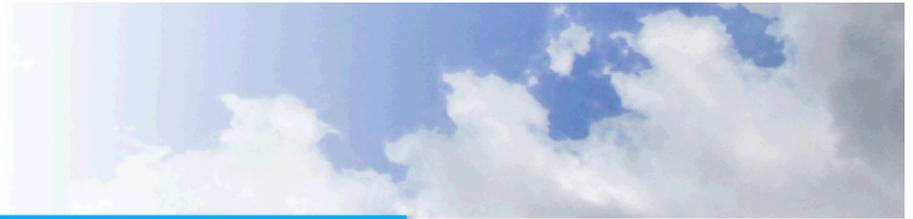
> *Similar future GHG emissions can result from very different socio-economic developments, and similar developments of driving forces can result in different future emissions (SRES).*

So → turn to third question: can we create useful storylines for IAV/mitigation work in accordance with RCPs

The 2 main observations (socio-economic assumptions are more-or-less independent of RCP level and the current set as a whole does not add much) allows considering alternative socio-economic assumptions

So, maybe try to design scenarios in a different way

This will above all be joint-community process as information is needed about many different drivers, at different scales, and for different purposes (IAM groups, IAV community).

Useful starting point proposal made in Tsukuba and elaborated by our group in Washington
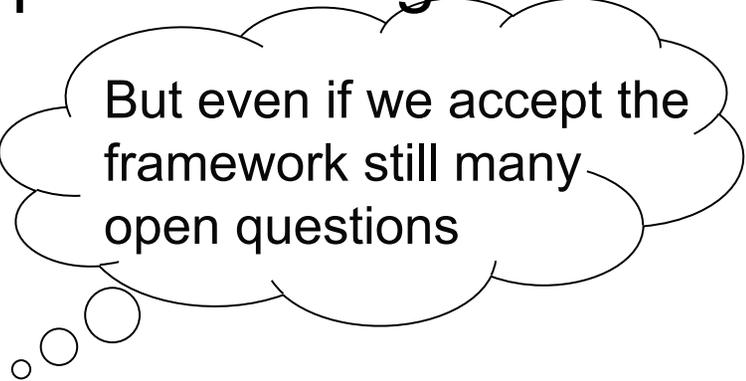
But even if we accept the framework still many open questions

Suggested use of RCPs in IAV research

➤ If the intention of the impact analysis is to map out all possibilities → analysis shows that it is safe to assume (some) decoupling of climate change and socio-economic assumptions
➤ Impacts = f (Exposure, Sensitivity, Adaptive Capacity)
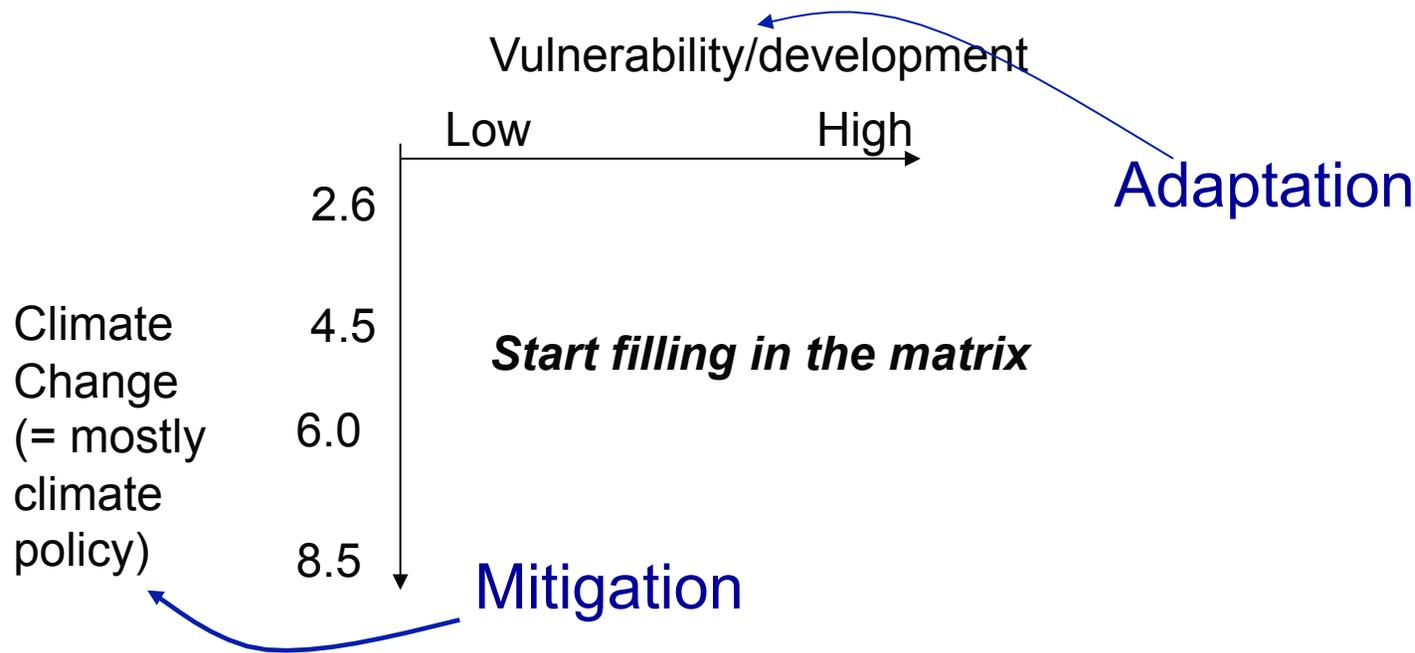
Vulnerability/development

Low   High

Climate
Change
(= mostly
climate
policy)

2.6

4.5   *Start filling in the matrix*

6.0

8.5

Adaptation

Mitigation

Suggested use of RCPs in IAV research

➢If the intention of the impact analysis is to map out all possibilities →
analysis shows that it is safe to assume (some) decoupling of
climate change and socio-economic assumptions
➢Impacts = f (Climate Change, Vulnerability)

Vulnerability/development

	low	mid	high
2.6		IM2.6	
4.5		GCAM4.5	
6		AIM6.0	
8.5			MES8.5

Climate signal

IMPACT = Exposure + Vulnerability!

high   **low**

Suggested use of RCPs in IAV research

Columns could just represent classification heuristic (IM2.6 for instance c... Mid scenario)

Columns could also form the basis of formulating preferred ...es

This can be combined:
> First fill up database with model runs that focus on RCPs (different models, invite to look into different socio-economics)

> Later select within each column more likely cases

Climate signal

6   AIM6.0

8.5   MES8.5

IMPACT = Exposure + Vulnerability!

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high ← low

Suggested use of RCPs in IAV research

How many columns: 2, 3?

Prefered model runs (like Climate modelling community)

Vulnerability

	low	mid	high
2.6	X		
4.5		X	
6			
8.5			X

Climate signal

Extreme cases

IMPACT = Exposure + Vulnerability!

high ← **low**

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CC scenarios
Detlef van Vuuren – 29 January 2009

Suggested use of RCPs in IAV research

How many columns should one use: 2, 3?

Should we identify prefered model runs (like climate modelling community)

Vulnerability

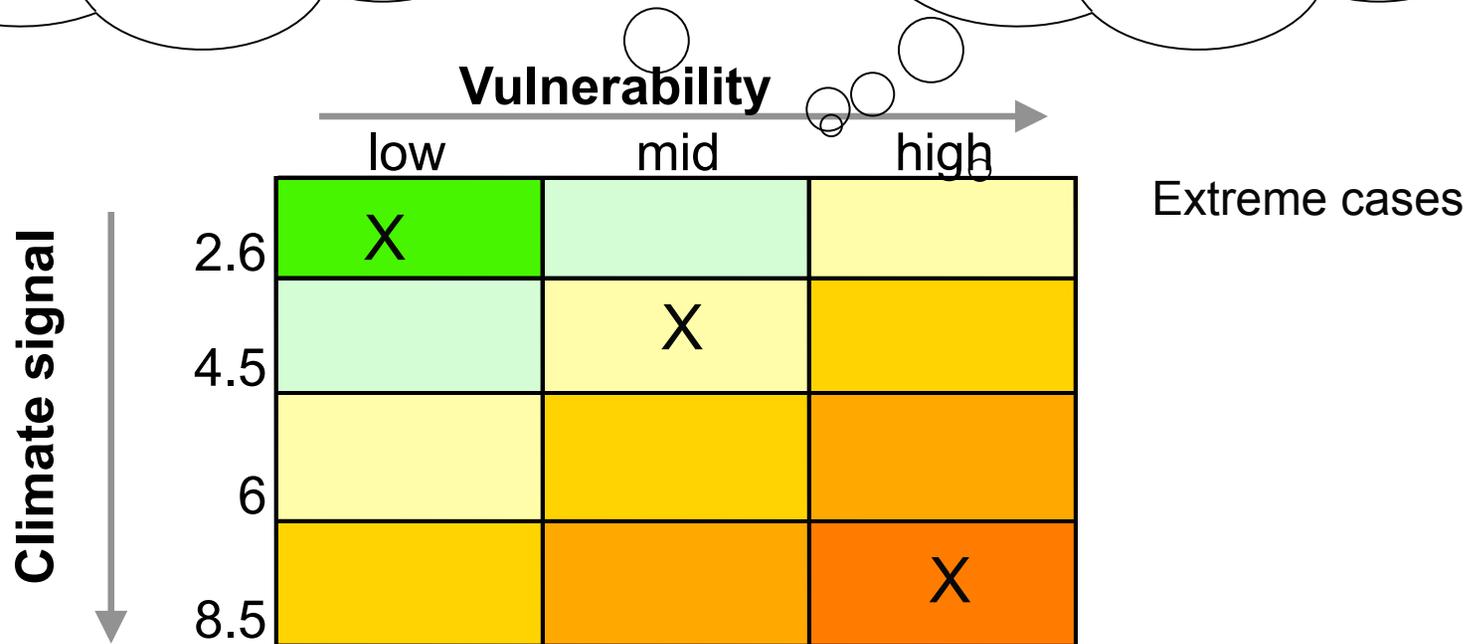| Climate signal	low	mid	high	
2.6		X		Extreme cases
4.5		X		Effect of mitigation
6		X		
8.5		X		

IMPACT = Exposure + Vulnerability!

high ← low

Suggested use of RCPs in IAV research

How many columns: 2, 3?

Prefered model runs (like Climate modelling community)

Vulnerability

	low	mid	high
2.6			
4.5	X	X	X
6			
8.5			

Climate signal

Extreme cases
Effect of mitigation
Effect of vulnerability/
    adaptation

IMPACT = Exposure + Vulnerability!

Suggested use of RCPs in IAV research

How many columns: 2, 3?
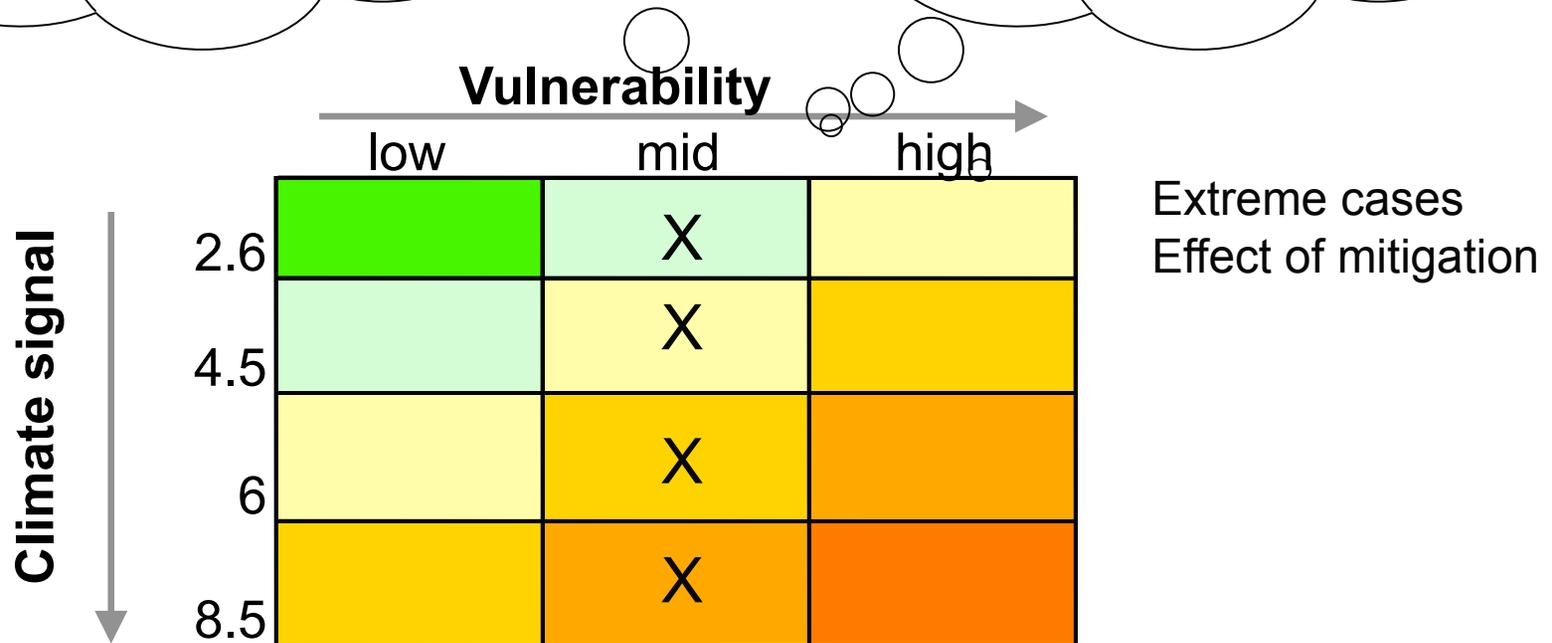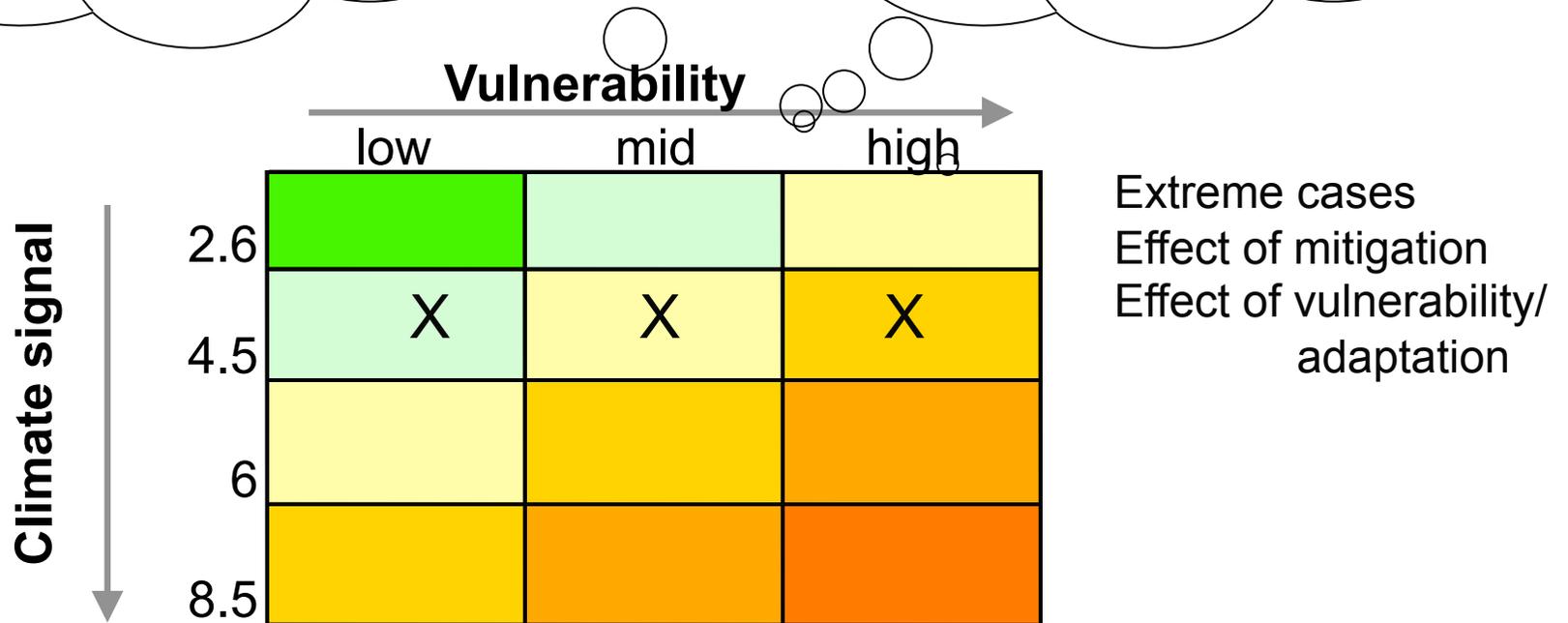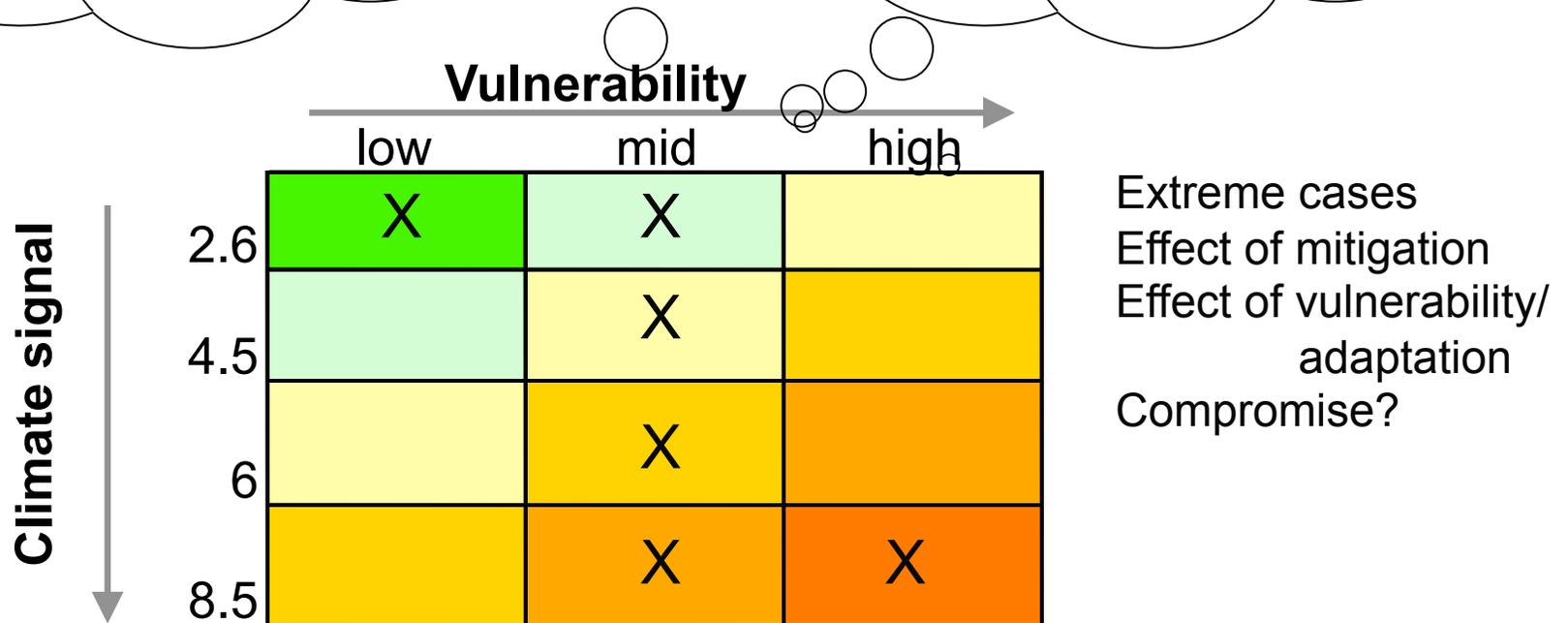
Prefered model runs (like Climate modelling community)

Vulnerability

	low	mid	high
2.6	X	X	
4.5		X	
6		X	
8.5		X	X

Climate signal

Extreme cases
Effect of mitigation
Effect of vulnerability/
adaptation
Compromise?

IMPACT = Exposure + Vulnerability!

high **low**

CC scenarios
Detlef van Vuuren – 20 January 2009
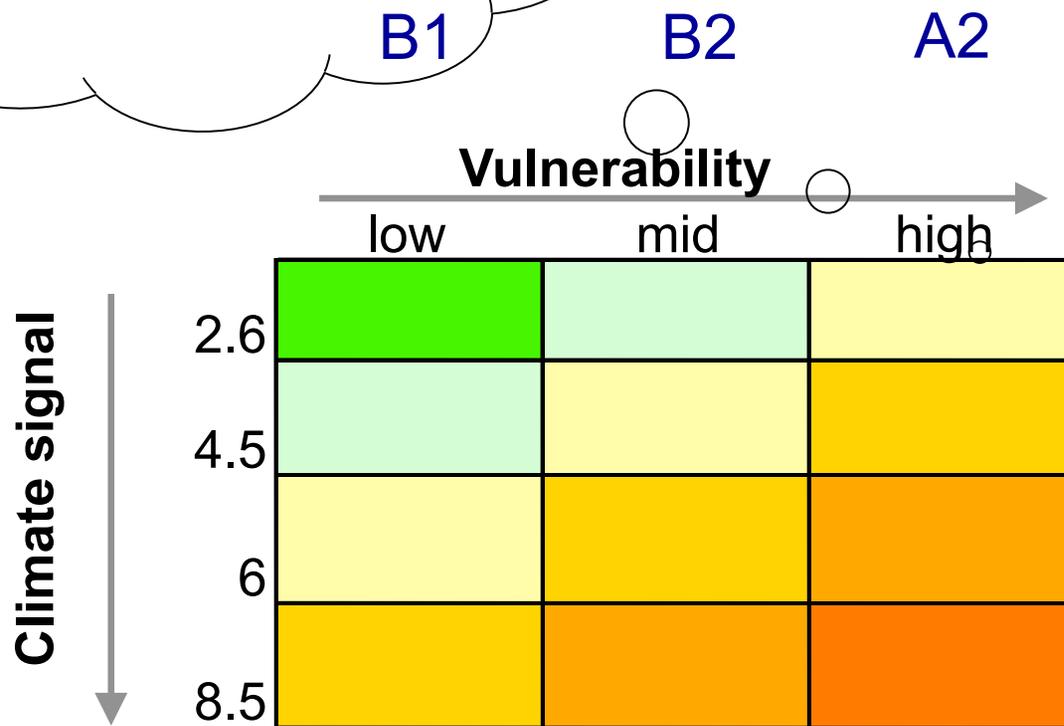
Suggested use of RCPs in IAV research

Elaborating other factors
determining vulnerability:
Maybe use storylines?

B1   B2   A2

Vulnerability

low   mid   high

Climate signal

2.6

4.5

6

8.5

IMPACT = Exposure + Vulnerability!

high ⟵ low

Suggested use of RCPs in IAV research

Vulnerability

	low	mid	high
2.6	Low population; High GDP; high tech; good governance	Intermediate assumptions	High population; Low GDP; low tech;
4.5			
6			
8.5			

Climate signal

IMPACT = Climate + Vulnerability!

high ⟵ low

C scenarios

Detlef van Vuuren – 20 January 2009

Use of even richer storylines

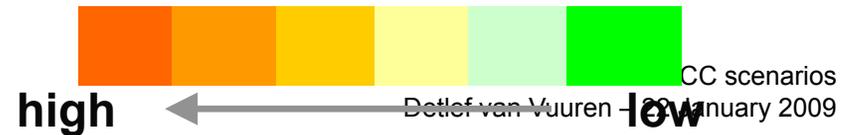|	*SRES*	*Millennium Ecosystem Assessment*	*GEO3/GEO4*	*Global Scenario Group*
Economic optimism	A1		Markets first	Market forces
Reformed markets	[A1T/A1-policy]	Global Orchestration	Policy first	Policy reform
Sustainable development	B1	Technogarden	Sustainability first	New sustainability Paradigm
Regional sustainability	[B2]	Adapting mosaic		Eco-communalism
Regional competition	A2	Order from Strenght	Security first	Barbarization
Business-as-usual	[B2]			

Suggested use of RCPs in I...

Less likely cases and definition of storyline also RCP dependent

For 8.5 scenario:
High energy use (coal use)
More likely with high population,
Medium population, if energy technology development is low
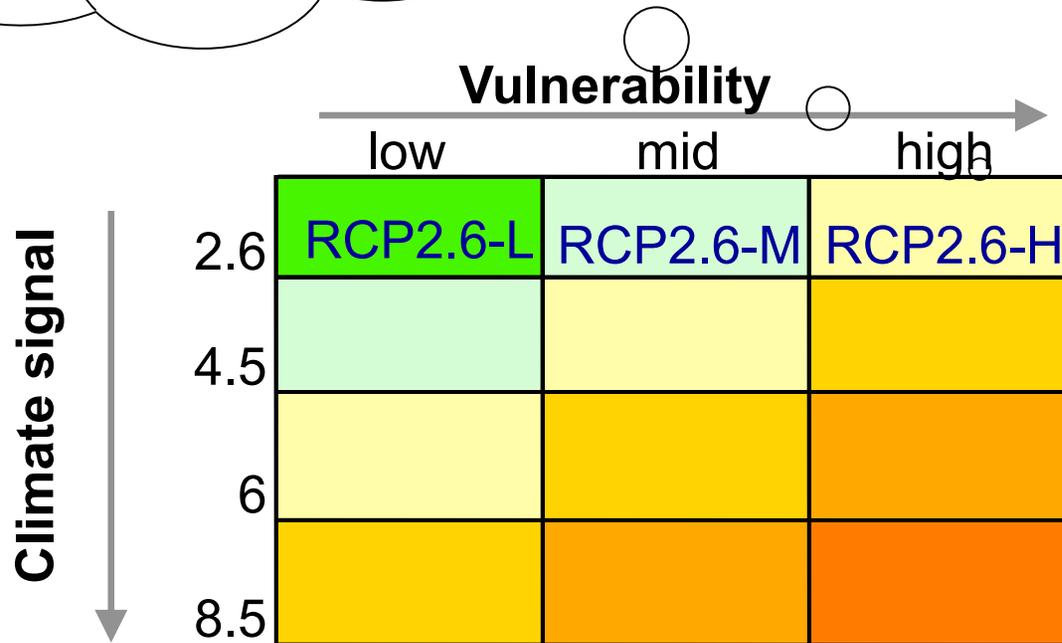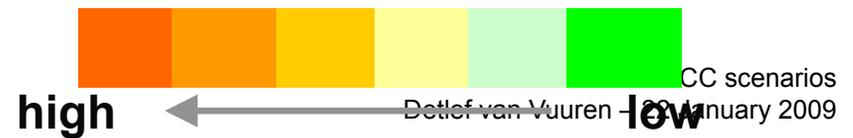In both cases, RCP8.5 more logically linked with high vulnerable world?

Vulnerability

| | low | mid | high |

Climate signal

2.6

4.5

6

8.5

IMPACT = Exposure + Vulnerability!

high ← low

CC scenarios
Detlef van Vuuren – 28 January 2009
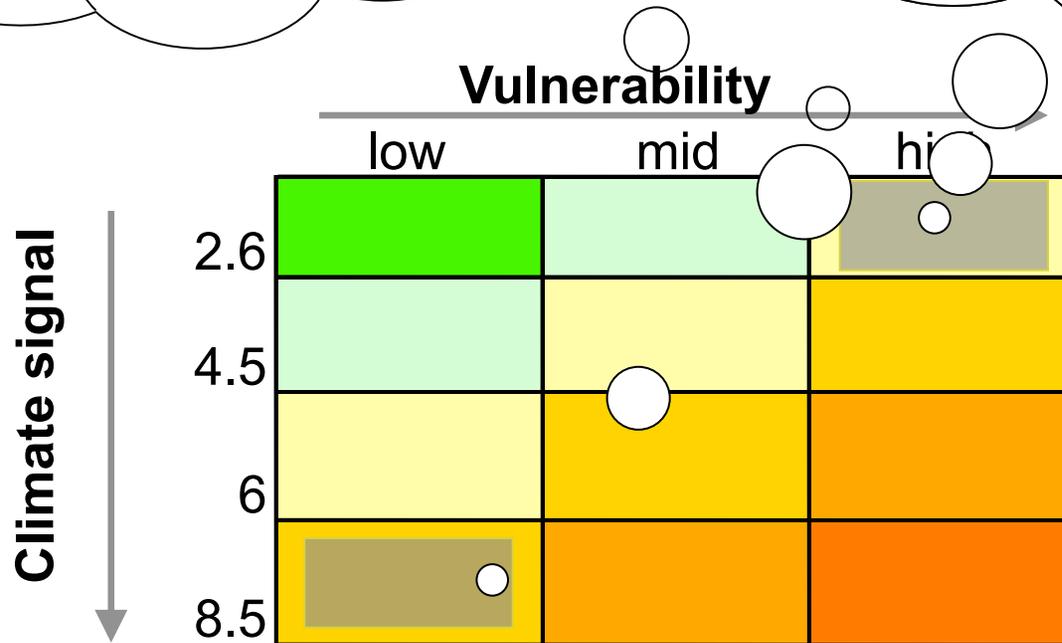
Suggested use of RCPs in IAV research

Use taxonomy for naming

Vulnerability

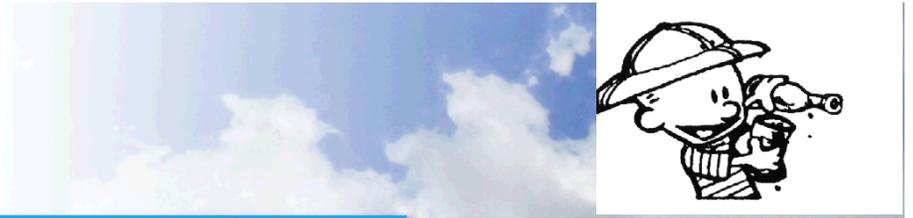|	low	mid	high
2.6	RCP2.6-L	RCP2.6-M	RCP2.6-H
4.5			
6			
8.5			

Climate signal

**IMPACT = Exposure + Vulnerability!**

high ← low

Lots of open questions:

➢ Does matrix help?
➢ Taxonomy versus selection of marker "storylines"
➢ Selection of priority cases
➢ Naming of scenarios
➢ Use of storyline elements others than economy/population
➢ Possibly use information on unlikely cases

➢ → Be careful not to design the ultimate set of scenarios that can do everything - and should be used be everybody.
> ➢ Not possible!
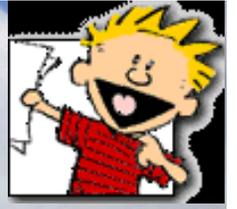> ➢ Not useful!

Netherlands Environmental Assessment Agency
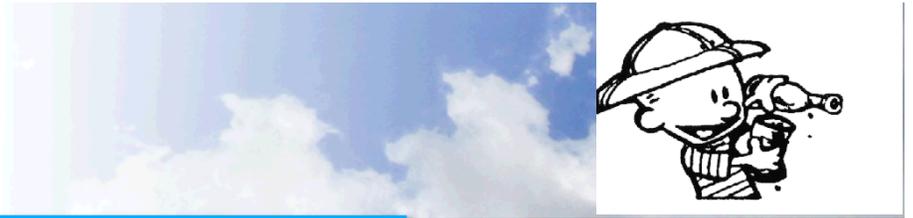
For mitigation

➢Needs a third axis?

➢Mitigation community probably want to look into:

  ➢Feasability of RCPs as function of global cooperation

  ➢Feasability of RCPs as function of technology assumptions

  ➢…

What have we learned?

- Clearly important to continue from RCP process.
- Socio-economic assumptions and RCPs are not hardwired
- Suggestion for how to develop a set of socio-economic assumptions and RCPs that together provide a relevant basis for impact research
- Discussion on how to fill in the matrix (use 2/3 "marker" socio-economic sets across all RCPs; possible small adaptations for specific RCP levels?)
- Consideration of likelihood of various matrix elements
- Need for further research in exploring relationships between storyline assumptions and RCPs! The current literature was not done specifically in that context…. Needs to be a community exercise.

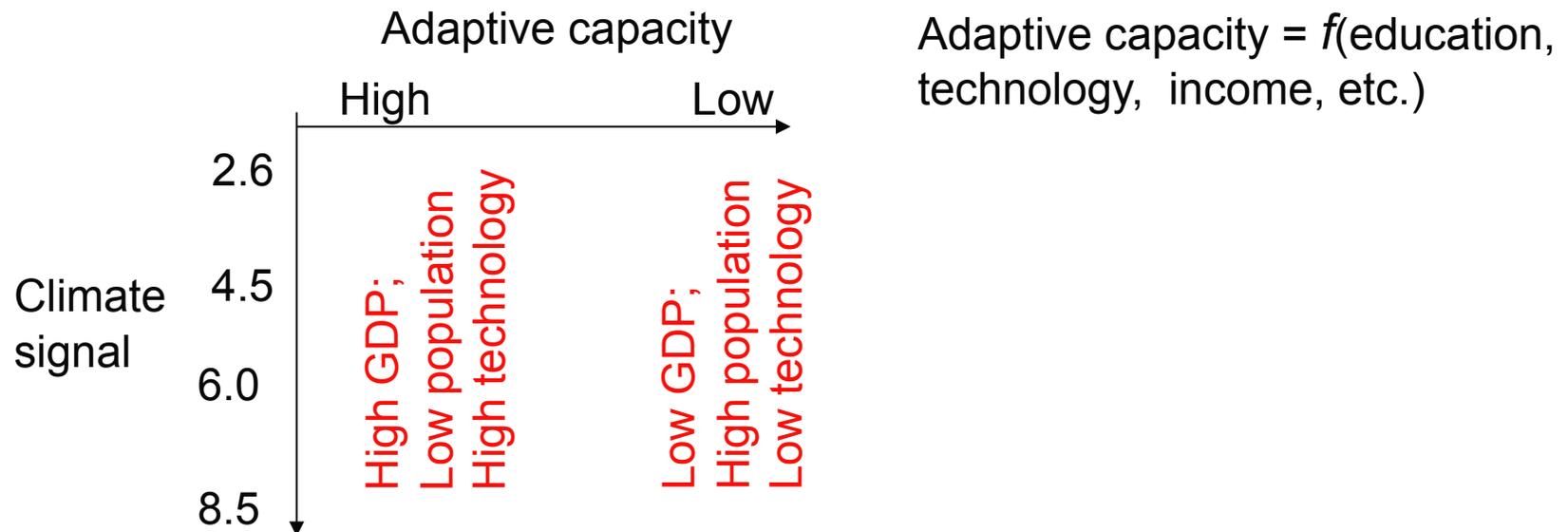Netherlands Environmental Assessment Agency

➢Thank you for your attention!

Suggested use of RCPs in climate research

➢ If the intention of the impact analysis is to map out all possibilities → analysis shows that it is safe to assume decoupling

Adaptive capacity

High   Low

Adaptive capacity = *f*(education, technology, income, etc.)

2.6

Climate   4.5
signal

6.0

8.5

High GDP;
Low population
High technology

Low GDP;
High population
Low technology

➢ Matrix with 8 elements; only 2 sets of GDP/population etc.
➢ Could further reduce (e.g. High climate/low AC; Low climate/ high AC)
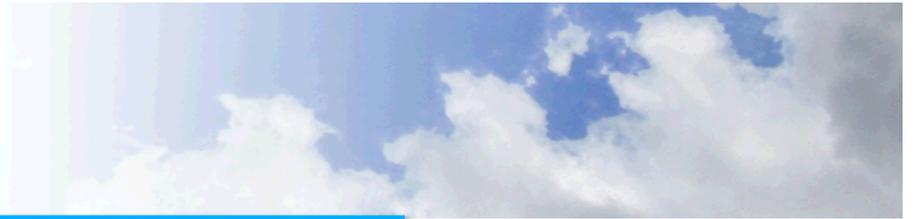
- The logic of most IAM analysis, as I understand it, is to select a reference or baseline case and then to conduct analysis of different mitigation possibilities (primarily technologies, but increasingly some types of policies) off of that. There are very good reasons for doing it this way--mostly a ceteris paribus approach that allows you to vary technology and policy to understand the implications of those for mitigation. But for IAV (and many other audiences), their interest is in varying the broader socio-economic conditions that are NOT changed in the different runs. Their assumption about the variation from low to high RF is that is is primarily a function of different population, economic, institutional scenarios, not just technologies and policies. We need to get everyone on the same page about this, and that part of what we are talking about is running new (or using existing)reference cases that systematically vary these broader socio-economic assumptions.
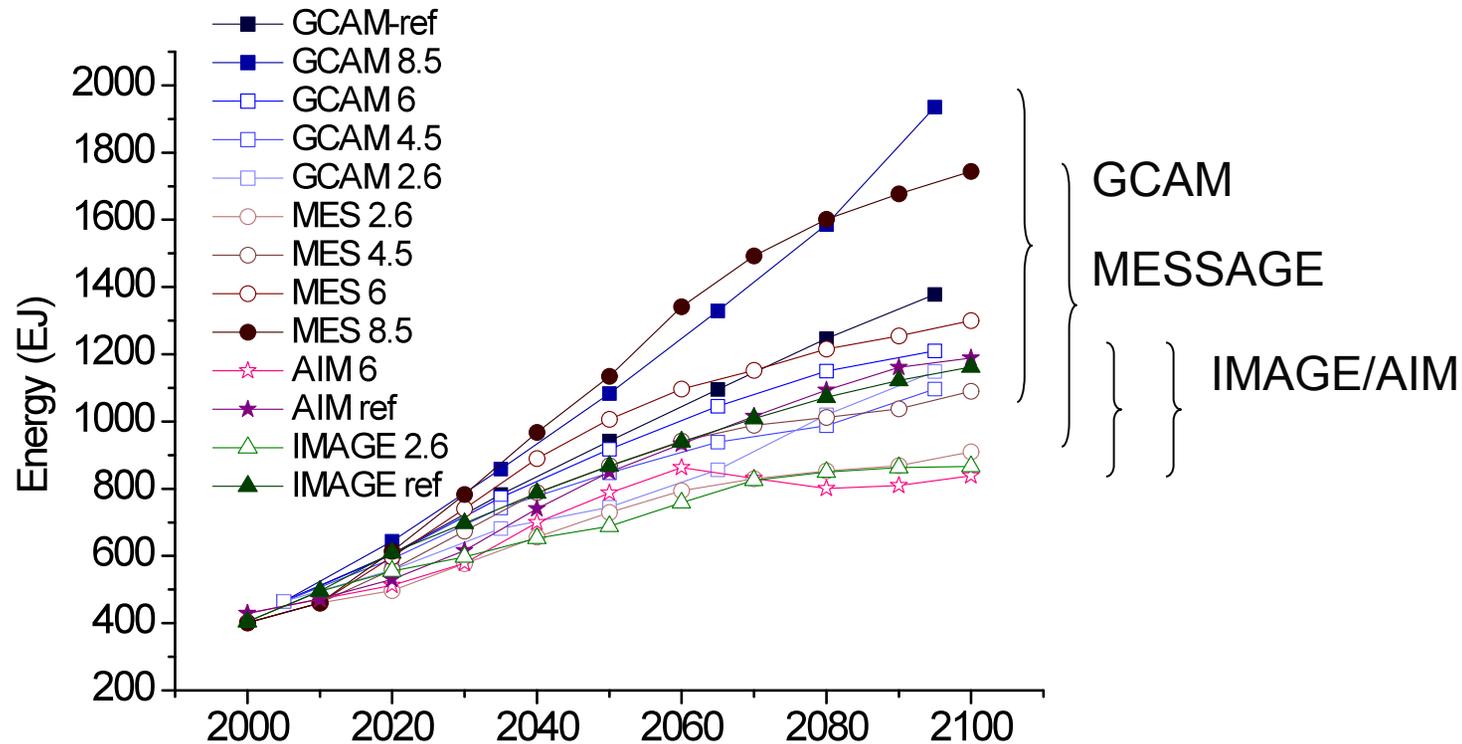
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Primary energy (EMF-22)
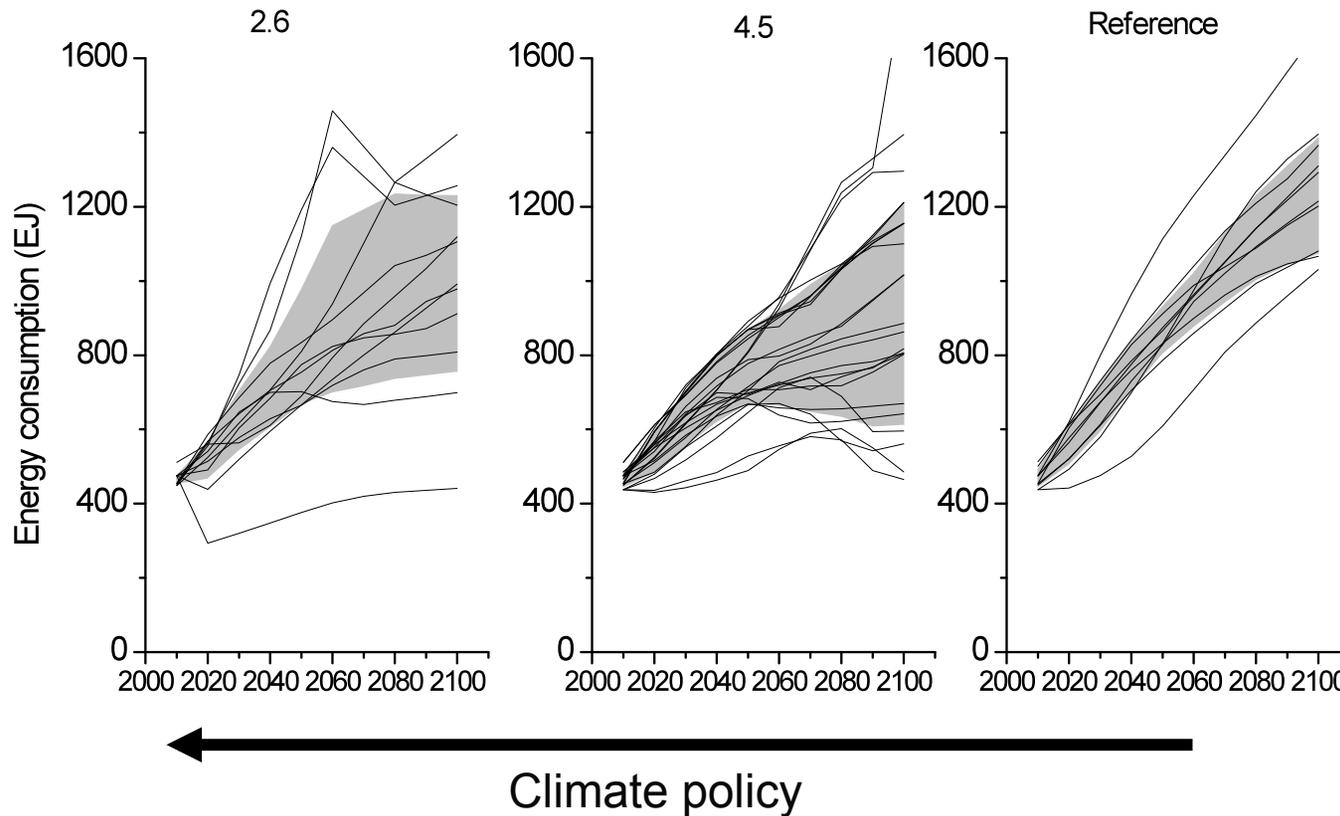
In the EMF-22 data, energy consumption is somewhat lower in the mitigation scenarios than in the reference cases. But no clear difference between 2.6 /4.5

Primary energy (consistent sets from RCP teams)

Position is determined by scenario assumptions and RF level: most baselines high; most 2.6 scenarios on the low side.