Planbureau voor de Leefomgeving

Detlef van Vuuren/Keywan Riahi

Probabilistic scenario analysis

Key guiding questions

As input to climate research:

- Is it important to assign probabilities to socio-economic scenarios?
- Is it possible to assign probabilities to scenarios?
- Is it possible to indicate the boundaries of emissions / forcing scenarios?

Why do we have scenarios in the first place?:

- Exploring policy decisions
- Exploring uncertainties

Different kinds of uncertainty

Socio-economic Uncertainty

System response depends on humans

Requires understanding likelihoods of human behavior, values, policy interventions, etc..

Uncertainty representation difficult since the future might follow different rules as the past

Geophysical Uncertainty

Well defined system (follows physical laws) Historical relationship hold also for the future

Formal uncertainty distributions can be derived from parameter (combinations) that describe history

Different kinds of uncertainty

- Ontic uncertainty (variability)
- Epistemic uncertainty (limited knowledge)
  - Probabilities (Baysian)
  - Conditional statements
  - Consious not knowing
  - Ignorance
- Disagreement among experts
- Reflexive uncertainty

Annual economic growth?

Energy resources
High growth, if globalisation

Actor interaction

Miracle technology

Technology development

Learning from scenarios

Two main scenario methods (handling uncertainty in different ways)

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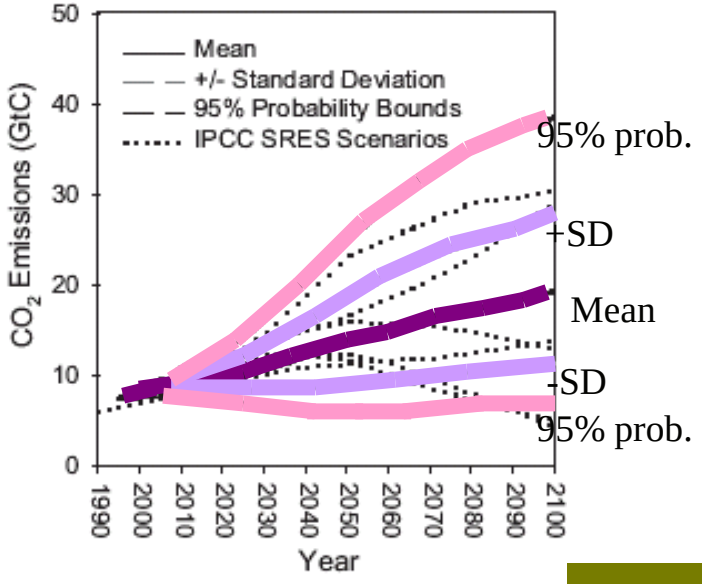
Probabilistic
Scenario development

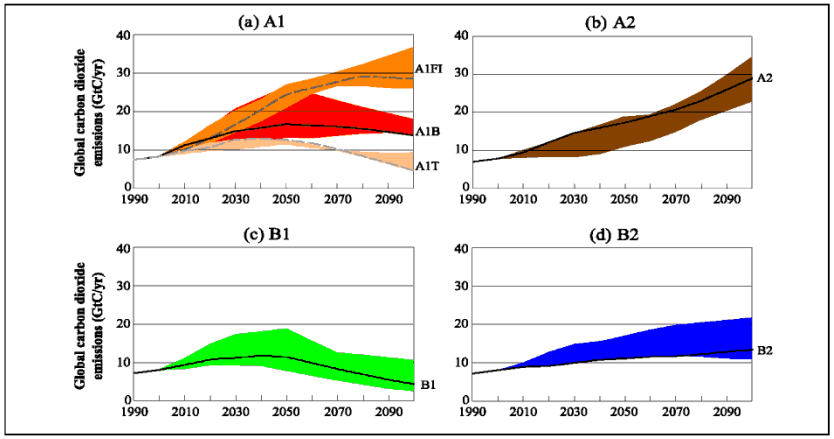
Estimate best-guess and uncertainties of all relevant parameter in model; gives best-guess outcome + uncertainty range



Webster et al. (2001)

A set of storyline based scenarios

Develop storylines around major uncertainties – and use storyline to estimate consistent values for other parameters. Explore the future



Nakicenovic et al (2000)

Two main scenario methods (handling uncertainty in different ways)

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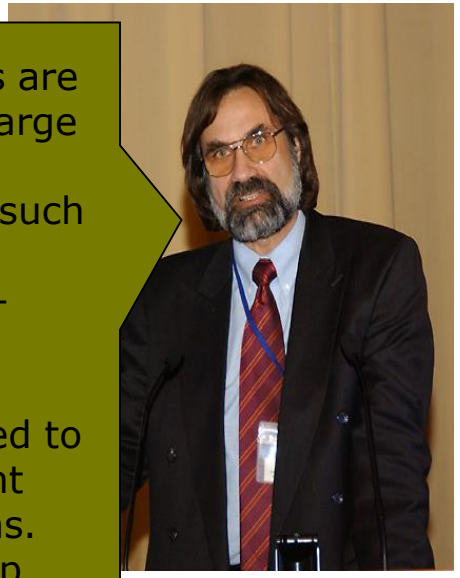
Probabilistic
Scenario development

A set of
storyline based
scenarios

There is no value in providing users " just a set of scenarios" . It is the task of experts to determine what are the most likely assumptions – and therefore the most likely outcomes. Scientists deal with uncertainty by indicating the most likely outcome – and an uncertainty range. In the end, the question is not whether a judgment about likelihood is needed but rather when and by whom the judgment is made

"Future emissions are the product of a large range of very uncertain factors such as population, technology, socio-economic development etc. Storylines are used to define a consistent set of assumptions. Scenarios can help exploring some of these futures; they are not predictions."



Two main scenario methods (handling uncertainty in different ways)

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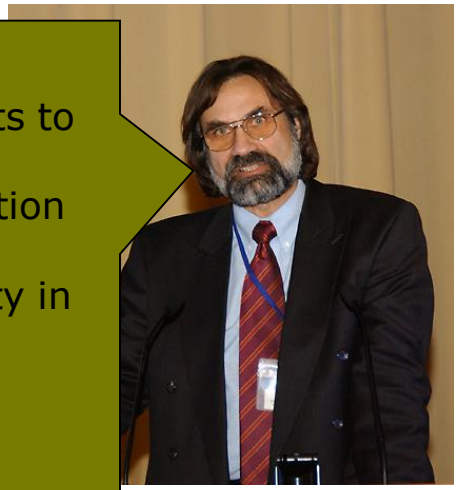
Probabilistic
Scenario development

A set of
storyline based
scenarios

Decision-makers need to address risks. Risks are determined by impacts AND probability. For instance, information that an asteroid can destroy the earth can only be properly assessed, if one knows that chances are 1 in a billion.

"The probabilistic approach only attempts to assign subjective probabilities in a situation of ignorance forms a dismissal of uncertainty in favor of spuriously constructed expert opinion".



Two main scenario methods (handling uncertainty in different ways)

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Probabilistic Scenario development

- Good in addressing ontic uncertainty and epistemic uncertainty that can be expressed in statistical terms
- Uses scientific rigidity of the model
- Users can easily interpret results
- In policy-studies one can focus on median case

But:

- How to deal with unknown pdfs?
- How to deal with choices
- How good is the model?
- What is not modelled?

A set of storyline based scenarios

- Good in addressing epistemic uncertainty; especially the more conditional statements
- Strong in exploring, allows creativity, flexible in including non-modelled elements
- Necessary if major uncertainties with unknown trends and consequences.

But:

- More difficult to use in policy analysis
- Risk of becoming fairy-tales

Implication

- Is it important to assign probabilities to socio-economic scenarios?
  - Would help certain applications…
- Is it possible to assign probabilities to scenarios?
  - Mmm…. How to assign probabilities to key uncertainties such as the emergence of stringent climate policy?

Much easier if we can do this conditionally… if there is climate policy….

Conditional probabilistic assessment

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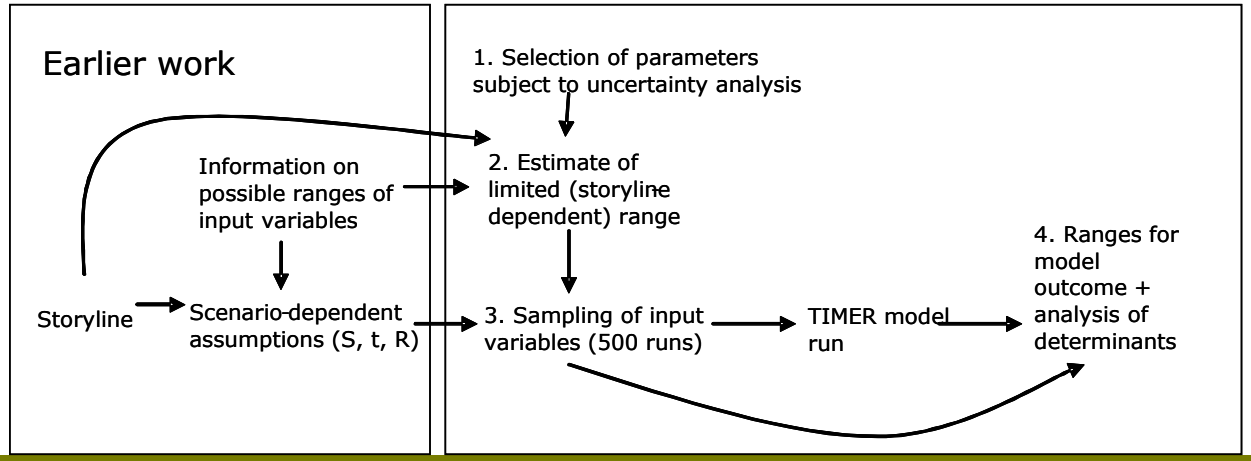
- Scenarios for the factors for which pdfs do not make sense (here scenario approach can add consistency in assumptions)
- But use pdf where it add rigidity

E.g. Van Vuuren et al., 2008 (based on discussions with O'Neill/Wigley)

- 1. Sensitivity analysis / expert elicitation to select most useful parameters to include
- 2. Estimate central values + ranges within IPCC SRES storylines
- 3. Monte-Carlo analysis
- 4. Determine ranges for outcome variables and identify contribution of input variables.



Monte-Carlo outcomes

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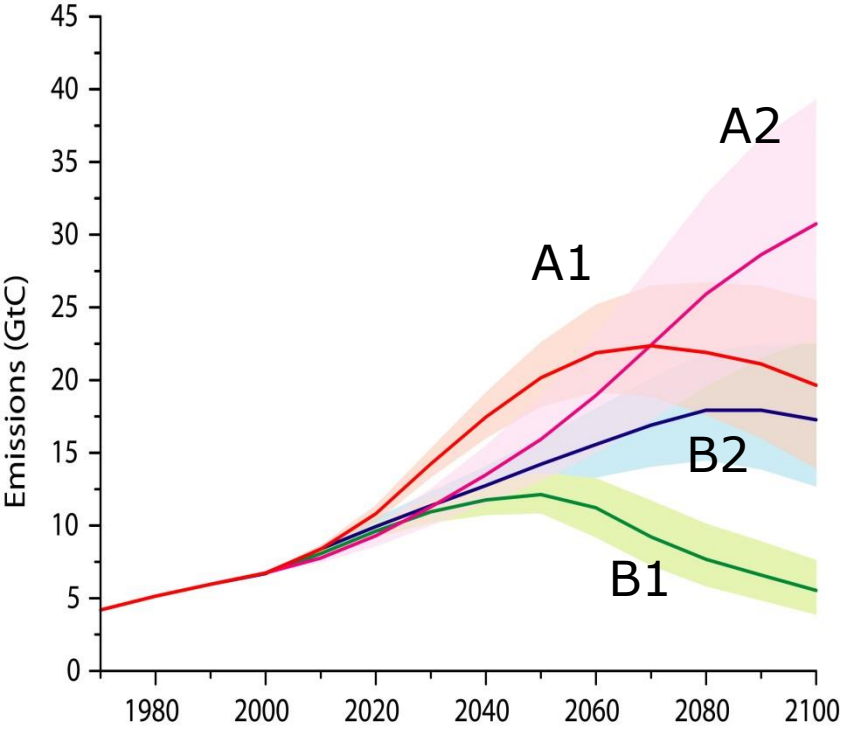
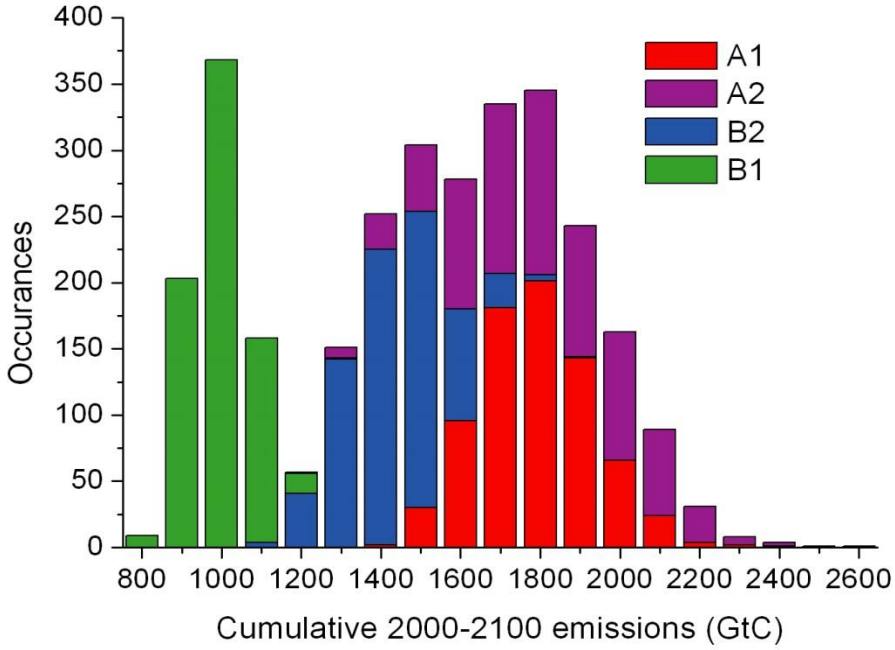
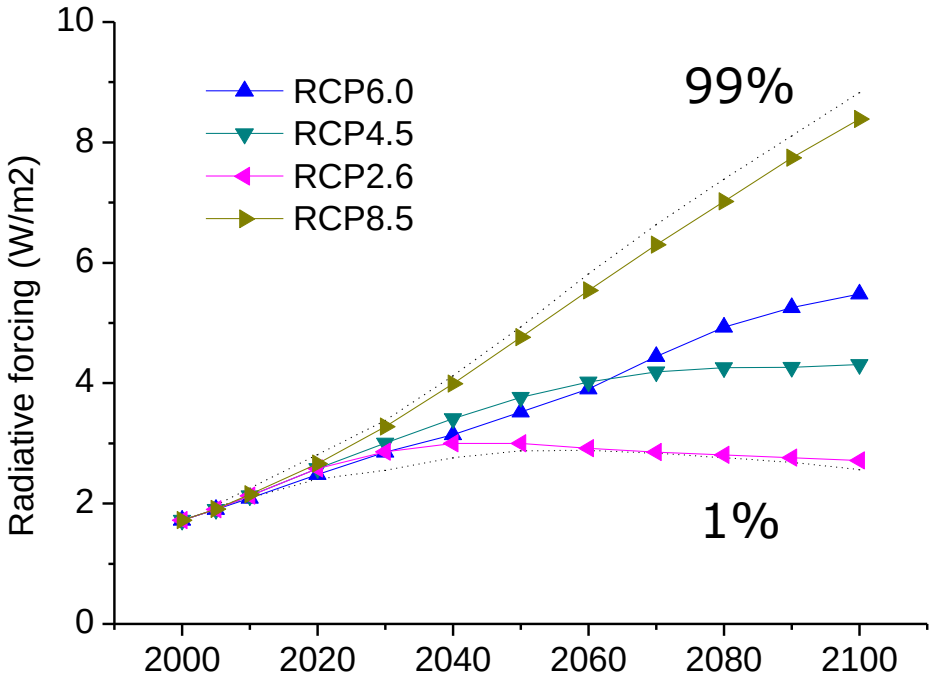




- 90% interval for each scenario shows a spread of 40% around the central value.
- Strong overlap A1, A2, B2
- Spread A2 particularly large

Boundary



>500 scenarios published in last 5 years by around 10 teams; consistent with total 1200 scenarios by larger #team

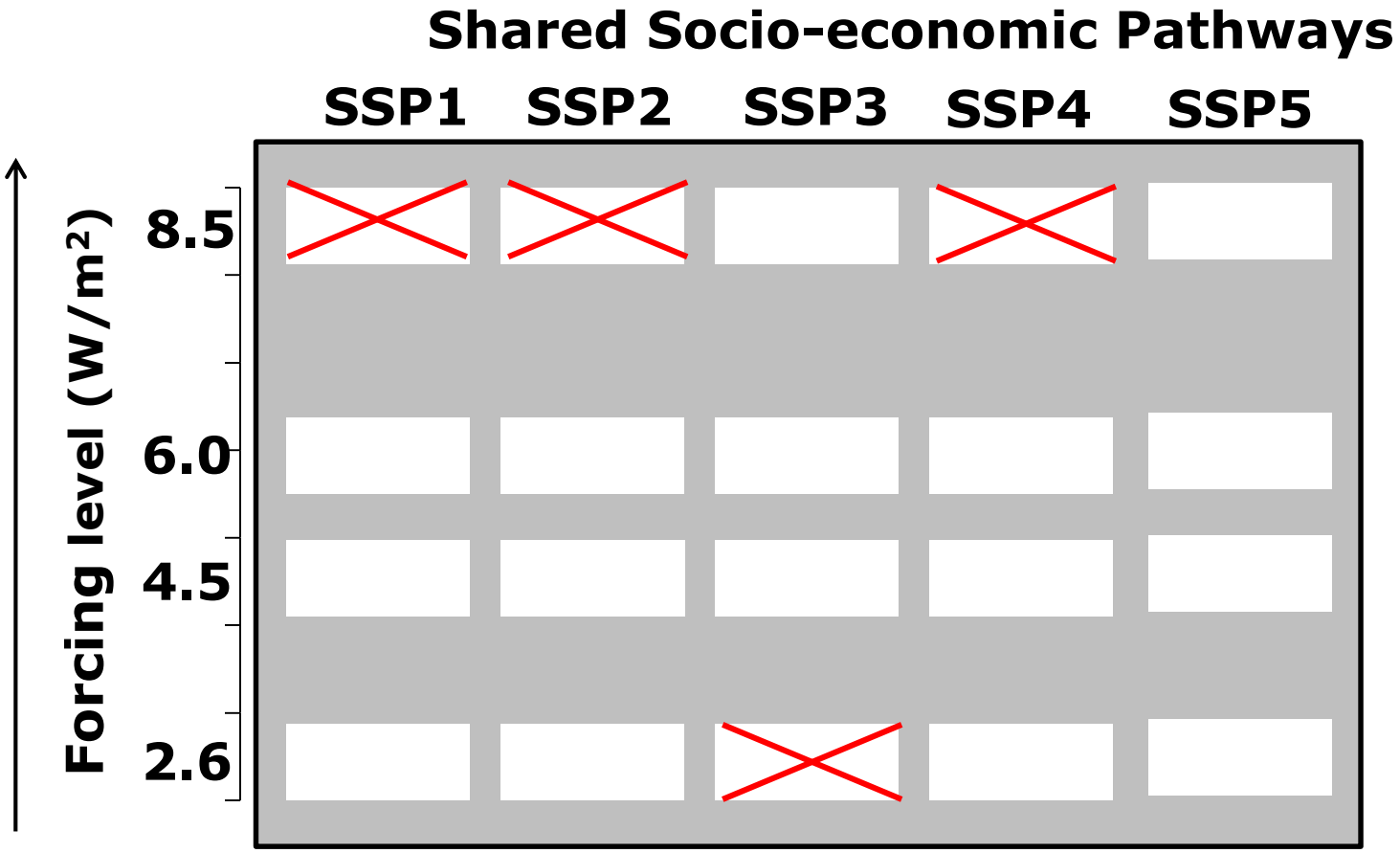
On high side: RCP8.5 – 12 billion people, transition towards coal.

On low side: RCP2.6 – emission peak in 2020, negative around 2070. Full participation in climate policy

Climate feedbacks obviously extend this range:

- Tundra; Amazon die back; wetland methane; ozone impact on vegetation

Can we bound the outcomes of future emissions?

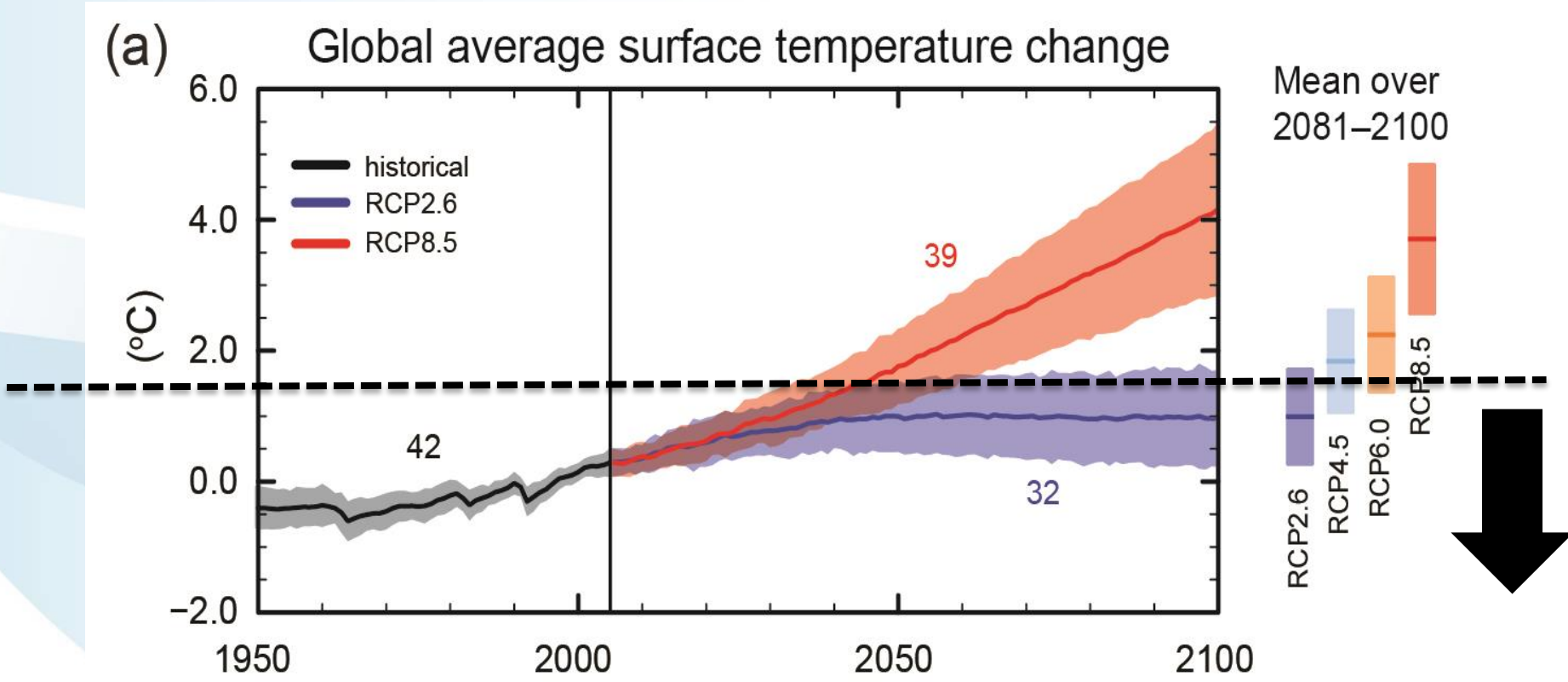


International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Recent studies using conditional uncertainty assessment

Temperature change - RCPs



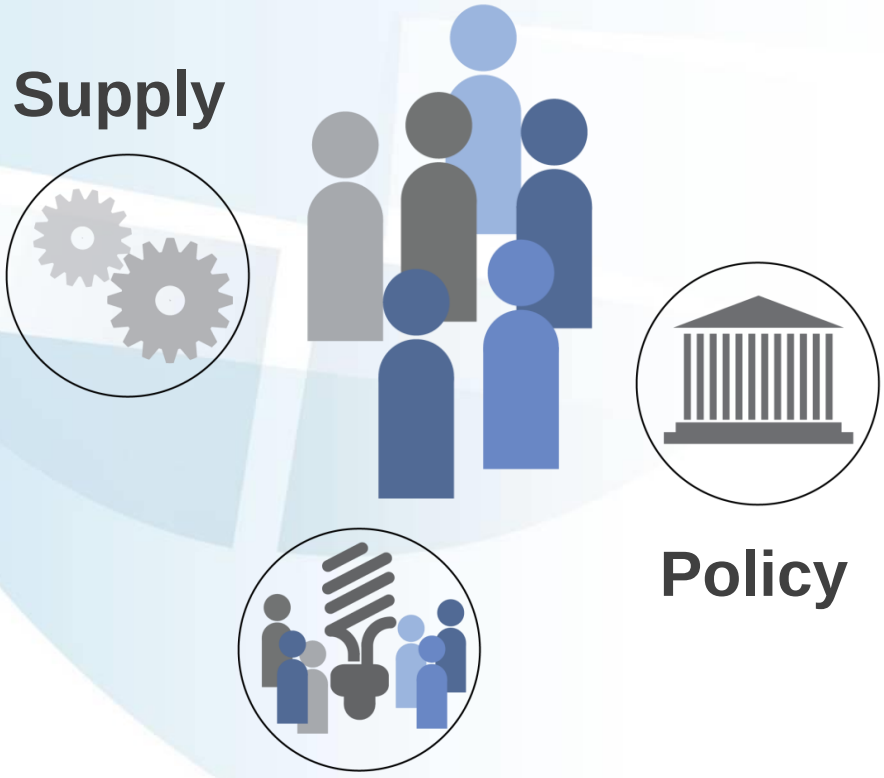
IPCC AR5, WGI

Focus on two types of recent studies

- Conditional (mitigation scenario) probabilities:
  - Probabilistic exploration of mitigation trade-offs
  - Under which conditions is it more/less likely to reach different targets?
    - Rogelj et al, 2013 (Nature)
    - Luderer et al, 2014 (ERL)
- Multi-model comparisons
  - Attempts to translate scenario results into mitigation risks (boundary conditions)

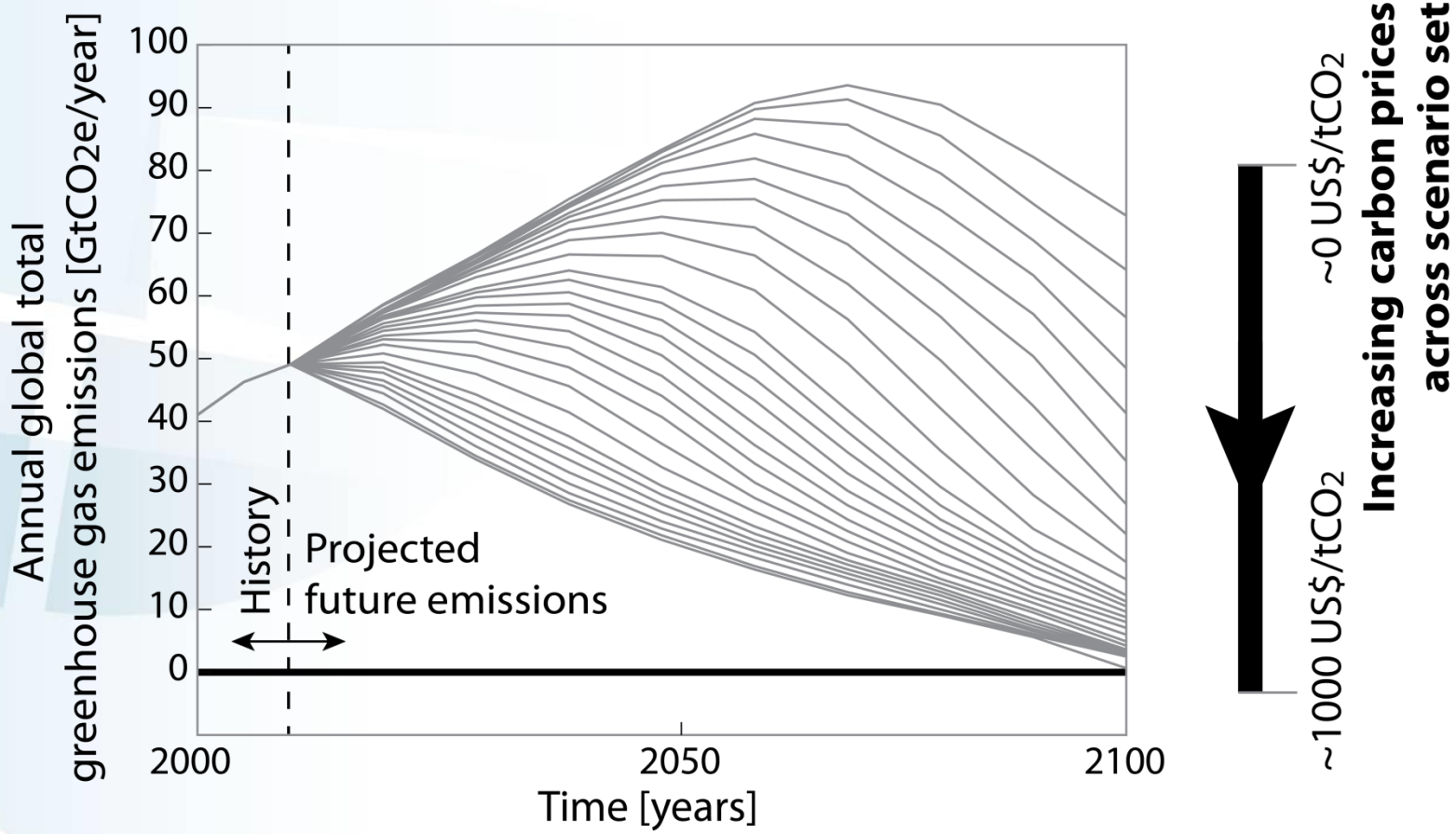
Integrating uncertainties

Conditions → Likelihood of 2C?



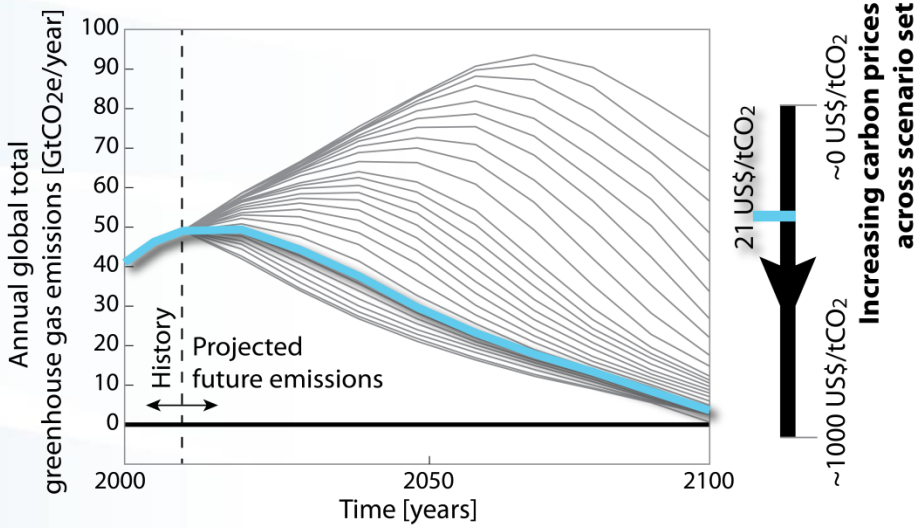
Rogelj et al, 2013

Methodology

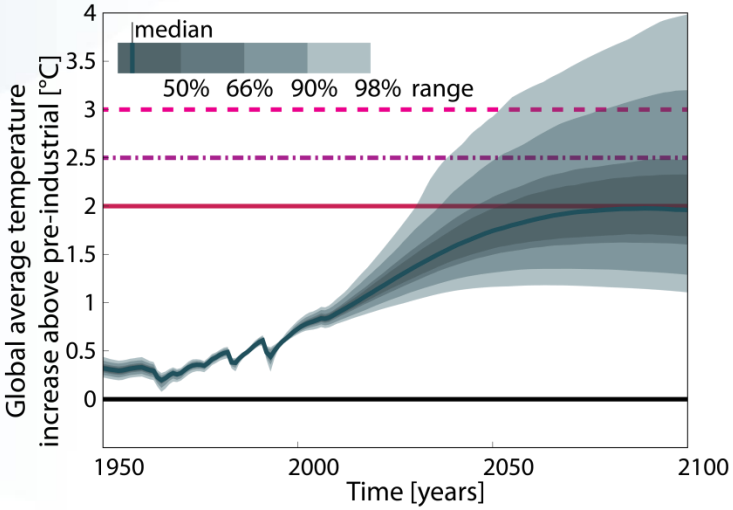


Rogelj et al, 2013

Methodology



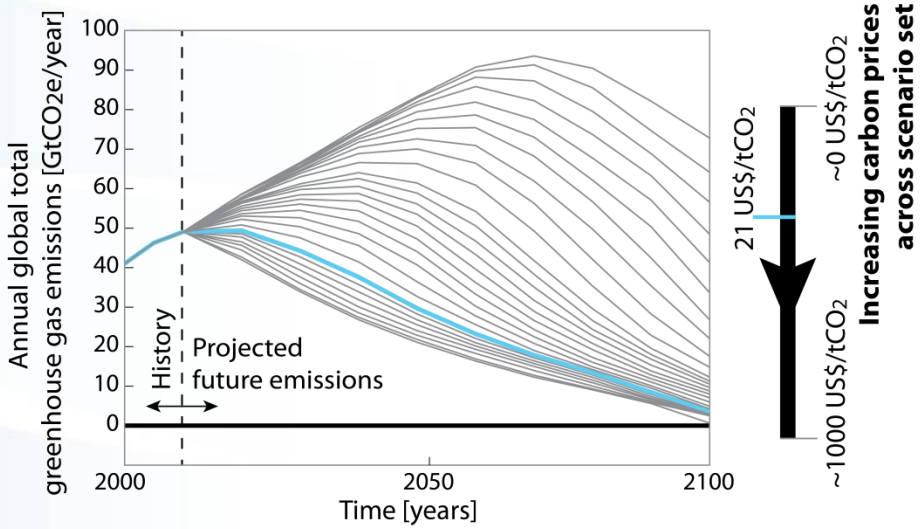
(MESSAGE)

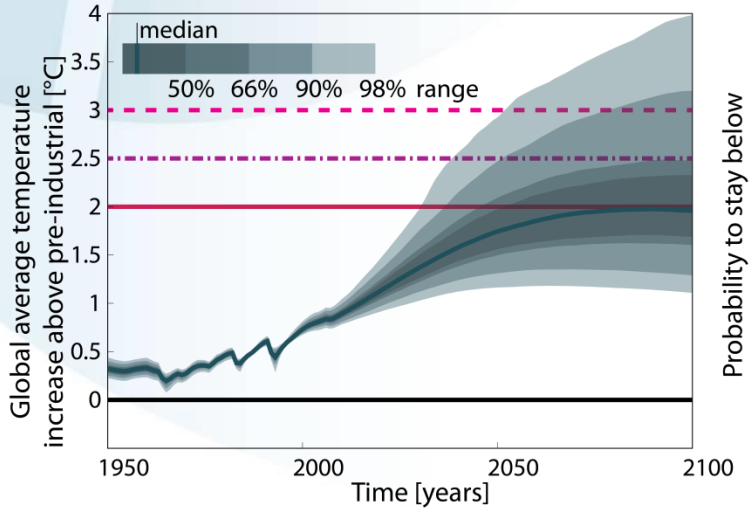


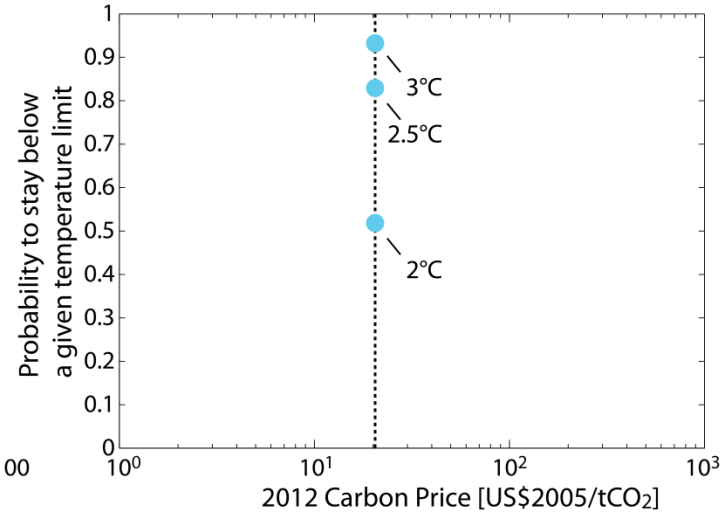
(MAGICC)

Rogelj et al, 2013

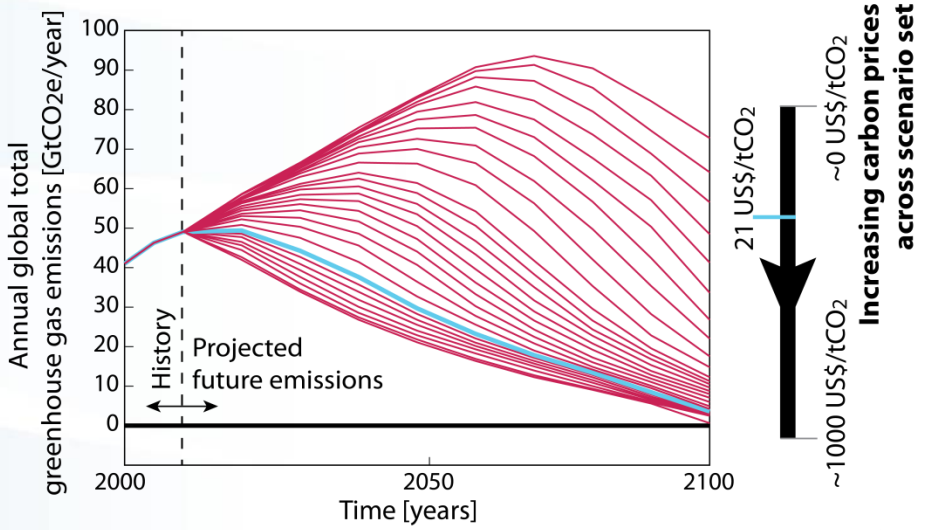
Methodology

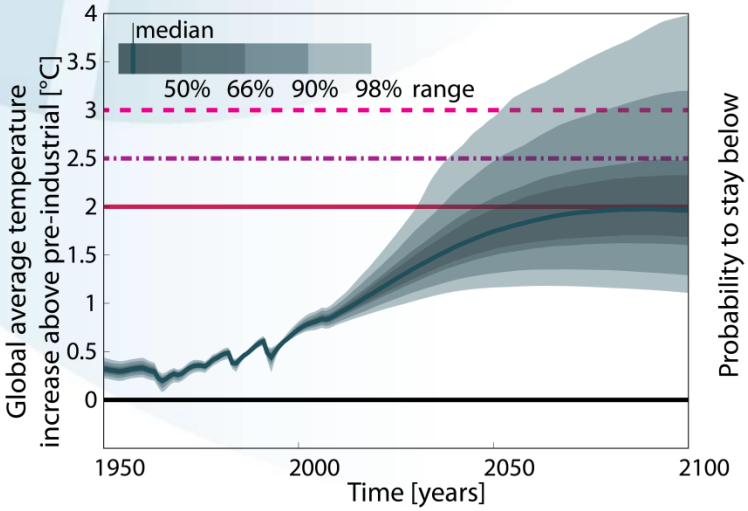


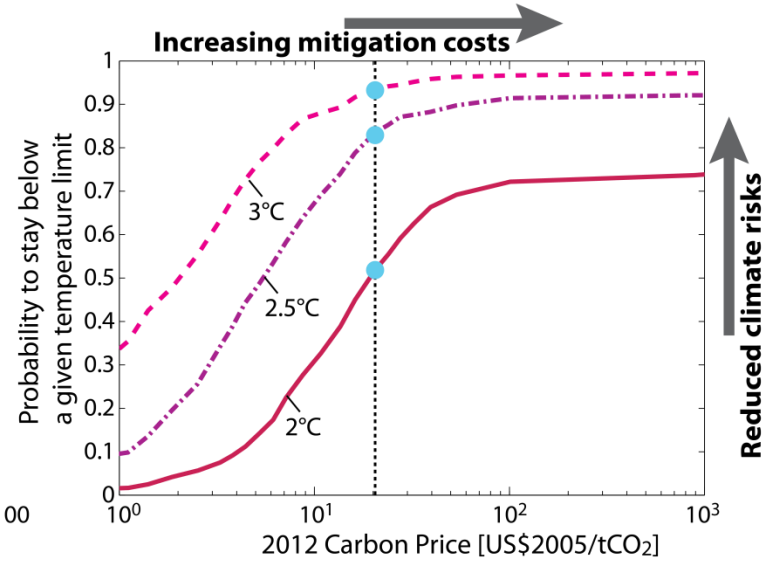




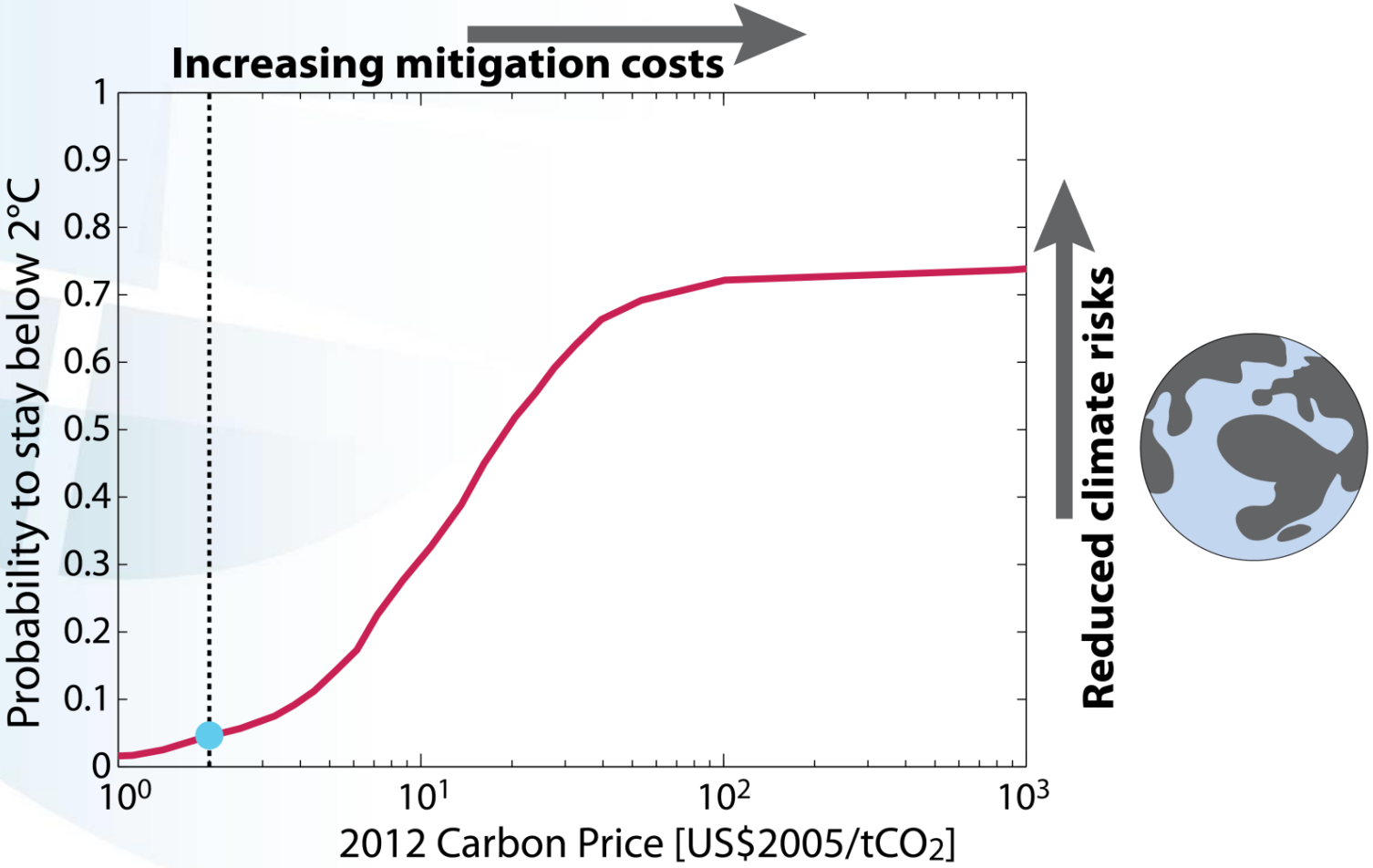
Methodology – cost-risk distributions





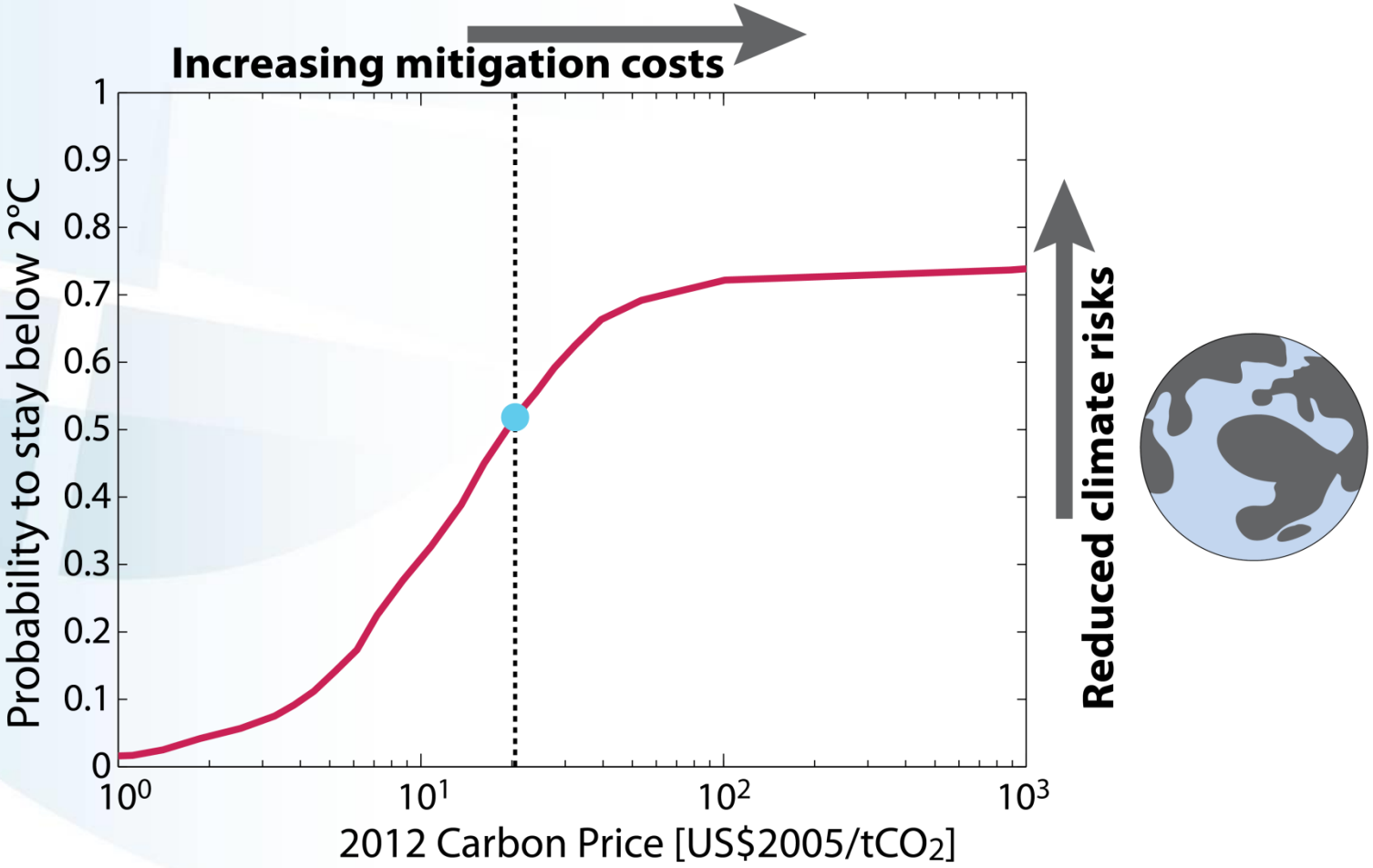


Cost-risk distributions



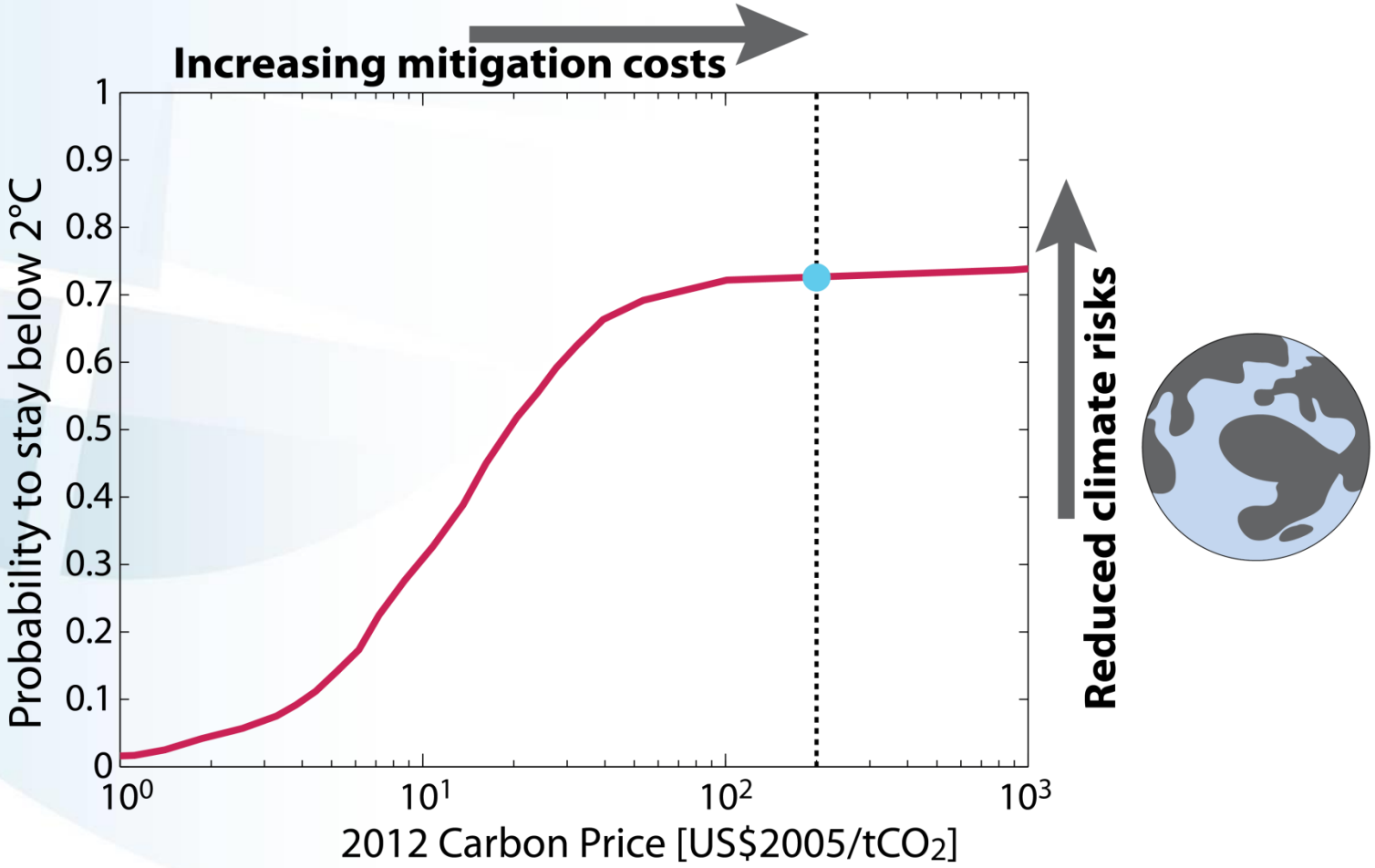
Rogelj et al, 2013

Cost-risk distributions



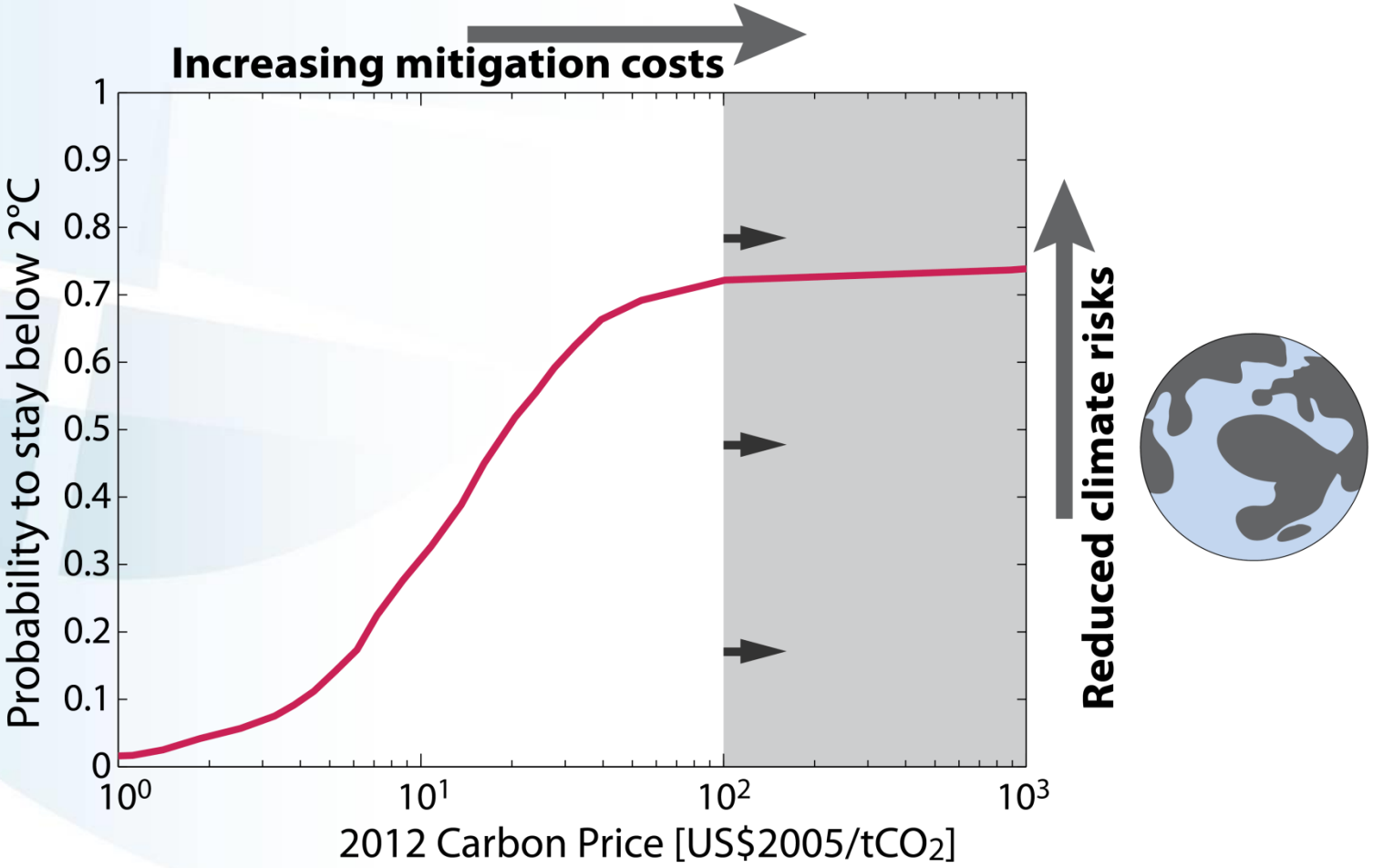
Rogelj et al, 2013

Cost-risk distributions



Rogelj et al, 2013

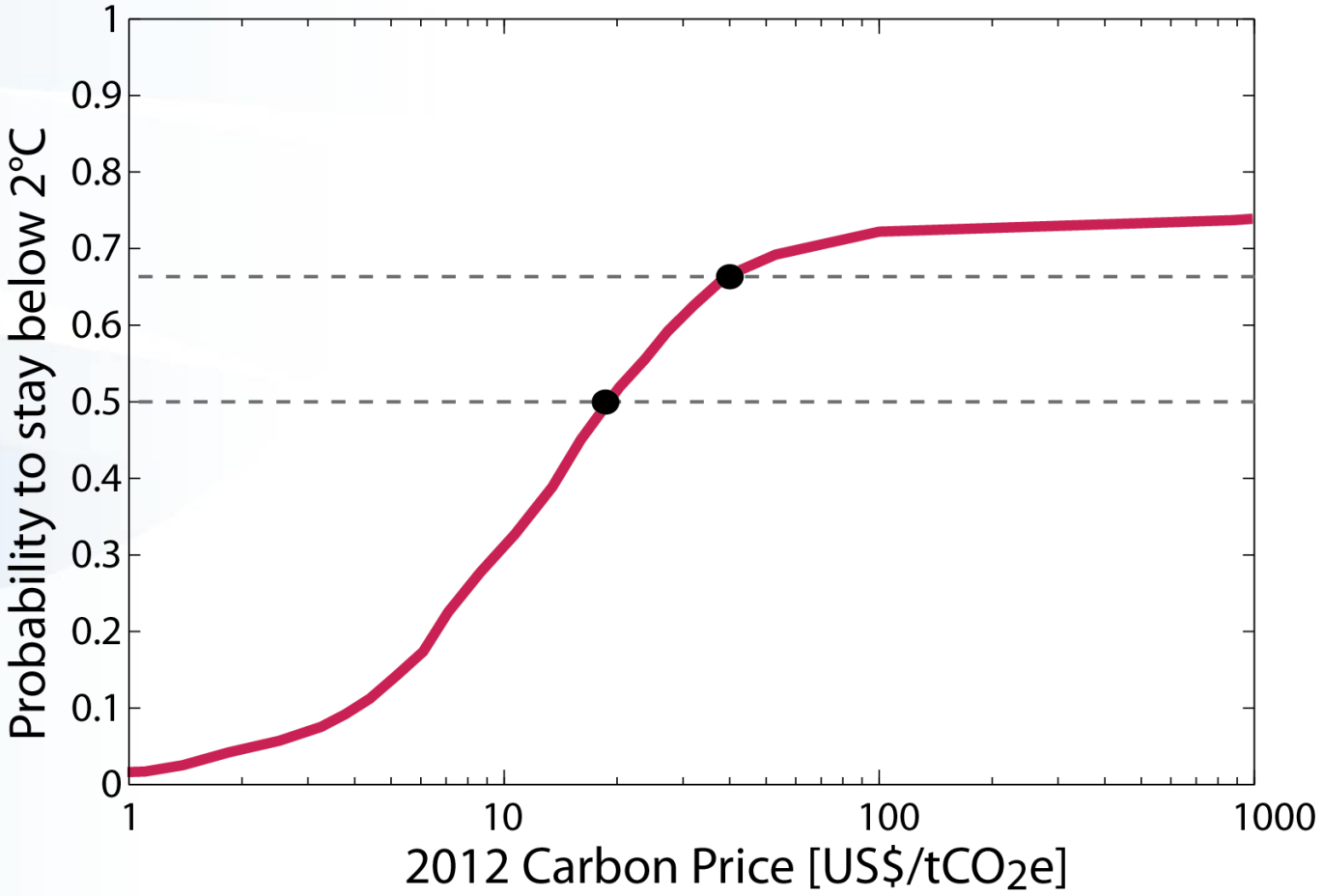
Cost-risk distributions



Rogelj et al, 2013

Cost-risk distributions

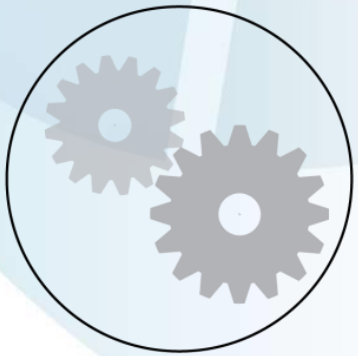
2°C

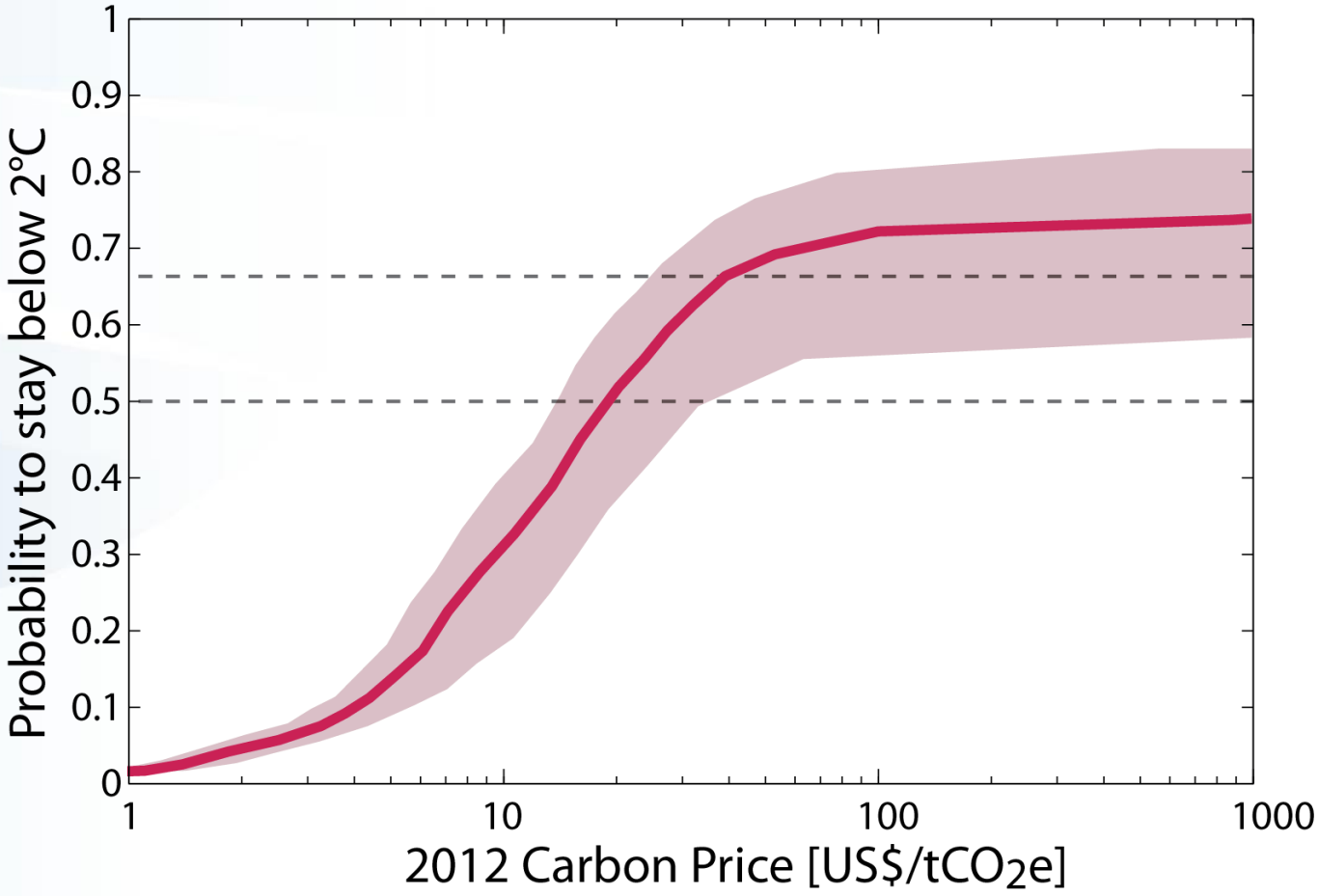


Rogelj et al, 2013

Technological uncertainties

2°C

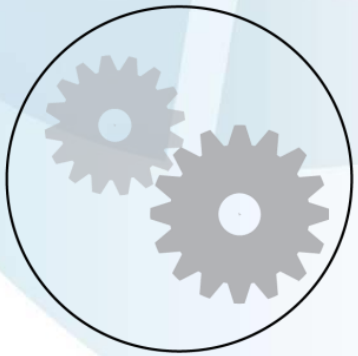


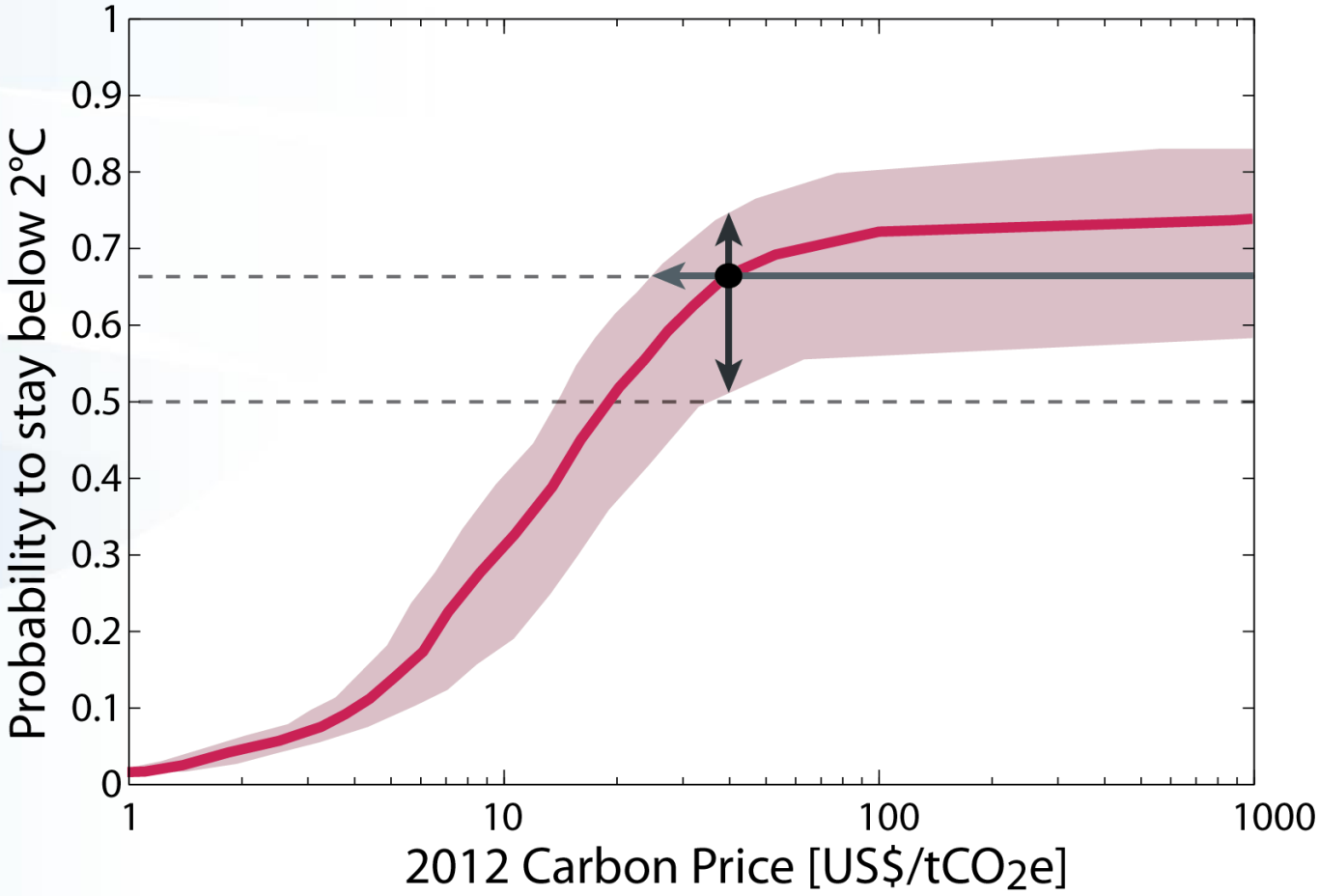


Rogelj et al, 2013

Technological uncertainties

2°C

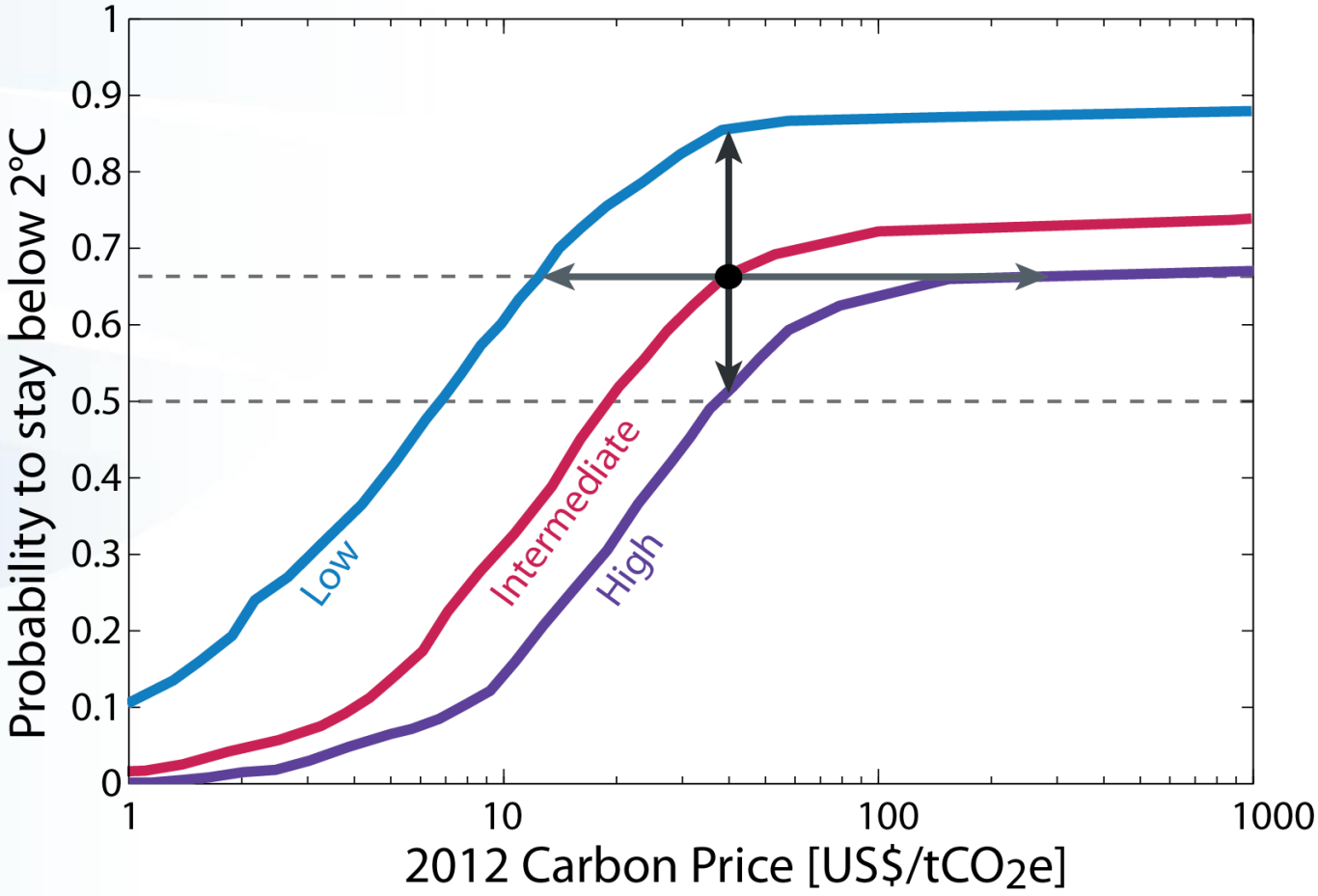




Rogelj et al, 2014

Energy demand uncertainties

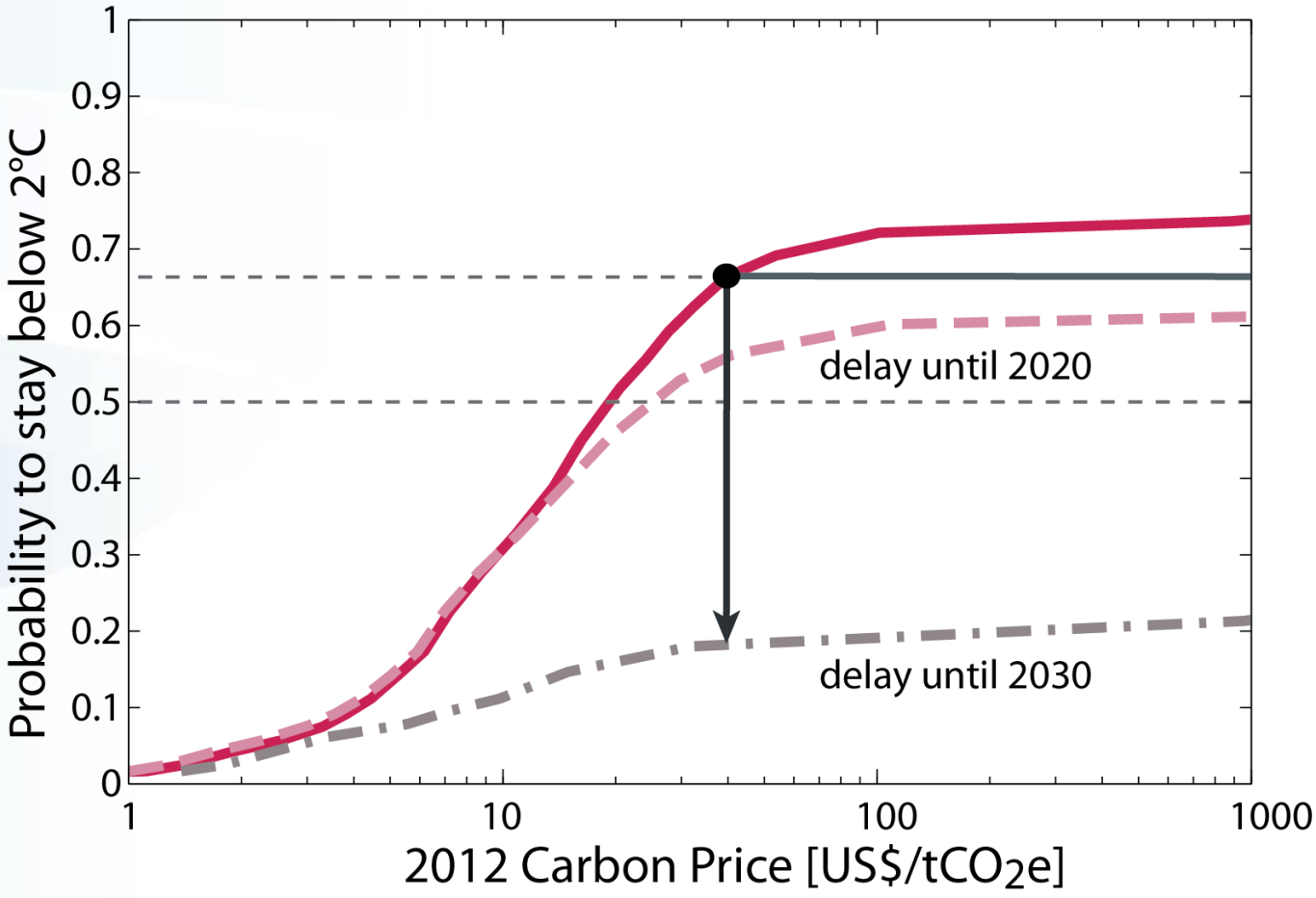
2°C



Rogelj et al, 2013

Political uncertainty (delay)

2°C

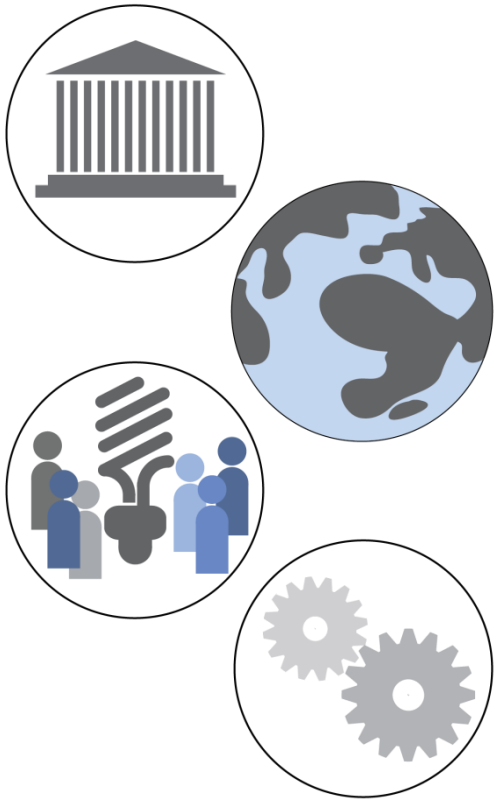


Rogelj et al, 2013

Which uncertainties matter (most)?

2ºC

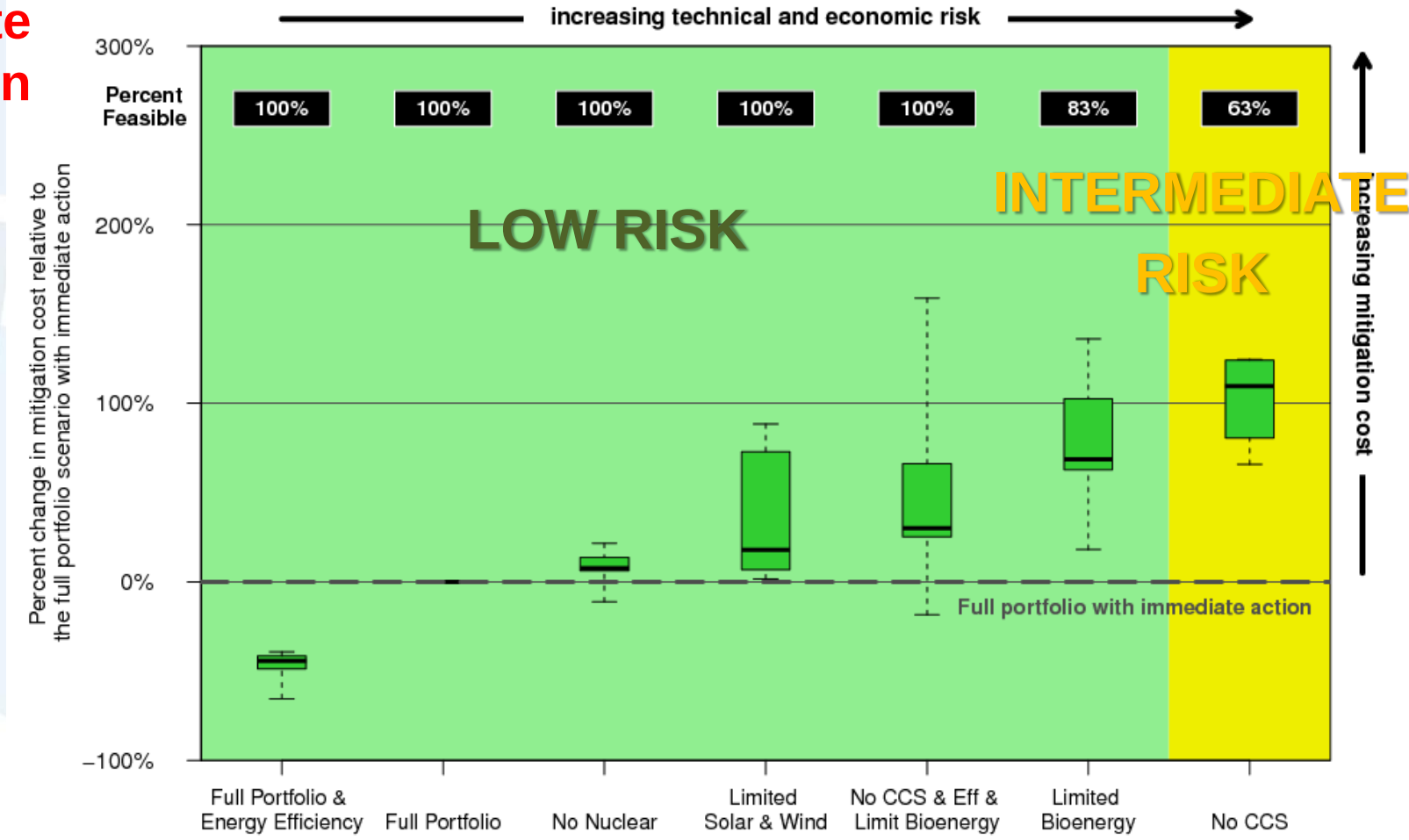
1. **Political (delayed action)**
2. **Geophysical**
3. **Societal (energy demand)**
4. **Technological**



Rogelj et al, 2013

Mitigation costs for different technology assumptions (AMPERE model-comparison)

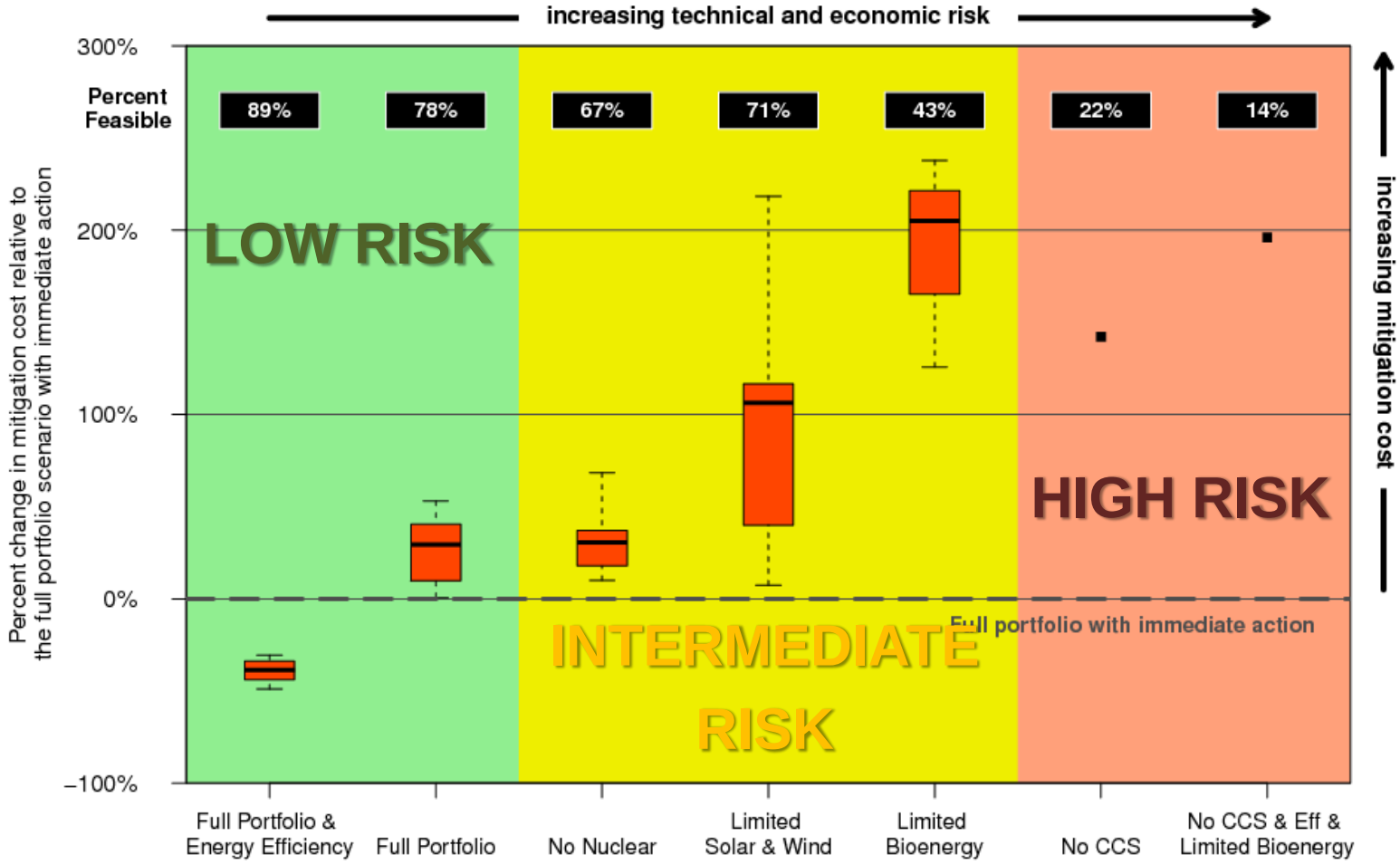
Mitigation costs of immediate action



Mitigation costs for different technology assumptions (AMPERE model-comparison)

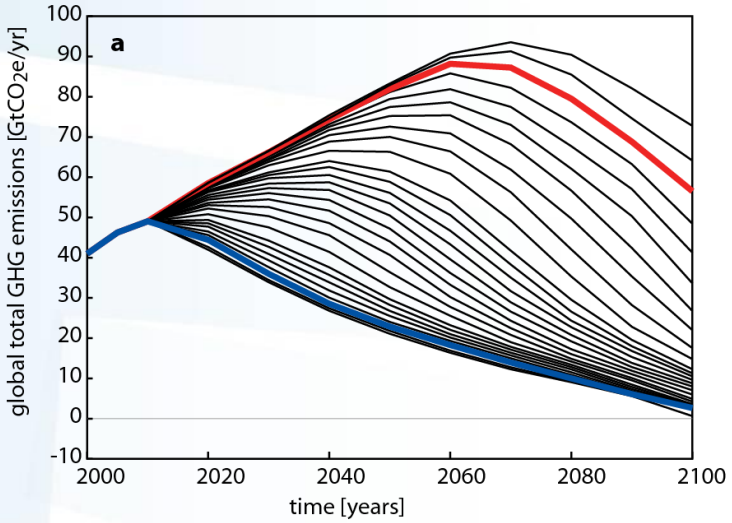
Delayed action until 2030

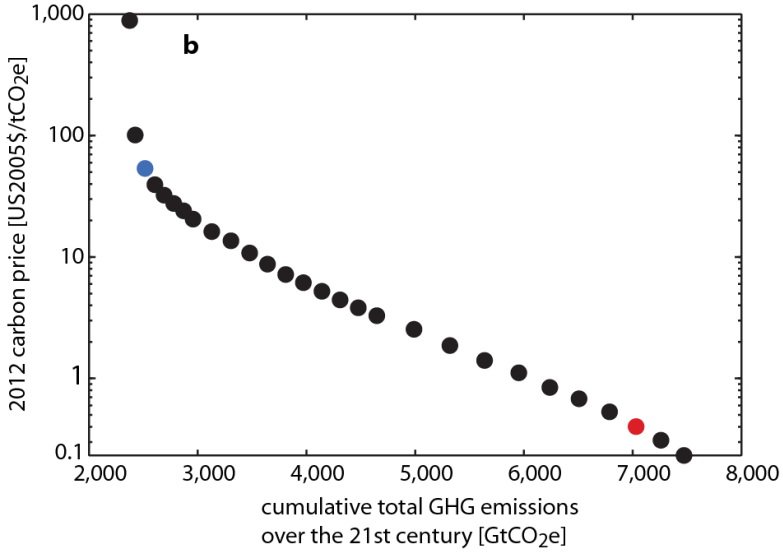
Mitigation costs of delayed action

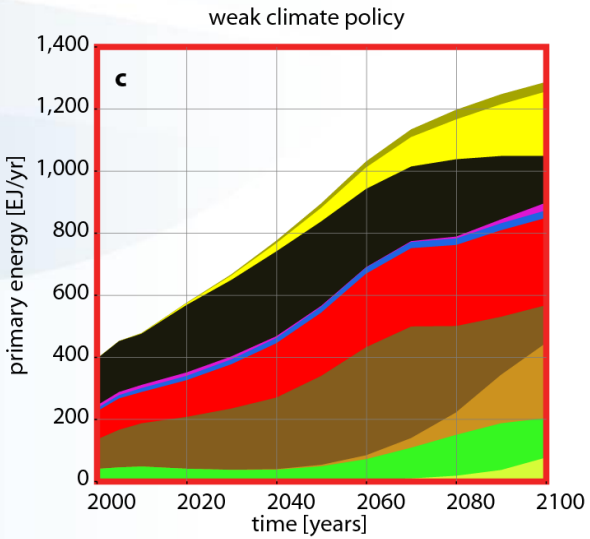


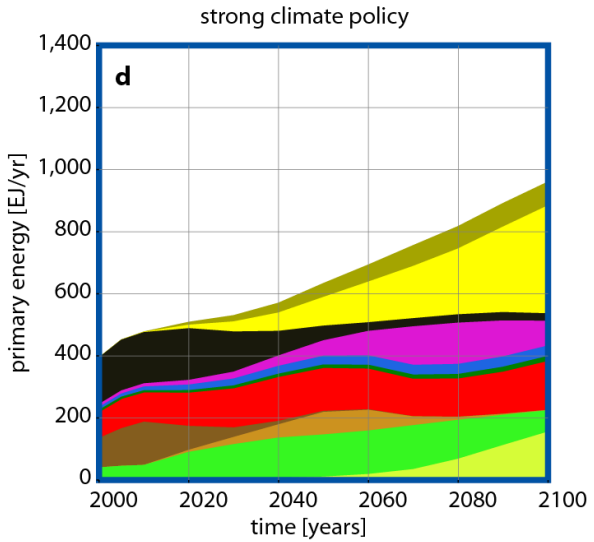
SUPPLEMENTARY SLIDES

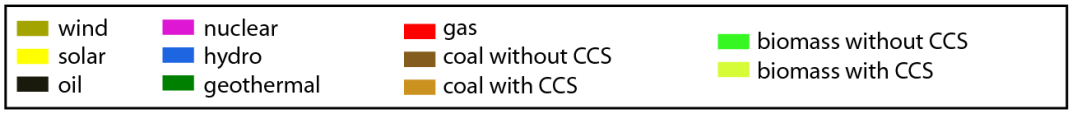
Back-up


a
global total GHG emissions [GtCO2e/yr]
time [years]

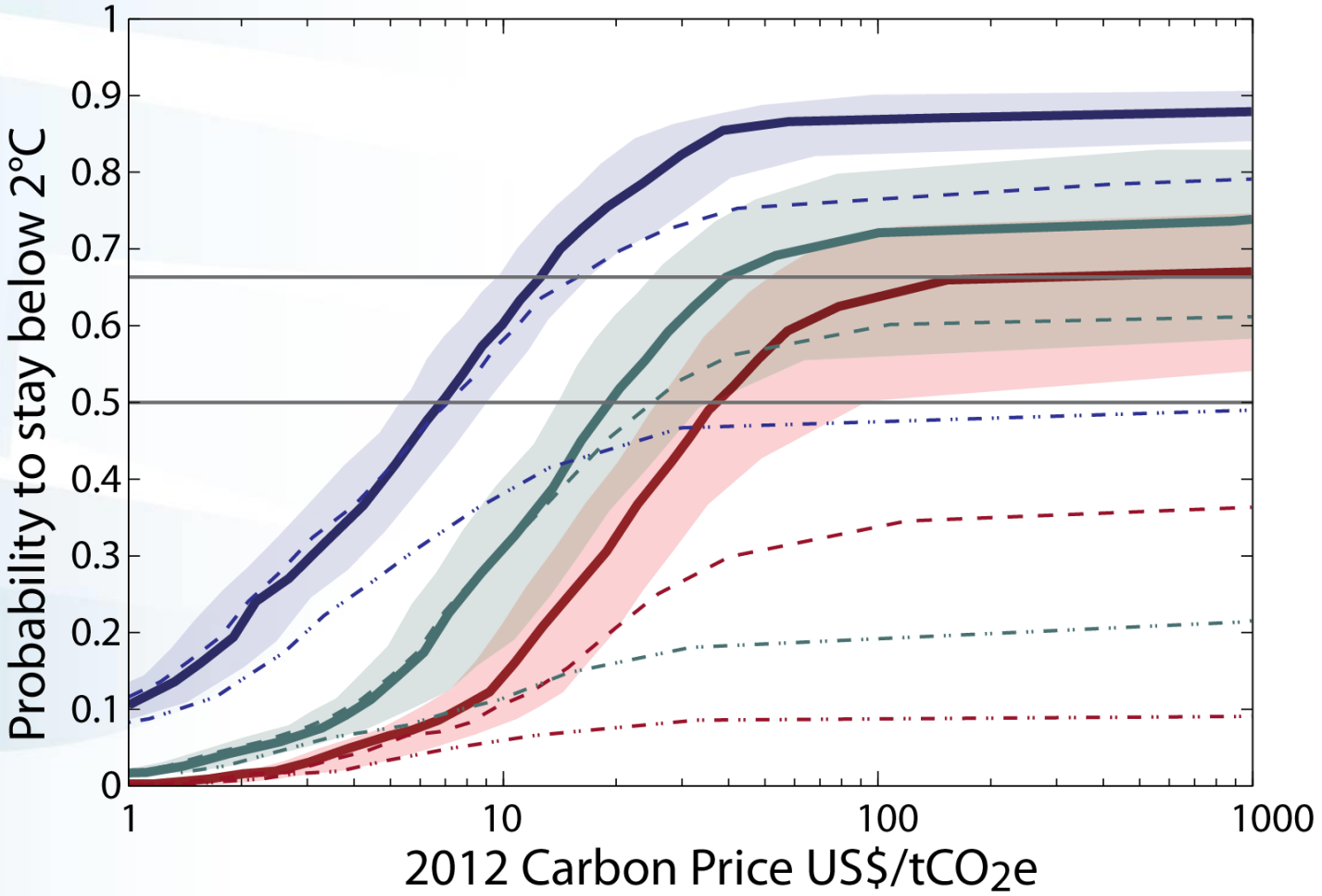

b
2012 carbon price [US2005$/tCO2e]
cumulative total GHG emissions
over the 21st century [GtCO2e]


weak climate policy
c
primary energy [EJ/yr]
time [years]


strong climate policy
d
primary energy [EJ/yr]
time [years]


wind
solar
oil
nuclear
hydro
geothermal
gas
coal without CCS
coal with CCS
biomass without CCS
biomass with CCS

Back-up

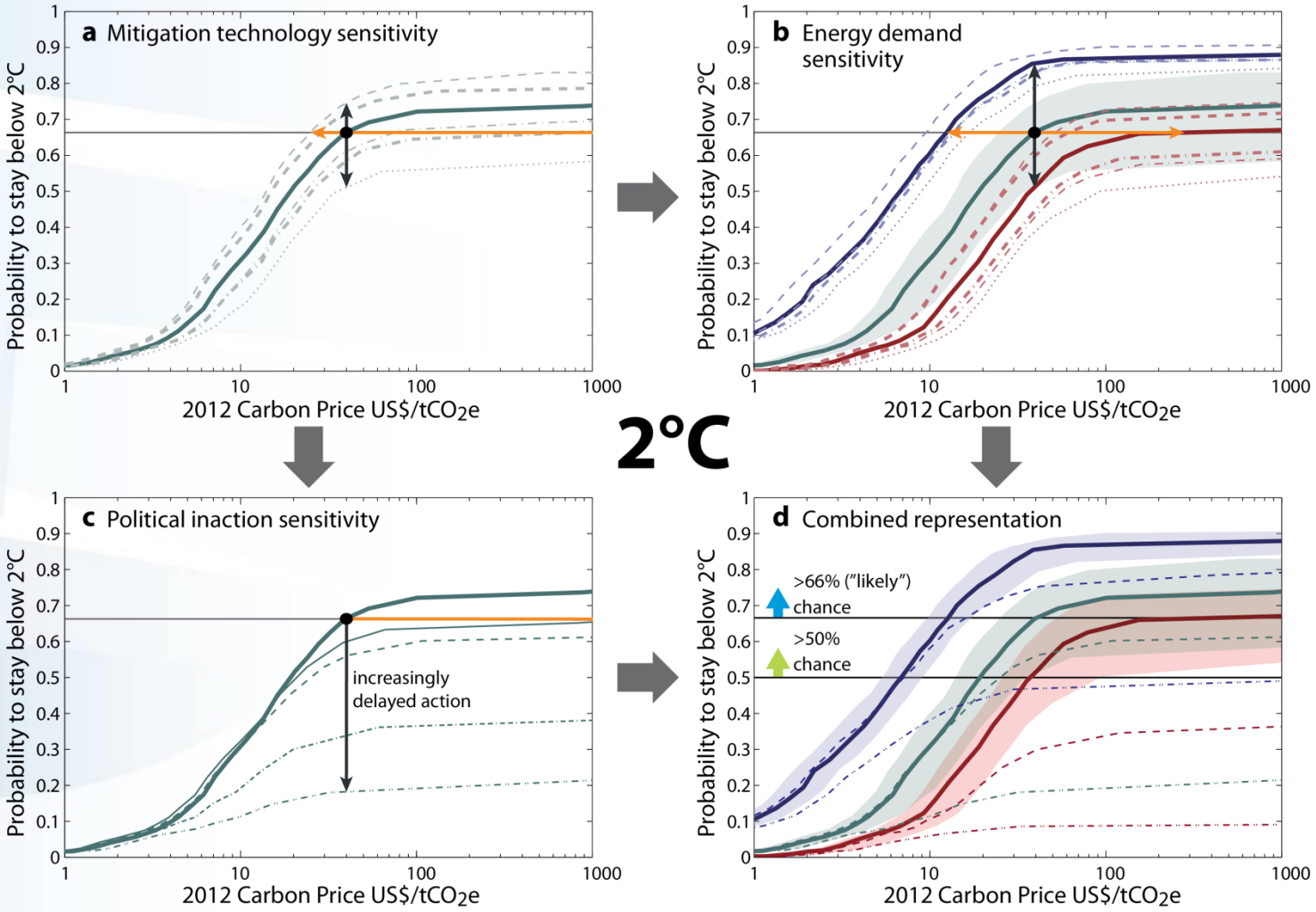


Legend

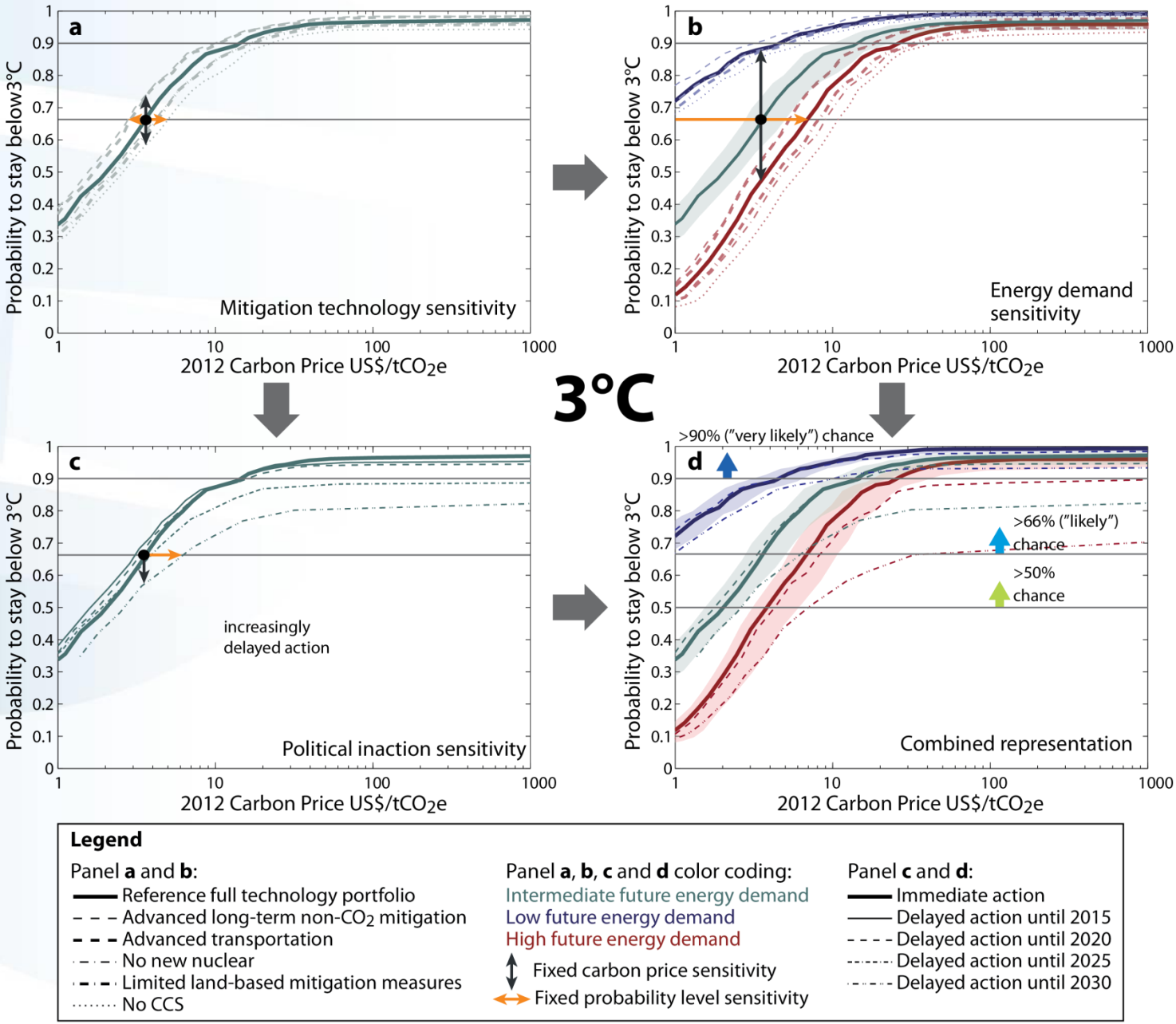
- Immediate action
- Delayed action until 2015
- Delayed action until 2020
- Delayed action until 2025
- Delayed action until 2030

Intermediate future energy demand
Low future energy demand
High future energy demand

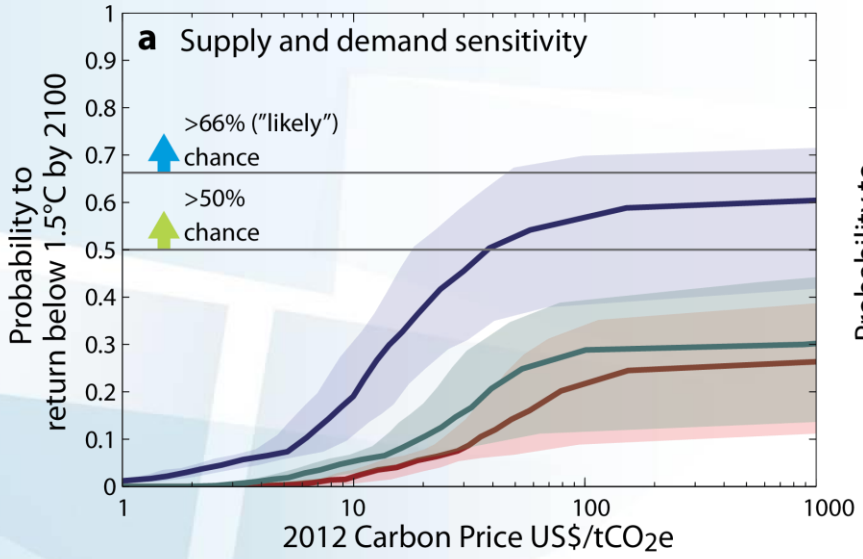
Back-up

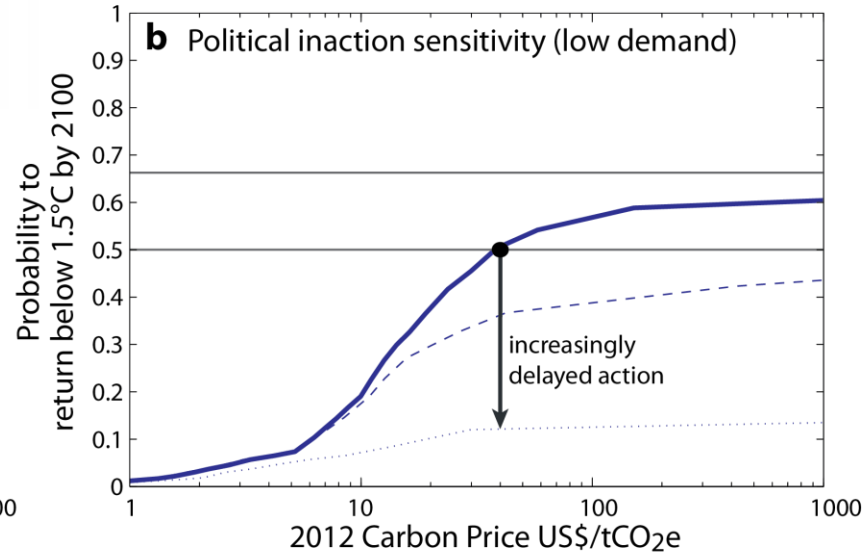

a Mitigation technology sensitivity
b Energy demand sensitivity
c Political inaction sensitivity
d Combined representation
2°C
Probability to stay below 2°C
2012 Carbon Price US$/tCO2e
increasingly delayed action
>66% ("likely") chance
>50% chance
Legend
Panel a and b:
Reference full technology portfolio
Advanced long-term non-CO2 mitigation
Advanced transportation
No new nuclear
Limited land-based mitigation measures
No CCS
Panel a, b, c and d color coding:
Intermediate future energy demand
Low future energy demand
High future energy demand
Fixed carbon price sensitivity
Fixed probability level sensitivity
Panel c and d:
Immediate action
Delayed action until 2015
Delayed action until 2020
Delayed action until 2025
Delayed action until 2030

Back-up


a
Probability to stay below3°C
Mitigation technology sensitivity
2012 Carbon Price US$/tCO2e
b
Probability to stay below 3°C
Energy demand sensitivity
2012 Carbon Price US$/tCO2e
3°C
c
Probability to stay below 3°C
increasingly delayed action
Political inaction sensitivity
2012 Carbon Price US$/tCO2e
>90% ("very likely") chance
d
Probability to stay below 3°C
>66% ("likely") chance
>50% chance
Combined representation
2012 Carbon Price US$/tCO2e
Legend
Panel a and b:
Reference full technology portfolio
Advanced long-term non-CO2 mitigation
Advanced transportation
No new nuclear
Limited land-based mitigation measures
No CCS
Panel a, b, c and d color coding:
Intermediate future energy demand
Low future energy demand
High future energy demand
Fixed carbon price sensitivity
Fixed probability level sensitivity
Panel c and d:
Immediate action
Delayed action until 2015
Delayed action until 2020
Delayed action until 2025
Delayed action until 2030

Back-up





Legend
Intermediate future energy demand
Low future energy demand
High future energy demand

Panel **b**:
Immediate action, full portfolio
Delayed action until 2020
Delayed action until 2030

Legend
Immediate action
Delayed action until 2015
Delayed action until 2020
Delayed action until 2025
Delayed action until 2030

Intermediate future energy demand
Low future energy demand
High future energy demand

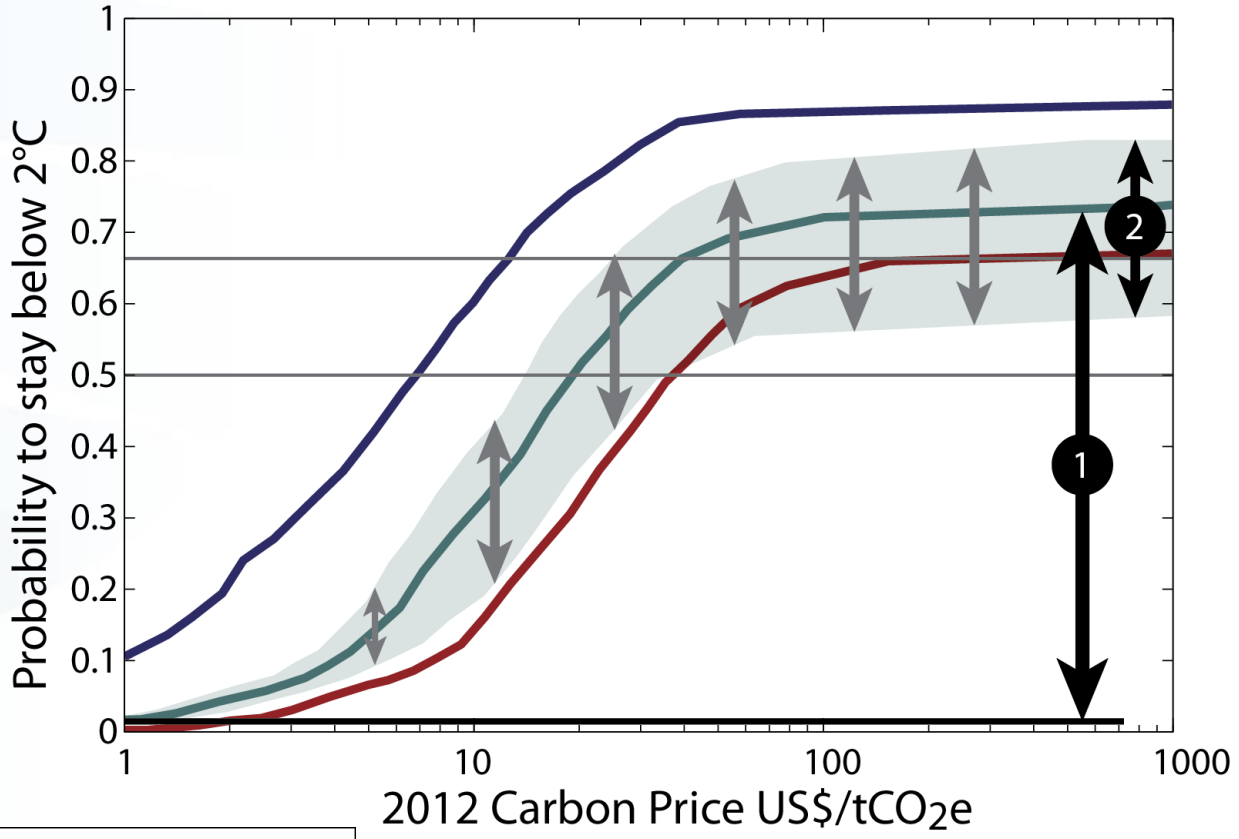
Uncertainty ranking Results

International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

2°C

1. Political (delayed action)
2. Geophysical
3. Social (energy demand)
4. Technological

Note: demographic and economic uncertainties not explicitly assessed.



Legend

- Immediate action
- Delayed action until 2015
- Delayed action until 2020
- Delayed action until 2025
- Delayed action until 2030

Intermediate future energy demand
Low future energy demand
High future energy demand

Uncertainty ranking Results

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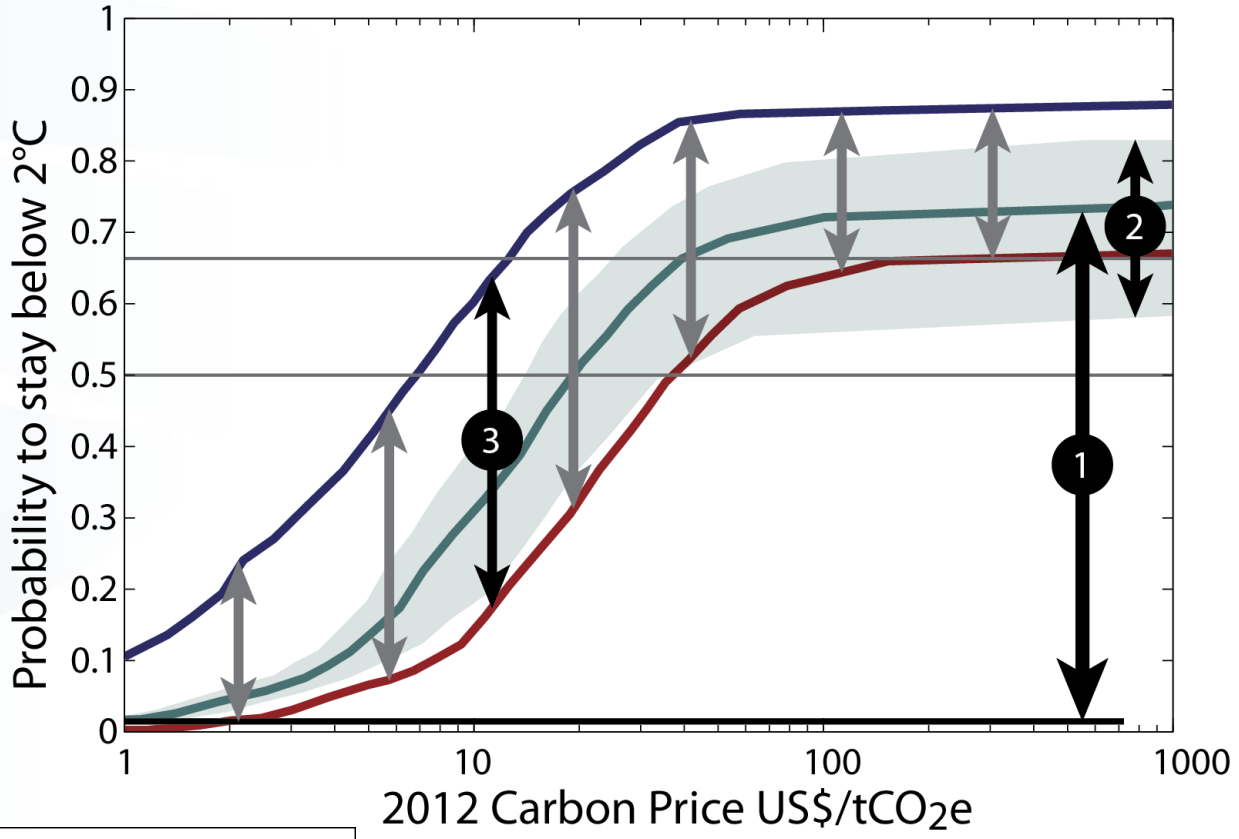
2°C

1. Political (delayed action)
2. Geophysical
3. Social (energy demand)
4. Technological

Note: demographic and economic uncertainties not explicitly assessed.



Legend

- Immediate action
- Delayed action until 2015
- Delayed action until 2020
- Delayed action until 2025
- Delayed action until 2030

Intermediate future energy demand
Low future energy demand
High future energy demand

Uncertainty ranking Results

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2°C

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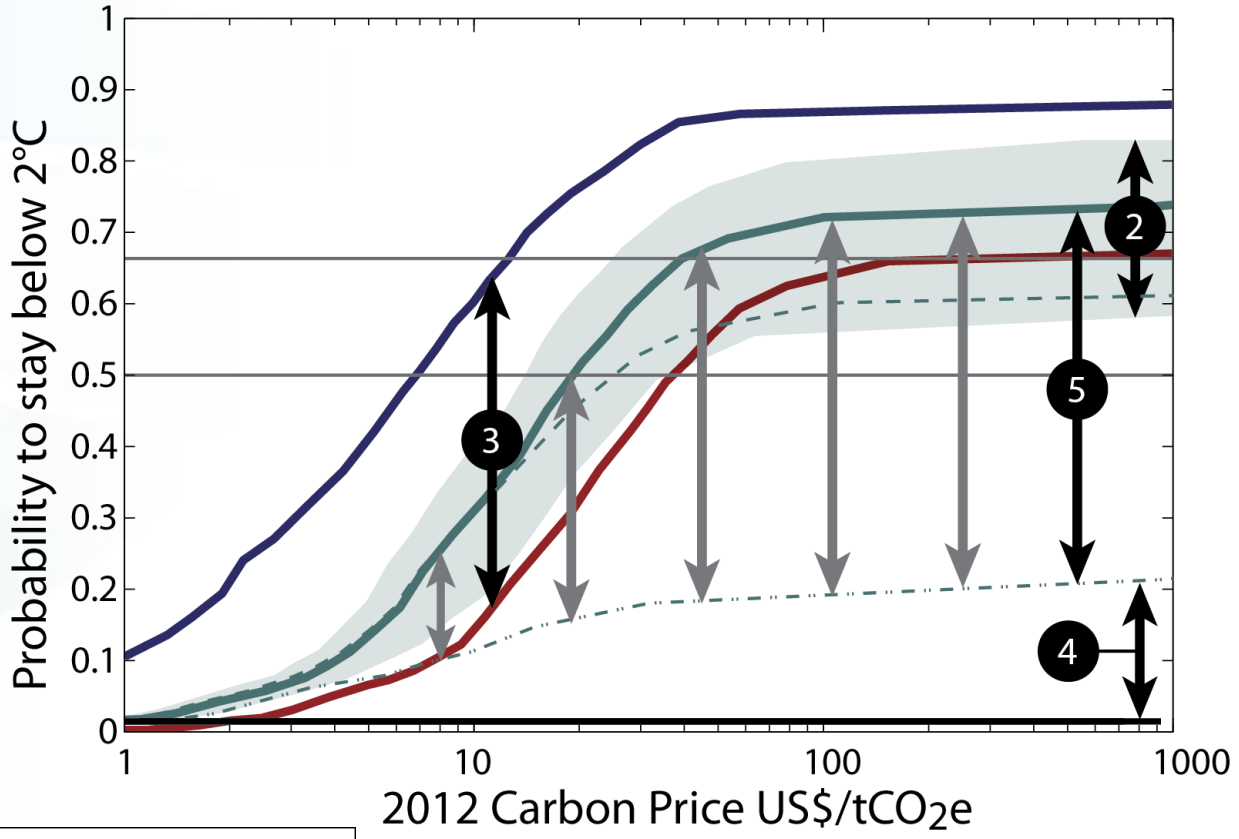
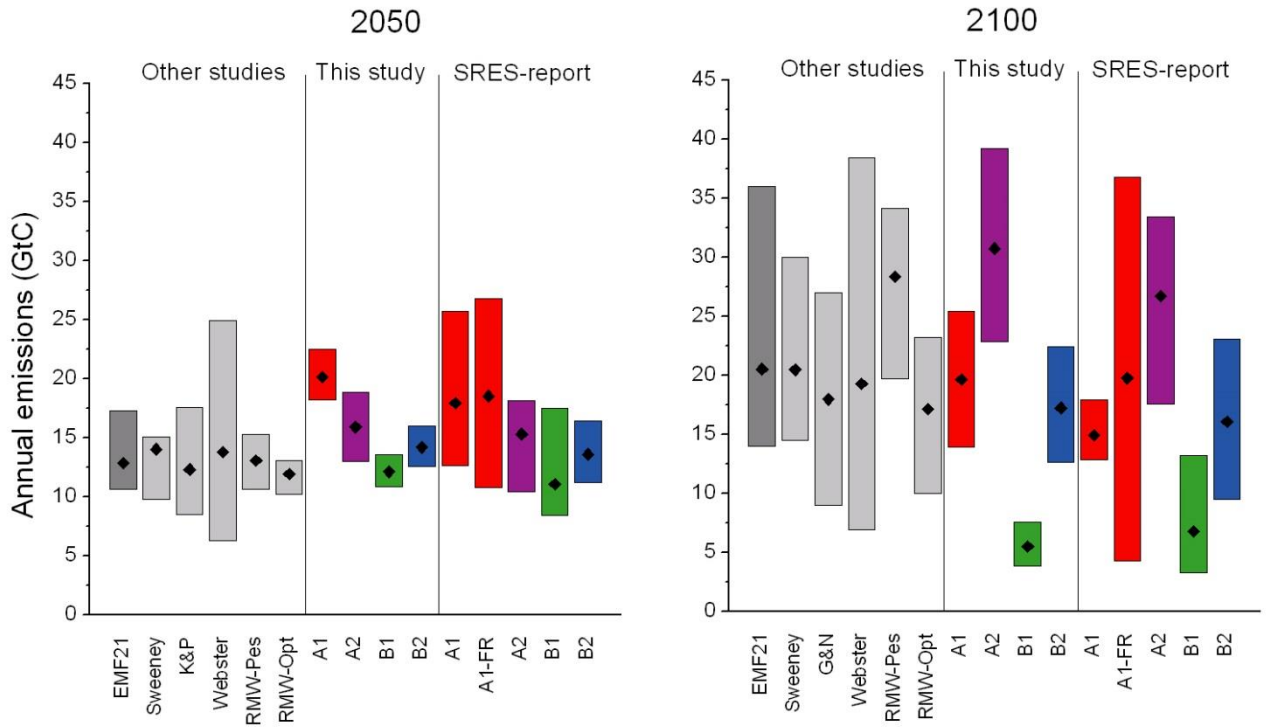


Comparison to other studies

Planbureau voor de Leefomgeving

Annual emissions



- Wide ranges for 2100 emissions
- Agreement on a central 2050 estimate of 15 GtC?

Comparison to other studies

Planbureau voor de Leefomgeving

Cumulative emissions