

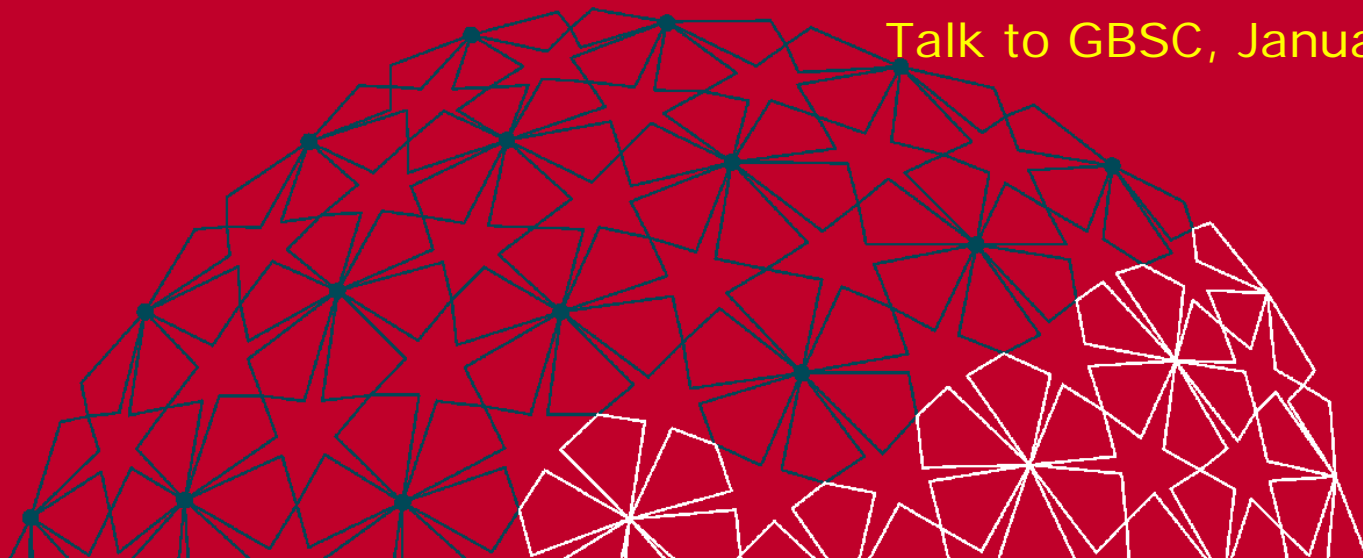
Geoengineering the climate

Science, governance and uncertainty

September 2009

Georgina Mace

Talk to GBSC, January 2010



What is it?

Geoengineering: the deliberate large-scale intervention in the Earth's climate system in order to moderate global warming

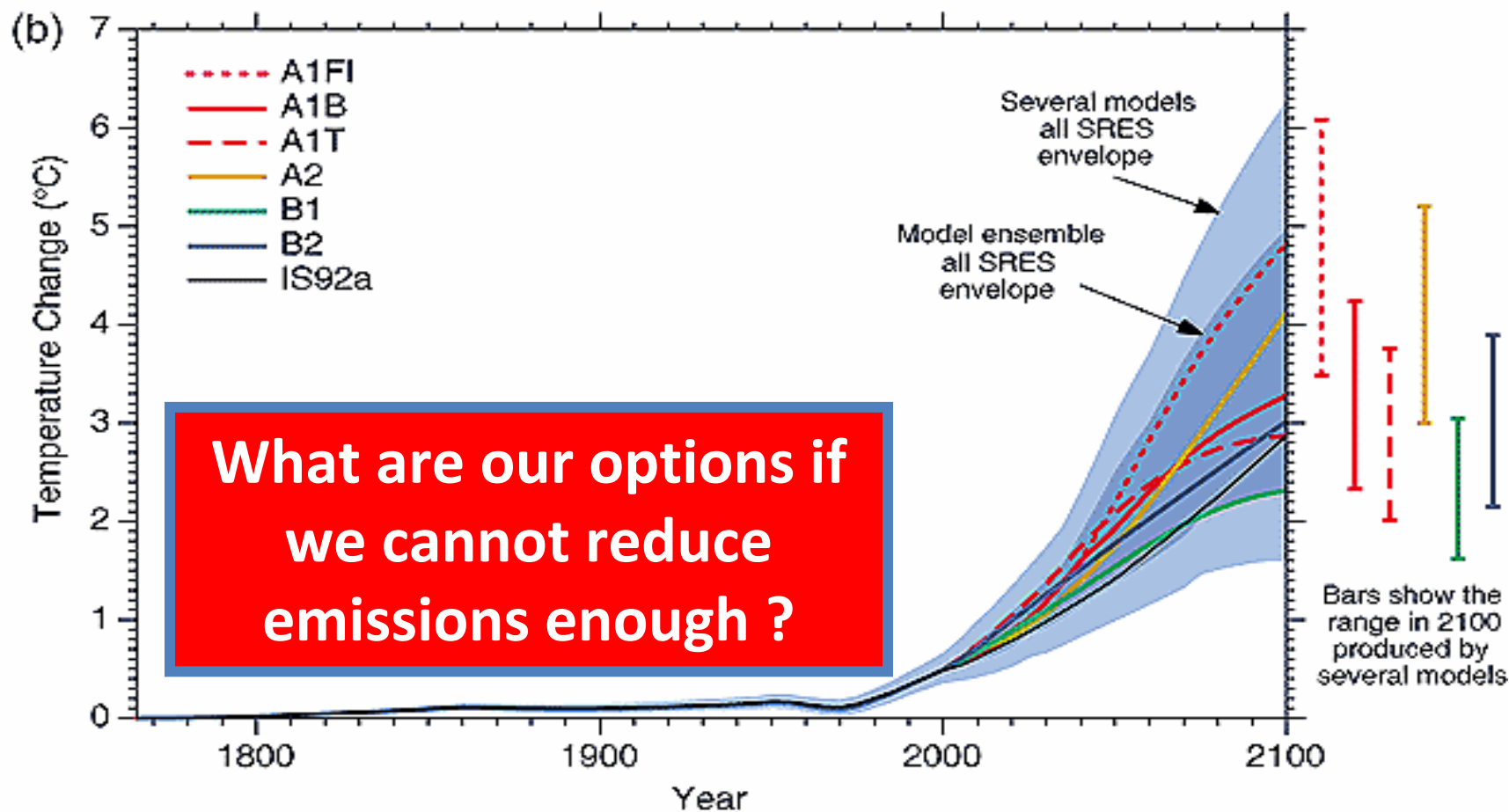
excluding:

- Low carbon energy & methods for reducing emissions of greenhouse gases
- carbon capture & storage (CCS) at the point of emission

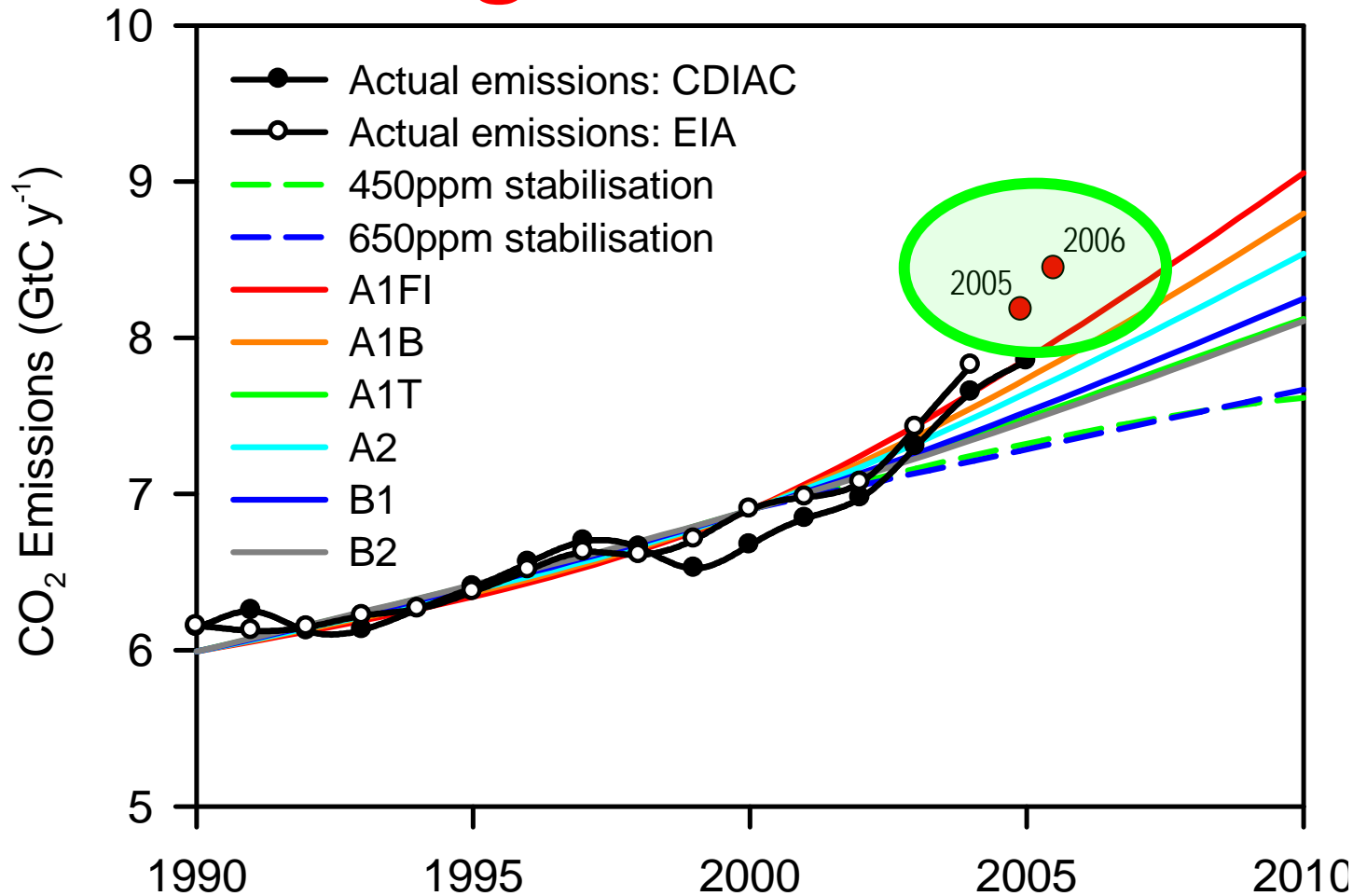
Why are some now seriously considering geoengineering?

- Projections of future climate change produce global warming between 1.1 and 6.4°C by 2100 (IPCC TAR).
- To have a reasonable chance of avoiding a potentially dangerous 2°C global warming through conventional mitigation requires global CO₂ emission cuts of about 60% by 2050 (..and continuous reductions thereafter...).
- However, global CO₂ emissions have continued to rise.
- Could Geoengineering provide an alternative way to avoid dangerous climate change ?

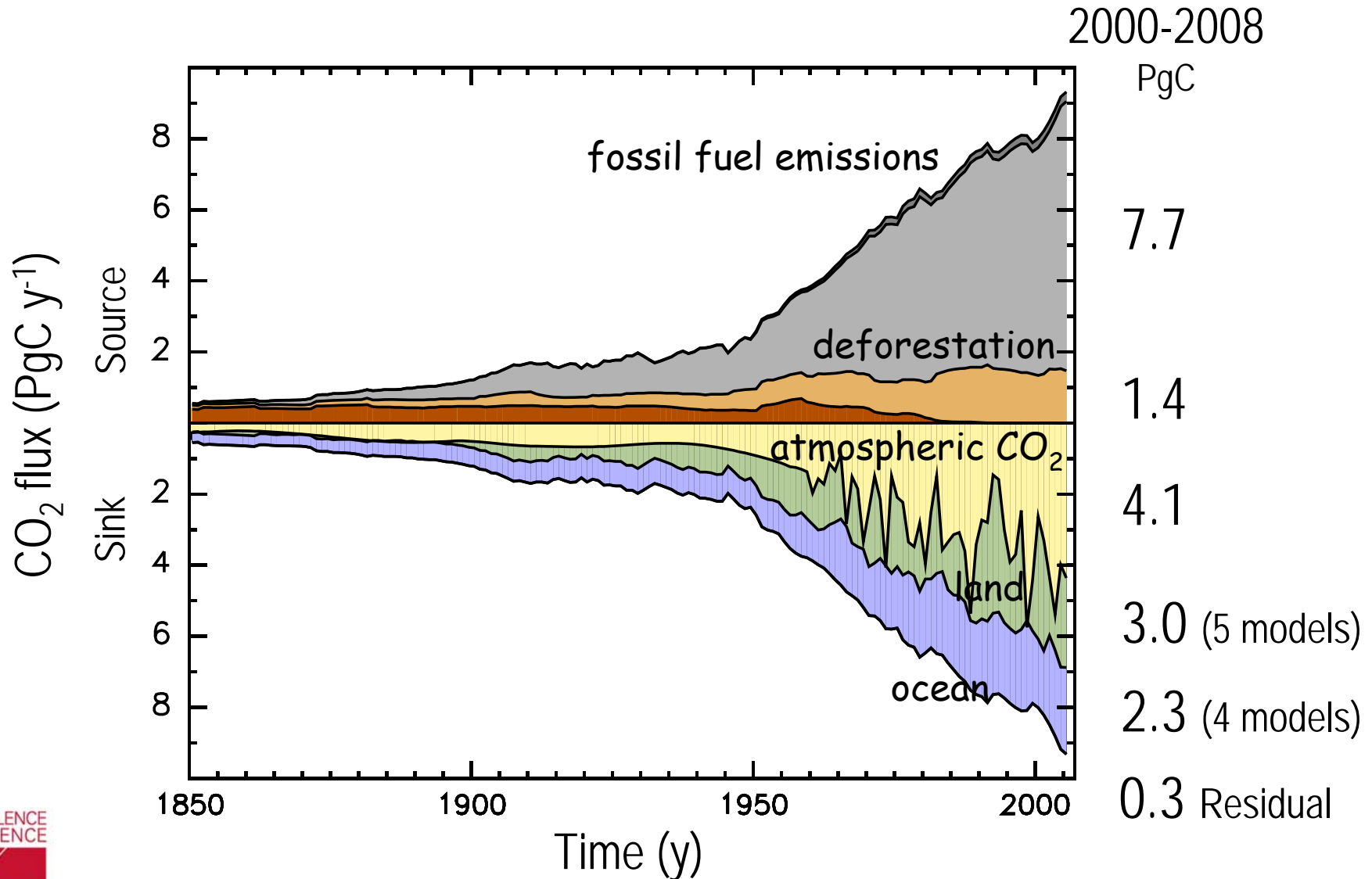
Do we need geoengineering?



..global emissions exceed the highest scenario....



CO₂ sources and sinks since 1850



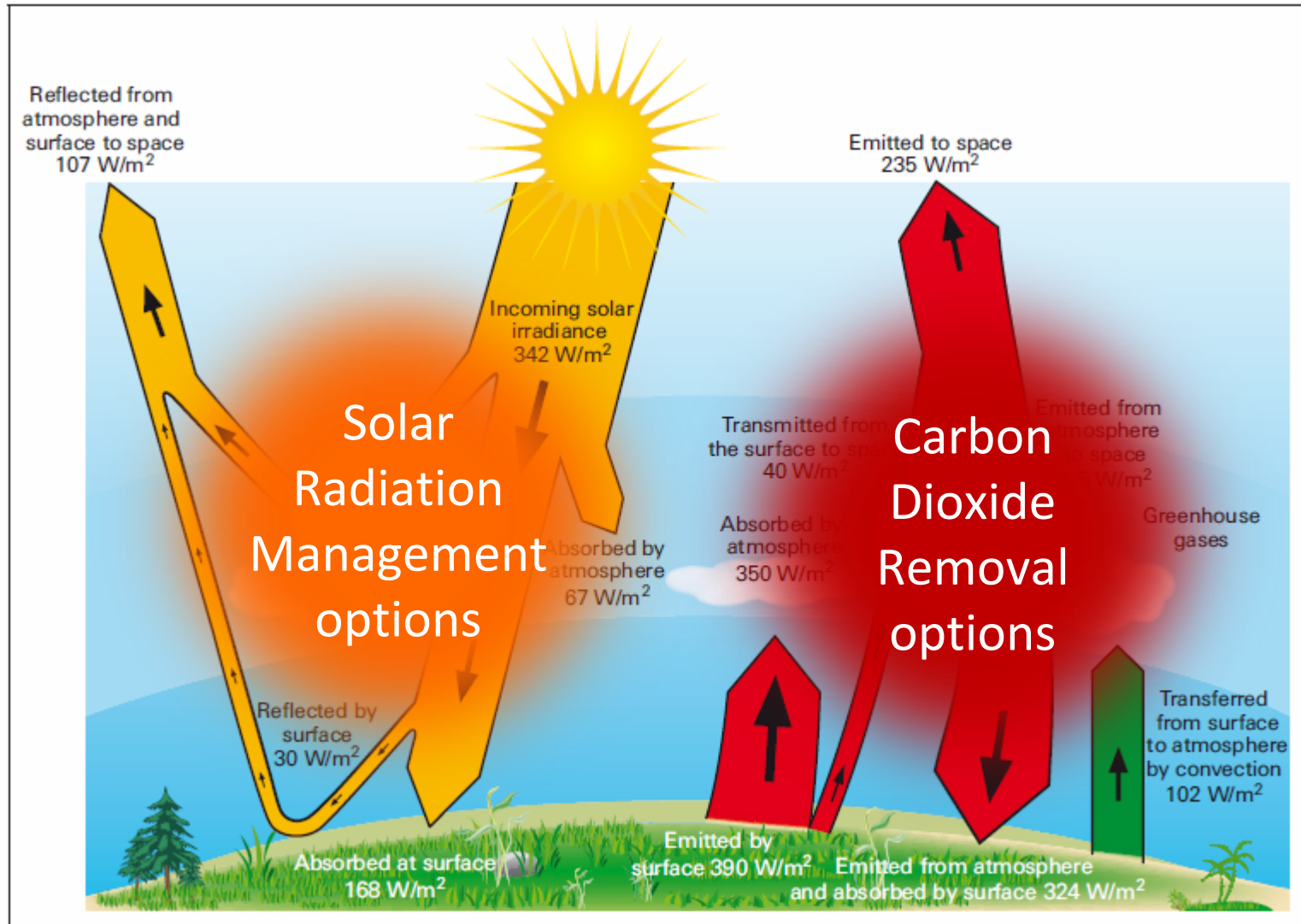
Key questions about geoengineering

- What is it?
- Do we need it?
- Is it feasible?
 - Technically
 - Socially/politically
- At what cost?
- What side-effects?
- Who would do it?
- When?
- Unintended consequences?
- Control?

Working group

- **John Shepherd**, University of Southampton (chair)
- **Ken Caldeira**, Carnegie Institution, USA.
- **Peter Cox**, University of Exeter
- **Joanna Haigh**, Imperial College, London
- **David Keith**, University of Calgary, Canada.
- **Brian Launder**, University of Manchester
- **Georgina Mace**, Imperial College, London
- **Gordon MacKerron**, University of Sussex
- **John Pyle**, University of Cambridge
- **Steve Rayner**, University of Oxford
- **Catherine Redgwell**, University College, London
- **Andrew Watson**, University of East Anglia

Climate Energy Balance



Two main methods

Carbon Dioxide Removal (CDR) techniques

- remove carbon dioxide from the atmosphere
- treat the cause of climate change

Solar Radiation Management (SRM) techniques

- Reflect a small percentage of sunlight back into space to cool the planet
- Mask the effects of climate change

Major criteria for evaluation

- **Effectiveness**
 - confidence in the scientific and technological basis, technological feasibility, and magnitude, spatial scale and uniformity of the effect achievable.
- **Timeliness**
 - including the state of readiness for implementation, extent to which any necessary experiments and/or modelling has been completed), speed with which the intended effect would occur.
- **Safety**
 - including predictability and verifiability, absence of unintended environmental impacts (especially effects on inherently unpredictable biological systems), low potential for things to go wrong on a large scale.
- **Cost** (*actually its inverse, affordability*)
 - of both deployment and operation, for a given desired effect evaluated over century timescales
 - information available on costs is extremely tentative and incomplete, and only order-of-magnitude estimates are possible.

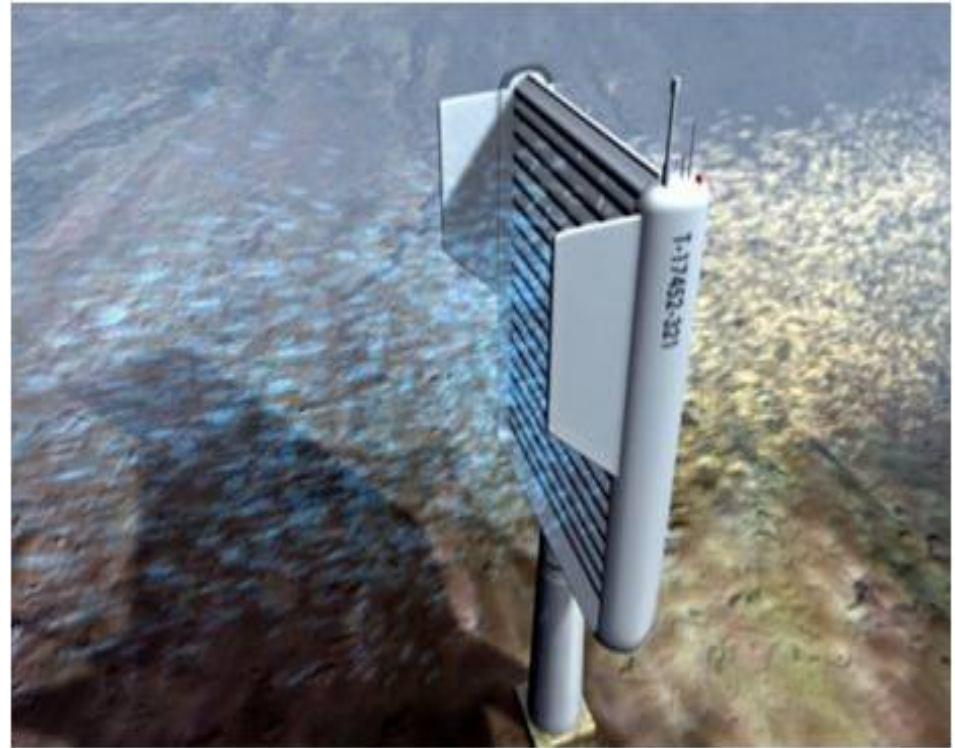
CDR: ocean fertilisation

Nutrients added to the ocean promote blooms of carbon-fixing algae.



CDR: ambient air capture

CO₂ is captured straight from ambient air, ready for compression and storage.



CDR: biochar

Biomass is partly burned for energy, then the remaining charcoal is buried, sequestering some of the carbon from the biomass.

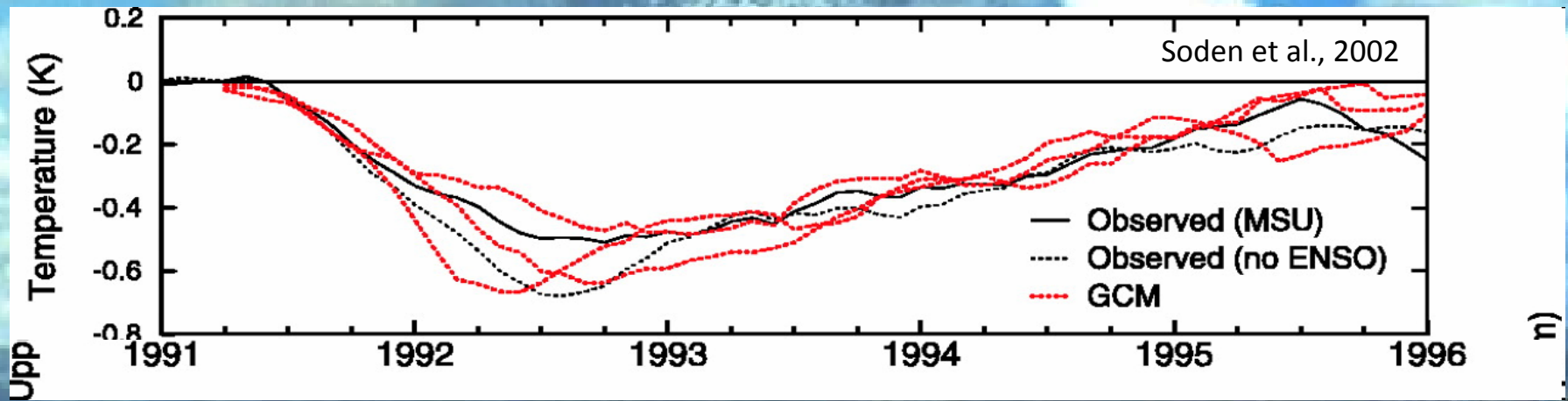


CDR methods:

- are generally preferable, because...
- they address the **root cause of climate change**,
- **return the climate system closer to its natural state**
- so involve fewer uncertainties and risks
- could even allow future **reductions of atmospheric CO₂ concentrations (negative emissions)**
- Address ocean acidification – over the long term.
- but they only take effect **very slowly**.

SRM methods mimic the effects of volcanic eruptions

Mt. Pinatubo, 1991



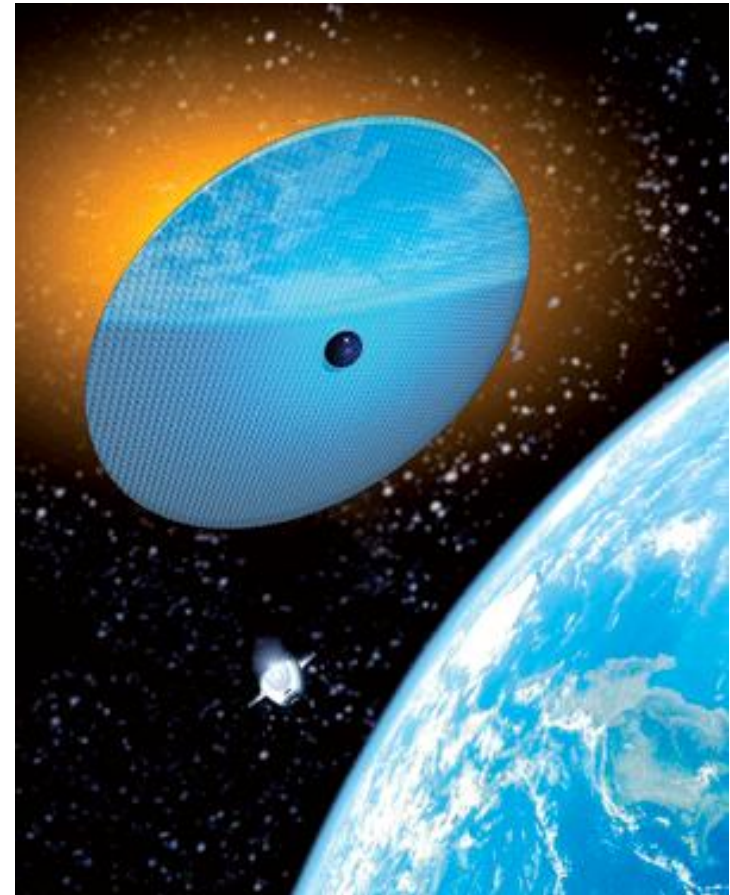
SRM: stratospheric aerosols

Tiny particles are distributed in the stratosphere where they reflect a small percentage of sunlight back into space (mimicking the effects of volcanic eruptions)



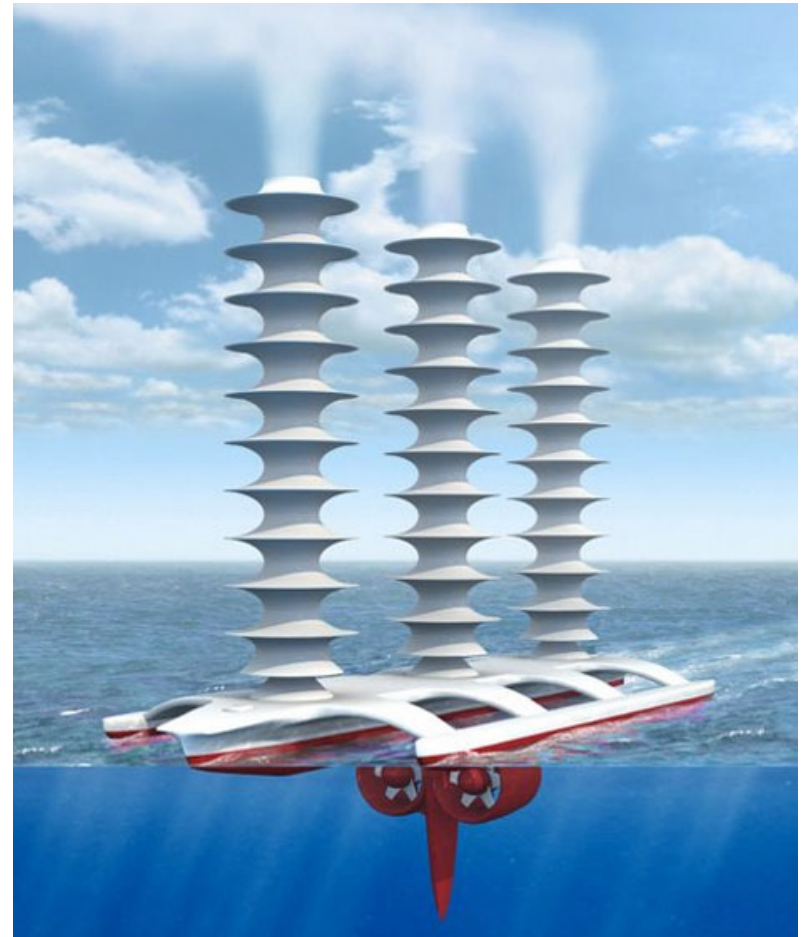
SRM: mirrors in space

Shields or deflectors are placed in space, reducing the amount of solar energy the Earth receives.



SRM: cloud brightening

The reflectivity of marine clouds is enhanced by spraying sea water into the lower atmosphere, causing the formation of more and brighter clouds.



SRM: whitening the built environment (surface albedo)

Manmade structures (such as roads and roofs) are painted white to make them more reflective.



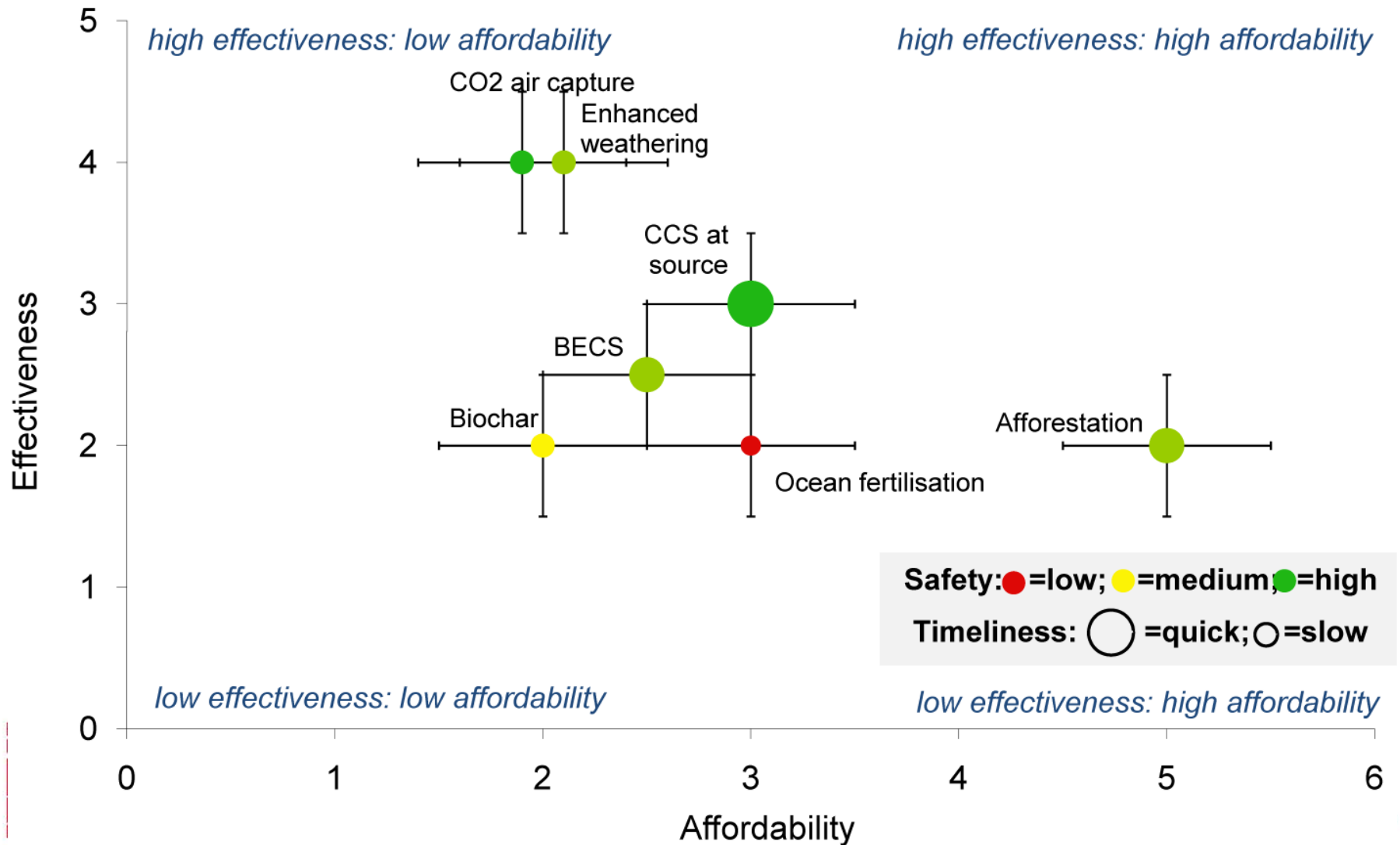
Solar Radiation Management techniques:

- directly modify the Earth's **radiation balance**
- would take **only a few years** to have an effect
- could be **useful in an emergency** (for example to avoid reaching a climate 'tipping point'...)
- would create an **artificial, approximate, and potentially delicate balance**
- which would have to be **maintained**, potentially **for many centuries**... which **may not be sustainable**

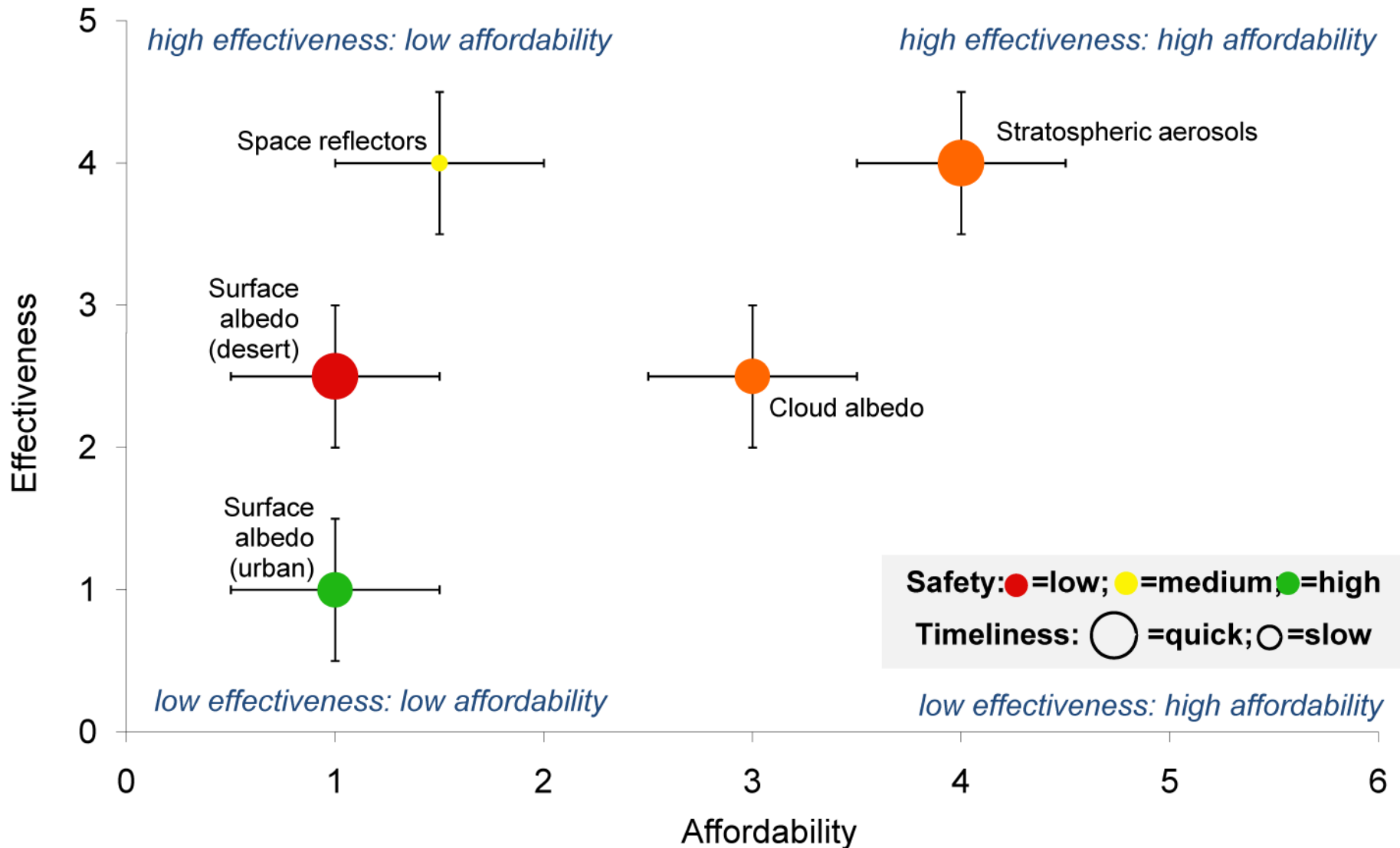
SRM techniques continued:

- Climate achieved will only *approximate* that with less greenhouse warming...
 - particularly for critical variables other than temperature
 - which are **very sensitive to regional differences**
 - such as **precipitation**, weather systems, wind speeds and ocean currents.
- should only be undertaken for a **limited period**
- and **in parallel** with conventional mitigation and/or Carbon Dioxide Removal methods.
- Do nothing to reduce **ocean acidification** or any consequences of a **high CO₂ atmosphere**

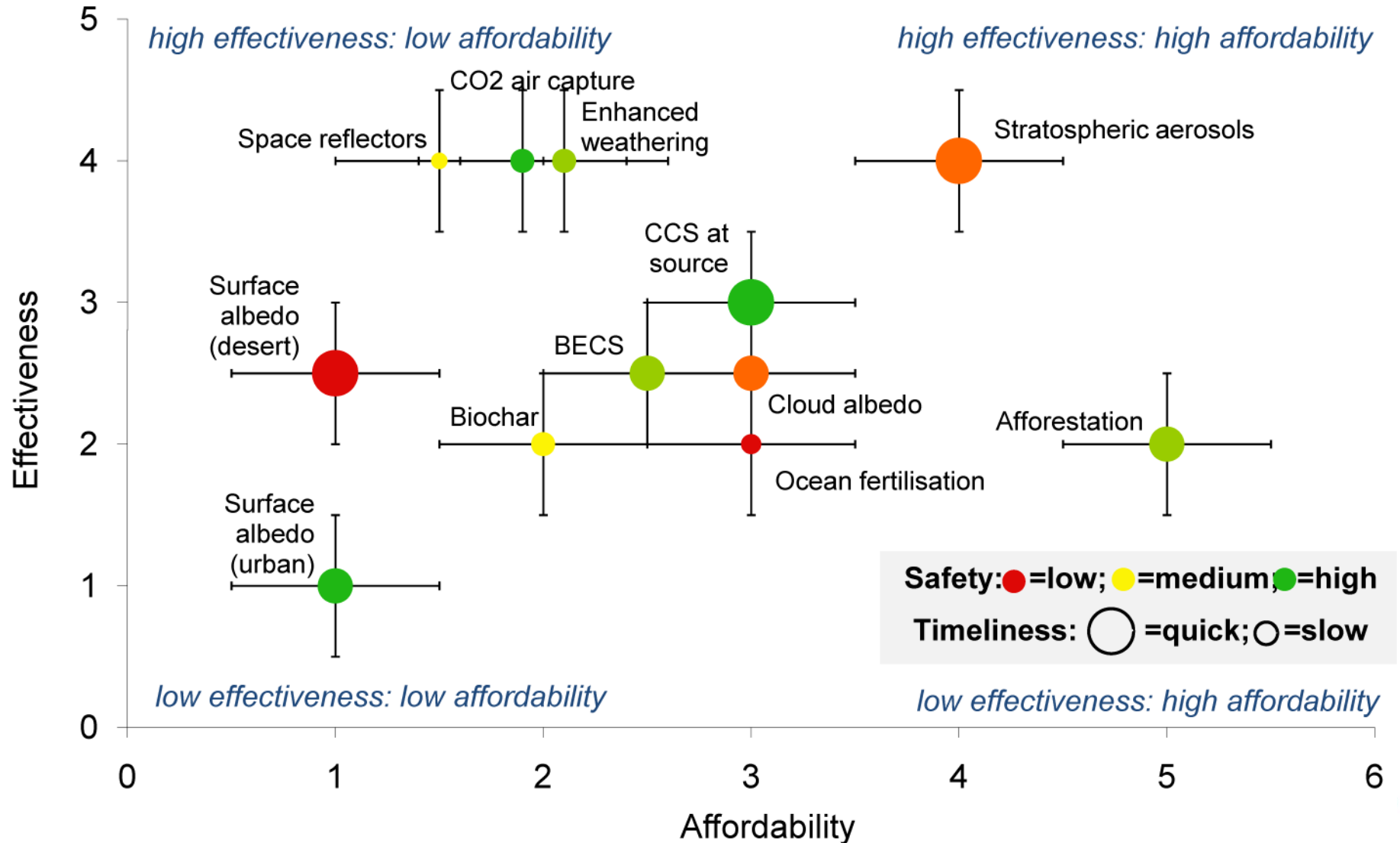
Carbon Dioxide Removal



Solar Radiation Management



All options together



Governance and policy issues

- Need for attention to international governance frameworks for these emerging technologies (both for research and deployment)
- Technological differences need to be appreciated. What is true for stratospheric aerosols unlikely to be true for ambient air capture.
- Control dilemma (Collingridge) – ideal safeguards for a technology are not obvious in the early evolution of a technology
- Potential for 'moral hazard' cannot be discounted and more work is needed on the public and political reactions to climate interventions technologies

Governance implications of SRM

- No clear governance mechanisms as things stand
- Potential for causing international tensions
- Even field testing could cause damage
- Potential for unilateralism – report called for international cooperation from early on
- Potential for moral hazard – will the perception of a ‘technofix’ result in reduced interest for emissions reductions

Main Conclusions

Cutting greenhouse gas emissions is still the key to reducing climate risk and damage

Nothing now known about geoengineering options gives any reason to diminish these efforts.

Nevertheless, we cannot afford to ignore other options that may have the potential to reduce climate risk and damage

Many geoengineering options are **very likely to be technically possible**, although there are **major uncertainties and potential risks**

Need more **research**, more **public engagement**, and development of a **system of regulation**

Research: Needed ASAP, on **both CDR and SRM**: (a small portfolio, since it's *too soon to pick a winner*). Need **observations**, the **development and use of climate models**, and carefully planned and executed **experiments**

Considerations for biodiversity

- Biodiversity is often considered only in terms of being impacted by climate change.
- But the biosphere is a key part of the climate system. There is great potential for biodiversity and ecosystem-based adaptation and mitigation methods, which may be low risk, low cost and have multiple benefits – though they can only act slowly compared to some geoengineering techniques.
- SRM techniques act quickly, reduce radiation but do nothing to reduce GHG concentrations in the atmosphere. What are the implications of a high CO₂ world for the biota? NB – slow rate of return to pre-industrial CO₂ levels is inevitable anyway.
- Special problem already recognised for corals and other marine organisms from ocean acidification. Might there be other surprises?

Returning to 350ppm?

Figure 1.10 CO₂-equivalent atmospheric concentrations for emissions trajectories peaking in 2016



Building a low-carbon economy – the UK's contribution to tackling climate change



EXCEL
IN SC

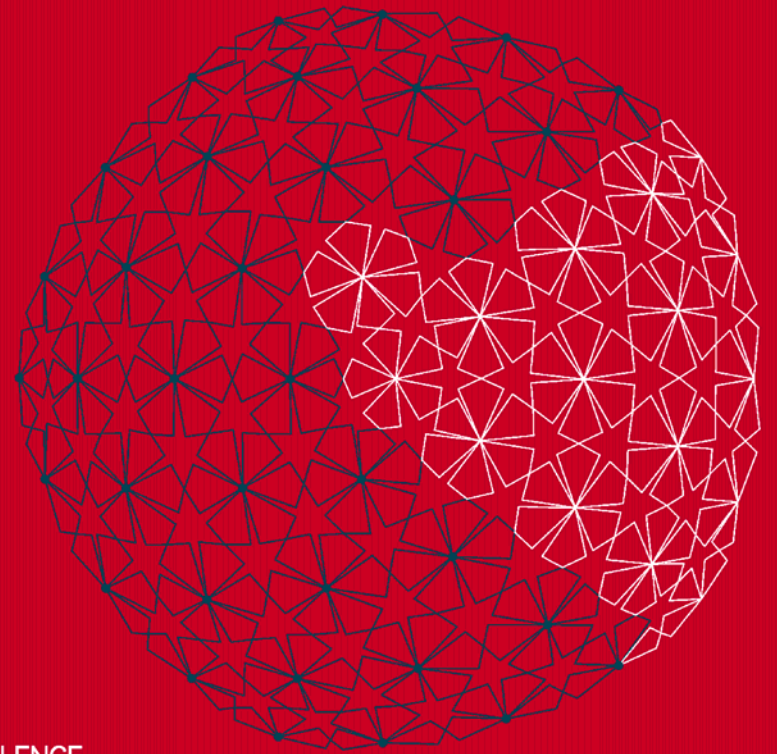


Note: Total CO₂-equivalent atmospheric concentrations (including Kyoto GHGs, ozone and aerosols) are given in parts per million (ppm) for emissions trajectories 2028:1.5% and 2028:3%. Upper and lower thin lines show the 10th and 90th percent bounds of model response, whilst the thick central line represents the central model estimate

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