Planbureau voor de Leefomgeving

Integrated assessment and geoengeenering

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What happened that last time that someone spoke about geoengineering at Snowmass?

Stanford professor John Weyant, the

In one presentation, Jae

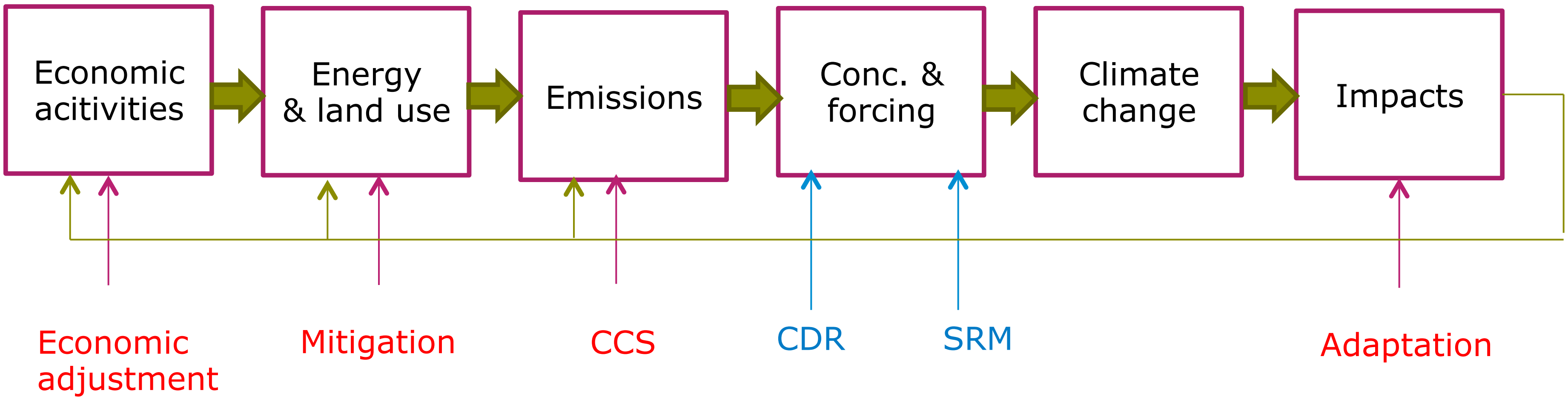
Then Lowell Wood approached the podium. Wood hooked up his laptop, threw his first slide onto the screen and got down to business. Getting the particles into the stratosphere wouldn't be a problem – you could generate them easily enough by burning sulfur, then dumping the particles out of high-flying 747s, spraying them into the sky with long hoses or even shooting them up there with naval artillery

I am affraid I will be much more boring

What can integrated assessment models tell us currently about geo-engeneering

Pindyck would probably say: Not much ;-)

Integrated assessment model



Models used to design strategies that maximize overall welfare (CBA) or minimize mitigation costs in achieving targets (cost-effectiveness)

Strenght: to bring different process under one framework – and link them (land-use, water, energy, climate, economy….)

,

But not so good in evaluating risks (impacts and solutions)

Carbon dioxide removal (CDR)

Techniques such as:

- Afforestation/reforestation
- Bio-energy + CCS
- Direct aircapture + CCS
- Biochar
- Enhanced weathering
- Ocean fertilisation

Some techniques already regularly included in models

Substantial costs

Some techniques have risks compared with mitigation; others might have higher risks

→ Can typically be evaluated in IAMs (shown further)

Solar radiation management (SRM)

Techniques such as:

- Stratospheric aerosols
- Wide cloud formation
- Space-based schemes
- Whitening of built structures
- Plant reflectivity

Hardly evaluated in IAM models

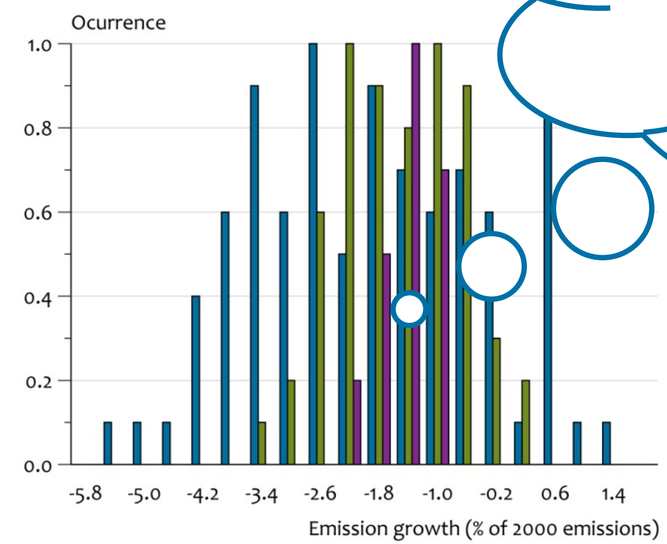
Costs vary from very low to high

Most techniques involve large risks

→ Difficult to evaluate in IAMs – as most IAMs are centered around costs notions, not around risk notions

Mitigation not … e measure

Growth of emissions in stringent mitiga…



Maybe possible to move beyond these rates with massive decommissioning of current infrastructure or massive behavior change

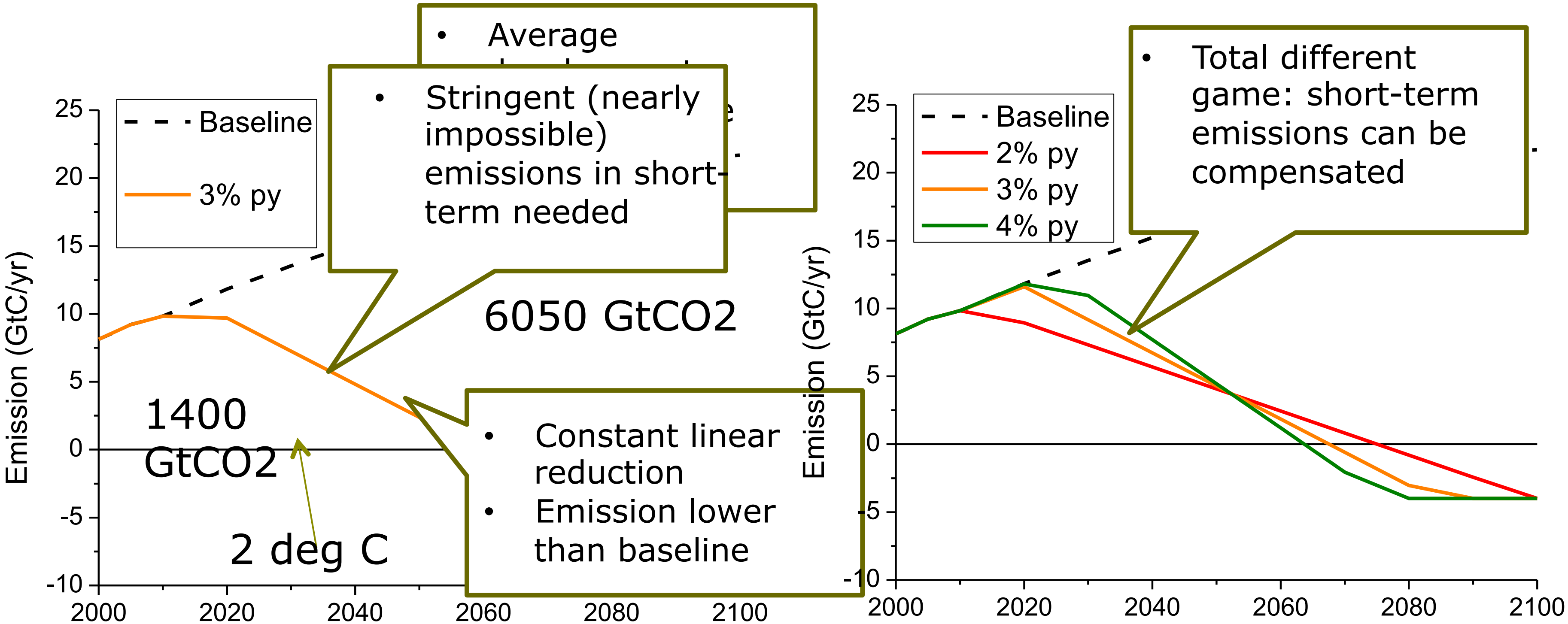
… ansitions

… to mature

… w of historical change and changes in scenarios: -4% emission reduction rate (= -6% decarbonisation) is extremely fast

Van Vuuren and Stehfest, 2013 What if climate response becomes urgent. Climatic Change. Accepted

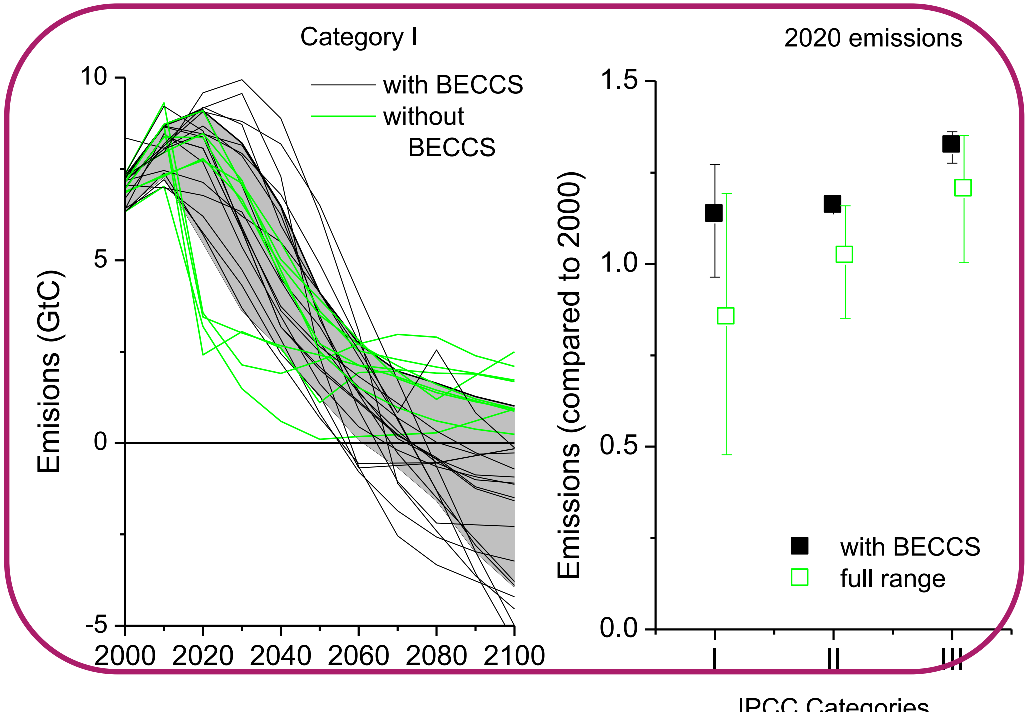
What can CDR offer?

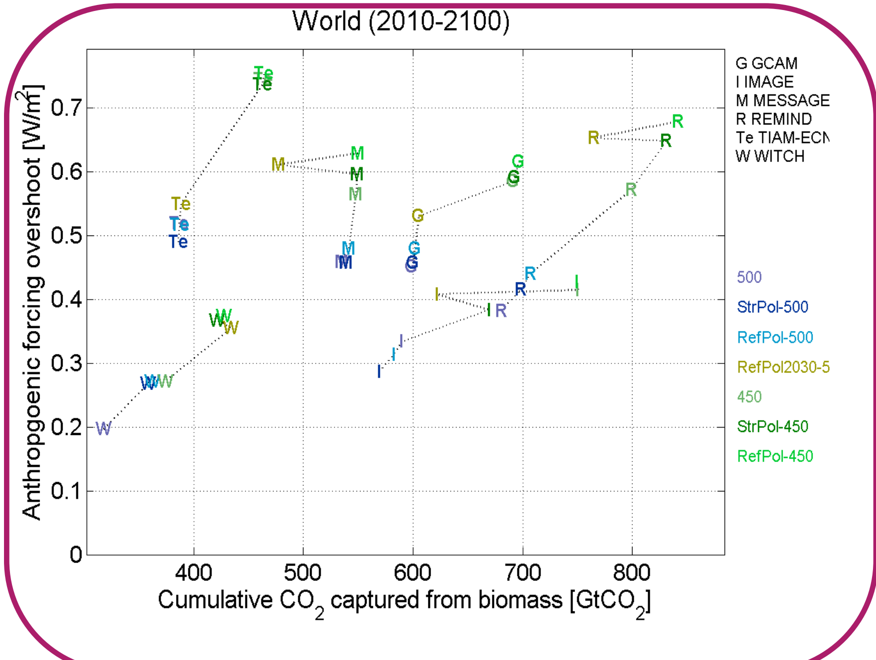


Van Vuuren et al, 2013 Special issue CDR, Climatic Change

Same results in IAM results: low GHG concentration in 2100 feasible at lower costs

AR4 (2007): 6 scenarios consistent with 2°C (BECCS); now 100s, nearly all using BECCS

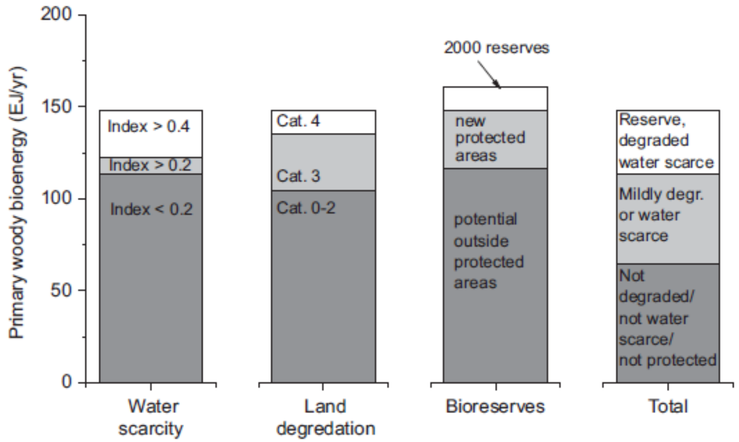




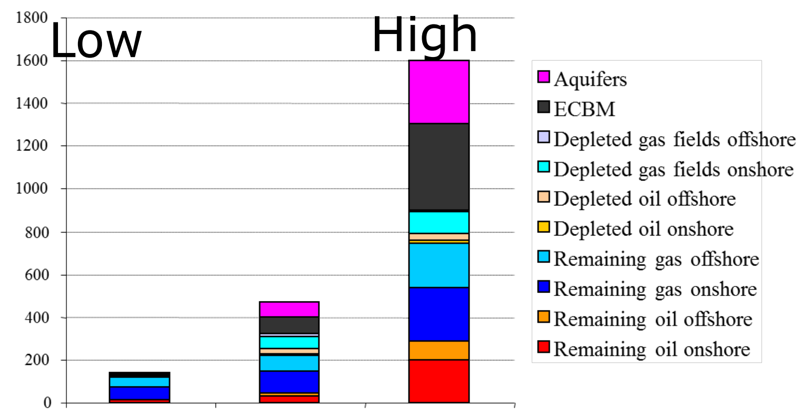
Van Vuuren and Riahi et al, 2011 / Kriegler et al. 2013

How much potential for negative emissions?

Bio-energy potential



CCS potential



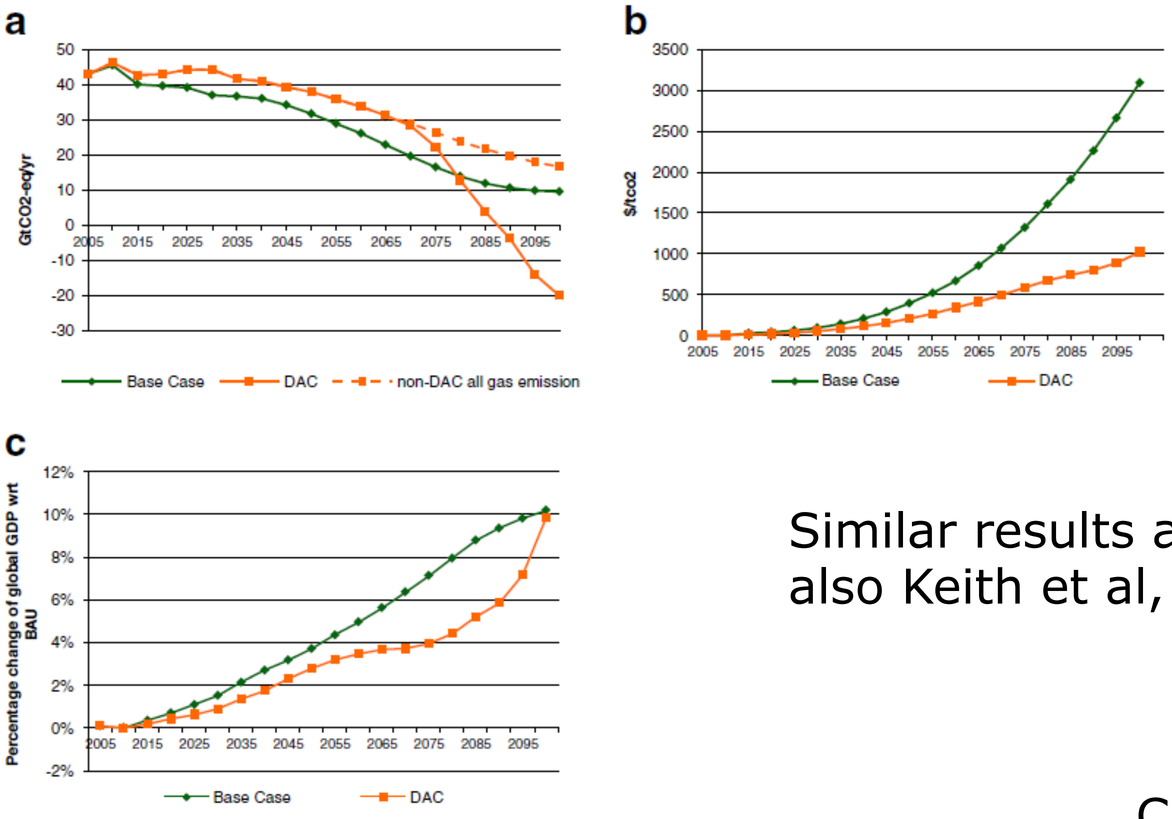
150 EJ/yr ~ 3.5 GtC /yr -→ but only if everything is used for BECCS (competing use from non-energy & transport)

Estimates of 1-16 GtC/yr on average available for storage in 100 years

Literature estimates 1.5 (afforestation)+ 4 Pg C/yr (BECCS) (Lenton, 2010); 1 Pg yr (Smith and Torn, 2013).

Van Vuuren et al, 2013 Special issue CDR, Climatic Change

Integrated assessment direct air capture (WITCH)



Default

DAC

Similar results as for BECCS (see also Keith et al, 2005)

Chen and Tavoni, 2013

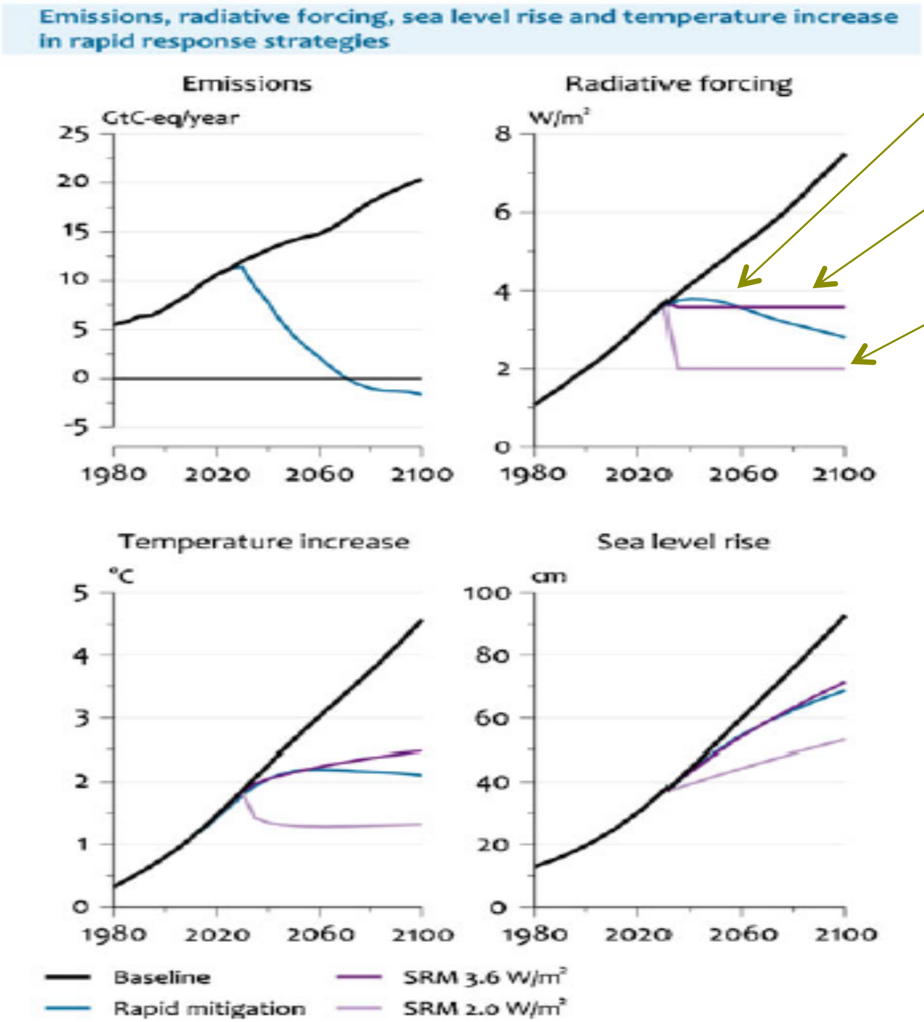
So CDR maybe important for long-term mitigation, but can CDR be reduced as rapid response?

- BECCS: Not so likely (implementation in energy system requires time)
- Direct air capture…. maybe, but might be very expensive (House et al., 2011)
- No real literature of using CDR as rapid response measure (little bit in AMPERE/LIMITS scenarios)
- Potential seems a big issue: in order to matter GtC-scale required.

What can Solar Radiation Mangement offer?

- → Most attractive SRM option seems to be aerosols in stratosphere (low costs, easily reversible) or wide cloud formation

Evaluation of Mit/CDR strategy vs. SRM

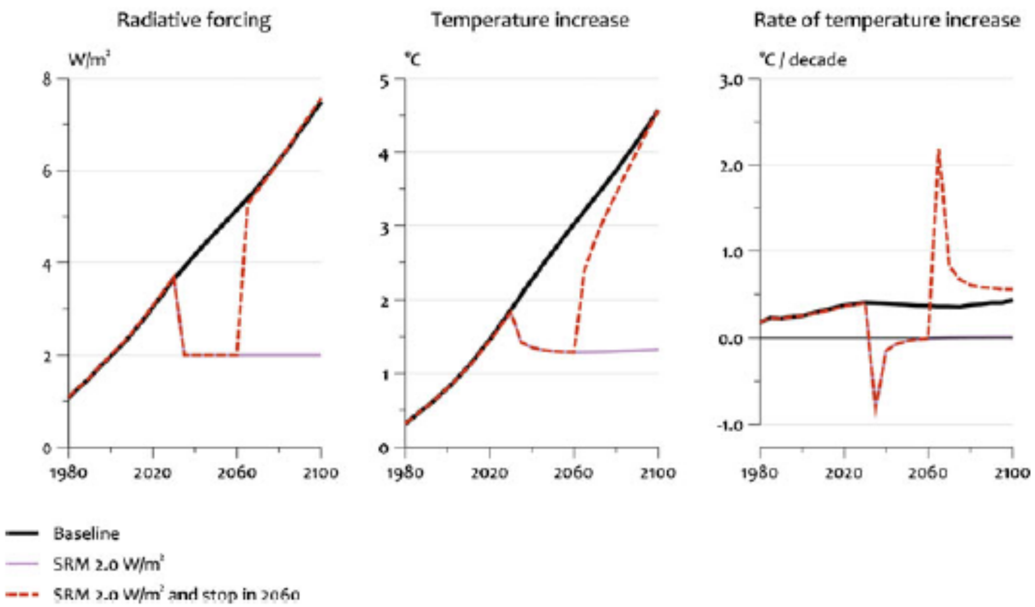


- Mitigation (including CDR – introduced at maximum rate)
- Solar radiation management (sulphur) stabilising at 3.5 W/m2
- Solar radiation management going back to 2 W/m2

→SRM provides a rapid response option… but even very strong SRM response not so effective for sea-level rise (see also Moore et al., 2010).

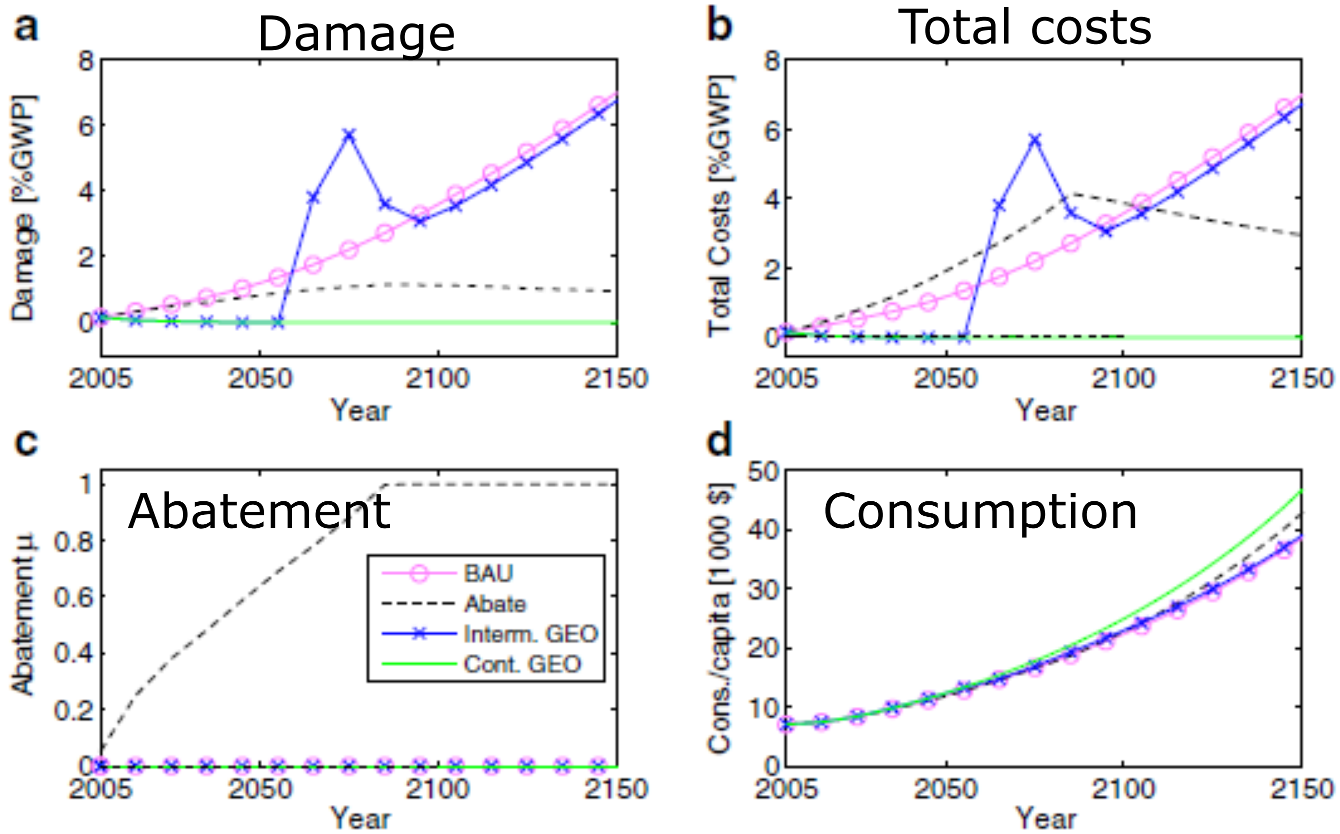
→CO2 concentration remains high (acidification)

Risks of SRM approach… how to get out again



- Risk associated with SRM (ozone chemistry, preciptation, Monsoon)
- Risk associated with stopping SRM – either as phase out or unintentional
- Reducing these risks requires a slow phase-out of many decades and thus commits future generations (ethical issues)
- Many practical governance issues (Barett, 2009)

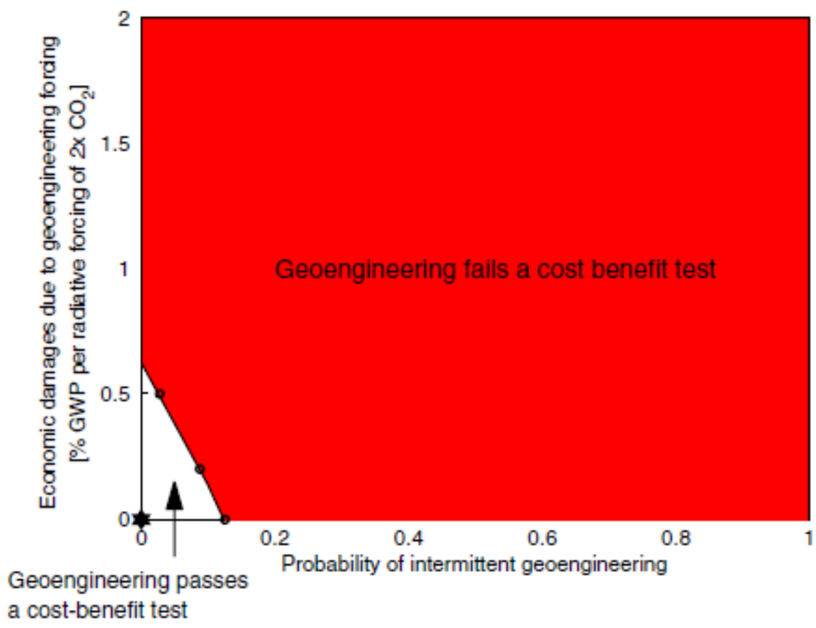
Cost-benefit analysis of SRM (revised DICE)



Goes et al., 2011

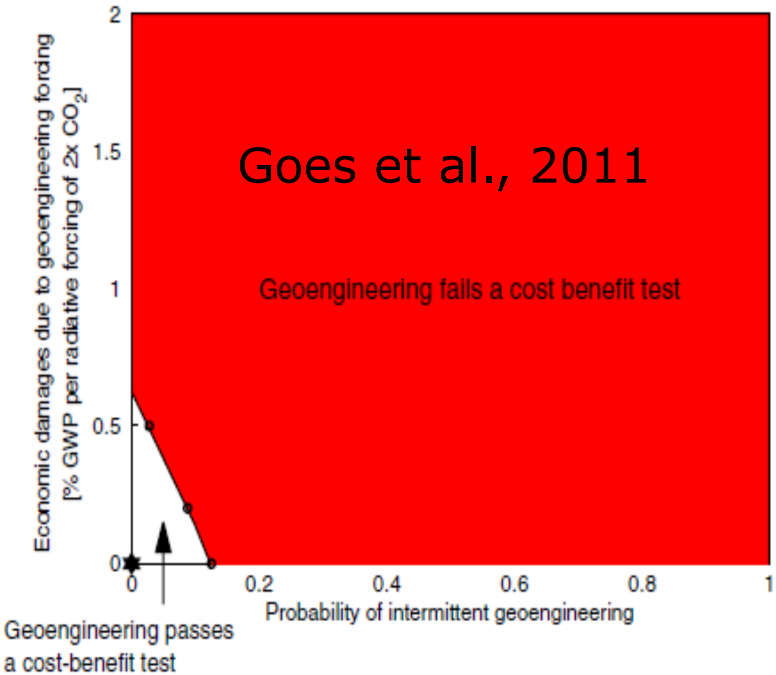
Costs benefit analysis

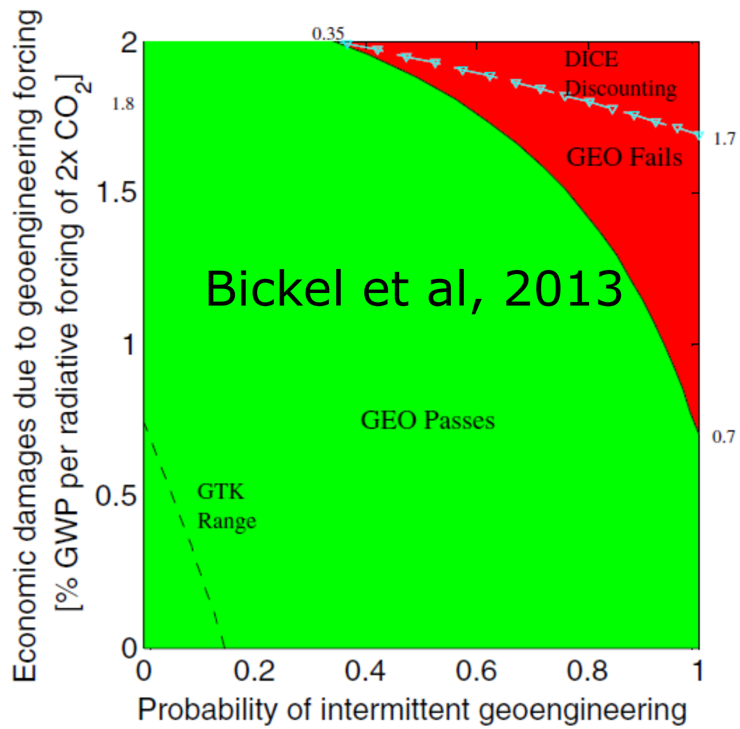
- Standard assumption: Costs of SRM maximum 8 billion for McClellan, 2013) for around -2.3 W/m2 (incredible economics of geo-engineering)
- Goes et at use DICE. Include the potential damage costs of aerosols + risks of a sudden-phase out. SRM as alternative to mitigation



Costs benefit analysis

- Bickel et al. 2013: Look into assumptions Goes et al. Different results if: 1) if SRM is combined with mitigation – but can also be stopped, 2) society can respond to SRM phase out.





Overall message SRM

- SRM does not seem alternative (e.g. ocean acidification) to mitigation, but can be attractive in combination with mitigation (Wigley, 2006; Bickel et al, 2013) or as rapid response measure.
- Strenght of SRM as rapid response measure is response time (certainly for temperature, possibly SLR), but only if introduced aggressively.
- SRM only attractive if maintained forever or combined with reasonable exit strategy; and environmental costs of aerosols are low.
- Large number of open questions regarding risks of aerosols, effectiveness, governance and ethical issues.

IAMs could also be used to evaluate consequences of geoengineering

- Geo-engineering runs by climate models (GEOMIP)
  - → Do these (already) have a distinct climate pattern?
    - Implications for agriculture / water scarcity (cost/benefits)
    - Implication of changes in radiative forcing?
    - Ocean acidification

  → Starting to add possible estimates for "costs" and "benefits" (maybe at least potential ranges)

Implications for IAMs

- → Further inclusion of risks / extreme events (see presentations last week)
- → CDR → No problem, maybe add other CDR options (direct air capture)
- → SRM: Probably interesting to explore further in simple climate models (Goes / Bickel debate) – risk management strategies - but seems not so useful to include in more complex models.
- → Especially focus on trade-offs (acidification, risks etc)
- → Further explorations in climate models for learning.

Evaluation of CDM/SRM by 'IAMs'

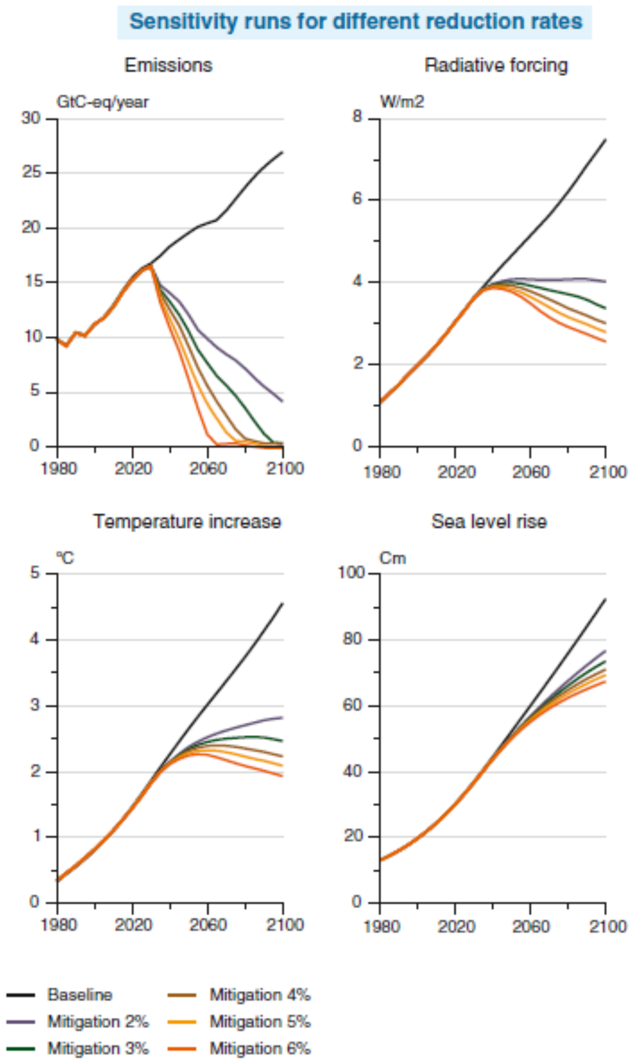
Both categories bring interesting new attributes to response portfolio

CDR

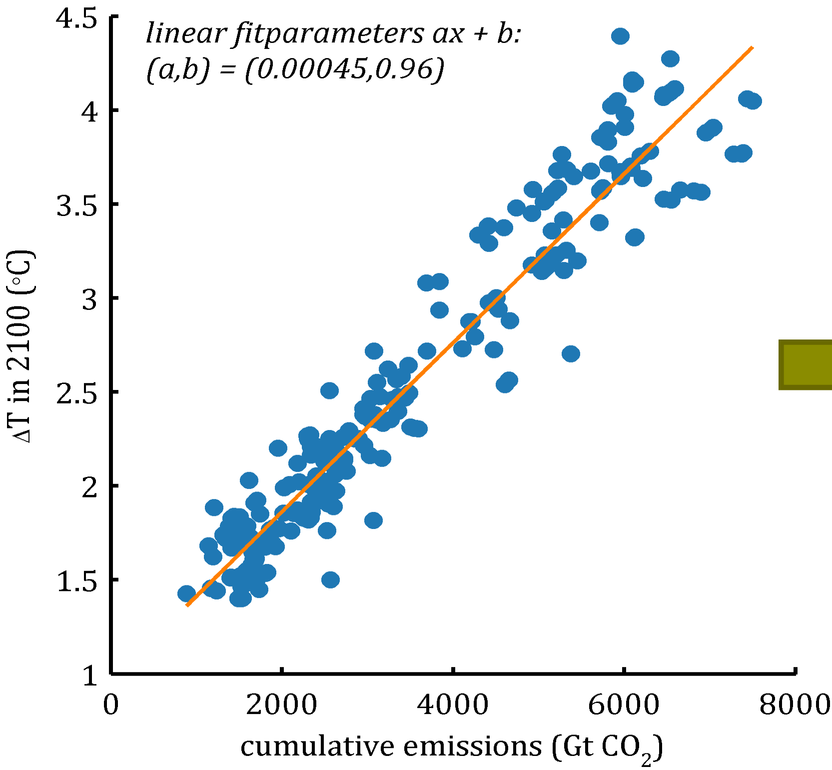
- Ability to reduce emissions faster
- Ability to go to negative emissions – thus speed-up concentration decrease (to challenge Solomon, 2009 – Nature)

SRM

- Break-link between concentration (governed by inertia) and climate change.
- Low costs


Sensitivity runs for different reduction rates
Emissions
GtC-eq/year
30
25
20
15
10
5
0
1980
2020
2060
2100
Radiative forcing
W/m2
8
6
4
2
0
1980
2020
2060
2100
Temperature increase
°C
5
4
3
2
1
0
1980
2020
2060
2100
Sea level rise
Cm
100
80
60
40
20
0
1980
2020
2060
2100
Baseline
Mitigation 2%
Mitigation 3%
Mitigation 4%
Mitigation 5%
Mitigation 6%

Very small CO_2 budgets associated with ambitious climate targets...

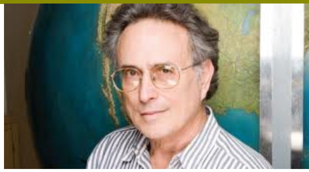


- Rerun of large set of IAM scenarios in MAGICC6

target	450 ppm CO_2eq in 2100
Fossil-fuel CO_2 2020 ($GtCO_2$/yr)	30 (28-33) 30 ±3
Fossil-fuel CO_2 2030 ($GtCO_2$/yr)	24 (22-28) 24 ±4
Fossil-fuel CO_2 2050 ($GtCO_2$/yr)	12 (8-14) 12 ±4
Fossil-fuel CO_2 budget 2000-2049 ($GtCO_2$)	1200 (1200-1400) 1200 ±100
Fossil-fuel CO_2 budget 2000-2100 ($GtCO_2$)	1300 (1300-1500) 1400 ±200

Schaeffer, van Vuuren et al. forthcoming

Main conclusions Tavoni/Socolow SI



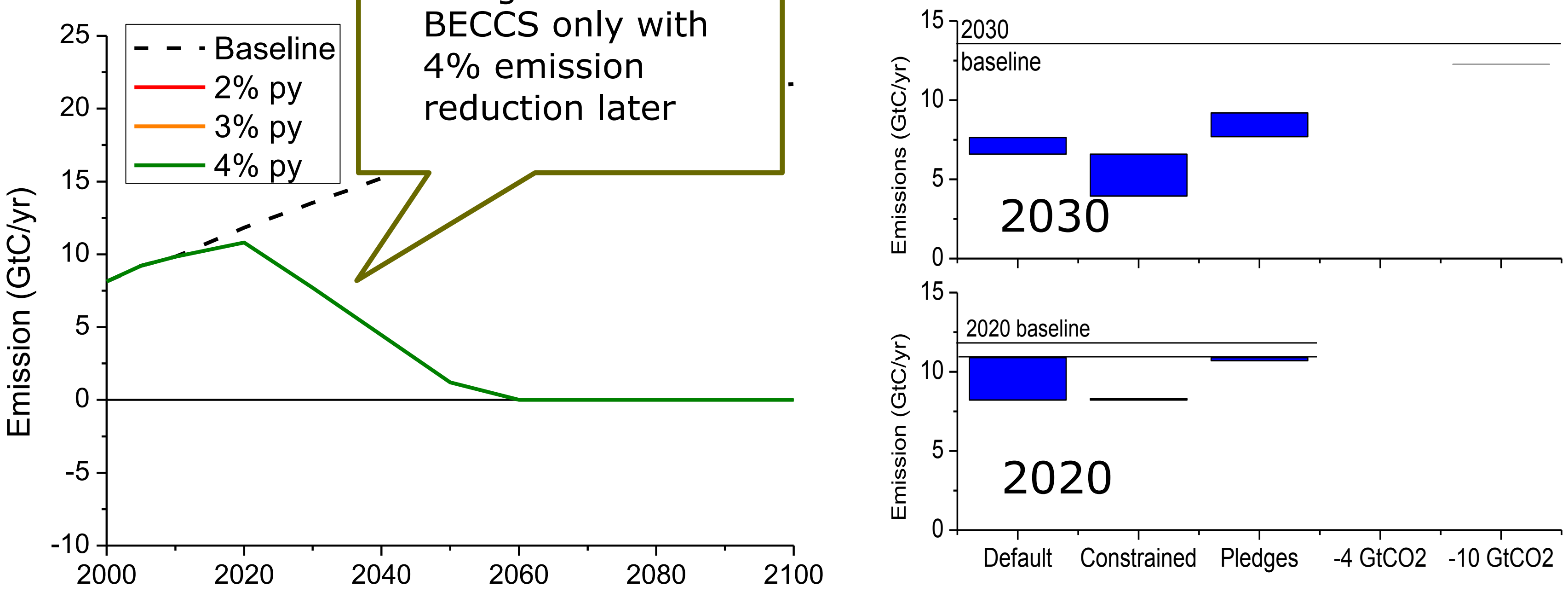
- Carbon dioxide removal (CDR) strategies could become competitive with further deployment of conventional mitigation strategies.
- It is far from certain that positive net environmental and societal benefits from CDR at very large scale will be achievable.
- CDR technologies are typically introduced late in the century.
- CDR could be instrumental in the far distant future in actually reducing the atmospheric carbon concentration and the associated globally averaged surface temperature.
- The modeling of CDR in integrated assessments can be much enriched by further iterative dialog with other disciplines.

History on BECCS in IAM scenarios

- AR4: Only 3 multigas scenarios from 2 IAM teams published consistent with high probability of achieving 2 deg C target (all 3 using BECCS).
- In Noordwijkerhout (2008) one of these scenarios (IMAGE 2.6) selected as one of the RCPs
  - Scenario described in paper Van Vuuren et al. (2007). Climatic Change. Stabilising GHG concentrations at low levels.
- During the meeting: "One of the key questions in the next 5 years will be whether other teams can confirm IMAGE results"
- By now hundreds of similar scenarios, mostly using BECCS.

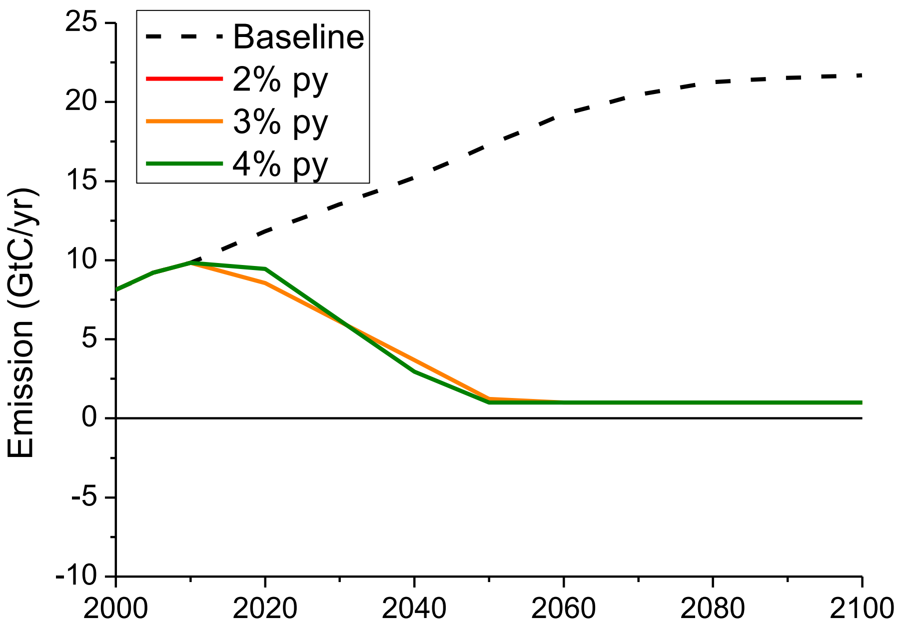
Scenarios without BECCS: Impact of reducing emissions less in 2020 (pledges)

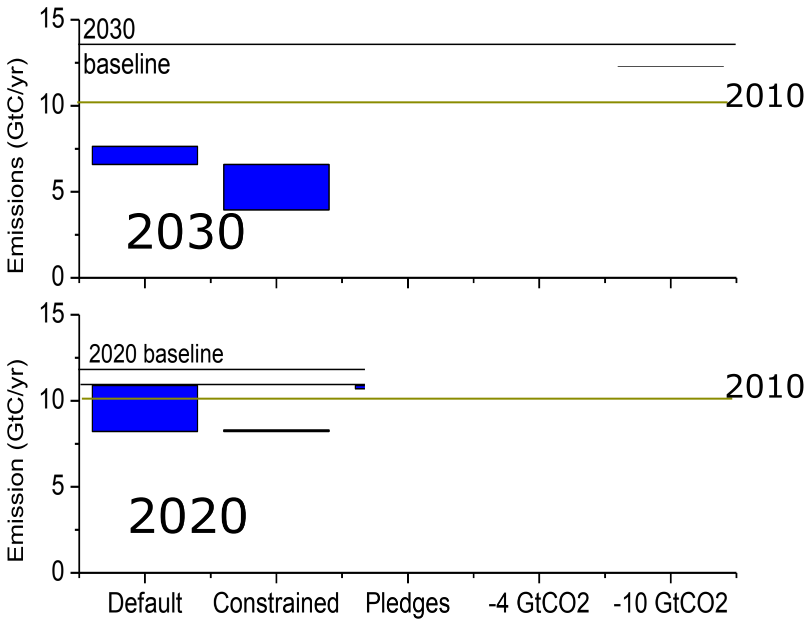
- Pledges without BECCS only with 4% emission reduction later



Van Vuuren et al, 2013 Special issue CDR, Climatic Change

Scenarios without BECCS: Impact with remaining emissions





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