

Geoengineering to prevent harmful climate change

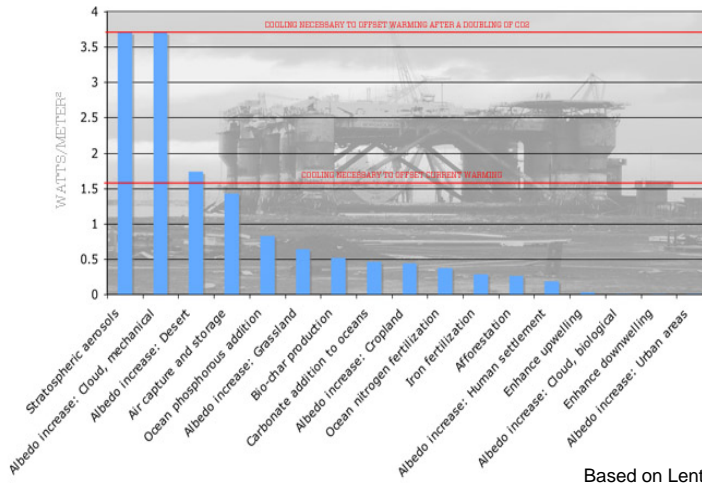
Jip Lenstra



Between emission reduction and adaptation...

Emission of greenhouse gasses	Emission reduction
Concentration in atmosphere	Air capture technologies
Global warming	Influencing energy balance
Dangerous interference	Adaptation

COOLING POTENTIAL OF GEOENGINEERING TECHNIQUES



Based on Lenton and Vaughan

Air capture options: Mineral sequestration

- Olivine is a mineable rock
- It binds CO₂ slowly
- Grinding to extreme small particles (< 40 micrometer) speeds up the process (150 kWh/ton)
- Costs 30 – 150 €/ton CO₂
- Reaction time is slow (40 – 4000 year)
- Faster at tropical beaches (30 yr) and in agriculture (6 yr)



Source: TNO report 2008-U-R0777/B

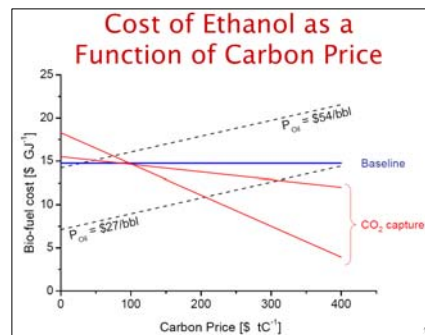
Air capture options: Scrubbers

- Klaus Lackner proposes a system based on a (secret) resin with lye
- Keith et al build a pilot based upon existing technology
- Estimated costs for air scrubbers 30-200 \$/ton CO₂



Biomass/CCS as air capture option

- Many biomass conversion processes have concentrated CO₂ emissions (a.o. Milena)
- CCS in these processes can be cheaper than market prices for CO₂
- CCS can be a secondary income stream for biomass energy



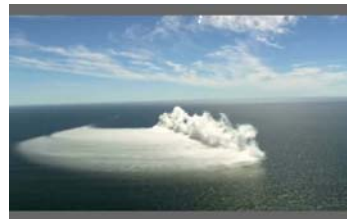
Source: Rhodes & Keith, Univ. of Calgary. 400 \$/tC = 73 €/ton CO₂

Overview of air capture options

	State of the art	Current cost estimate €/ton CO ₂	Remarks
Mineral sequestration	Laboratory research	30 - 150	Slow and impracticable
Soil sequestration	Pilot scale	Comparable with biomass	Limited potential, hard to monitor
Air scrubbers	Pilot scale	30 - 200	Costs and energy consumption
Biomass/CCS	Demonstrable	20 – 70 (CCS only)	Sustainable biomass potential

Albedo enhancement options

- Crutzen proposed SO₂ injection in the stratosphere
- The SO₂ scatters the sunlight (direct aerosol effect)
- Latham proposes to inject sea salt aerosol above oceans to whiten clouds
- Both options do not reduce GHG concentrations
- But they can considerably reduce the most painful effects of climate change



Source: Discovery Chanel

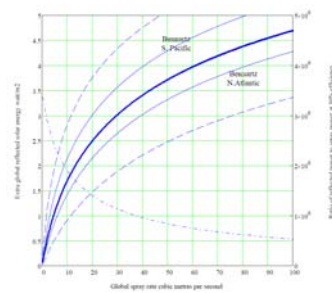
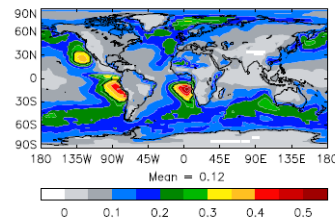
Comparison of sea salt versus SO₂

- | | |
|---|--|
| <ul style="list-style-type: none"> • Sea salt (mostly harmless) • Short lifetime (week) • Very low cost (0,05 € for 100 yr masking of a ton CO₂) • Effect is non linear • Mostly (strong) local impacts | <ul style="list-style-type: none"> • SO₂ (health and ecological risks) • Lifetime more than a year • Low cost (0,25 € for 100 yr masking of a ton CO₂) • Effect is linear • Mostly global impacts |
|---|--|

For both options:
Negative side effects are possible and not yet fully understood!

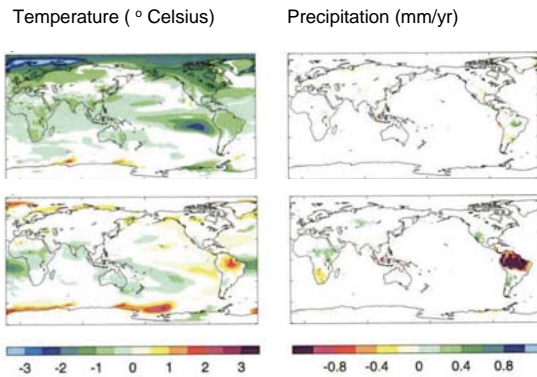
Sea salt option details

- Work done by Latham, Salter, Bower, Choulaton, and others
- ECN has made an assessment of possible spray technologies and costs



Sea salt option: effects

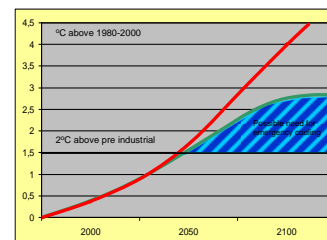
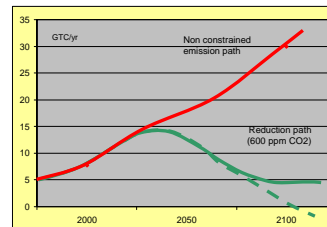
- Effects differ depending on spray area
- South Pacific area has best results
- South Atlantic has least results and more negative impacts



Source: Jones et al

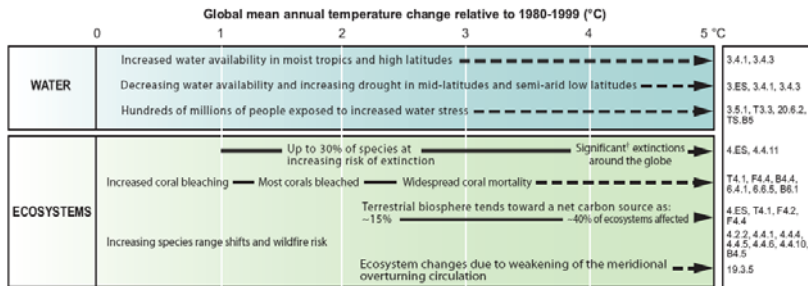
Possible overshoot strategy

- Assume strict and global reduction policies to start soon
- Include air capture options in reduction policies (with biomass/CCS as reference for costs)
- Investigate sea salt option and SO₂ option to be available by 2020 as emergency cooling



Albedo enhancement does not decrease ocean acidification

- Ocean acidification can be one of the early damages caused by CO₂ concentration



Source: IPCC AR4 WG2

Three caricatures of the geoengineer



- The sorcerer's apprentice: unknown, uncontrollable risks

- The fire fighter: emergency, accept collateral damage



- The physician: apply medicine temporarily until underlying causes removed

Source: Rob Swart (WUR)

Conclusions

- Policy makers and researchers should take overshoot scenario's into account
- We have to start reducing risks now!
- Carbon(dioxide) removing technologies will be needed
- Emergency cooling should be available when climate damage exceeds acceptance

Other geoengineering events

- Thursday December 10, 15.00 – 17.00 hours,
Geoengineering knowledge and technology development, Saxo Grammaticus Room
- Friday December 11, 13.00 – 14.30 hours,
Geoengineering, global equity and sustainable development, Crown Plaza Copenhagen Hotel
- Thursday December 17, 19.00 – 21.00 hours:
Extreme climate change, extreme responses?
Holland Climate House
- Friday December 18, 09.00 – 10.30,
International governance of geoengineering research, Halfdan Rasmussen Room

