The role of carbon capture and storage technologies in a carbon-constrained world

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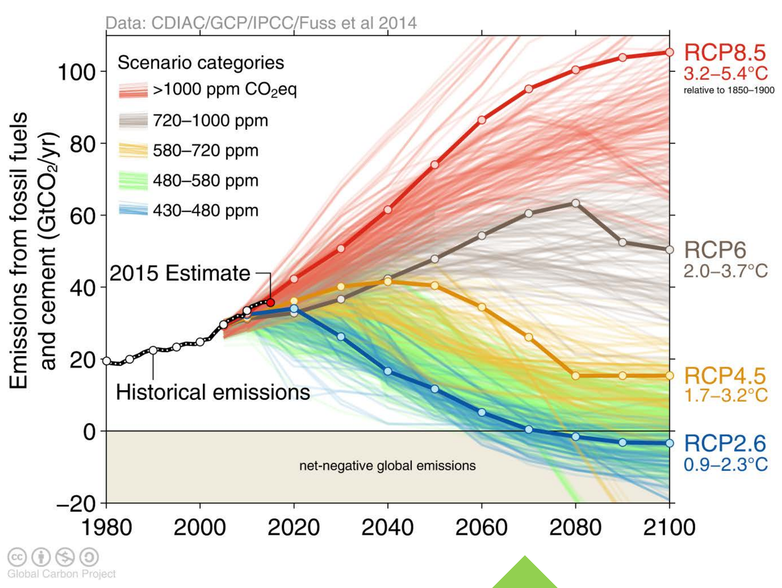
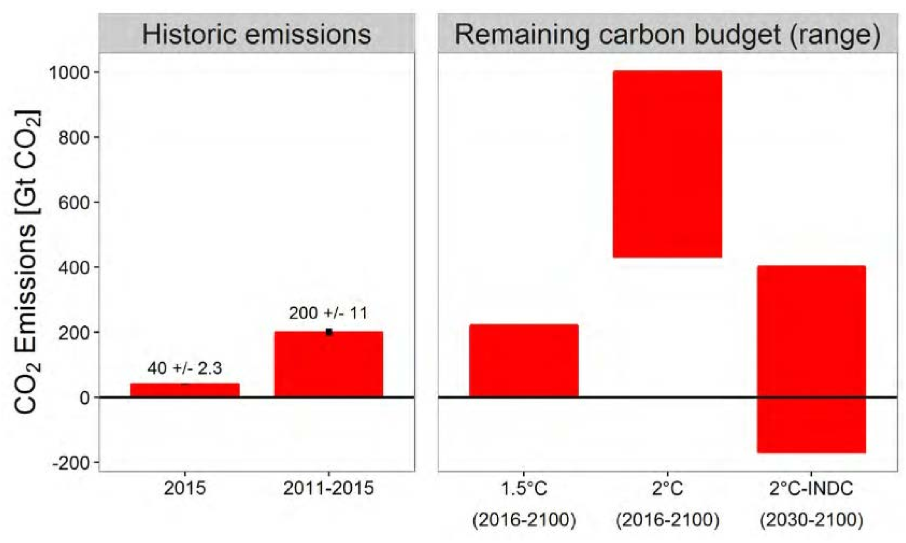
1.5 degrees – Meeting the challenges of the Paris Agreement

1.5°C and 2°C scenarios

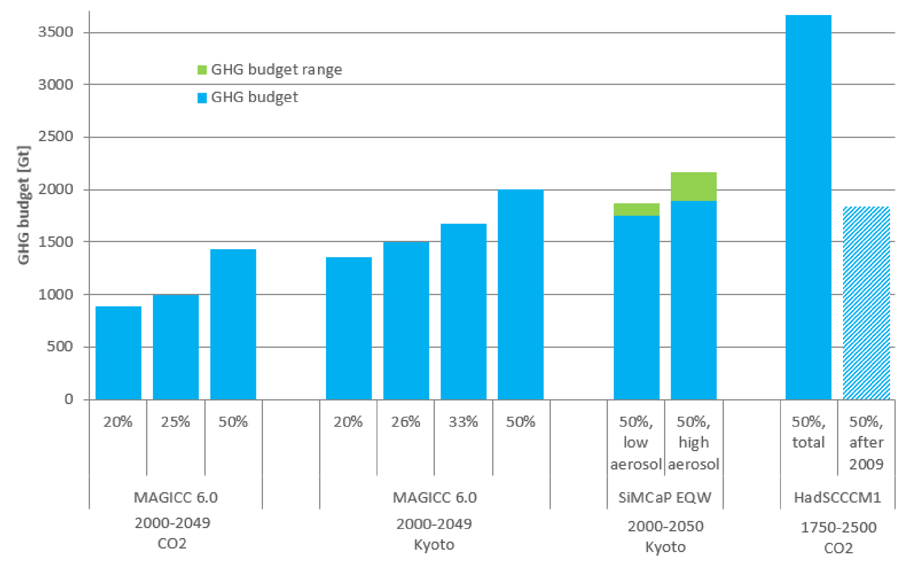


- Net negative emissions are crucial for achieving a 1.5°C target

Carbon budget



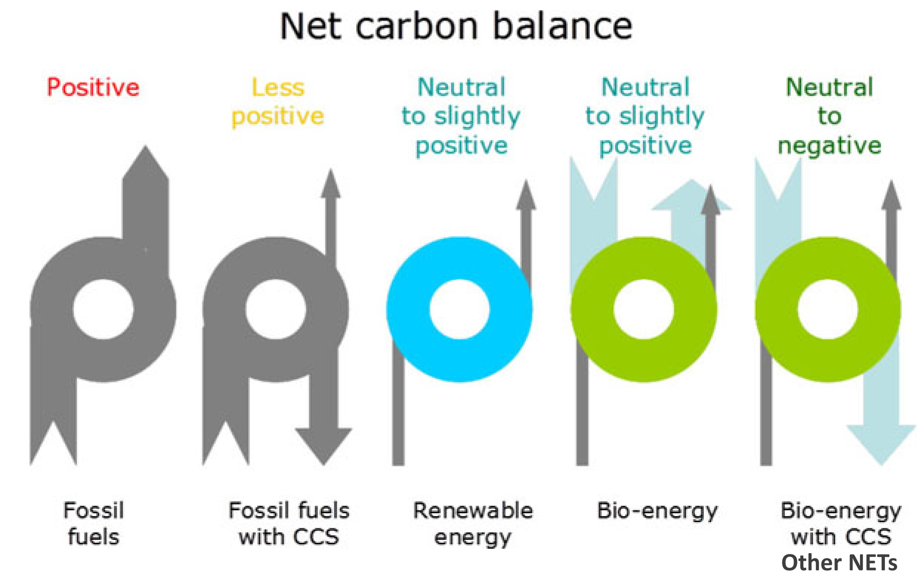
Fuss 2016 (Figure by Jan Minx 2016 with data from Le Quere et al. 2015, Rogelj et al. 2013/2015, Luderer et al. 2013)



IEAGHG/SGI 2016 (% = probability to exceed 2°C, Kyoto = CO_2, CH_4, N_2O, HFCs, PFCs, SF_6)

- Carbon budgets usually include fossil sources as well as land use change (LUC)
- Non-CO_2 greenhouse gases (GHGs) can contribute up to 33%
- Carbon budget 1750-2500 is ~3670 $GtCO_2$ → already used up half of this until 2009 → only 1800 $GtCO_2$ left (to have a 50% chance of meeting 2°C) (Allen et al. 2009)
- Estimation of carbon budgets contains uncertainties
- But: current emissions rate 40 $GtCO_2$/yr → quick erosion of carbon budget

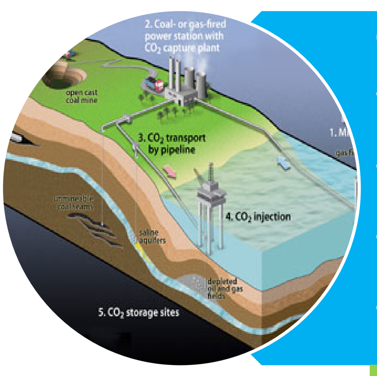
Carbon balance of energy systems



IEAGHG/Ecofys 2011 (adapted from ecofriendlymag.com; grey denotes carbon of fossil origin, blue denotes carbon of biogenic origin)

- Past/current energy systems based on the far left (fossil fuels)
- Now efforts underway transitioning to the mid three technologies (Fossil-CCS, RE, bioenergy)
- Should we stop at Fossil-CCS/RE/bioenergy?
- Need help from the far right (NETs) to make up for "damage done" in the past

What are CCS, NETs and Bio-CCS/BECCS?



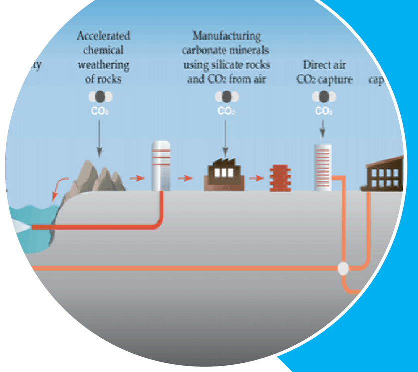
NERC

CCS (carbon capture and storage)

- Process of capturing, transporting and permanently storing CO_2 emission from anthropogenic large-point sources
- Capture
  - Pre-combustion, post-combustion, oxyfuel-combustion
- Transport
  - Pipeline, ship
- Storage
  - Enhanced oil recovery (EOR), depleted oil/gas fields, deep saline aquifers

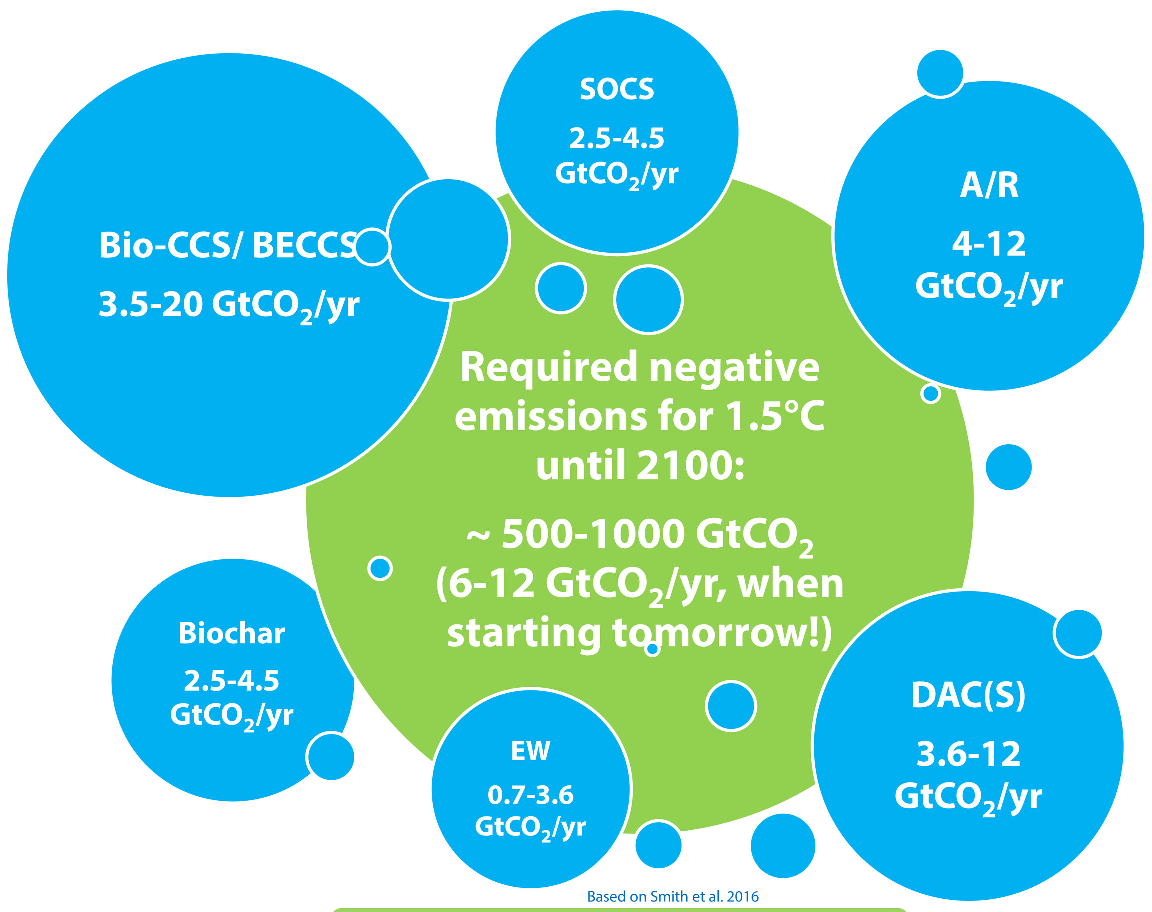
- All parts of CCS chain technically feasible, issues remain with costs and public perception
- 15 large-scale projects with 29 $MtCO_2$/yr in operation, 7 with additional 11 $MtCO_2$/yr under construction (GCCSI 2016)

NETs (negative emission technologies)



Virgin Earth Challenge

- Bio-CCS/BECCS (bioenergy with CCS) – using biomass that has previously taken up CO_2 during growth to produce power/heat/fuels, then capturing and storing the emitted CO_2
- A/R (afforestation/reforestation) – planting trees where previously (a) there were none or (b) they have been cut down
- DAC(S) (direct air CCS) – capturing CO_2 directly from air
- EW/MC (enhanced weathering/mineral carbonation) – spreading pulverised rock on land/water to take up CO_2 and form bicarbonate
- SOCS (soil organic carbon sequestration) – storing CO_2 in soil through advanced farming methods, restoration and land creation
- Biochar – adding burnt/torrefied biomass to soil for long term storage
- Ocean fertilisation – adding Fe or N to accelerate CO_2 uptake by microorganisms for photosynthesis
- Cloud/ocean treatment – (a) using alkalis to wash CO_2 out of the atmosphere, (b) using lime to absorb CO_2 from the oceans



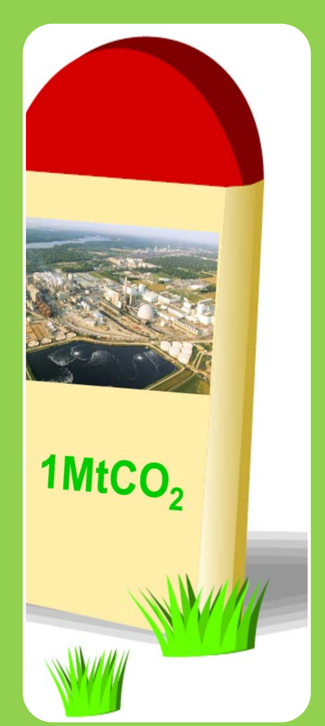
Based on Smith et al. 2016

Most important NET trade-offs

Impact on soil	Energy demand
Impact on albedo	Water demand
Costs	Land demand

Case study: Bio-CCS/BECCS

Bio-CCS/BECCS status



ADM

- Many studies conclude: Bio-CCS, incl. its CCS components, technically feasible as of today (TRL 3-7) (except microalgal biomass)
- Perceived „double benefit": heat/power + negative emissions → would be less so for fuels due to release of CO_2 during combustion
- 5 operating Bio-CCS projects: 0.1-1 $MtCO_2$/yr (all ethanol based, 3 for EOR, 4 in US, 1 rather Bio-CCU), several more underway
- GHG accounting: only 2006 IPCC GLs, CDM/JI, Ca LCFS and EU RED/FQD cover Bio-CCS
- Plenty of research on public perception of CCS but very limited and contradictory on Bio-CCS
- Bio-CCS generally has lower profile than Fossil-CCS
- Main drivers/barriers for Bio-CCS:
  - CO_2/NG price, infrastructure/clusters, sustainable feedstocks, public perception

- Competition: food vs bioenergy crops
- Shift of GHG/CO_2 emissions from one sector to another ("carbon leakage")
- Impact of large-scale biomass infrastructure, trade, and supply chains
- Impact of climate change on crop yields
- Water footprint of Bio-CCS systems
- Effects of increased fertiliser use
- Land availability and lock-in
- Land use change (LUC) impacts
- Biomass sustainability

Main nexus concerns

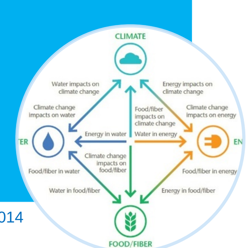
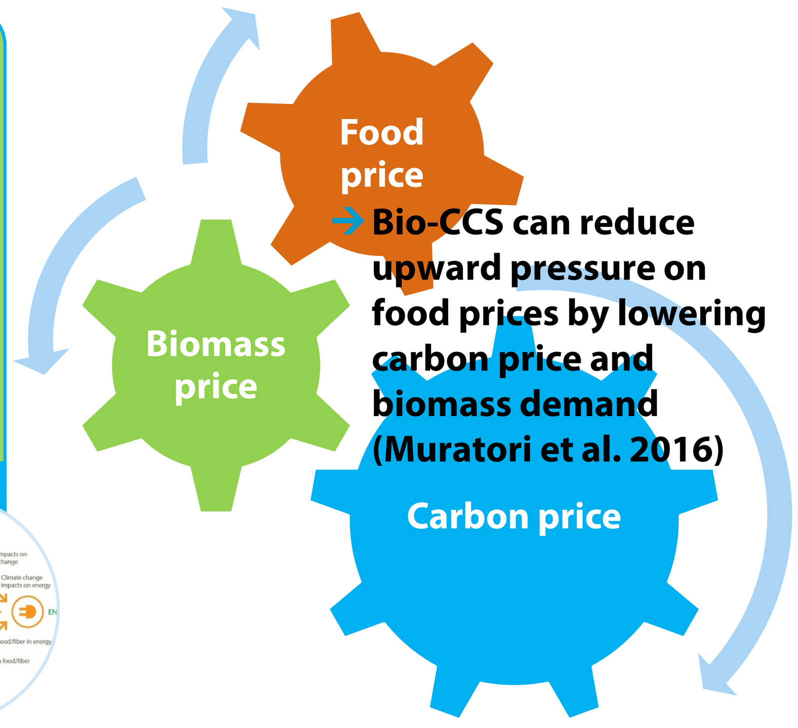
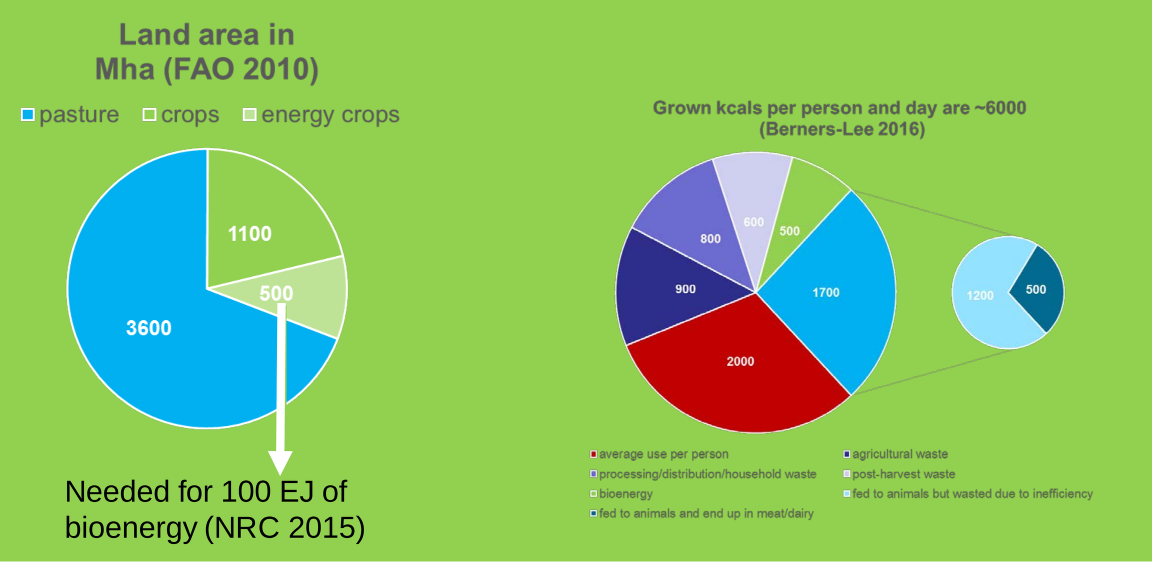


Image: World Business Council on Sustainable Development 2014

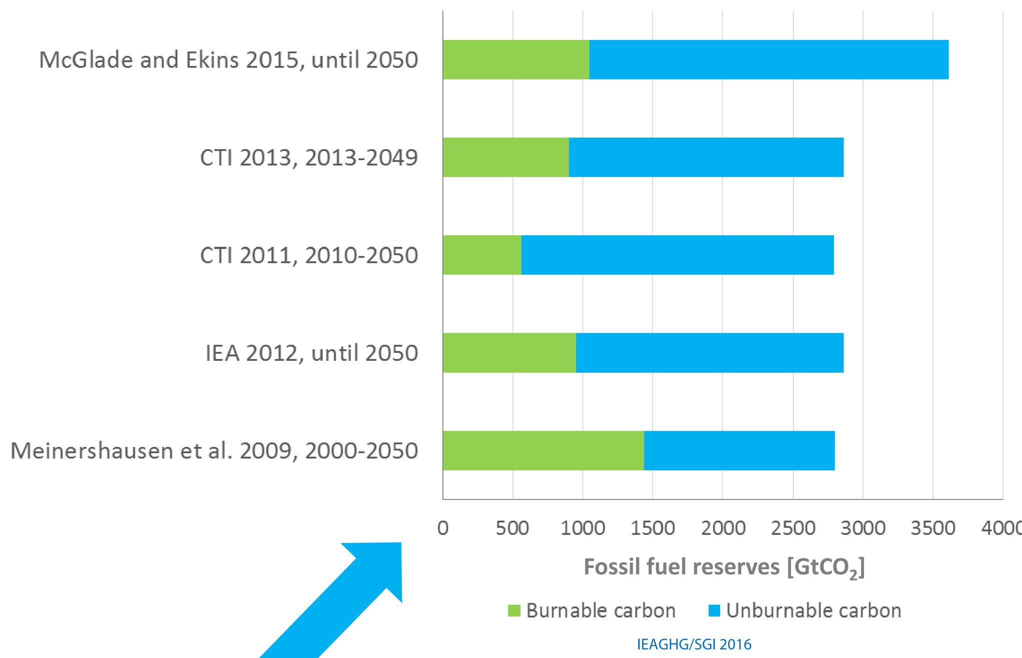


How to overcome the "lack" of land?

- Demand-side changes
- Yield increases
- Better land management



"Unburnable carbon" concept



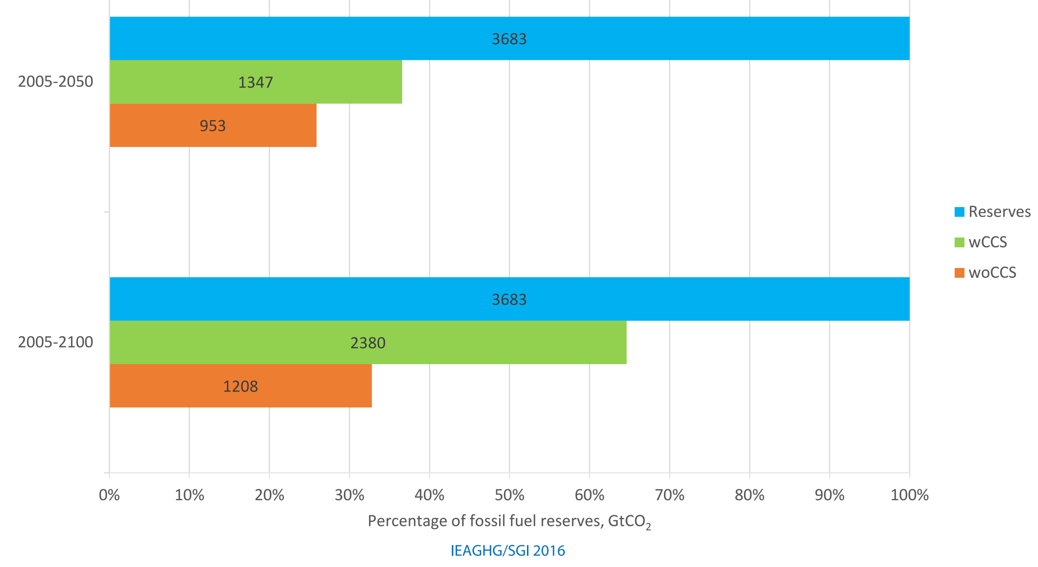
IEAGHG/SGI 2016

"Unburnable carbon":

- Carbon budget for emission scenarios implies → certain amount of fossil fuel reserves "unburnable", i.e. their carbon not emittable, to stay within target
- CCS prevents/reduces emission of carbon to the atmosphere
- NETs can even remove historic emissions from the atmosphere
- Both are key to enable continued use of fossil fuels

Key messages from IEAGHG/SGI study:

- Investigated effect of CCS on unburnable carbon
- Impact of CCS is material until 2050 and further increases until 2100
- 11% resp. 32% more fossil fuels can be used with CCS in a 2°C scenario
- For scenarios < 2°C higher capture rates, i.e. >> 90%, might be necessary



IEAGHG/SGI 2016

Conclusions

- Due to quick erosion of remaining carbon budget for a 1.5°C scenario → timely action required!
- CCS technology components are mature and CCS can enable continued access to fossil fuels under carbon-constrained scenarios
- NETs, like Bio-CCS/BECCS, could make up for historic emissions and previous inaction
- Mitigation portfolio containing various options is best bet, as each has pros and cons
- Whole systems approaches required to address the food-water-energy-climate nexus

Further work requirements

- Evaluate/quantify the role of CCS and NETs on "unburnable carbon" under a 1.5°C scenario
- Quantification of Bio-CCS/BECCS nexus → water/land/carbon/energy intensities
- Identify the sweet spots for CCS and NET implementation
- For Bio-CCS/BECCS: develop/optimise supply chains for sustainable biomass
- Develop financial mechanisms and policy frameworks to support CCS and NETs

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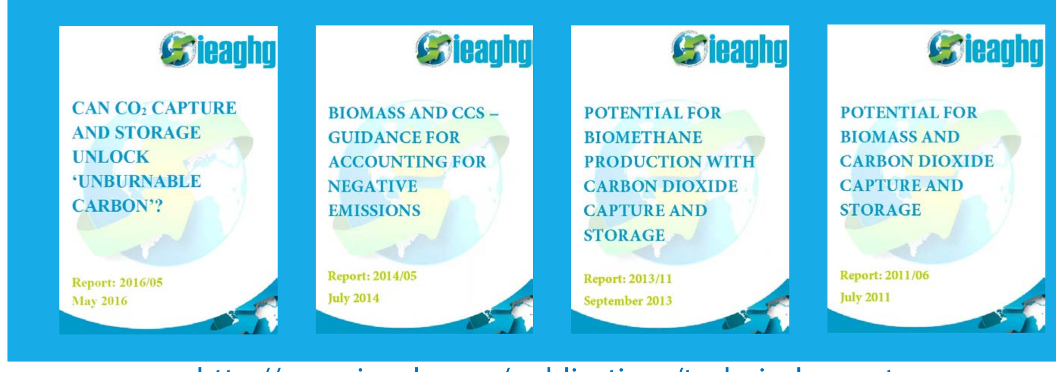

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