KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

Reducing atmospheric CO_2 through CO_2 capture and storage

KNAW Summary of EASAC reports

Atmospheric CO_2 levels can be brought down by capturing CO_2 from factory chimneys or from the air, and storing it. This factsheet summarizes[1] what EASAC, the European Academies' Science Advisory Council, says about the contribution of such CO_2 removal to greenhouse gas reductions.[1] EASAC is the association of the National Academies of Science of the EU Member States, Norway and Switzerland and provides independent science-based advice for policy-makers. KNAW is an active member of EASAC. The factsheet is supplemented with quotes from the IPCC 2018 Special Report on Global Warming of 1.5°C. IPCC points out that all pathways that limit global warming to 1.5°C envisage massive use of carbon dioxide removal.[2] IPCC also stresses the feasibility and sustainability constraints of Carbon Capture and Storage (CCS).[3]

There are also major public concerns about underground CO_2 storage, but that issue is not analysed extensively in the EASAC reports. Therefore it is not discussed here.

Methods to collect and store CO_2

The main approaches to the removal and storage of CO_2 are as follows:

1. **Planting or conserving trees**
The least costly and most easily deployable technology to catch and store CO_2 is to plant trees.[4] However, 20–60% of the arable land of the entire world would have to be planted with new trees in order to absorb the required gigaton quantities of CO_2.[5] Also, new trees take decades before they store appreciable amounts of CO_2. Reducing the cutting of existing trees has an immediate beneficial effect on atmospheric CO_2.[6]

2. **Carbon Capture and Storage (CCS)**

2.1. **Capturing CO_2 emitted by factories**
Coal- and gas-fired power plants, cement, steel, fertilizer and other plants emit concentrated streams of CO_2.[7] This CO_2 could be separated out and stored underground in empty gas fields. EASAC noted the importance of such Carbon Capture and Storage (CCS).[8] Efforts should continue to develop CCS into a

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relatively inexpensive mitigation technology.[9] Some progress has been made with transport and storage clusters that can accept captured CO_2,[10] and the technological maturity of CO_2 capture has improved considerably. However, costs have not come down between 2005 and 2015[11] and commercial-scale development projects have been withdrawn owing to lack of adequate government support.[12]

2.2. **Capturing CO_2 from biomass-fired plants**
CCS can also be used to capture the CO_2 emitted by biomass-fired plants. It is then called BECCS (**B**io **E**nergy with **C**arbon **C**apture and **S**torage). Growing biomass is an existing technology, and CCS is a viable technology.[13] A large negative emissions capability is claimed for BECCS in climate scenarios limiting warming to 1.5°C or 2°C, but this is not supported by recent analyses.[14] BECCS has substantial risks and uncertainties, related to its impact on availability of water and fertiliser, biodiversity, and competition for land.[15] It is also not yet clear if BECCS will achieve net removal of CO_2 from the atmosphere. The simplistic vision is that one ton of CO_2 captured in the growth of biomass equates one ton of CO_2 sequestered geologically. However, emissions throughout the biomass production and usage chain may 'leak' more carbon into the atmosphere than is captured and stored. That would result in a net increase not decrease of greenhouse gases.[16]
Another fact is that biomass cannot trap solar energy efficiently; biomass requires 50–100 times more land area usage than solar panels to produce the same amount of electricity.[17] Producing the amounts of biomass foreseen in current BECCS scenarios requires millions of km^2, equivalent to 7–25% of the world's total agricultural land (including grasslands).[18]

2.3. **Capturing CO_2 from the air and storing it underground**
This is called Direct Air Capture with Carbon Storage (DACCS). DACCS-factories capture CO_2 directly from the atmosphere. The CO_2 is then transported to underground reservoirs. Significant technological progress has been achieved in DACCS, but it is not yet possible to identify a preferred technology.[19] Direct Air Capture could be particularly suitable for factories that use wind and solar electricity to convert CO_2 into synthetic fuels;[20] CO_2 could then be generated directly where it is needed.
Capturing CO_2 from the air consumes more energy than capturing it directly from industrial chimneys and stacks, because the CO_2 concentration in air is 100–300 times lower.[21]

3. **Treating rocks so that they will absorb CO_2**
We do not know if this will work on a large scale. Such enhanced weathering and carbon mineralisation require further basic research before their potential can be properly assessed.[22]

Conclusions of EASAC

- Large-scale planting of trees is the most easily deployable technology for removing CO_2. However, it requires huge areas, long-term good governance,[23] and it takes decades before trees start to take up large amounts of CO_2. Less harvesting of existing trees has an immediate favourable effect on CO_2 emissions.

- The large negative emissions capability assumed for **B**io **E**nergy with **C**arbon **C**apture and **S**torage (BECCS) is not supported by recent analyses. BECCS remains associated with substantial risks and uncertainties, both over its environmental impact and its ability to achieve net removal of CO_2 from the atmosphere.[24]

- Efforts should continue to develop CO_2 capture and storage (CCS) into a relevant and relatively inexpensive mitigation technology.[25]

- Enhanced weathering and carbon mineralisation require further basic research.

Notes

[1] European Academies Scientific Advisory Council (2017). Multi-functionality and sustainability in the European Union's forests. https://easac.eu/publications/details/multi-functionality-and-sustainability-in-the-european-unions-forests

European Academies Scientific Advisory Council (2018). Negative emission technologies: What role in meeting Paris Agreement targets? https://easac.eu/fileadmin/PDF_s/reports_statements/Negative_Carbon/EASAC_Report_on_Negative_Emission_Technologies.pdf

European Academies Scientific Advisory Council (2019). Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update. https://easac.eu/publications/details/forest-bioenergy-carbon-capture-and-storage-and-carbon-dioxide-removal-an-update/

[2] IPCC (2018), p. 17, C3. 'All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 GtCO_2 over the 21st century.'

[3] IPCC (2018), p. 17, C3. 'Carbon dioxide removal deployment of several hundreds of GtCO_2 is subject to multiple feasibility and sustainability constraints (high confidence).'
p. 270, re BECCS and afforestation: "Large-scale deployment of land-based CDR would have far-reaching implications for land and water availability (high confidence). This may impact food production, biodiversity and the provision of other ecosystem services (high confidence)."
p. 346, 4.3.7.5 Direct air carbon dioxide capture and storage (DACCS): 'Energy consumption could be up to 12.9 GJ tCO2-eq−1;translating into an average of 156 EJ yr−1 by 2100 (current annual global primary energy supply is 600 EJ)' <The energy consumption of Europe including non-EU countries in 2018 was 85 EJ yr−1, so DACCS could require almost twice the total European energy consumption (BP Statistical Review of World Energy 2019, p. 8)

[4] EASAC (2019) p. 4: 'Regarding the role of afforestation, reforestation and other natural climate solutions, this remains the least costly and most easily deployable existing CDR [**C**arbon **D**ioxide **R**emoval] technology.'

[5] EASAC (2018), p. 7: 'to absorb gigaton quantities of CO_2, large (and ever-increasing) areas would be required to absorb CO2 through forest growth (or regrowth). Capacity estimates for the global potential of afforestation and reforestation are 1.1–3.3 GtC/year (Smith et al., 2016) given sufficiently large areas of land (320 million to 970 million hectares or ~20–60% of the current global area of arable land).'

[6] EASAC (2017), p 21: 'Harvesting immediately reduces the standing forest carbon stock compared with less (or no) harvesting (Bellassen and Luyssaert, 2014; Sievänen *et al.*, 2014) and it may take from decades to centuries until regrowth restores carbon stocks to their former level—especially if old- growth forests are harvested'.

EASAC (2017), p. 22: 'if trees with a large ongoing carbon storage potential are harvested, then the emissions from burning the biomass would be associated with the loss of a carbon sink, and the net effect on the climate is likely to be negative'.

EASAC (2017), p. 23: 'While using sources of residual wood (for example residues, tree thinning) for energy can make a positive contribution to climate mitigation within a decade or so, expanding demand to include whole trees can swiftly move to scenarios that exacerbate climate change for centuries.'

[7] Bains, P., Psarras, P., and Wilcox, J. (2017). CO_2 capture from the industry sector. Progress in Energy and Combustion Science 63, 146–172.

[8] EASAC (2019), p. 1: 'The EASAC analysis of the role of negative emission technologies (NETs) had noted the importance of CCS and the lost opportunities resulting from the lack of progress in its development in Europe.'

[9] EASAC (2019), p. 4: "EASAC … reiterates its earlier conclusion that 'efforts should continue to develop CCS into a relevant and relatively inexpensive mitigation technology'"
[10] EASAC (2019), p. 1: 'some progress has been made in the concept of transport and storage clusters that can accept captured CO_2'.
Ringrose, P.S. (2018). The CCS hub in Norway: some insights from 22 years of saline aquifer storage. Energy Procedia *146*, 166–172.

[11] IPCC (2018), p. 326: 'The technological maturity of CO_2 capture options in the power sectors has improved considerably (Abanades et al., 2015; Bui et al., 2018), but costs have not come down between 2005 and 2015 due to limited learning in commercial settings and increased energy and resources costs'.

[12] EASAC (2018), p. 10: 'In both European and Member State research programmes, momentum has been lost, with commercial-scale development projects withdrawn owing to lack of adequate government support.'

[13] EASAC (2018) p. 8: 'The positive aspect of BECCS is that growing biomass is an existing technology, and that CCS is also a viable technology'.

[14] EASAC (2019) p. 2: 'The large negative emissions capability given to BECCS in climate scenarios limiting warming to 1.5°C or 2°C is not supported by recent analyses'.

[15] EASAC (2019) p. 6: 'EASAC [5] pointed to the risks identified in multiple studies of large-scale deployment of BECCS (especially on water, fertiliser, biodiversity, competition for land) and these concerns remain'.

EASAC (2019) p. 8: 'BECCS risks and uncertainties remain substantial in other aspects such as water, fertiliser, food security and biodiversity'.

[16] EASAC (2019) p. 6: The simplistic vision of BECCS (Figure 3A) is that one ton of CO2 captured in the growth of biomass would equate to one ton of CO_2 sequestered geologically—which we can regard as a carbon efficiency of 1. However, as with the simplistic concept of carbon neutrality in the bioenergy debate, this is far from the reality. GHG emissions throughout the biomass supply-chain 'leak' carbon, which reduces the carbon efficiency (Figure 3B). Some life cycle analyses [e.g. 31] of the entire process chain for a BECCS crop to final carbon storage in the ground have shown leakage of CO_2 to be greater than the CO_2 captured at the point of combustion, thus resulting in carbon efficiencies of less than 50%.

[17] EASAC (2019) p. 8: 'the amount of electricity that can be produced from a hectare of land using photovoltaics is at least 50–100 times that from biomass'.

[18] EASAC (2018) p. 8: 'deployment at the scale required to remove gigaton quantities of carbon would require very large areas of land'.

IPCC (2018), p. 343: 'The average amount of BECCS in these pathways requires 25–46% of arable and permanent crop area in 2100.' BECCS delivering negative emissions of 3.3 Gt Ceq per year requires 25–46% of the area used for growing plant foods on Earth [Smith, P. et al. (2016) p 46. Biophysical and economic limits to negative CO_2 emissions. Nature Clim Change *6*, 42–50]. 'Arable' means crops that are replanted yearly, such as wheat or potato; 'permanent' refers to e.g. fruit trees or coffee shrubs. [FAO Production Yearbook – land use www.fao.org/waicent/faostat/agricult/landuse-e.htm] When pasture lands (meadows, prairies) are included, the area required for BECCS is 7–25% of the world's total agricultural land [Smith et al 2016, p. 46].

[19] EASAC (2019), p.2: 'Significant technological progress has been achieved with direct air capture with carbon storage (DACCS) but it is not yet possible to identify a preferred technology.'

[20] EASAC (2018) p. 26: 'The possibility of generating the CO_2 directly where it is used makes DAC particularly suitable for utilisation applications.'

[21] EASAC (2019) p. 9: 'CO_2 in air is approximately 300 times more dilute than from a coal-fired power plant flue gas'

IPCC (2018), p. 346: 'the CO_2 concentration in ambient air is 100–300 times lower than at gas- or coal-fired power plants (Sanz-Pérez et al., 2016) thus requiring more energy than flue gas CO_2 capture (Pritchard et al., 2015). This appears to be the main challenge to DACCS (Sanz- Pérez et al., 2016; Barkakaty et al., 2017).'

EASAC (2019). Forest bioenergy, carbon capture and storage, and carbon dioxide removal: an update, p.9: 'because CO_2 in air is approximately 300 times more dilute than from a coal-fired power plant flue gas, the separation process for the same end CO_2 purity will probably be costlier than capture from fossil-fuel power plants. Furthermore, the energy requirements for the absorbent regeneration would require an enormous increase in low- or zero-carbon energy, which would compete with use of such energy sources to mitigate emissions from other sectors.'

[22] EASAC (2019). p. 2: 'Enhancing weathering and in situ and ex situ carbon mineralisation requires further basic research before its potential can be properly assessed.'

[23] EASAC (2019), p. 5: 'they <i.e. newly planted forests> could revert to <being cut for> carbon sources unless appropriate management is maintained indefinitely.'

[24] EASAC (2019), p.2: 'The role of bioenergy with carbon capture and storage (BECCS) remains associated with substantial risks and uncertainties, both over its environmental impact and ability to achieve net removal of CO_2 from the atmosphere. The large negative emissions capability given to BECCS in climate scenarios limiting warming to 1.5°C or 2°C is not supported by recent analyses'.

[25] EASAC (2018), p. 13: 'efforts should continue to develop CCS into a relevant and relatively inexpensive mitigation technology.'