The Natural Environment Research Council (NERC), the Engineering & Physical Sciences Research Council (EPSRC), the Economic & Social Research Council (ESRC), the Department for Business, Energy & Industrial Strategy (BEIS), the Met Office Hadley Centre and the Science & Technology Facilities Council (STFC) are inviting research proposals for a new four-year research programme on Greenhouse Gas Removal (GGR) from the Atmosphere.

The large-scale removal of greenhouse gases from the atmosphere is assumed in nearly all scenario based climate models that succeed in “holding the increase in the global average temperature to well below 2 °C above pre-industrial levels” as well as the more ambitious pursuit of “efforts to limit the temperature increase to 1.5 °C above pre-industrial levels” – as agreed in Paris in December 2015 at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Important knowledge gaps exist for GGR include those relating to technological efficiency, environmental impacts (that may be both positive and negative), cost-effectiveness, governance, geo-political equity, social impacts, financing and public acceptability.

This bibliography can be read stand alone for information but also provides additional background detail for the Announcement of Opportunity: Greenhouse Gas Removal call that was announced in September 2016, and should be read in conjunction with the Greenhouse Gas Removal Workshop report from April 2016.

Please note that this bibliography is not exhaustive.

The ~410 papers listed here were published between January 2014 and mid-October 2016, covering the main issues relevant to the removal of greenhouse gases from the atmosphere, also known as negative emissions techniques (NETs) or carbon dioxide removal (CDR). New additions since v1 of this listing (to mid-September) are shown in dark red. Grouping as follows:

1. General considerations for GGR
2. Specific removal techniques:
   2.1 Crop bioenergy with carbon capture and storage (BECCS)
   2.2 Micro-algal biofuels
   2.3 Afforestation and reforestation
   2.4 Soils and biochar
   2.5 Enhanced weathering and ocean alkalinisation
   2.6 Ocean fertilization and enhanced upwelling
   2.7 Direct air capture (DAC)
   2.8 Methane and other non-CO₂ greenhouse gases
3. Long-term CO₂ storage
4. Socio-economic issues:
   4.1 General considerations
   4.2 Ethics, framing and discourse analysis
   4.3 Public perceptions
   4.4 Governance policy and regulation
5. Climate change context

This bibliography is based on references used for the report Update on Climate Geoengineering in relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework (CBD Secretariat/
Williamson & Bodle, eds) to be published in November 2016 as CBD Technical Series 84. Earlier references can be found within the listed papers; in the IPCC 5th Assessment Report (2013-2014); in CBD Technical Series no 66 (2012); and in the LWEC Geoengineering Report (2013).

Note that: i) whilst the bibliography aims to be as complete as possible for Section 2, some important publications will inevitably have been missed; ii) papers on the engineering and geotechnical aspects of carbon capture and storage are not generally included in Section 3; iii) for Sections 1 and 3-5, the listing is intended to be representative, rather than comprehensive; iv) duplication between Sections has been kept to a minimum; and v) some of the papers in Section 1, and many of the papers in Section 4, primarily relate to solar radiation management; however, several of the issues covered are also relevant to at least some greenhouse gas removal techniques, e.g. ocean fertilization.

1. GENERAL CONSIDERATIONS FOR GGR also see (4) below


Boucher O, Forster PM, Gruber N, Ha-Du Haoong M et al. (2014) Rethinking climate engineering categorization in the context of climate change mitigation and adaptation. WIREs Climate Change, 5, 23-35; doi: 10.1002/wcc.261


Keller DP, Feng EY & Oschlies (2014) Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario. Nature Communications 5, 3304; doi: 10.1038/ncomms4304


2. SPECIFIC REMOVAL TECHNIQUES:

2.1 Bioenergy with carbon capture and storage (BECCS)


Creutzig F (2016) Economic and ecological views on climate change mitigation with bioenergy and negative emissions. *Global Change Biology Bioenergy*, 8, 4-10; doi: 10.1111/gcbb.12235


McCalmont JP, McNamara NP, Donnison IS, Farrar K & Clifton-Brown JC (2016) Partitioning of ecosystem respiration of CO₂ released during land-use transition from temperate agricultural grassland to Miscanthus x giganteus. GCB Bioenergy. 10.1111/gcbb.12380


Richards M, Pogson M, Dondini M, Jones EO et al. (2016). High-resolution spatial modelling of greenhouse gas emissions from land-use change to energy crops in the United Kingdom. GCB Bioenergy (online); doi: 10.1111/gcbb.12360

2.2 Micro-algal biofuels


### 2.3 Afforestation and reforestation


2.4 Soils and biochar


Devi P & Saroha AK (2014) Risk analysis of pyrolised biochar made from paper mill effluent treatment plant sludge for bioavailability and ecotoxicity of heavy metals. *Bioresource Technology* 162, 308-315


Marks EAN, Mattana S, Alcaniz JM et al. (2014) Biochars provoke diverse soil mesofauna reproductive responses in laboratory bioassays. European Journal of Soil Biology, 60, 104-111


Powlson DS, Stirling CM, Jat ML, Gerard BG et al. (2014) Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change, 4, 678683; doi: 10.1038/nclimate2292


Singla A & Inubushi K (2014) Effect of biochar on CH4 and N2O emission from soils vegetated with paddy. Paddy Water Environment, 12, 239-243


### 2.5 Enhanced weathering and ocean alkalinisation


Schuiling RD (2014) A natural strategy against climate change. *Journal of Chemical Engineering & Chemistry Research* 1, 413-419


### 2.6 Ocean fertilization and enhanced upwelling

Batten SD & Gower JFR (2014) Did the iron fertilization near Haida Gwaii in 2012 affect the pelagic lower trophic level ecosystem? *Journal Plankton Research* 36, 925-932; doi: 10.1093/plankt/fbu049


Winckler G, Anderson RF, Jaccard SL & Marcantonio F (2016) Ocean dynamics, not dust, have controlled equatorial Pacific productivity over the past 500,000 years. *Proceedings of the National Academy of Sciences*, 113, 6119-6124; doi: 10.1073/pnas.1600616113


2.7 Direct air capture (DAC)

Agee E, Orton A & Rogers J (2013) CO₂ snow deposition in Antarctica to curtail anthropogenic global warming. *Journal of Applied Meteorology and Climatology*, 52, 281-288; doi: 10.1175/JAMC-D-12-0110.1

Alkhabbaz MA, Bollini P, Foo GS, Sievers C & Jones CW (2014). Important roles of enthalpic and entropic contributions to CO₂ capture from simulated flue gas and ambient air using mesoporous silica grafted amines. *Journal of the American Chemical Society*, 136, 13170-13173; doi: 10.1021/ja507655x

Bhatt PM, Belmabkhout Y, Cadiau A, Adil K et al. (2016) A fine-tuned fluorinated MOF addresses the needs for trace CO₂ removal and air capture using physisorption. *Journal of the American Chemical Society*, 138, 9301-9307; doi: 10.1021/jacs.6b05345


Liu FQ, Wang L, Huang ZG, Li CQ et al. (2014) Amine-tethered adsorbents based on three-dimensional macroporous silica for CO₂ capture from simulated flue gas and air. ACS Applied Materials & Interfaces, 6, 4371-4381; doi: 10.1021/am500089g.


2.8 Methane and other non-CO₂ greenhouse gases


3. LONG-TERM CO₂ STORAGE Relevant to 2.1, 2.5 and 2.7


4. SOCIO-ECONOMIC ISSUES

4.1 General considerations

Buck HJ. Rapid scale-up of negative emissions technologies: social barriers and social implications. Climatic Change (online); doi: 10.1007/s10584


Shpuza E (2014) Will geoengineering the climate bring the world hope and safety or desolation? Journal of Science Policy and Governance 5, 1-9


4.2 Ethics, framing and discourse analysis


Harnisch S, Uther S & Boettcher M (2015) From ‘go slow’ to ‘gung ho’? Climate engineering discourses in the UK, the US, and Germany. *Global Environmental Politics*, 15(2), 57-78; doi: 10.1162/GLEP_a_00298


Huttunen S & Hildén M (2014) Framing the controversial: Geoengineering in academic literature. *Science Communication* 36, 3-29


Morrow DR (2014) Why geoengineering is a public good, even if it is bad. *Climate Change*, 123, 95-100; doi: 10.1007/s10584-013-0967-1


4.3 Public perceptions


4.4 Governance, policy and regulation

Armeni C (2015) Global experimentalist governance, international law and climate change technologies. *International & Comparative Law Quarterly*, 64, 875-904; doi: 10.1017/S0020589315000408


Geden O (2016) The Paris Agreement and the inherent inconsistency of climate policymaking. WIREs Climate Change (online); doi: 10.1002/wcc.427


Stilgoe J (2015a) Experiment Earth. Responsible Innovation in Geoengineering. Routledge, Abingdon, UK. 240 pp


Tanimura E (2014) Geoengineering research governance: Foundation, form, and forum. Student Article, University of California, Davis, 37, 2; http://environs.law.ucdavis.edu/volumes/37/2/Articles/Tanimura.pdf


5. CLIMATE CHANGE CONTEXT


Clark PU, Shakun JD, Marcott SA, Mix AC et al. (2016) Consequences of twenty-first-century policy for multi-millennial climate and sea-level change. Nature Climate Change, 6, 360-369; doi: 10.1038/nclimate2923

Committee on Climate Change (2016) UK Climate Change Action following the Paris Agreement. https://www.theccc.org.uk/publication/uk-action-following-paris/


Flannery T (2015) *Atmosphere of Hope: Solutions to the Climate Crisis*. Penguin; 288 pp


Huntingford C & Mercado LM (2016) High chance that current atmospheric greenhouse concentrations commit to warmings greater than 1.5°C over land. *Scientific Reports*, 6, 30294; doi: 10.1038/srep30294.


Mitchell, D, James, R, Forster, PM, Betts RA et al. (2016). Realizing the impacts of a 1.5°C warmer world. *Nature Climate Change*, 6, 735-737; doi: 10.1038/nclimate3055

Peters GP (2016) The 'best available science' to inform 1.5°C policy choices. *Nature Climate Change* (online); doi: 10.1038/nclimate3000


Sachs JD, Schmidt-Traub G & Williams J (2016) Pathway to zero emissions. *Nature Geoscience* (online)


