Greenhouse Gas Removal: recent bibliography (2014-2016)

Version2 - 20th October 2016

Updates below in red font

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-CO_2 greenhouse gases
3. Long-term CO_2 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 and3- 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*

Anderson K & Peters G (2016) The trouble with negative emissions. *Science*, 354,182-183.

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Kruger T (2015) *Dimensions of Geoengineering – an Analysis of the Royal Society's 'Blob' Diagram*. Climate Geoengineering Governance (CGG) Working Paper 26

Lefale PF & Anderson CL (2014) *Climate Engineering and Small Island States: Panacea or Catastrophe?* Opinion Article, 6 May, 2014, www.geoengineeringourclimate.com.

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Mathesius S, Hofman M, Caldeira K & Schellnhuber HJ (2015) Long-term response of oceans to CO_2 removal from the atmosphere. *Nature Climate Change* (online); doi: 10.1038/nclimate2729

McCormack CG, Born W, Irvine PJ, Achterberg EP, Amano T et al. (2016) Key impacts of climate engineering on biodiversity and ecosystems, with priorities for future research. *Journal of Integrative Environmental Sciences* (online) doi: 10.1080/1943815X.2016.1159578

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2. SPECIFIC REMOVAL TECHNIQUES:

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