



The Royal Society / Royal Academy of Engineering report on:

Greenhouse Gas Removal

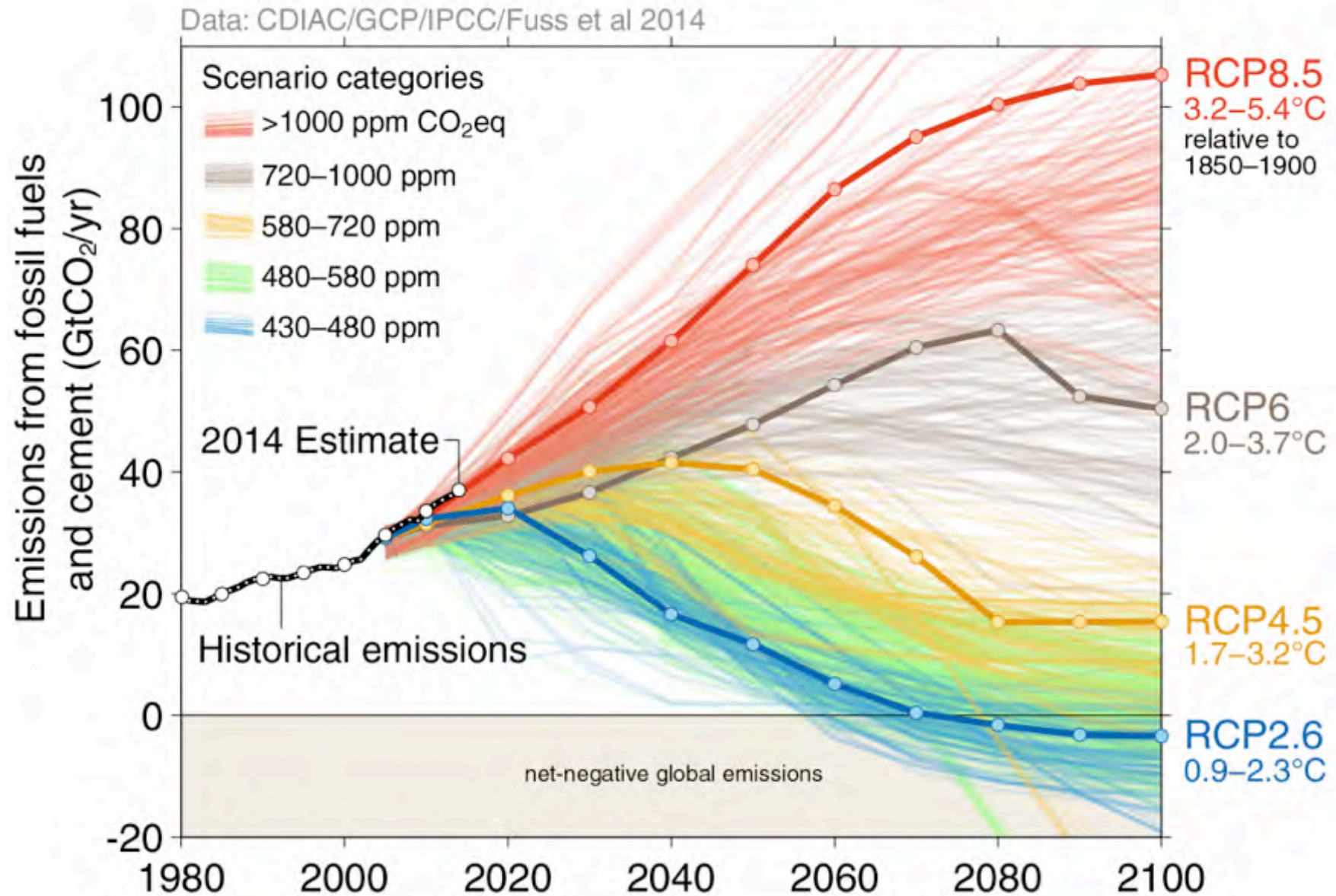
Gideon Henderson

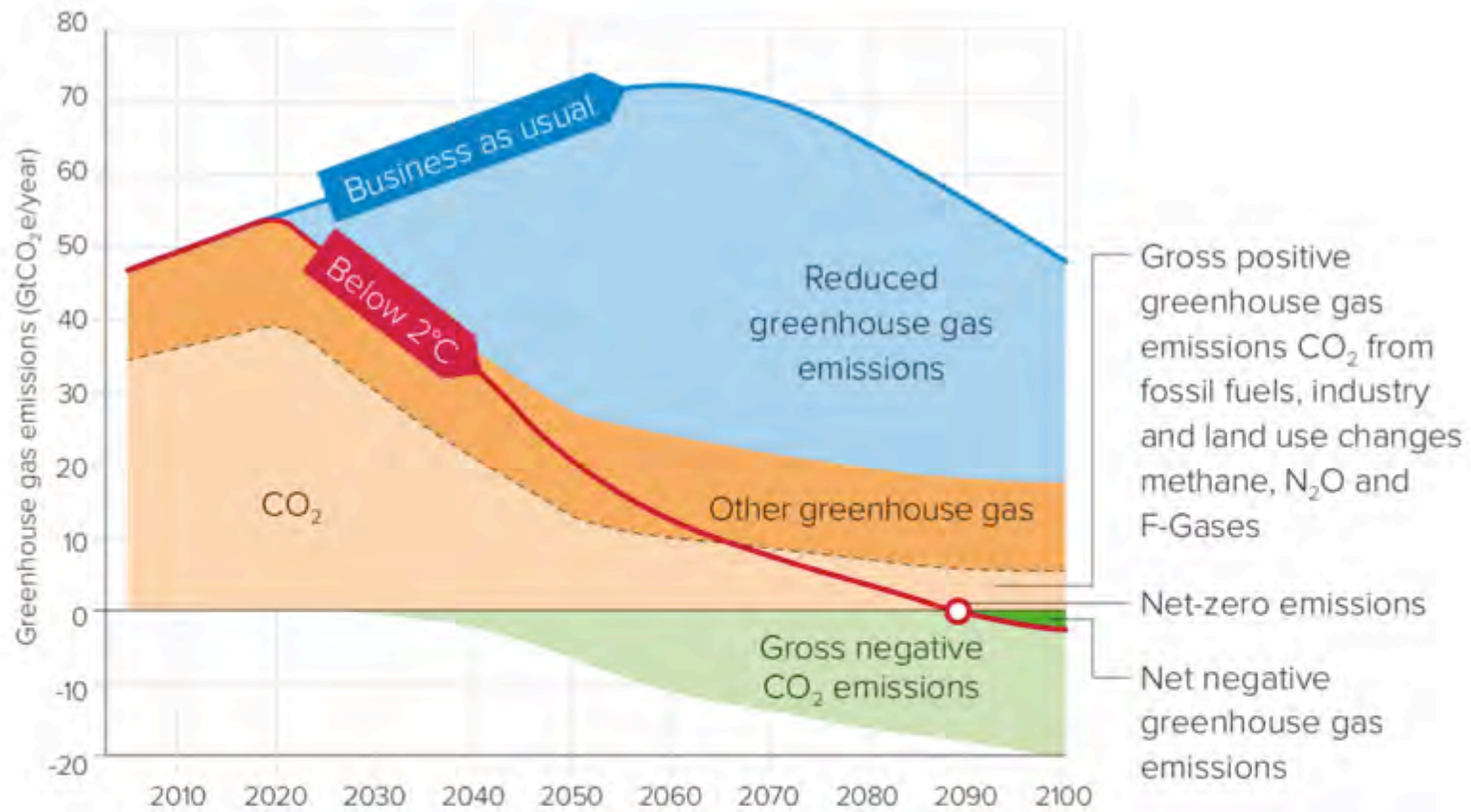
University of Oxford

<https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal/>



Integrated assessment models – future emission scenarios





+ Emissions



= Reduced emissions



- GGR methods

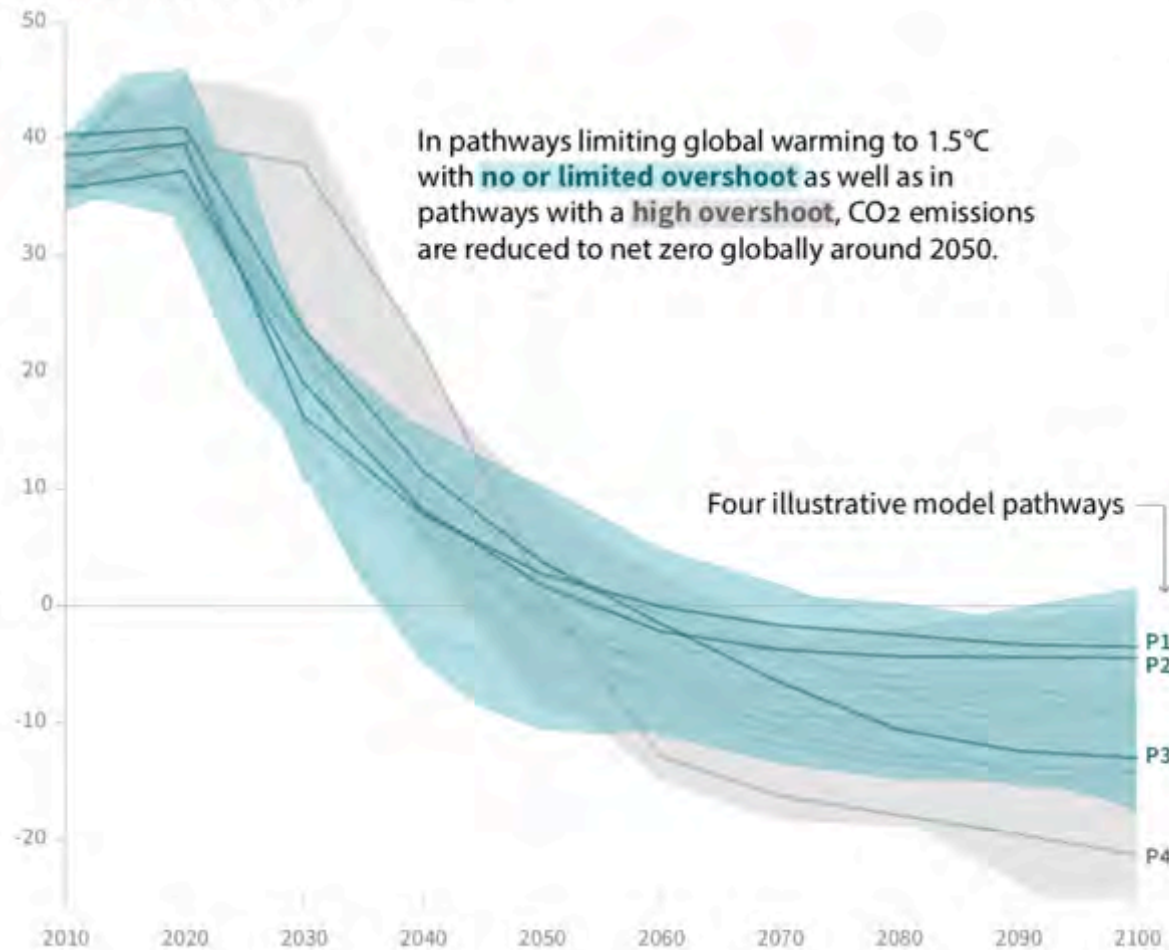


From RS/RAEng GGR report

Emissions scenarios in IPCC 1.5°C

Global total net CO₂ emissions

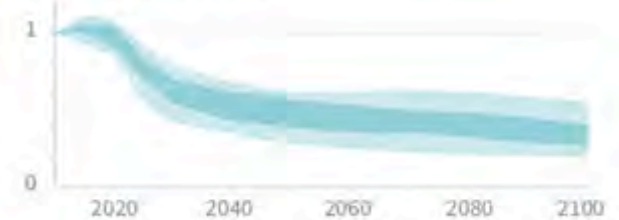
Billion tonnes of CO₂/yr



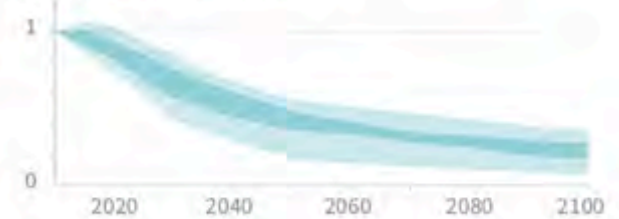
Non-CO₂ emissions relative to 2010

Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with **no or limited overshoot**, but they do not reach zero globally.

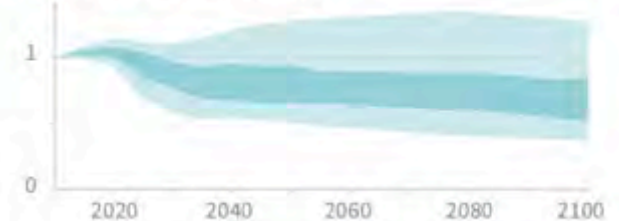
Methane emissions



Black carbon emissions



Nitrous oxide emissions



GGR / CDR statements from IPCC 1.5°C report

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 GtCO₂ over the 21st century
(SPM C3)

In IPCC scenarios, CDR is with reforestation and bioenergy with CCS (BECCS), but 1.5°C report recognizes other methods exist

BEIS Green Growth Strategy, Autumn 2017

From key policies and proposals

2.5: Demonstrate international leadership in [carbon capture usage and storage \(CCUS\)](#), by collaborating with our global partners and investing up to £100 million in leading edge CCUS and industrial innovation to drive down costs

2.7: Develop our strategic approach to [greenhouse gas removal](#) technologies, building on the Government's programme of research and development and addressing the barriers to their long term deployment



Greenhouse gas removal



Working group

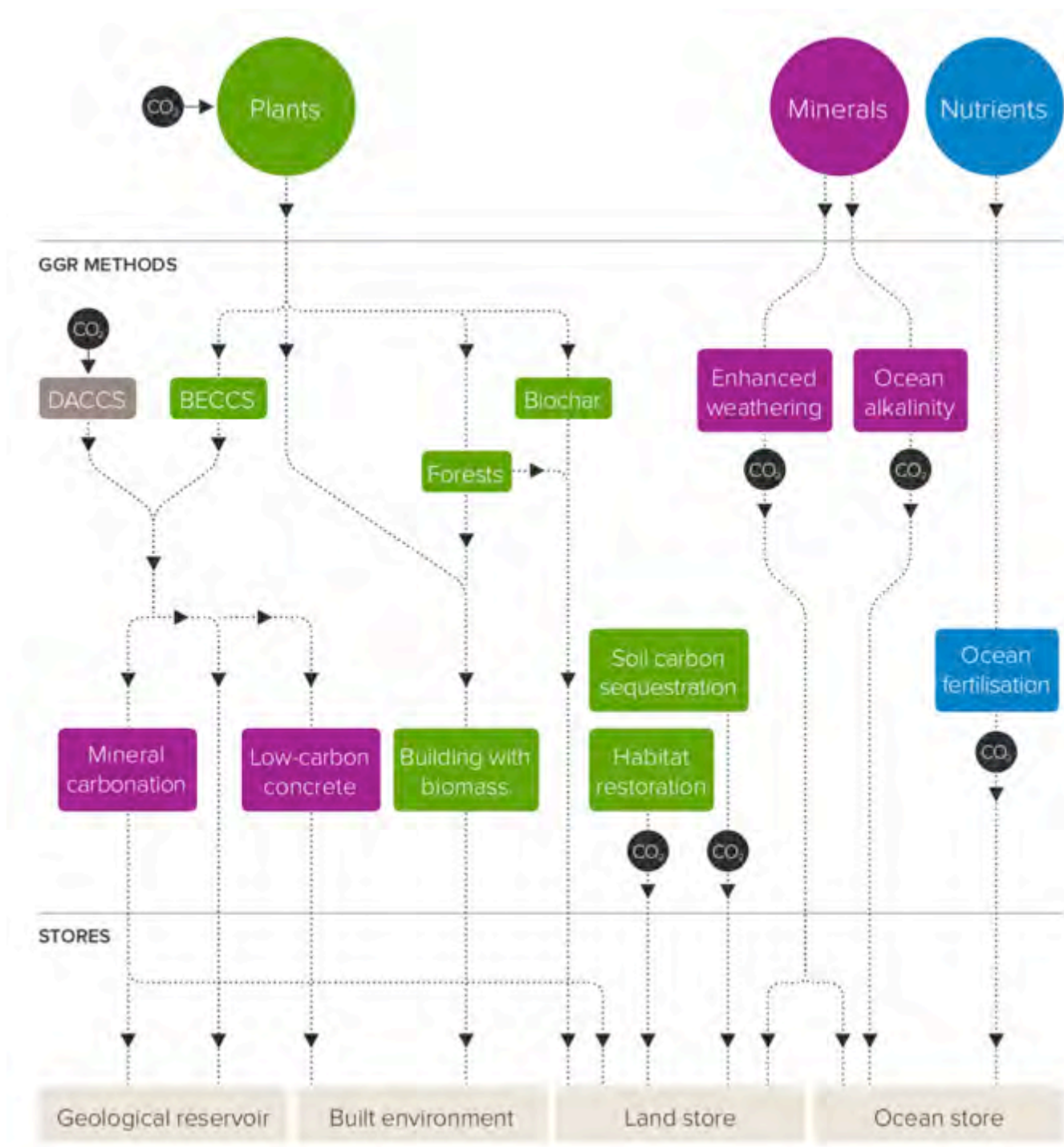
Adisa Azapagic FREng	University of Manchester
David Beerling FRS	University of Sheffield
Chris Cheeseman	Imperial College London
Gideon Henderson FRS (Chair)	University of Oxford
Cameron Hepburn	University of Oxford
Jo House	University of Bristol
Corinne Le Quéré FRS	University of East Anglia
Nils Markusson	University of Lancaster
Nilay Shah FREng	Imperial College London
John Shepherd FRS	University of Southampton
Pete Smith FRS	University of Aberdeen

Focus on technical aspects of GGR

Published Sept 2018

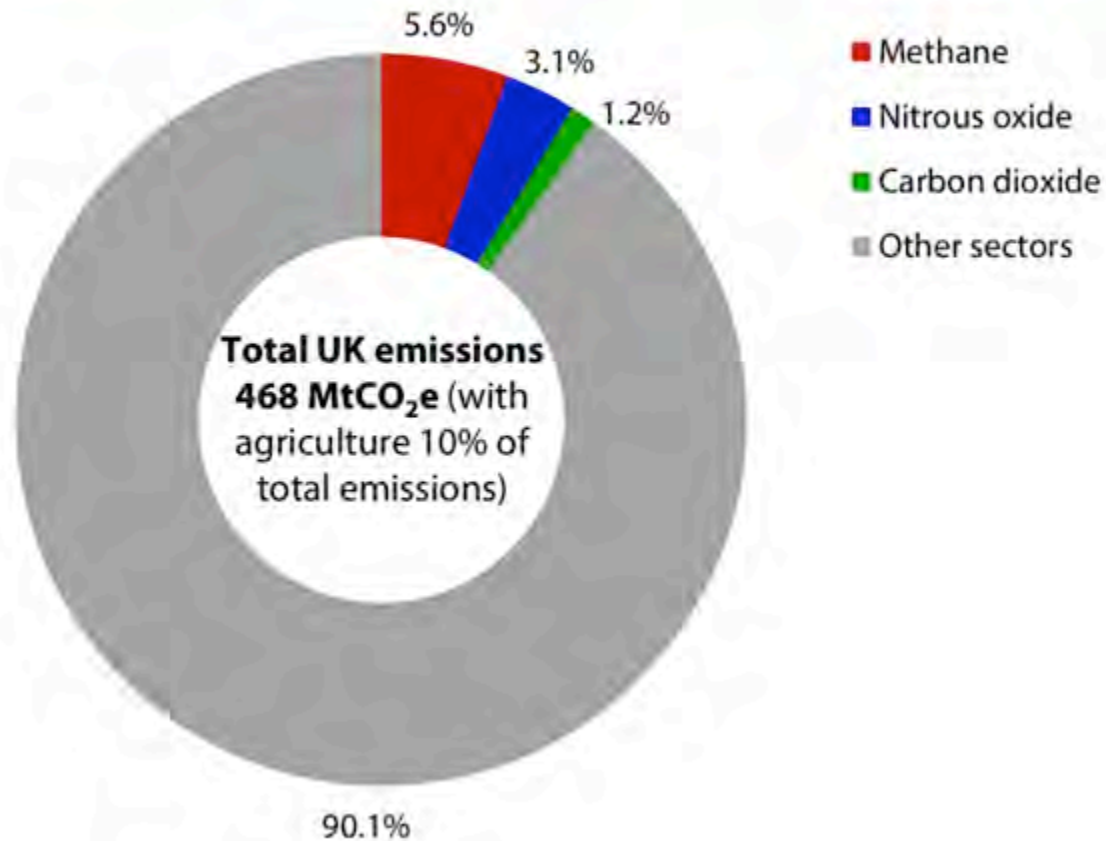
GGR methods – must both remove and store CO₂

		Greenhouse gas removal method		
		Increased biological uptake	Natural inorganic reactions	Engineered removal
Storage location	Land vegetation (living)	Afforestation, reforestation and forest management; Habitat restoration;		
	Soils and land vegetation (dead)	Soil carbon sequestration; Biochar	Enhanced terrestrial weathering	
	Geological	BECCS	Mineral carbonation at surface	DAC + geological storage DAC + sub-surface mineral carbonation
	Oceans	Ocean fertilisation	Ocean alkalinity	DAC + deep ocean storage
	Built environment	Building with biomass		Low-carbon concrete



2017 UK emissions – 367 MtCO₂ (468 MtCO₂e)

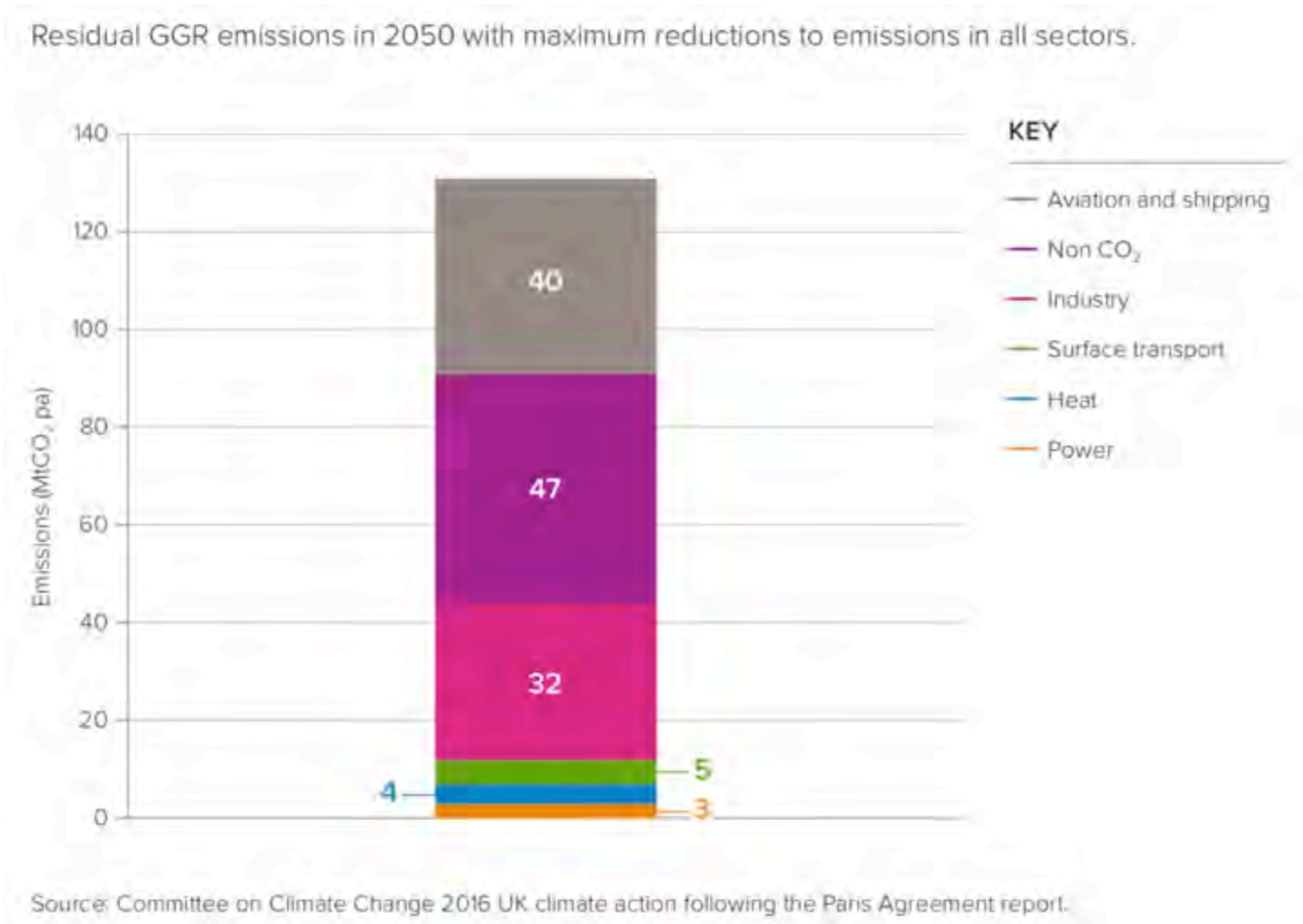
Figure 6.2. Agriculture GHG emissions as share of UK total (2016)



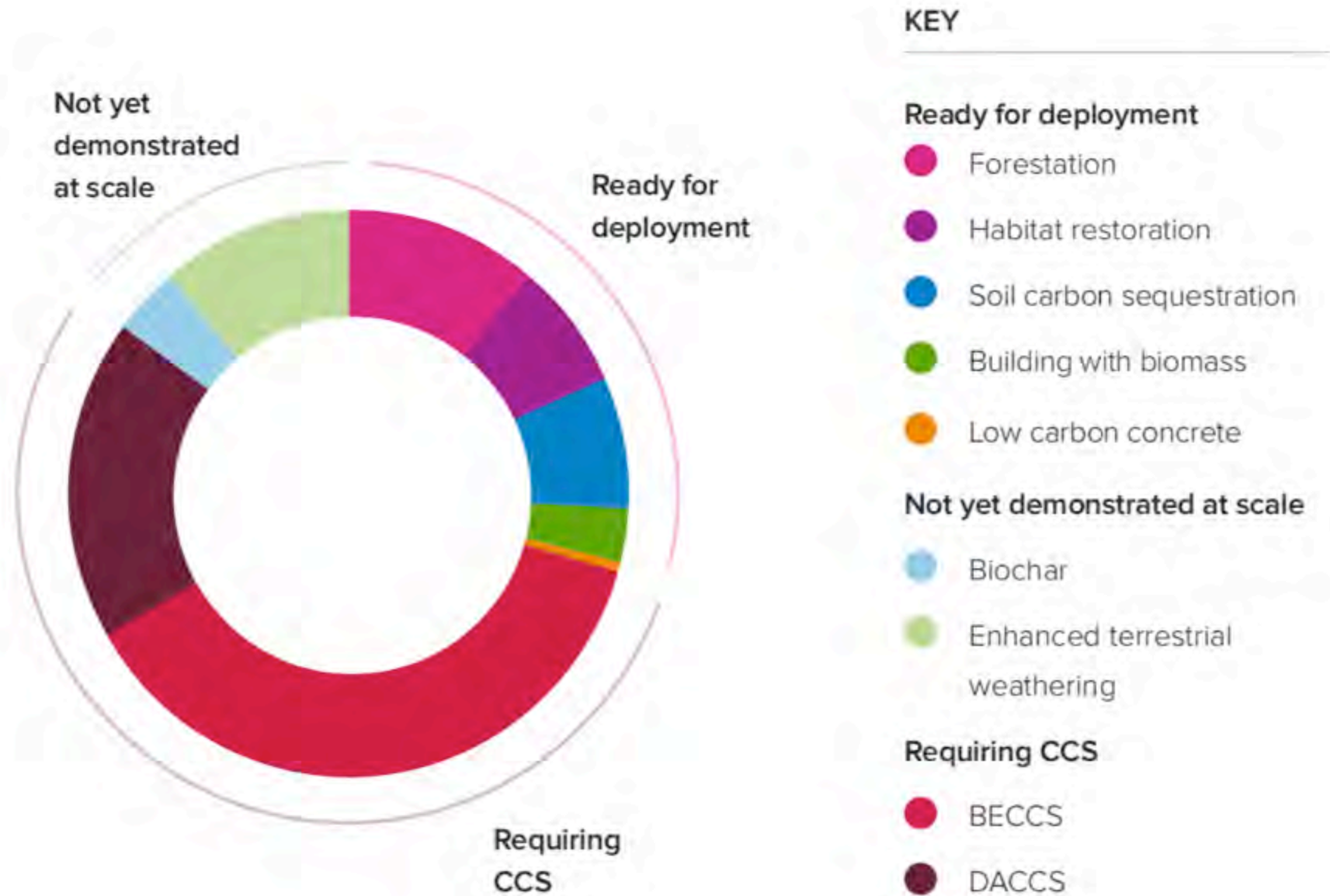
“Measured from 1990, emissions have now fallen by 43%, over a period when the economy grew by over 70%”

UK emissions in 2050

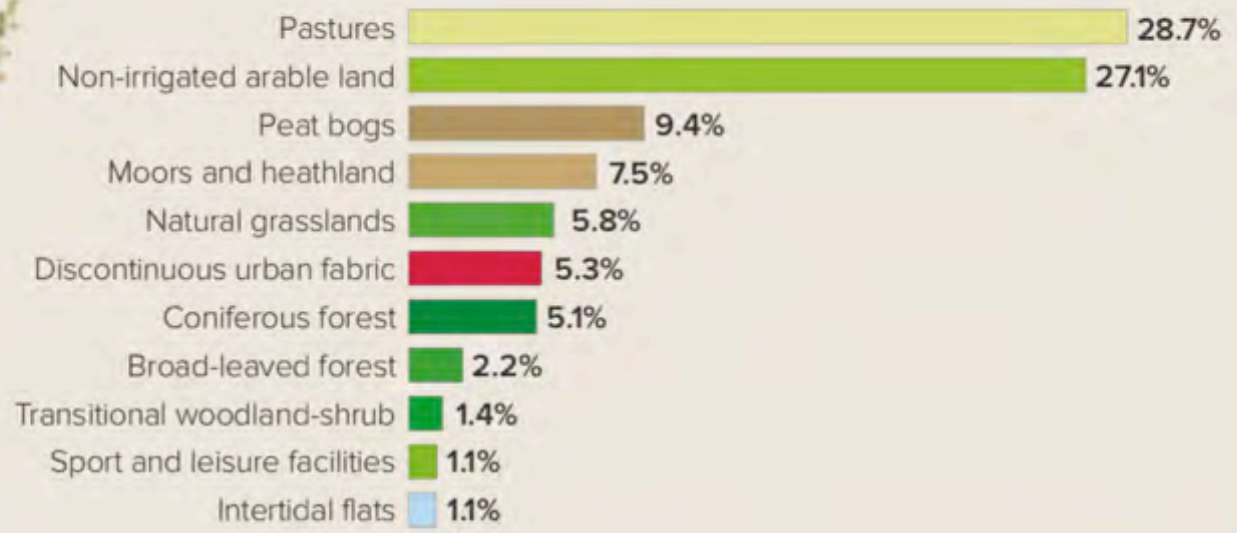
Climate Change Act commits us to reduce to 160 MtCO₂e pa
Climate Change Committee considers 130 MtCO₂ pa absolute minimum we could reach



A suite of GGR methods are required to remove 130 MtCO₂ pa



UK land cover as determined by satellite imaging.



Categories of use	Current area (Mha)
UK	24.3
All agricultural land	17.5
Pastures and meadows	5.9
Arable land	6
'Available' land	1.5
Forests	3.2
Peatlands	2.7
Freshwater wetlands	0.8
Salt marshes	0.45

	Land (Mha)	Primary Uses (Mha)	Complementary methods (Mha)		
'Available' land	1.5	Forest	1.2	Enhanced weathering	1.2
		Biomass for BECCS	0.3	Soil carbon sequestration	0.3
				Enhanced weathering	0.3
Arable land	6	Biomass for BECCS	0.7	Soil carbon sequestration	4.5
		Biomass for biochar	0.1	Biochar	1.5
				Enhanced weathering	6
Total					
				Soil carbon sequestration	4.8
				Biochar	1.5
				Enhanced weathering	7.5

Summary of “Key actions for UK net-zero”

- Ramp-up of forestation, habitat restoration, and soil carbon sequestration
- Establish an incentive or subsidy system to encourage changes of land practice (e.g. post EU Common Agricultural Policy)
- Encourage changes in building practice to use wood and concrete manufactured with carbonated waste
- Develop monitoring and verification procedures to track the effectiveness of GGR
- Grow and import sustainable biomass at large scale to meet the need for both energy and GGR demands
- Pursue research into the GGR.... enhanced weathering and biochar in UK soils, and into BECCS and DACCS... include field- based pilot demonstrations
- Capitalise on UK access to suitable reservoirs for CCS, and relevant engineering and industry expertise