Taking it back:

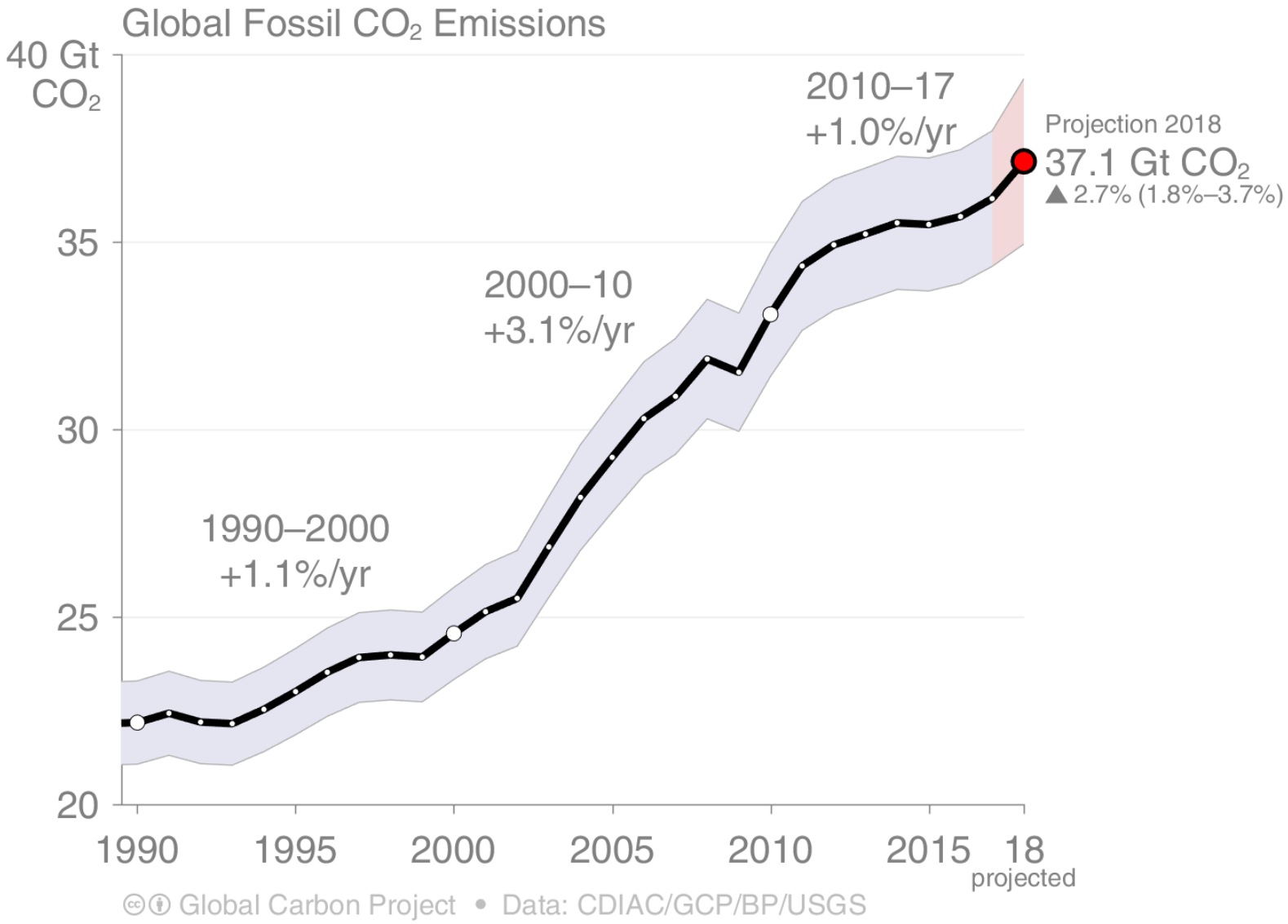
Removing CO_2 from the atmosphere to limit climate change

Gideon Henderson
University of Oxford

UNIVERSITY OF OXFORD

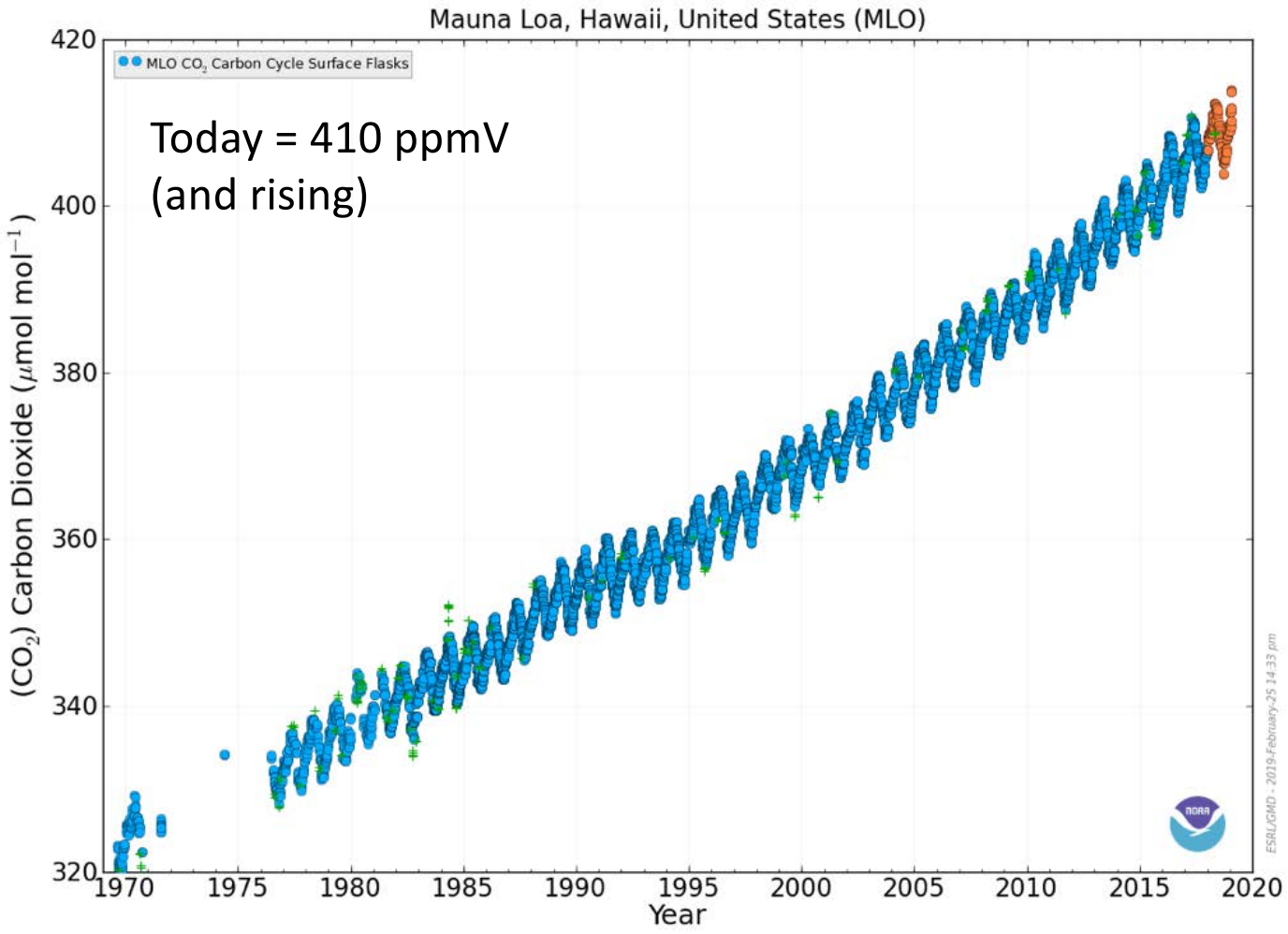
Human emissions of carbon dioxide

Emissions in billion tonnes of CO_2 (= $GtCO_2$, $PgCO_2$, 10^{15} gCO_2)



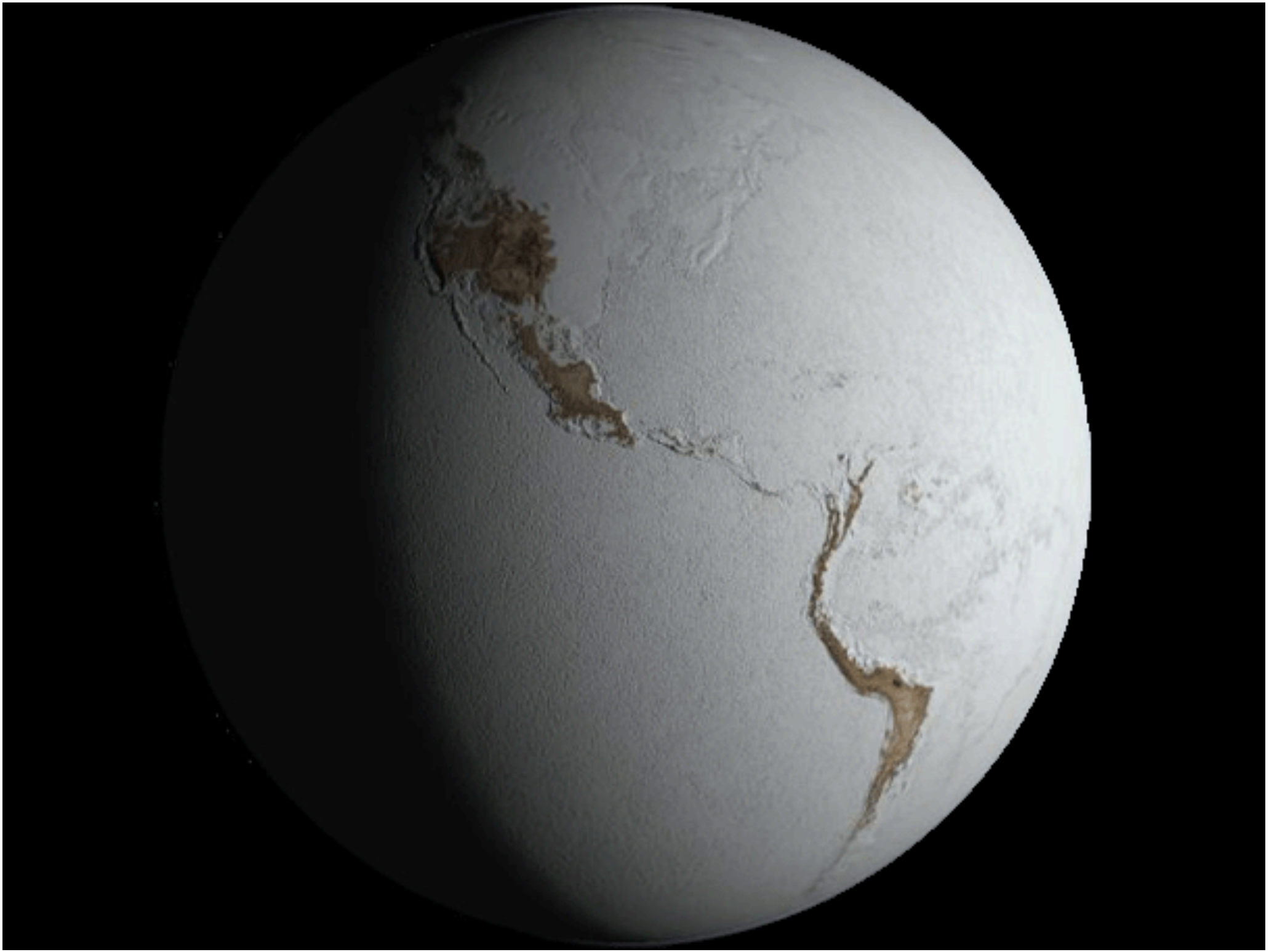
http://www.globalcarbonproject.org/carbonbudget/

Resulting rise in atmospheric CO_2

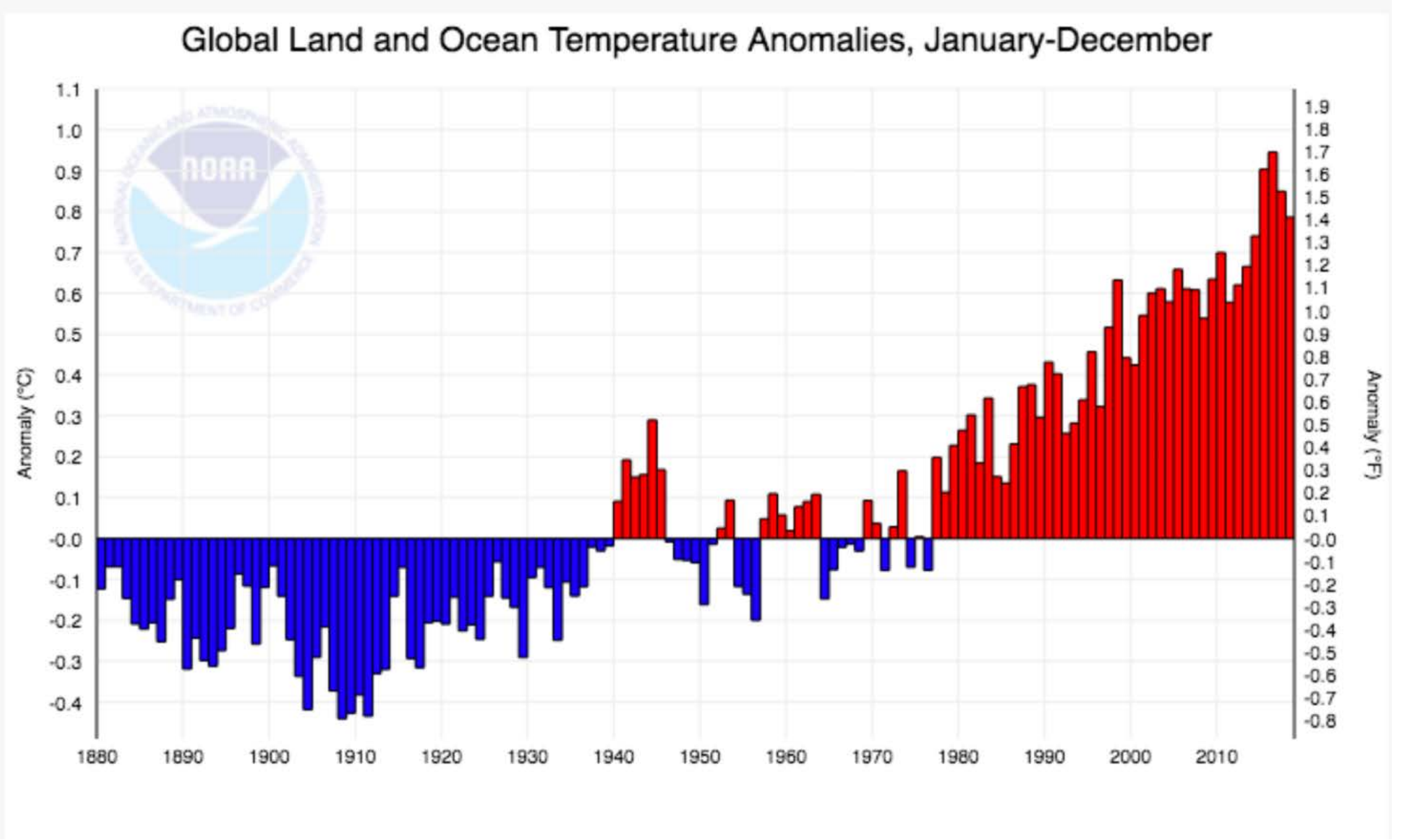


Compares to 280 ppmV before human activity
And 200 ppmV during the last ice age

http://www.esrl.noaa.gov/gmd/dv/iadv/

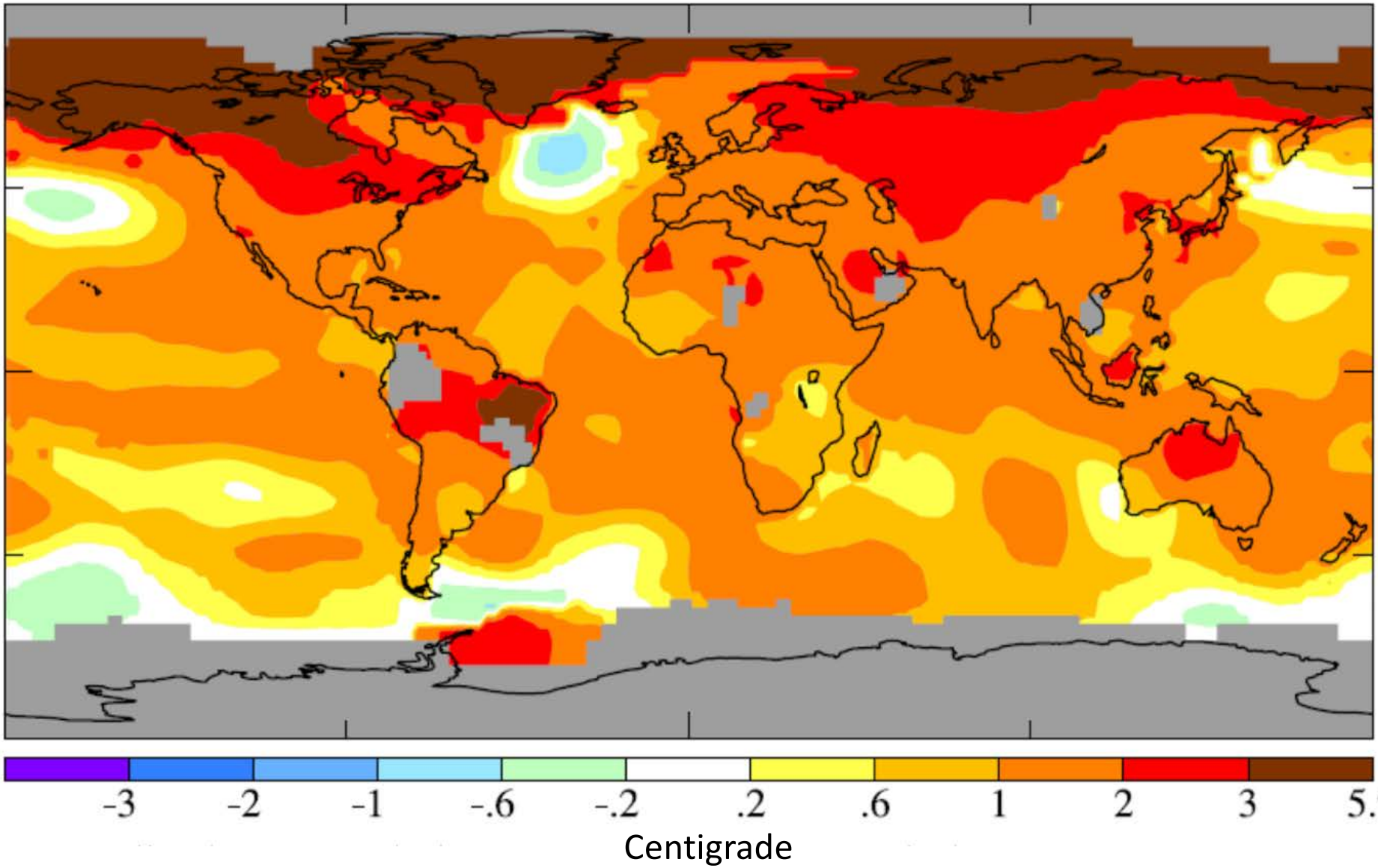


Global temperature



https://www.ncdc.noaa.gov/cag/

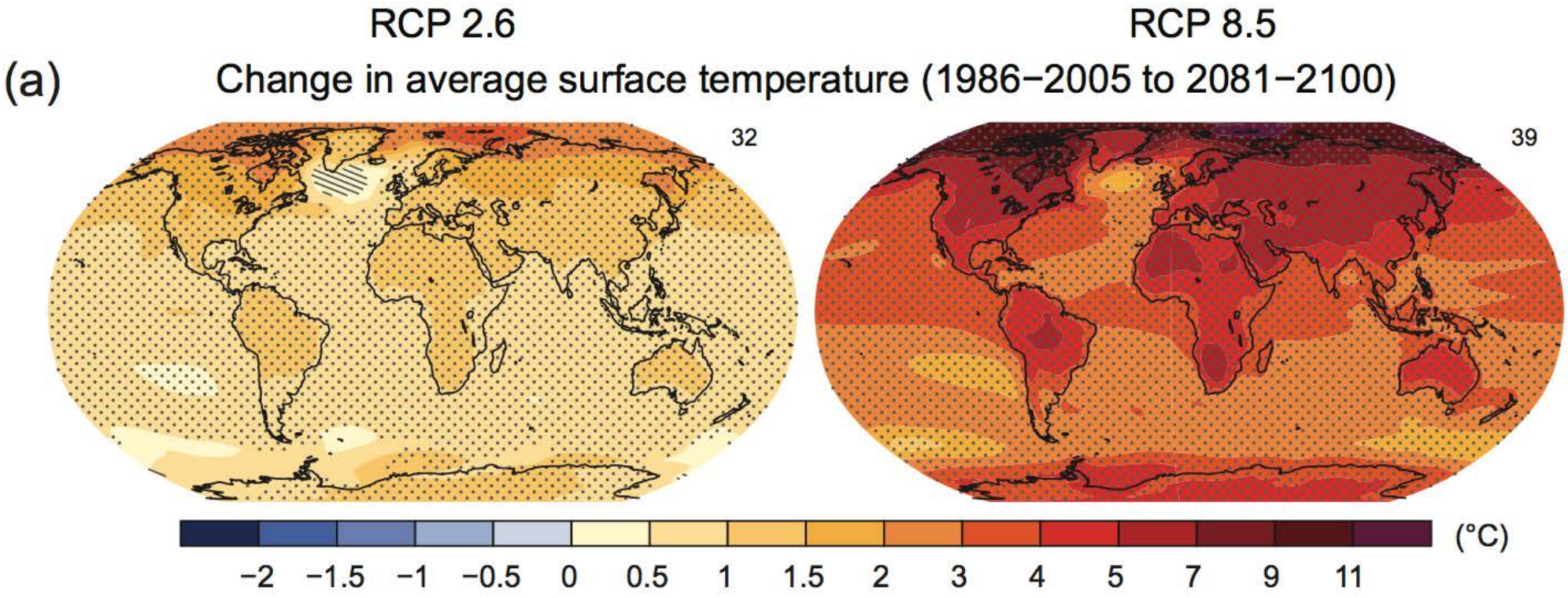
2016 Mean Annual Temperature (relative to 1880-1920)



We can choose our future temperature

Stop releasing CO_2

Carry on as we are



Average < 2°C

Average >4°C

IPCC AR5 2013

The Paris agreement 2015/16

Paris COP21 agreement

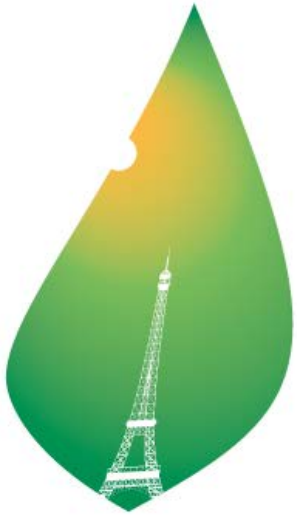
Agreed to limit warming to substantially less than 2°C (1.5°C target)

Peak in global emissions asap, rapid reductions thereafter

Net zero emissions in 2nd half of this century

Countries submitted national climate action plans

Meet every 5 years to and set more ambitious targets



PARIS2015
CONFÉRENCE DES NATIONS UNIES
SUR LES CHANGEMENTS CLIMATIQUES
COP21·CMP11

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CONFÉRENCE DES NATIONS UNIES
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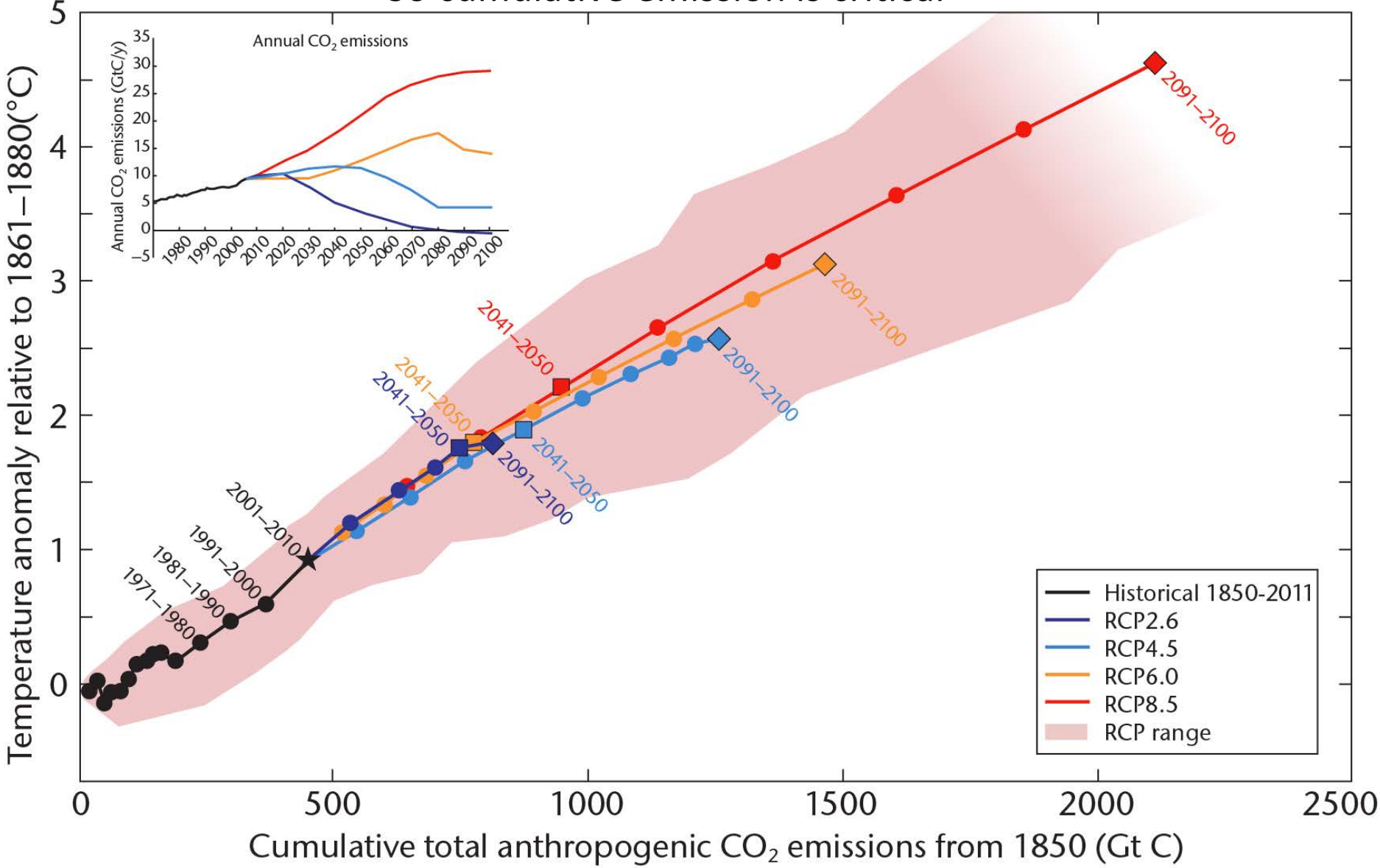
Why we need to reach net zero

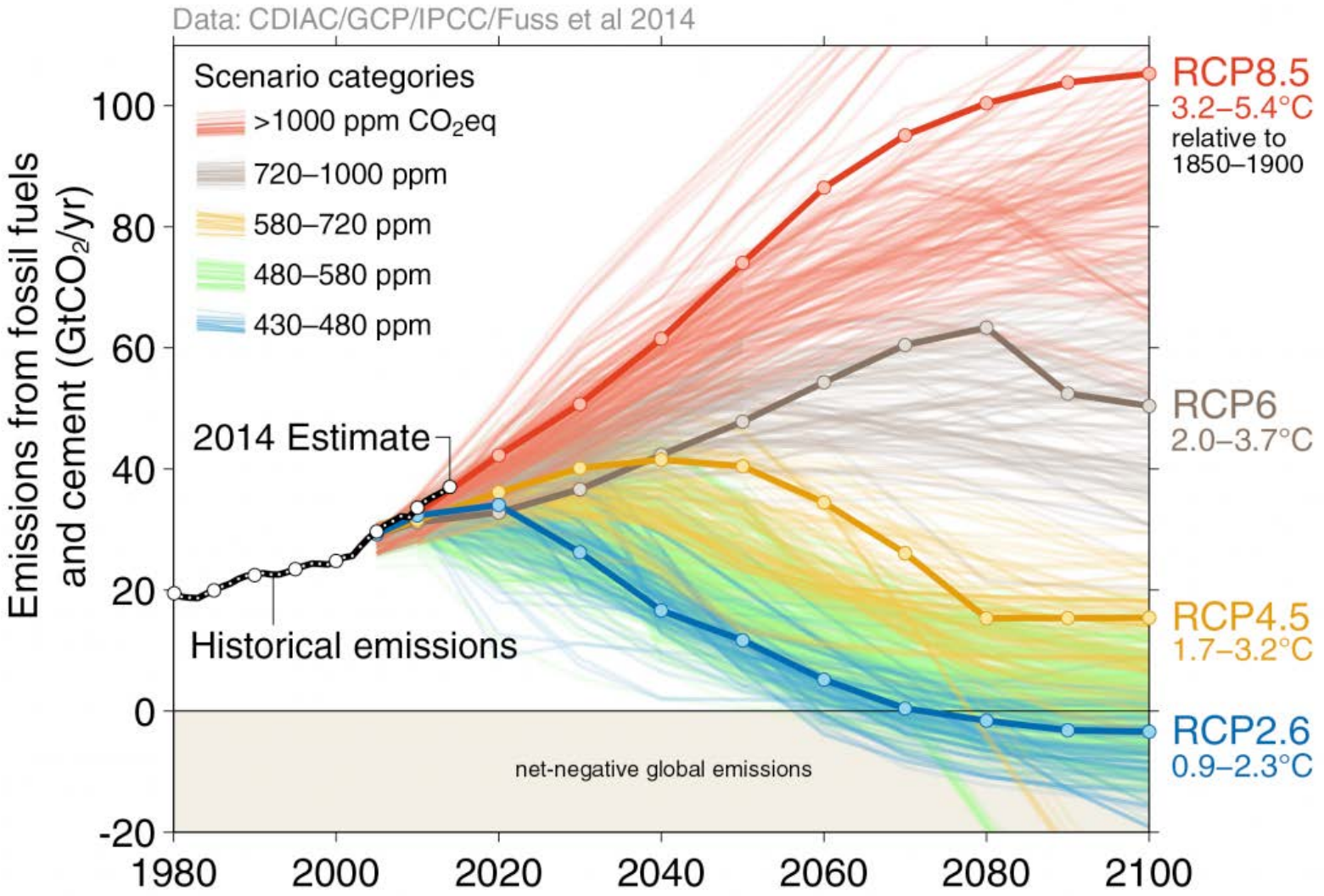
More than half of the CO_2 stays in atmosphere for thousands of years

So cumulative emission is critical




The Sun

Integrated Assessment Models: Future emission scenarios



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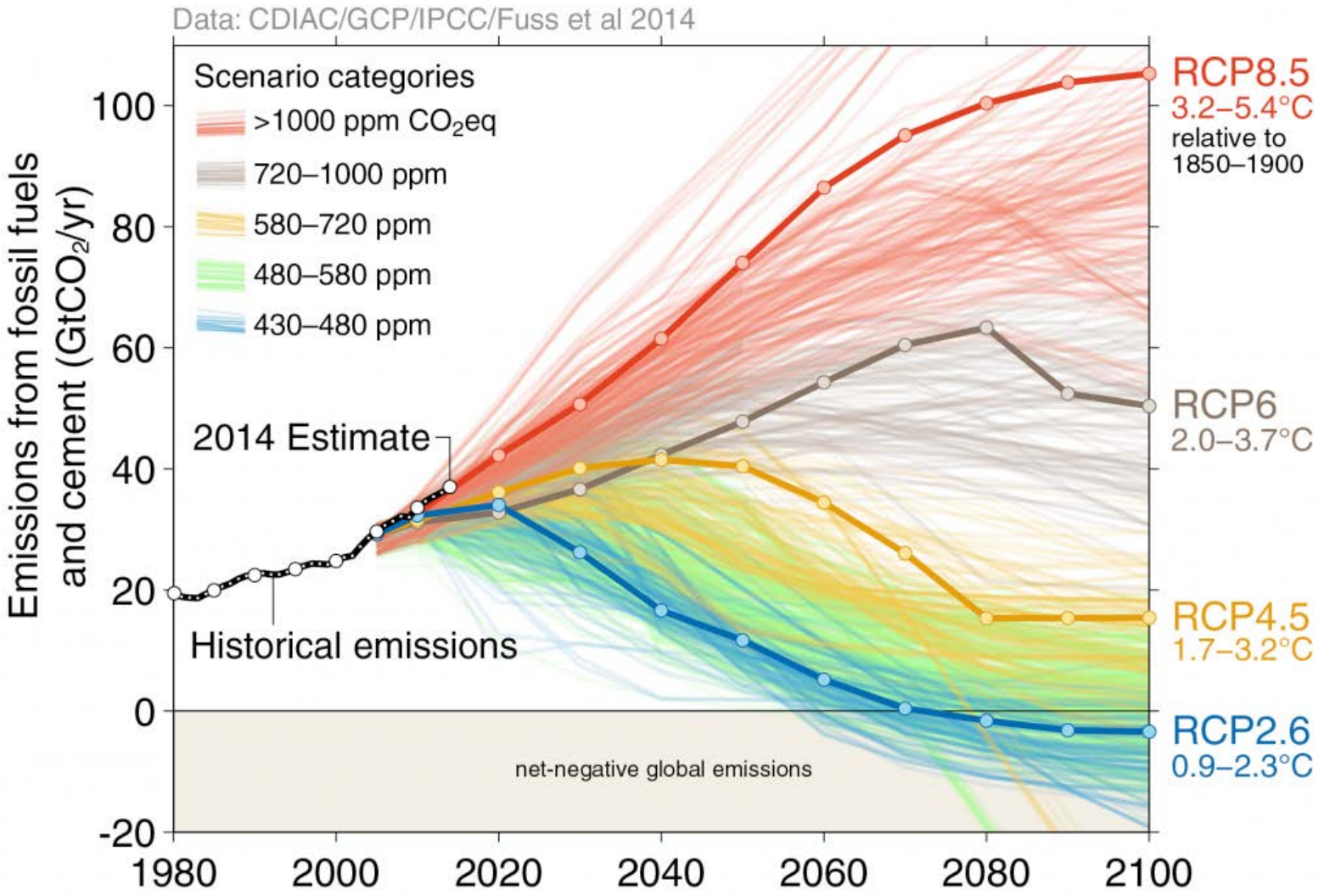
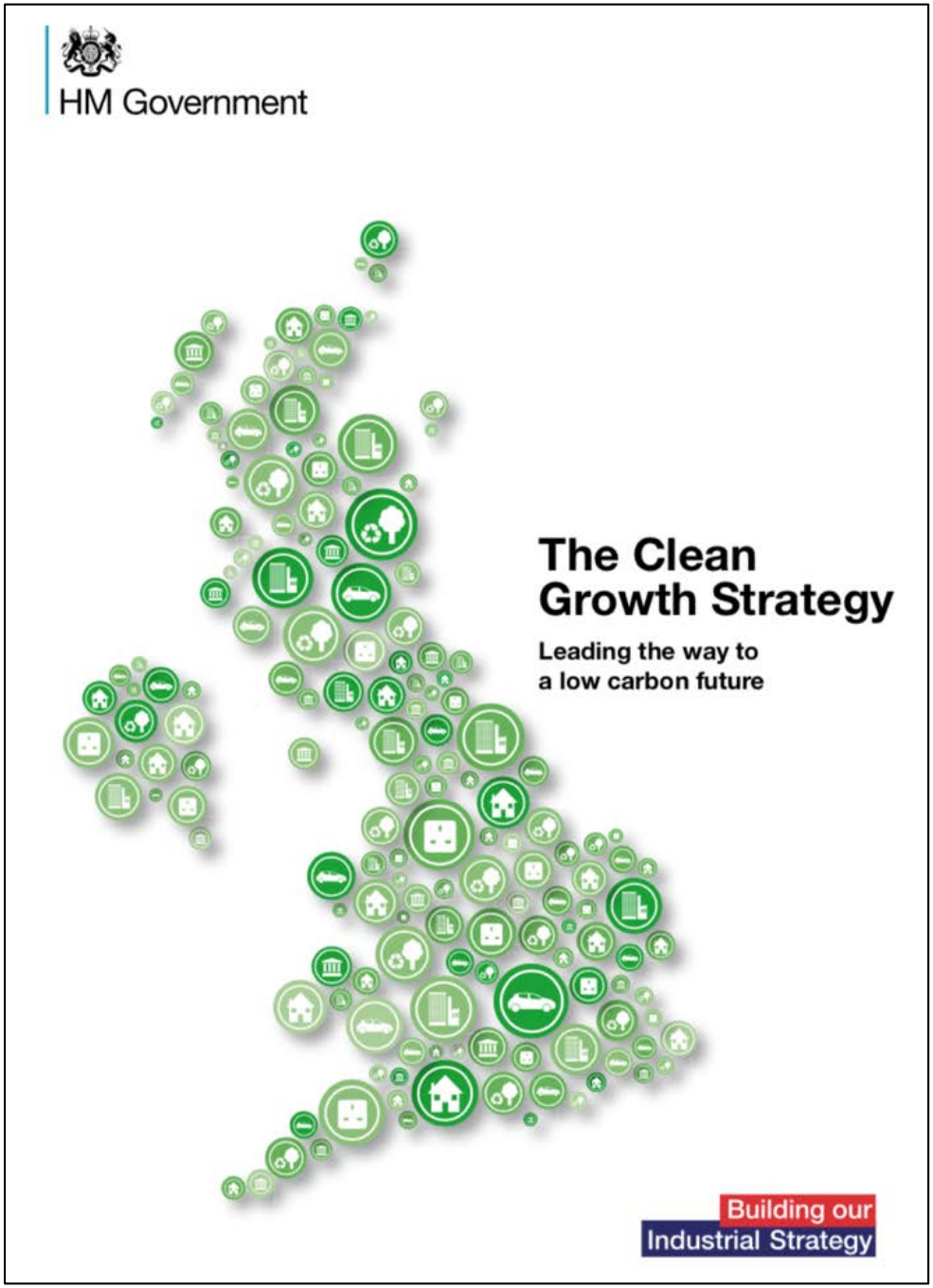


At the time of Paris Agreement

87% of 2°C scenarios and 100% of 1.5°C scenarios use some greenhouse gas removal (GGR)

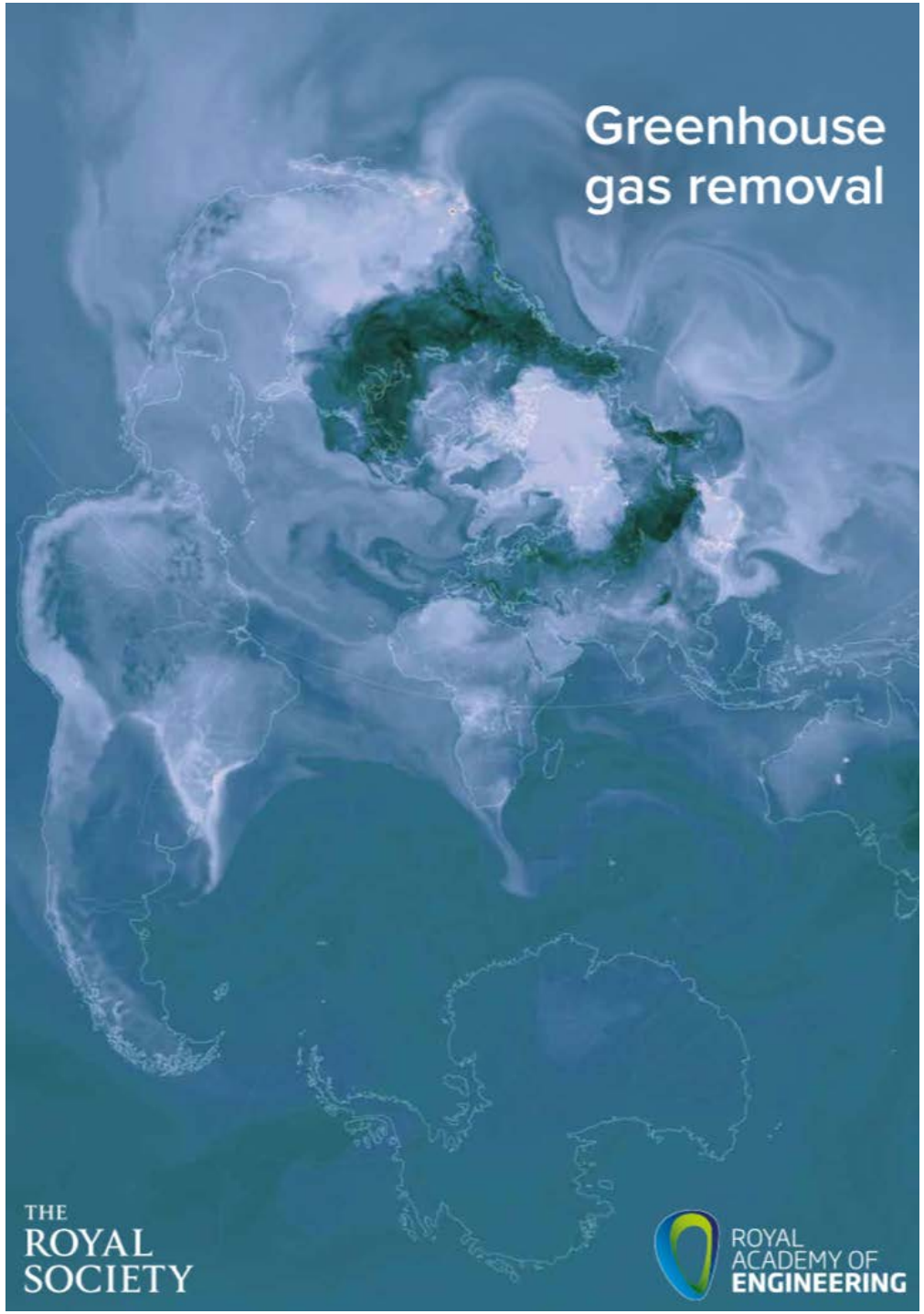


A UK perspective in 3 reports

i. UK Clean Growth Strategy Autumn 2017

From key policies and proposals

"Develop our strategic approach to greenhouse gas removal technologies…. addressing the barriers to their long term deployment."



A UK perspective in 3 reports

ii. Report to BEIS on GGR September 2018

UK scenario indicated that the UK could realize sufficient GGR to balance residual emissions of greenhouse gases to make the UK net zero in 2050

THE ROYAL SOCIETY

ROYAL ACADEMY OF ENGINEERING

A UK perspective in 3 reports

iii. Committee for Climate Change Net Zero Report May 2019

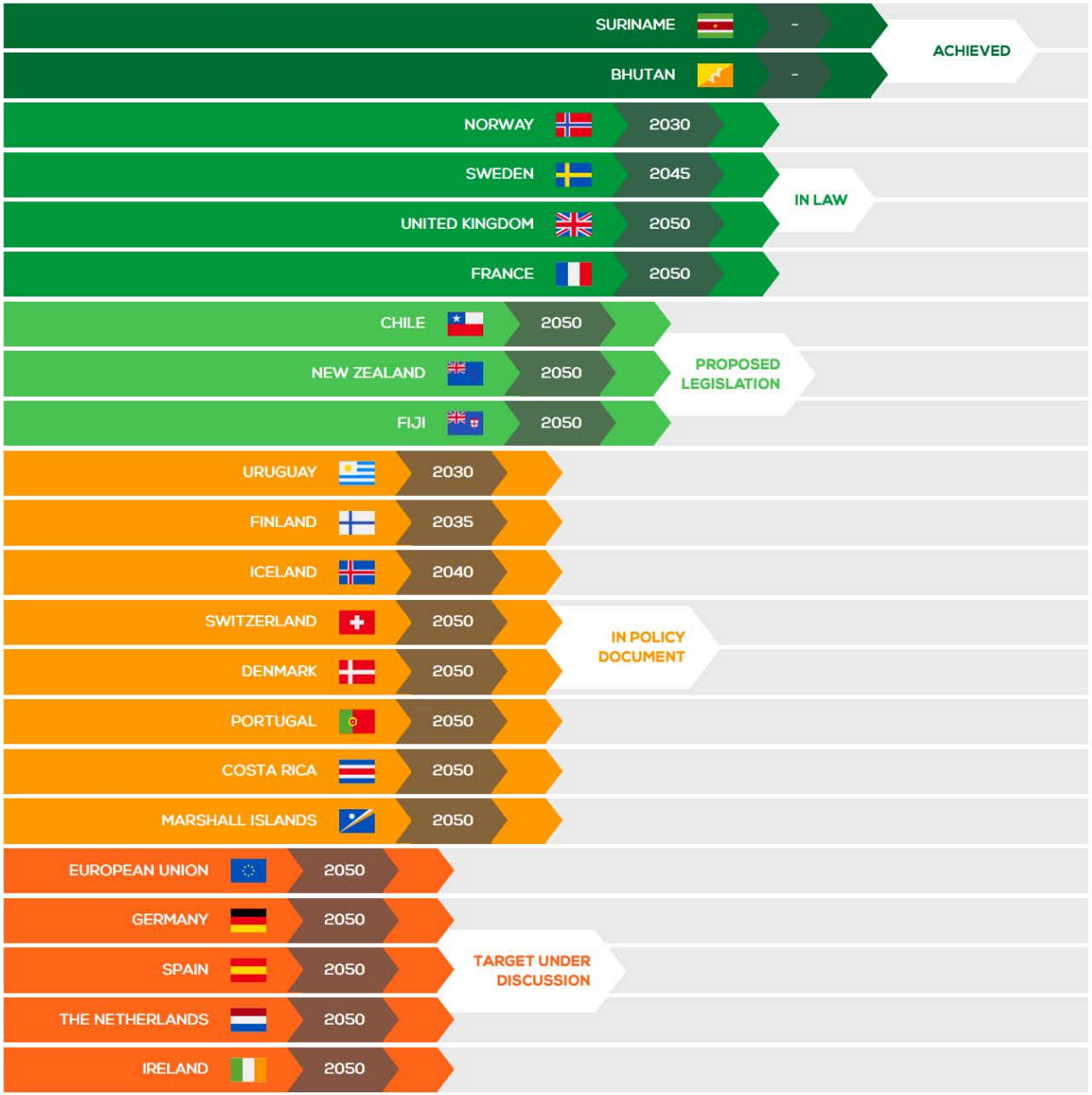
"The UK should set and vigorously pursue an ambitious target to reduce greenhouse gas emissions (GHGs) to 'net-zero' by 2050"

UK law changed in June 2019 requiring England to be net zero by 2050

ENERGY & CLIMATE INTELLIGENCE UNIT

NET ZERO EMISSIONS RACE

2019 SCORECARD



Countries aiming for net zero

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GGR methods: Must both remove and store CO_2

		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

THE ROYAL SOCIETY

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Reforestation

Photosynthesis:

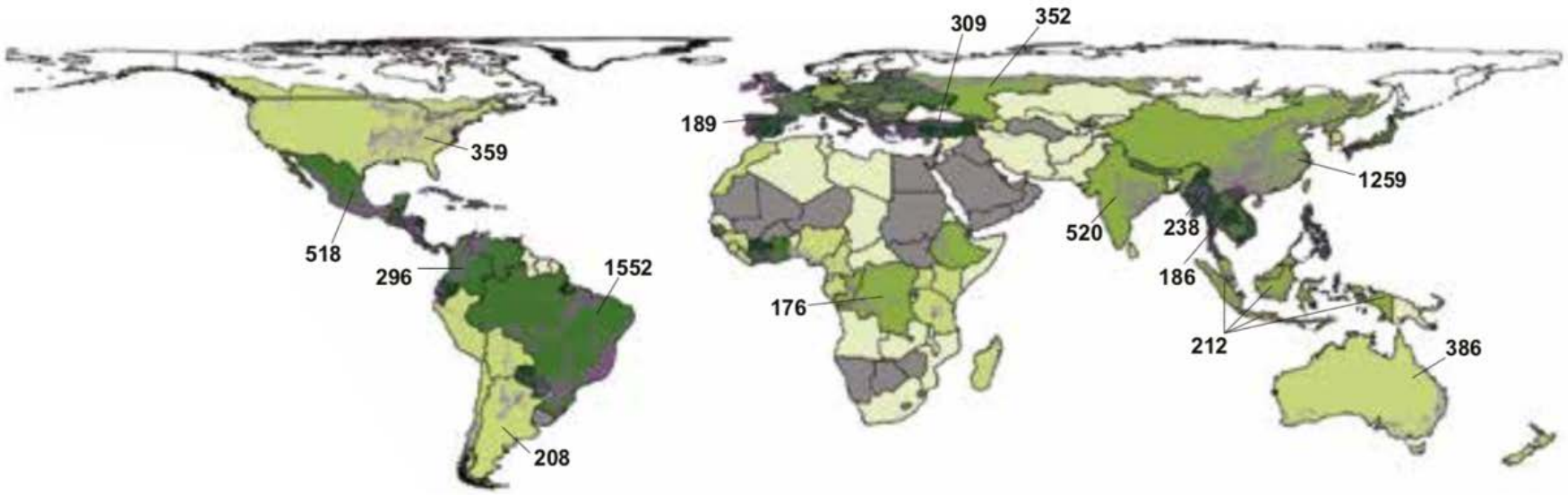
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Growing forests is good but…

There is only so much space to put them
Need to be careful they don't have other negative impacts

FIGURE 4

Distribution of potential GGR by reforestation by country.



KEY

Reforestation extent $kgCO_2 e\ ha^{-1}\ yr^{-1}$ | 0 | 1 – 211 | 212 – 758 | 759 –1,749 | 1,750 – 3,000 | 3,001 – 7,700 | No mitigation (Boreal zone)

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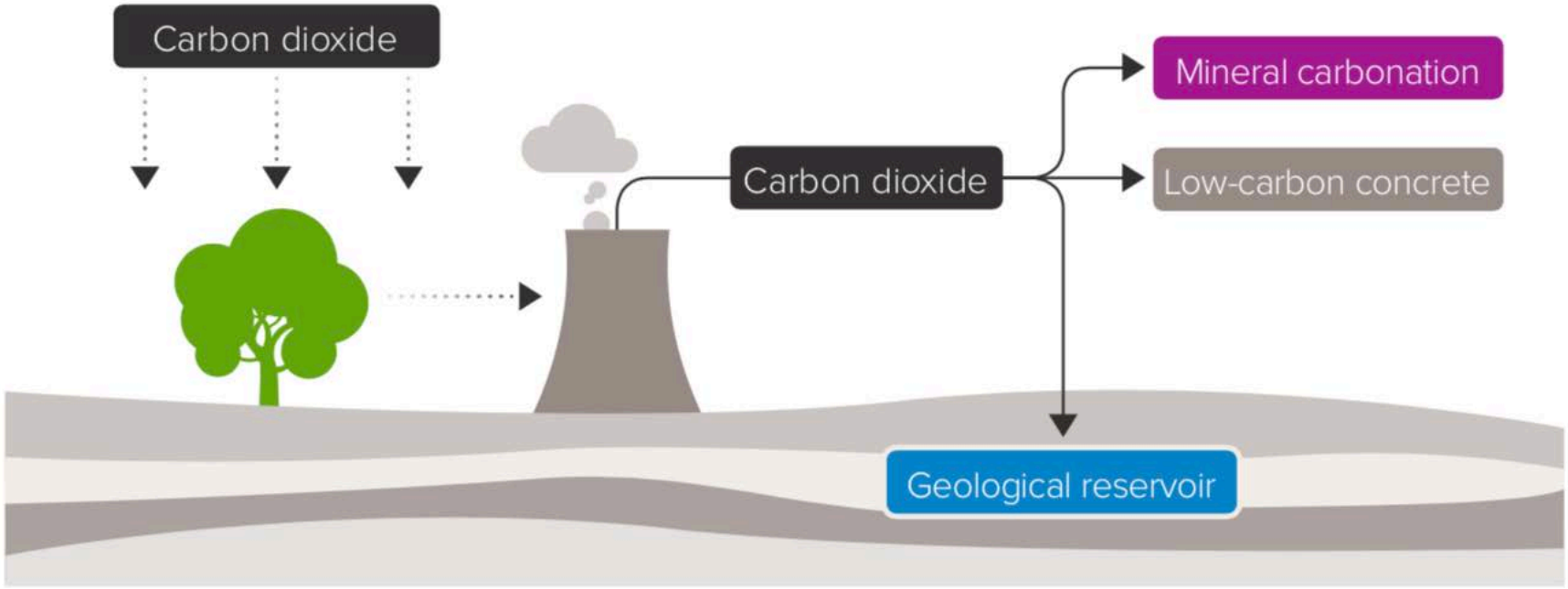
Bioenergy with Carbon Capture and Storage (BECCS)



Utilising biomass for energy, capturing the CO_2 emissions and storing them to provide lifecycle GGR

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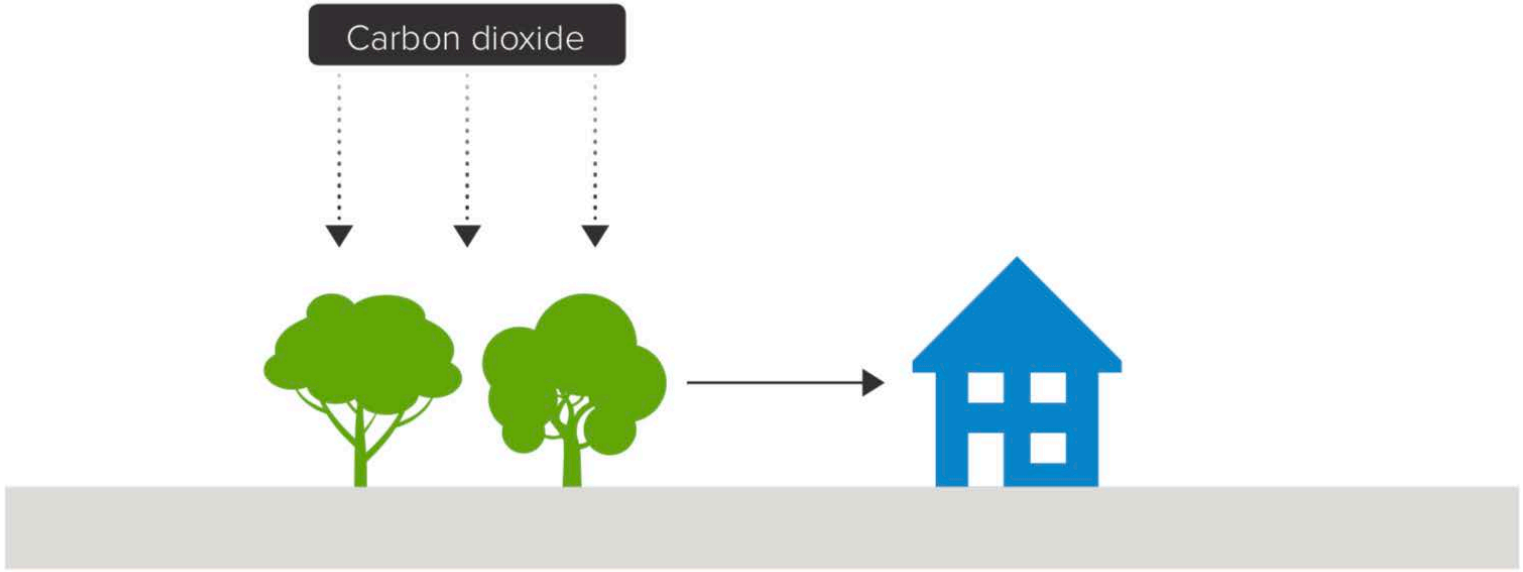
Building with Biomass



Using forestry materials in building extends the time of carbon storage of natural biomass and enables additional forestry growth

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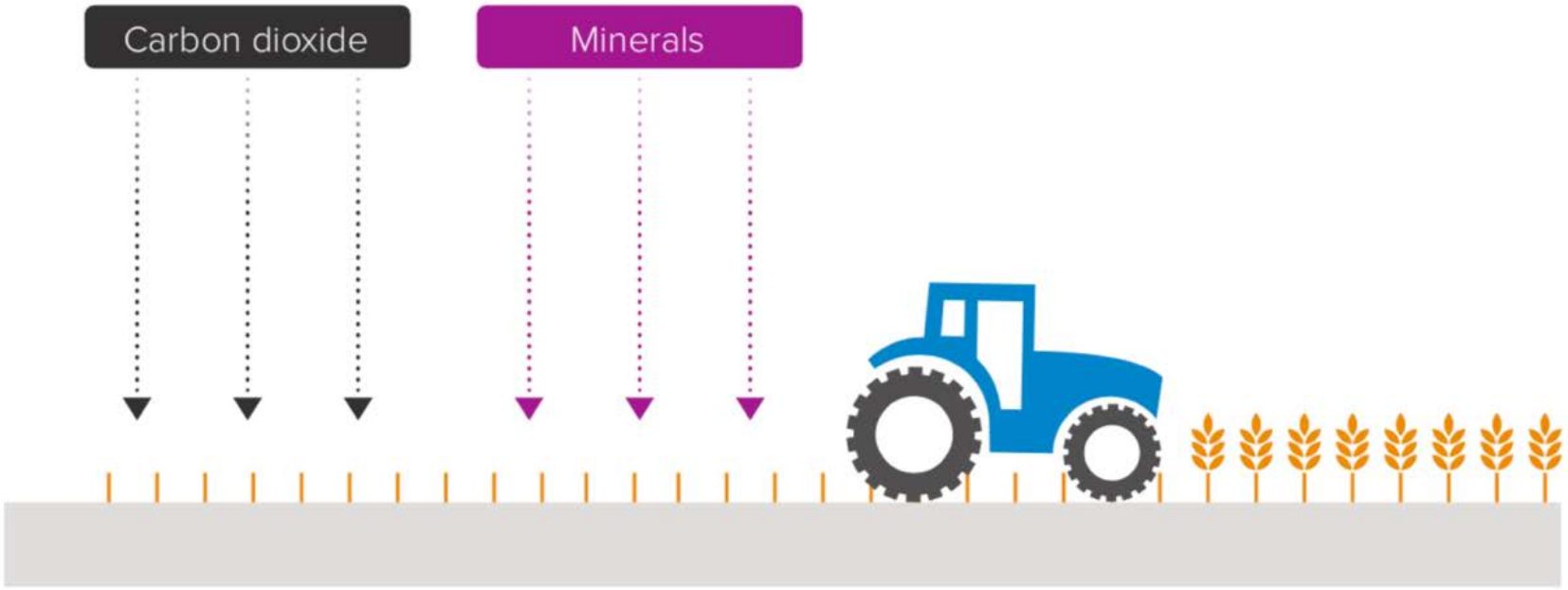
Enhanced Terrestrial Weathering

$$CaSiO_3 + 2CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^- + SiO_2$$



Ground silicate rocks spread on agricultural land react with CO_2 to remove it from the atmosphere

Positive need to add silicate to some soils

Grinding up silicates uses huge amounts of energy

But we have already done a lot of grinding

Mine tailings as a source of silicates

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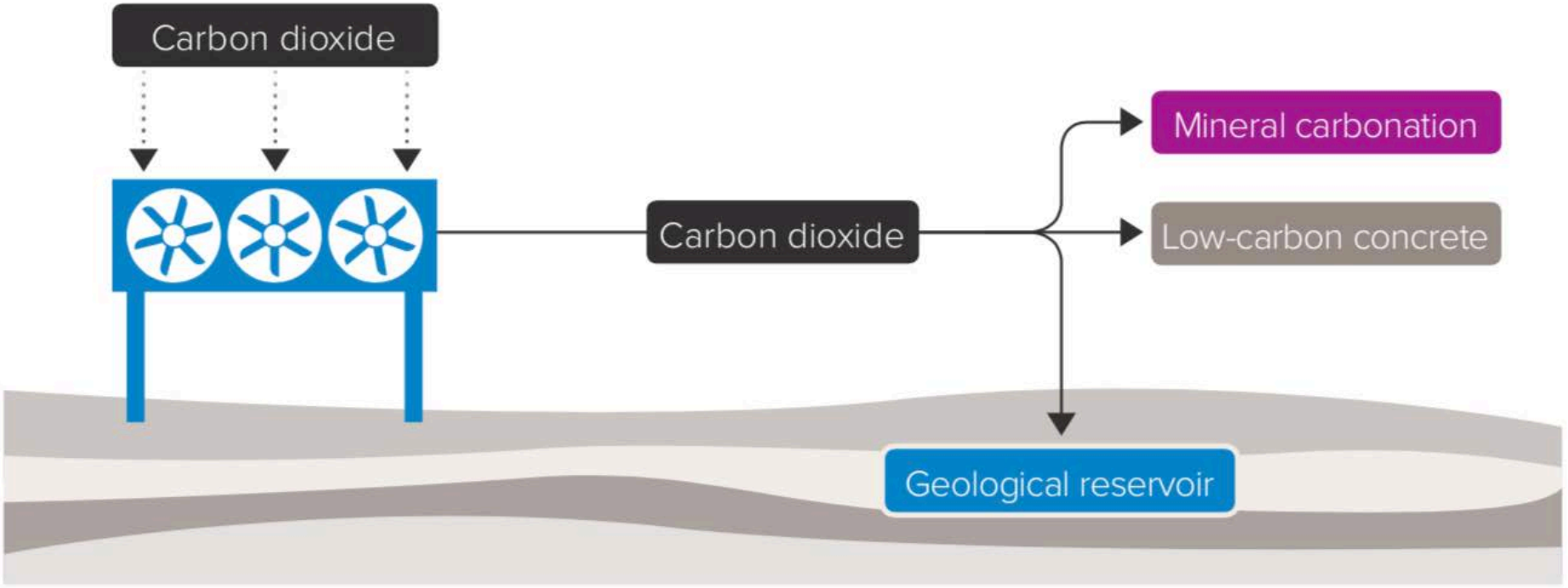
Direct Air Capture and Carbon Storage (DACCS)



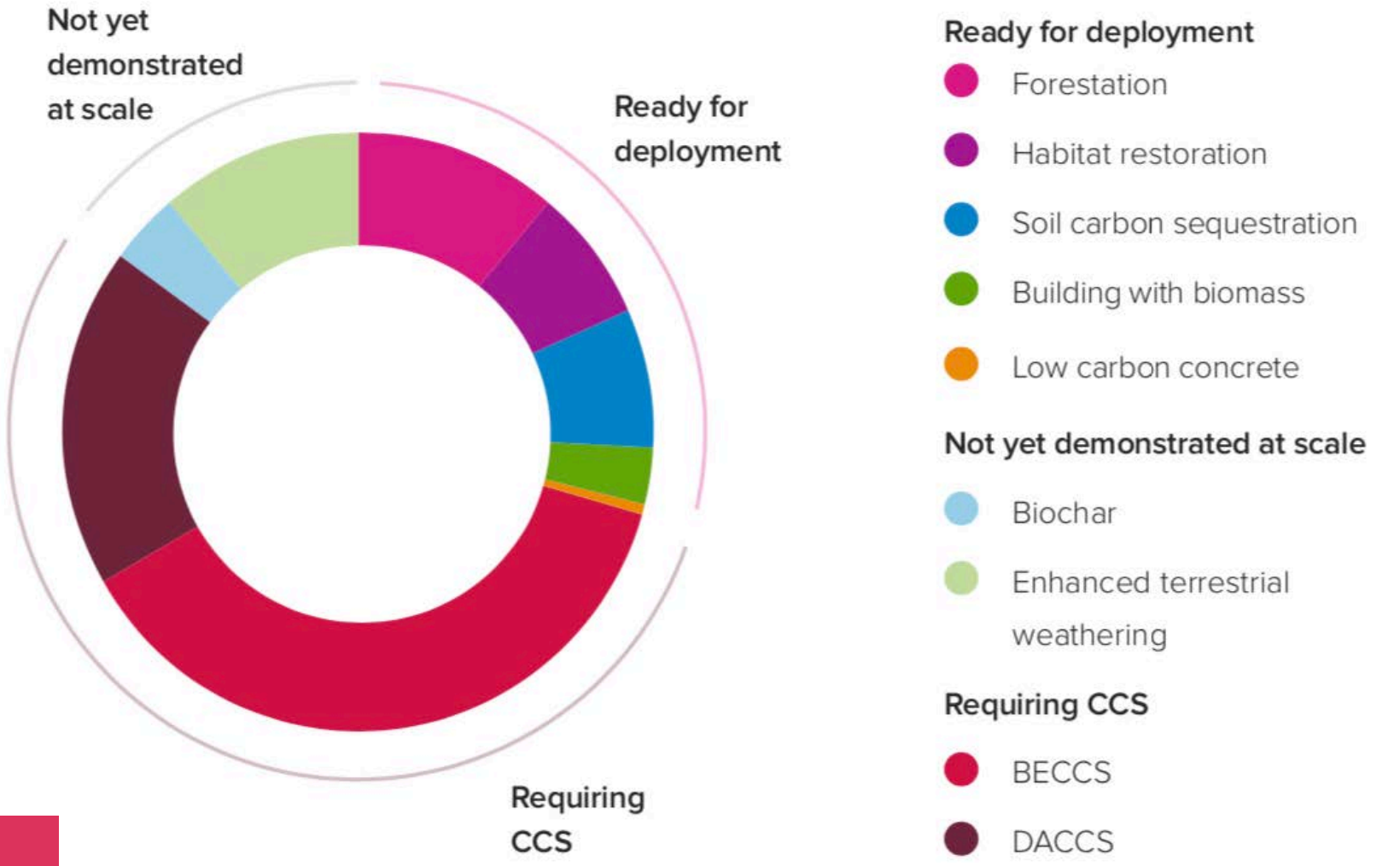
Using engineered processes to capture atmospheric CO_2 for subsequent geological storage


Sleipner oil field CCS operation (Norway, North Sea)

The UK as a case study

Can the UK reach net zero emissions

Possible to use suite of GGR to balance recalcitrant UK emissions



THE ROYAL SOCIETY

Note absence of oceanic approaches

How about NZ?


WE'LL STOP BEING ACTIVISTS WHEN YOU STOP BEING Shit
THE TIME FOR VOLUNTARY ACTION IS OVER.
HOLD THE GOVERNMENT TO ACCOUNT NOW
SOS
WE NEED Change NOW
Climate action, climate jobs now!
SOCIALIST CHANGE NOT CLIMATE CHANGE
METRO

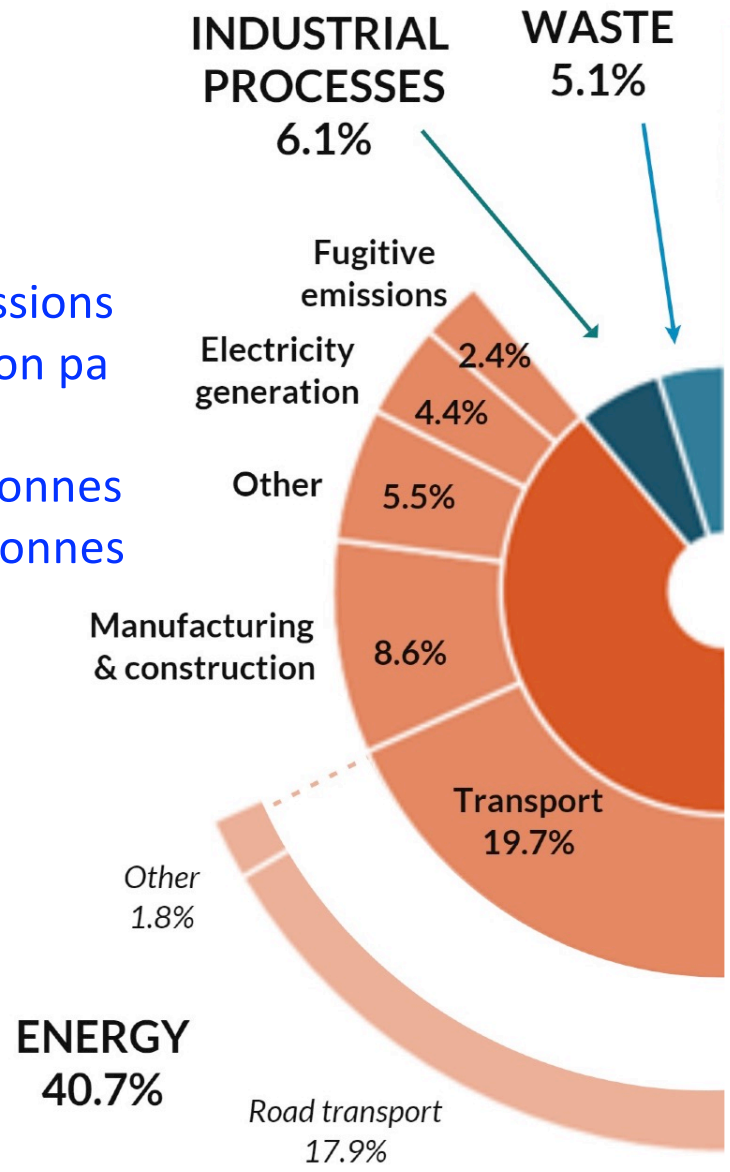

THERE'S NO PLANET B
MESS WITH OUR CLIMATE
WE'LL MES
WHATS THE P
GOING TO SO
NO ONE LISTEN
the EDUCA
IS IN THE AIR
SPEAK UP TAKE
STOP DENYING!!!
WE SPEAK FOR THE TREES
It is Late..... BUT Not too Late!!
WHERE'S OUR
WHY AM STUDYING FOR FUTURE THAT D EXIST
LEARN TO
IF YOU ARE NOT

NEW ZEALAND'S Greenhouse Gas Emissions

Source: New Zealand's Greenhouse Gas Inventory 1990-2017, published April 2019

CO_2 emissions per person pa

NZ: 7.5 tonnes
UK: 7.1 tonnes



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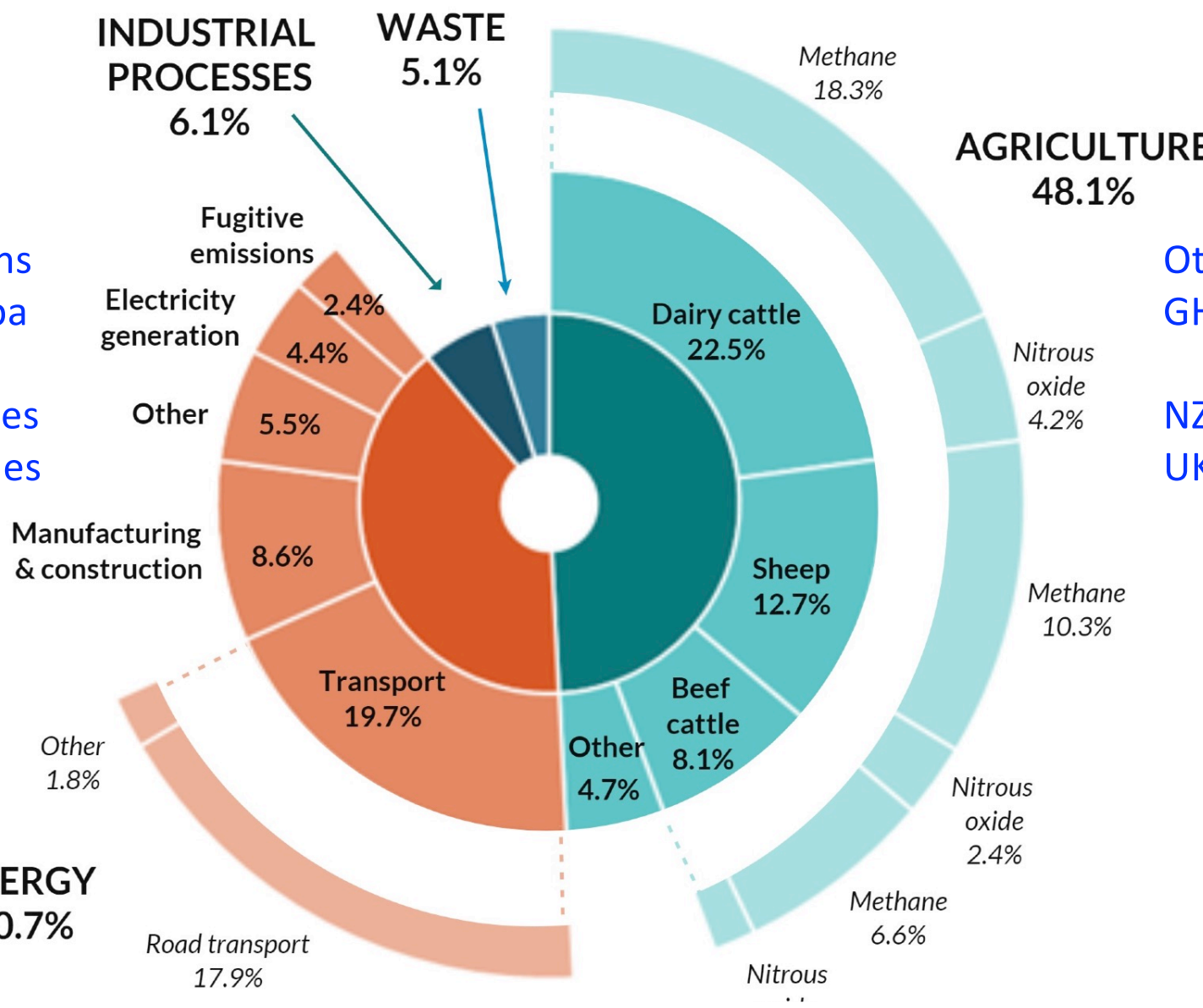
Other emissions GHG (CO_2 e)

NZ: 9.1 tonnes
UK: 1.3 tonnes



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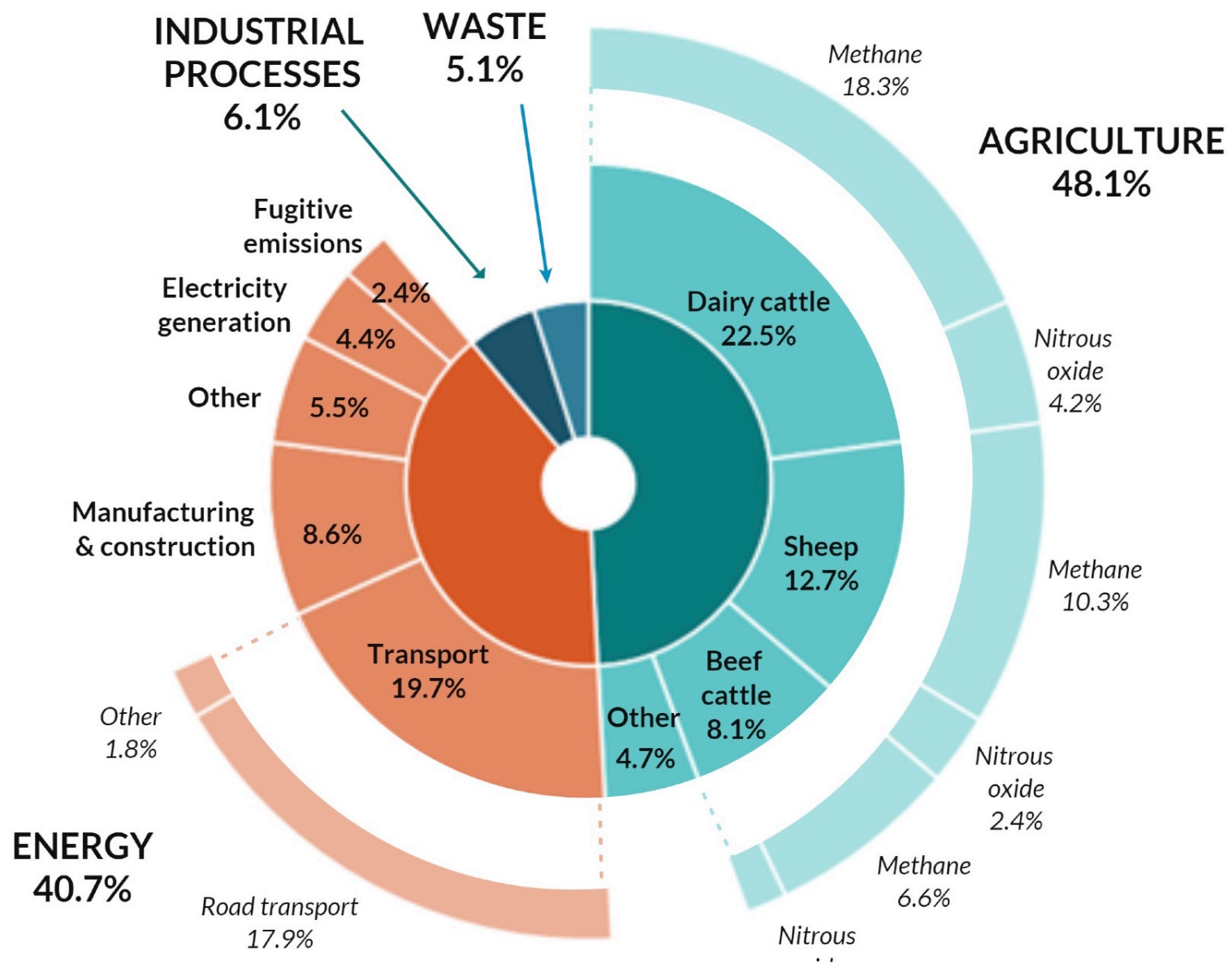
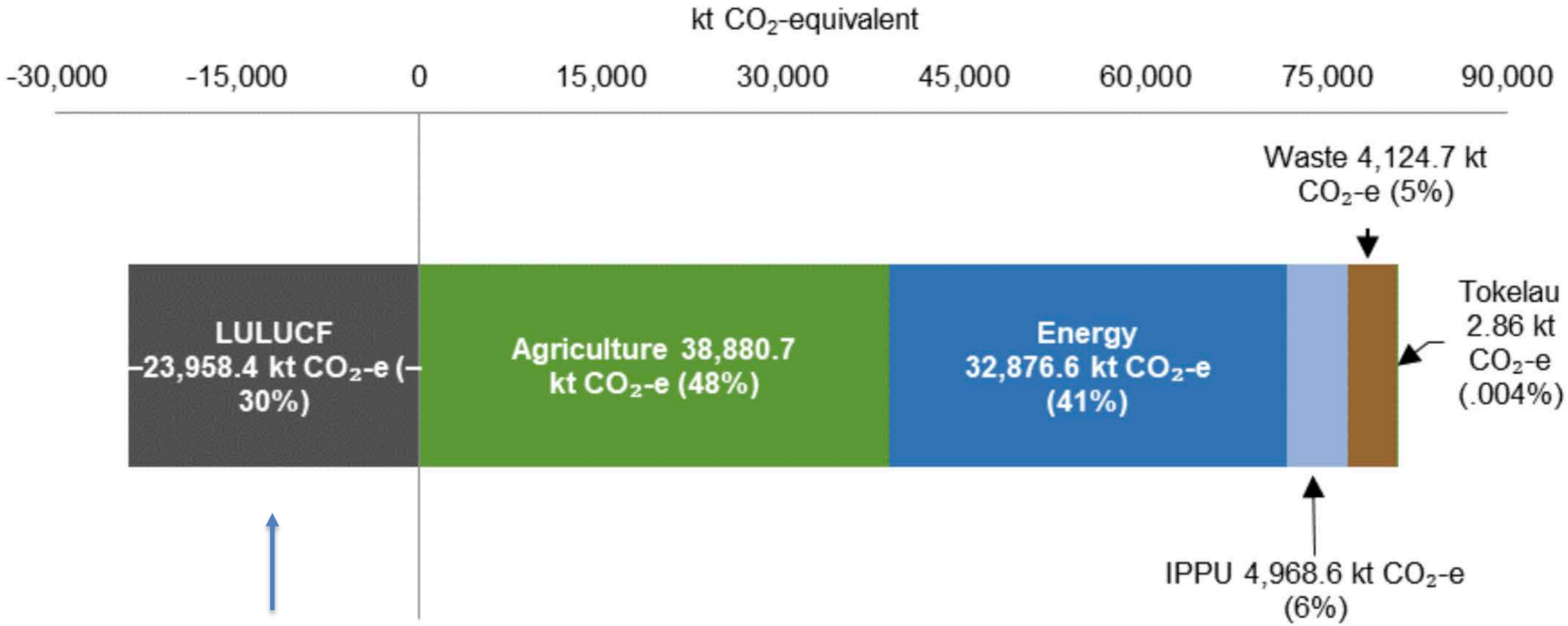


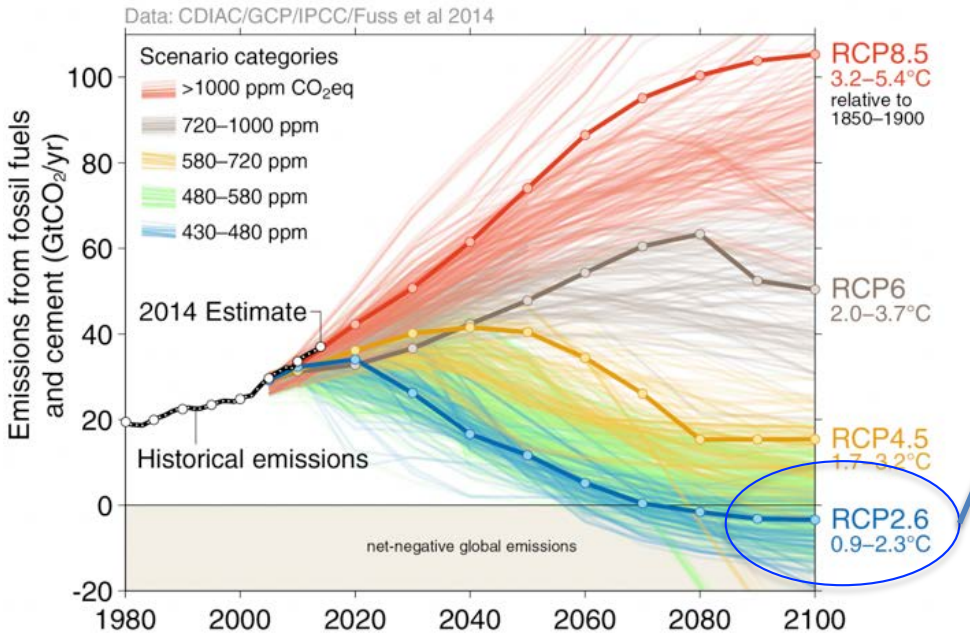
New Zealand Emissions per sector 2017



i.e. new forests

NZ GHG Inventory

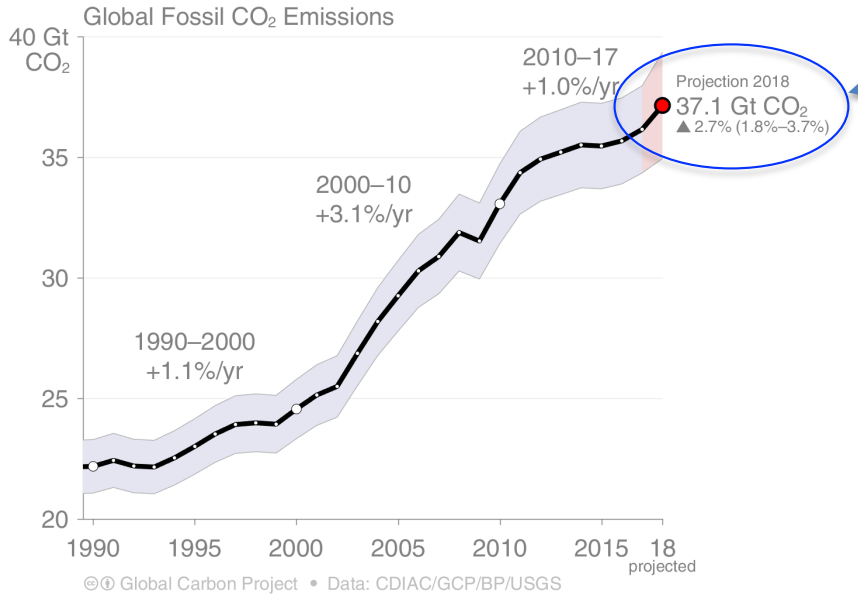
If money makes the world go around



Median GGR in scenarios meeting 1.5°C is 810 Gt CO_2 by end of century

So, 10 Gt CO_2 per year

At US$50 per tonne (e.g. 45Q bill in the USA)
= US$ 0.5 trillion per year



10 GtCO2 ≈ ¼ of present emissions

Global oil/gas market = US$2 trillion

¼ of US$2.0 trillion
= **US$0.5 trillion per year**

Summary Comments

- Removal of CO_2 from the atmosphere is required to meet climate targets agreed internationally at Paris, and to avoid dangerous climate change, *in addition to stringent cuts in emissions*
- CO_2 removal can be achieved by approaches relying on biology, accelerated natural inorganic reactions, or engineered removal
- Even in land-constrained Britain, it is possible to reach net-zero emissions by using CO_2 removal to compensate for recalcitrant emissions
- The same will be true for New Zealand, but will need planning, and consideration of new approaches to CO_2 removal
- This will not be cheap, but there will be money to be made
- We all have a part to play in realising net zero emissions and protecting our planet for future generations

He waka eke noa
A canoe which we are all in with no exception