Can the UK Achieve Net Zero Greenhouse Gas Emissions by 2050?

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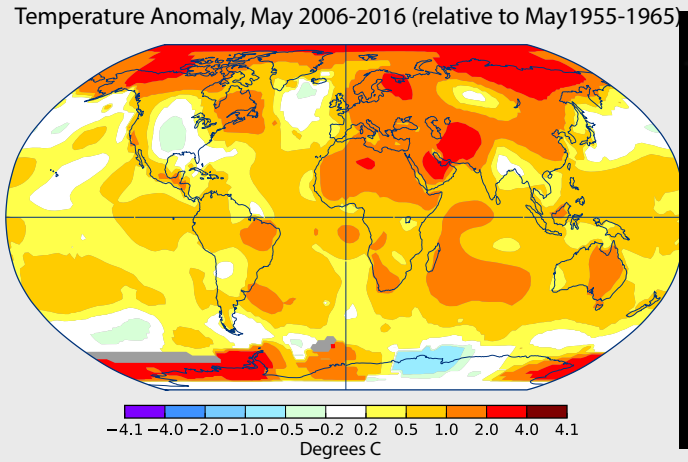
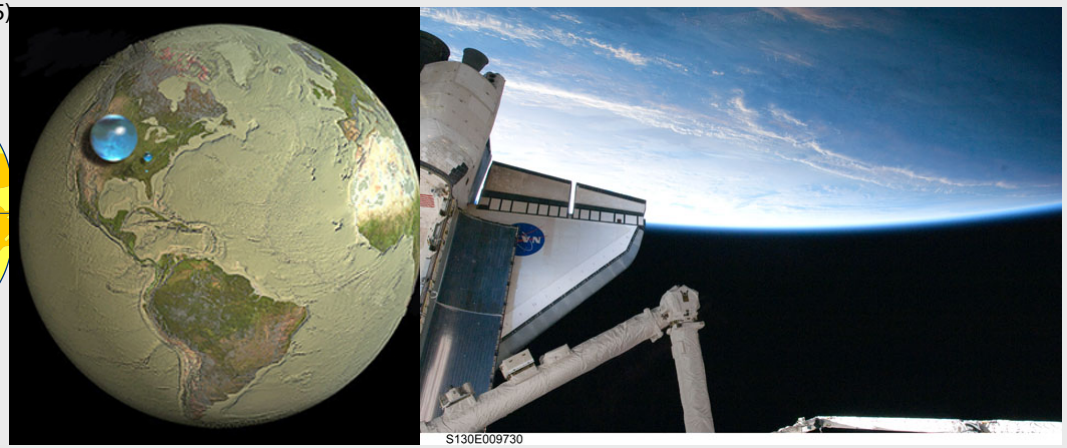
Route Map





(1) **UK climate change**

(2) **Non-GHG ‘green’ electricity generation**

(3) **Decarbonize ground transport**

(4) **Decarbonize households and construction**

(5) **Decarbonize industry, chemical manufacturing and waste**

(6) **Reduce GHG emissions from agriculture**

(7) **Conclusions**

UK climate change policy

UK's 2008 Climate Change Act (CCA08) was world's first legally binding legislation on greenhouse gas (GHG) emissions.
Target of 80% reduction in UK net GHG emissions by 2050.

CCA08 created Climate Change Committee, independent statutory body to monitor, analyse, advise & report to Parliament: latest has more than 300 policy recommendations.

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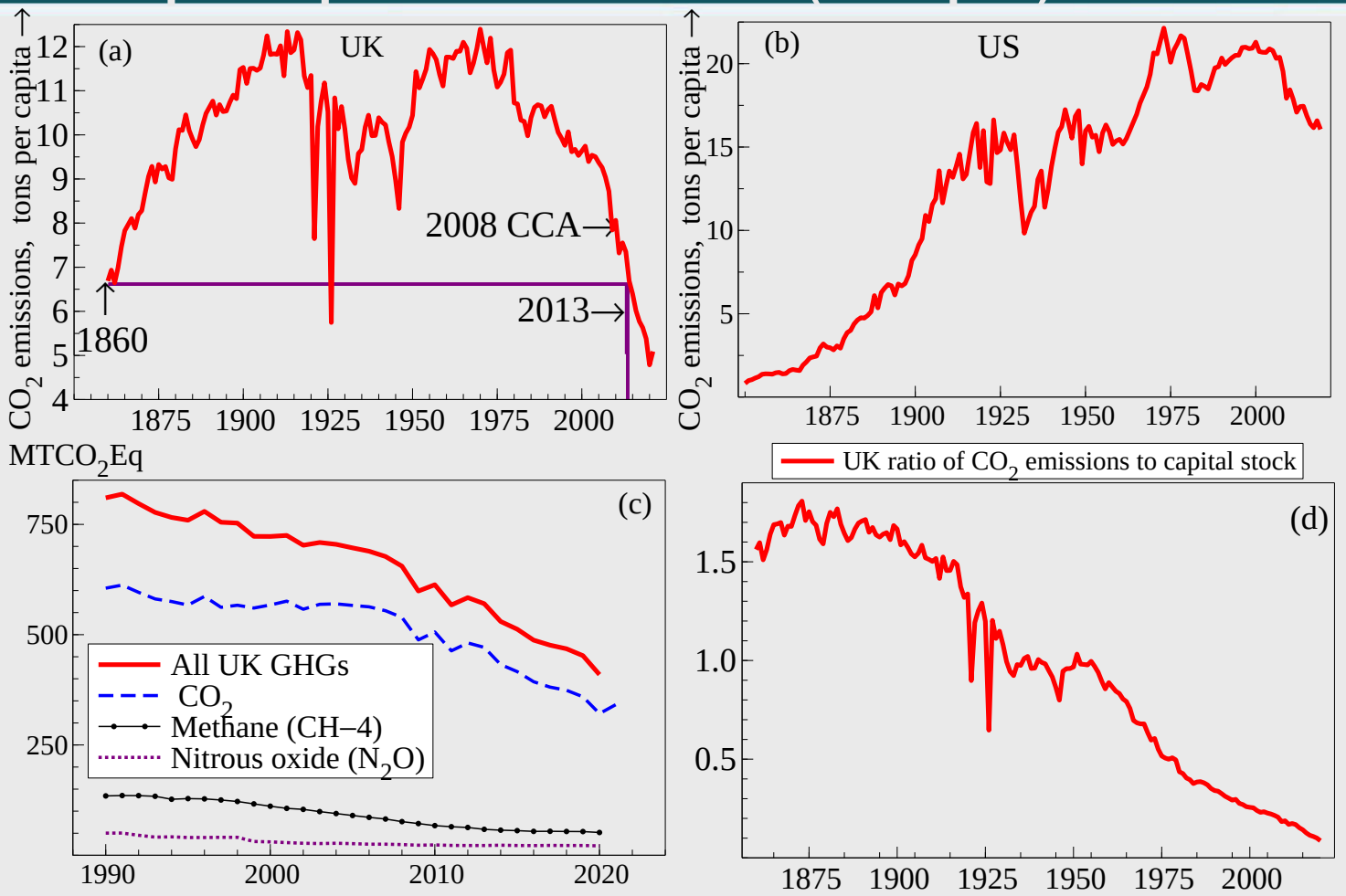
Castle and Hendry (2020) found CCA08's impact reduced CO_2 by 50Mt by 2015, and Castle, Doornik, and Hendry (2022) showed this was due to faster adjustment.

UK climate policy effective: big reductions in territorial CO_2 emissions at little aggregate cost as renewables fully competitive.

In 2013, fell below 1860 levels when UK was 'workshop of the world', partly from 'off-shoring' and dominance of services.

Where is the UK now in controlling its GHG emissions?
UK territorial per capita CO_2 emissions (tons p.a.)



(a) UK CO_2 territorial emissions per capita in tons p.a. 1860–2018;
(b) US CO_2 emissions per capita in tons p.a., 1850–2019;
(c) UK GHG emissions in weighted CO2Eq Mt since 1990;
(d) ratio of CO_2 emissions to capital stock (log scale) to 2017.

Implementing UK climate change policy

UK's important steps strengthened in 2010 by EU Renewables Directive, revised in 2018, and legally binding from June 2021.

UK had banned sale of new petrol & diesel cars and vans by 2030, now 2035.

Despite a legislative & advisory framework, issues remain.

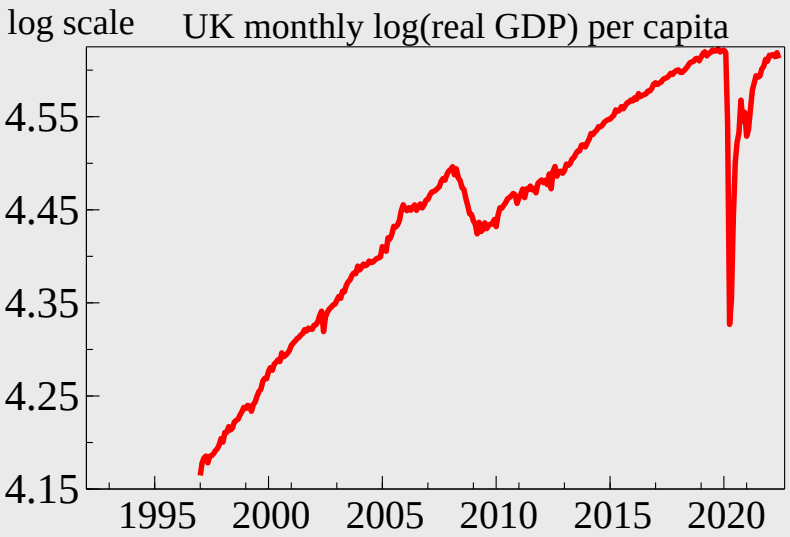
Covid-19 pandemic, recent energy crisis and inflation added awkward if temporary hurdles given a near 30-year time frame to achieve net zero.

Emphasis on energy security could accelerate progress to domestic renewables.

Will look at how legislation has affected UK GDP per capita, fuel & electricity use, and travel; but

current pernicious government backtracking on both climate and environment creating damage and huge uncertainty.

UK real GDP, fuel usage, domestically generated electricity and numbers of cars and distances travelled.



(a) UK real GDP per capita rose by 58% between 1997 and 2019, approximately 2% p.a., despite 'great recession': no evidence climate policy had –ve effect.

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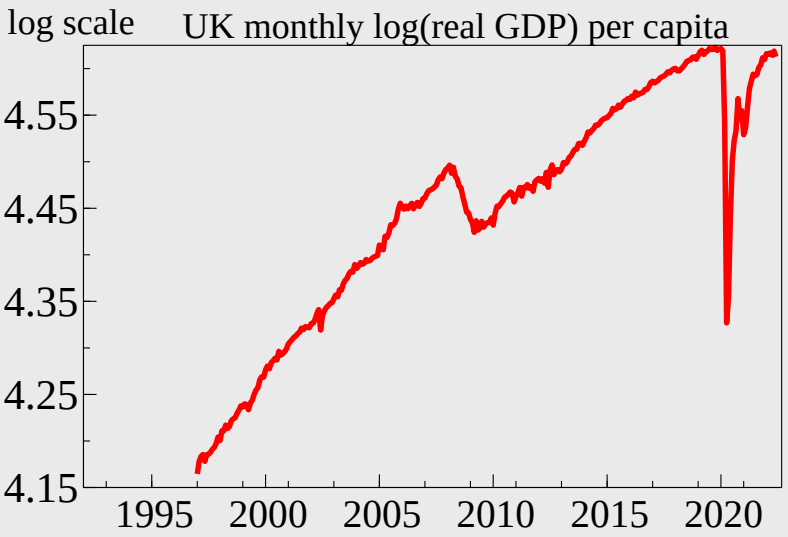

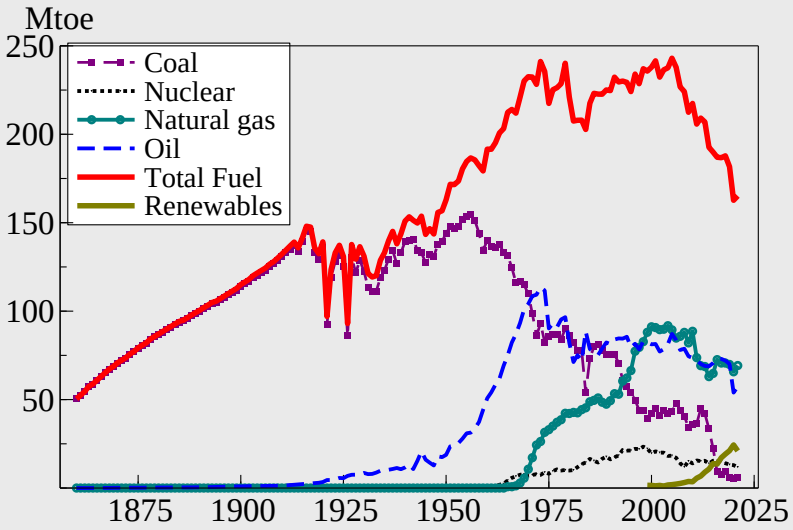

(b) UK fossil fuel usage and renewables total 180 million of tonnes of oil equivalent (Mtoe) to 2021, generating 2100TWh equivalent energy.

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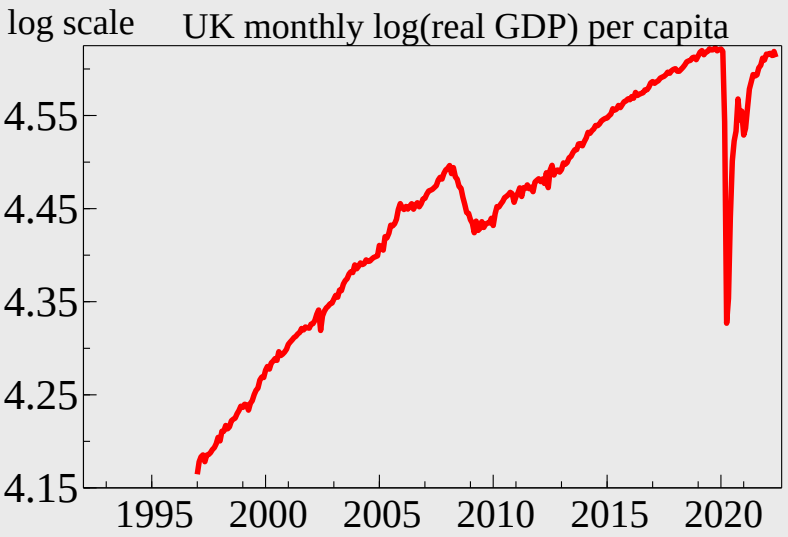

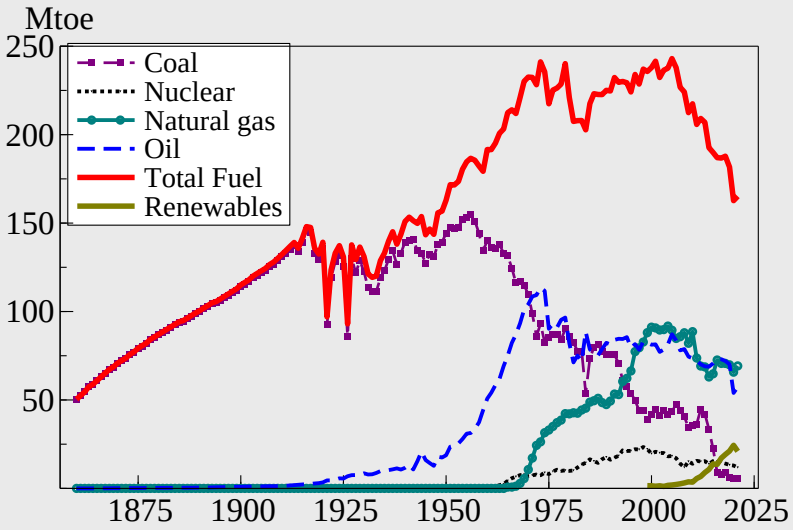

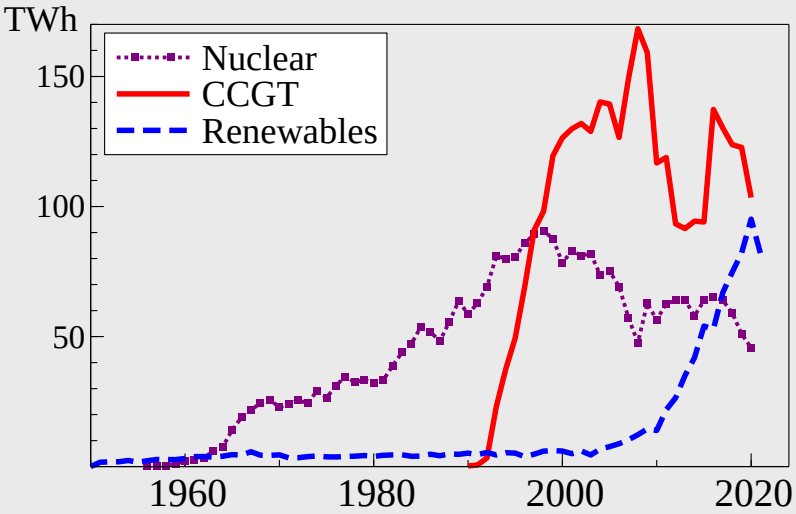

(c) Main non-coal sources of electricity, about 325TWh: 20TWh bioenergy & 25TWh imported via 3 interconnectors (CCGT: Combined Cycle Gas Turbine.)

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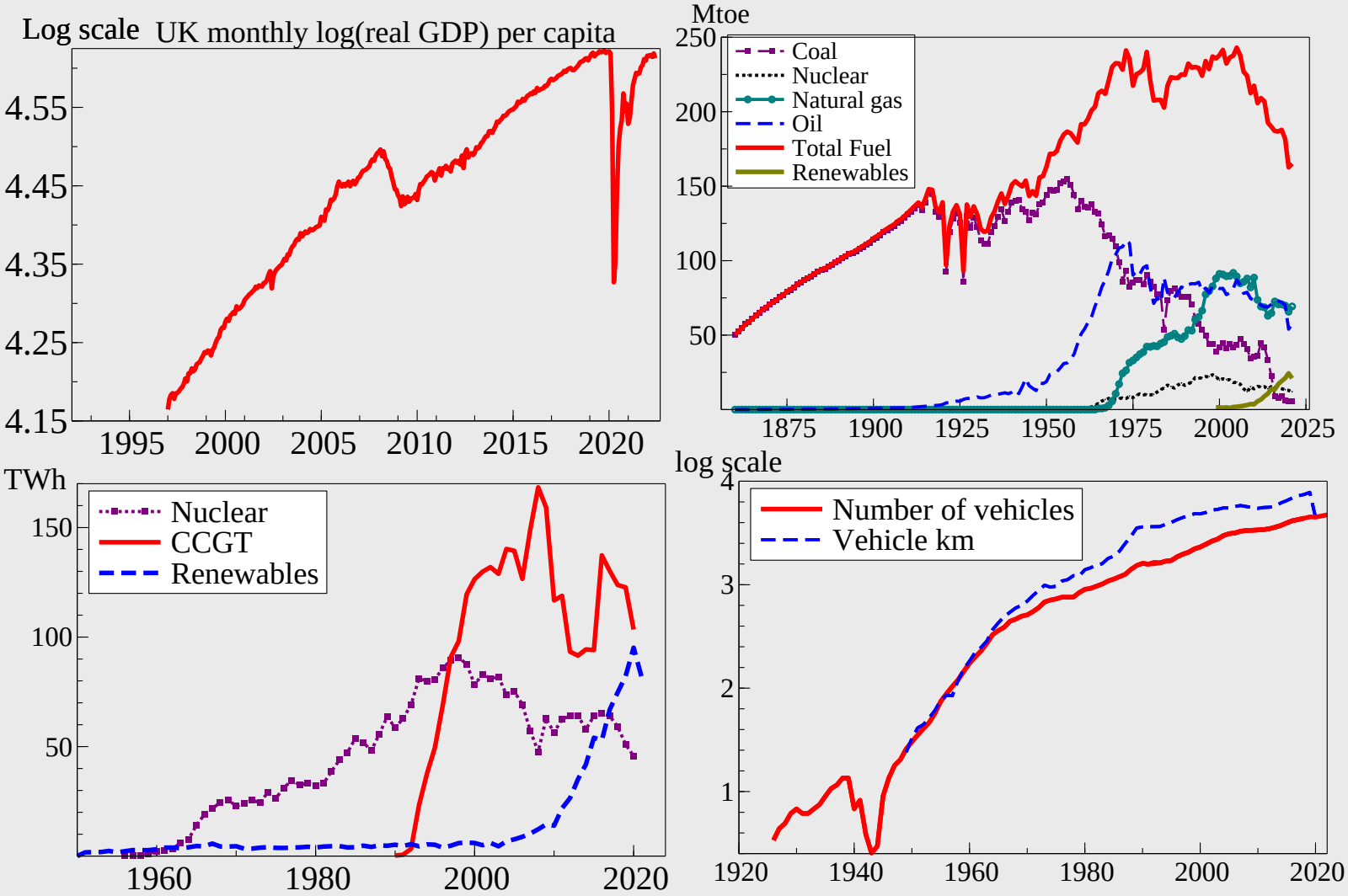
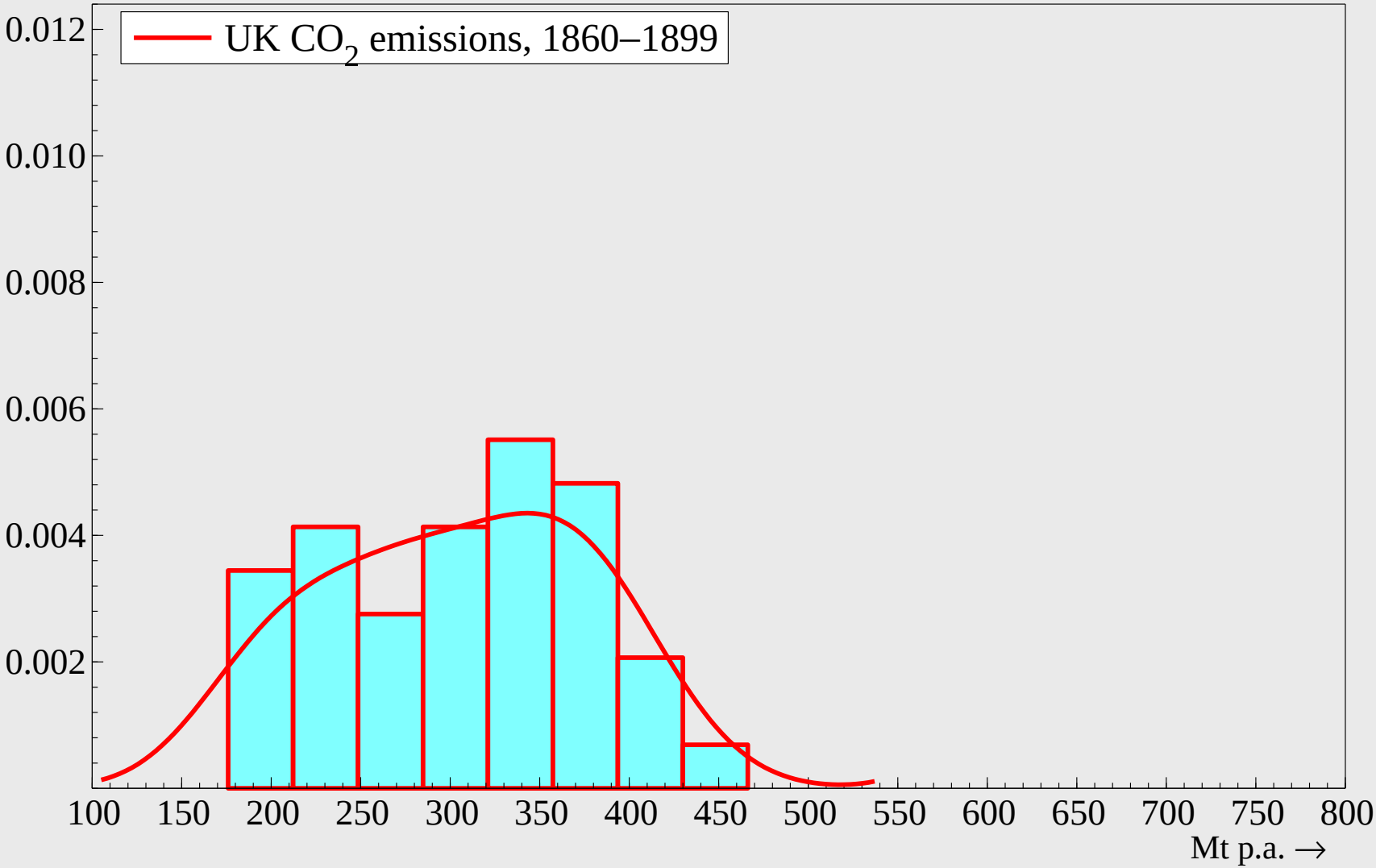


(d) Number of vehicles (millions) and kilometers driven p.a. (billions) on log scale (matched in 1949 as distance-travelled data start) on 70Mtoe petroleum.

Distributional shifts of total UK CO_2 emissions in Mt p.a.



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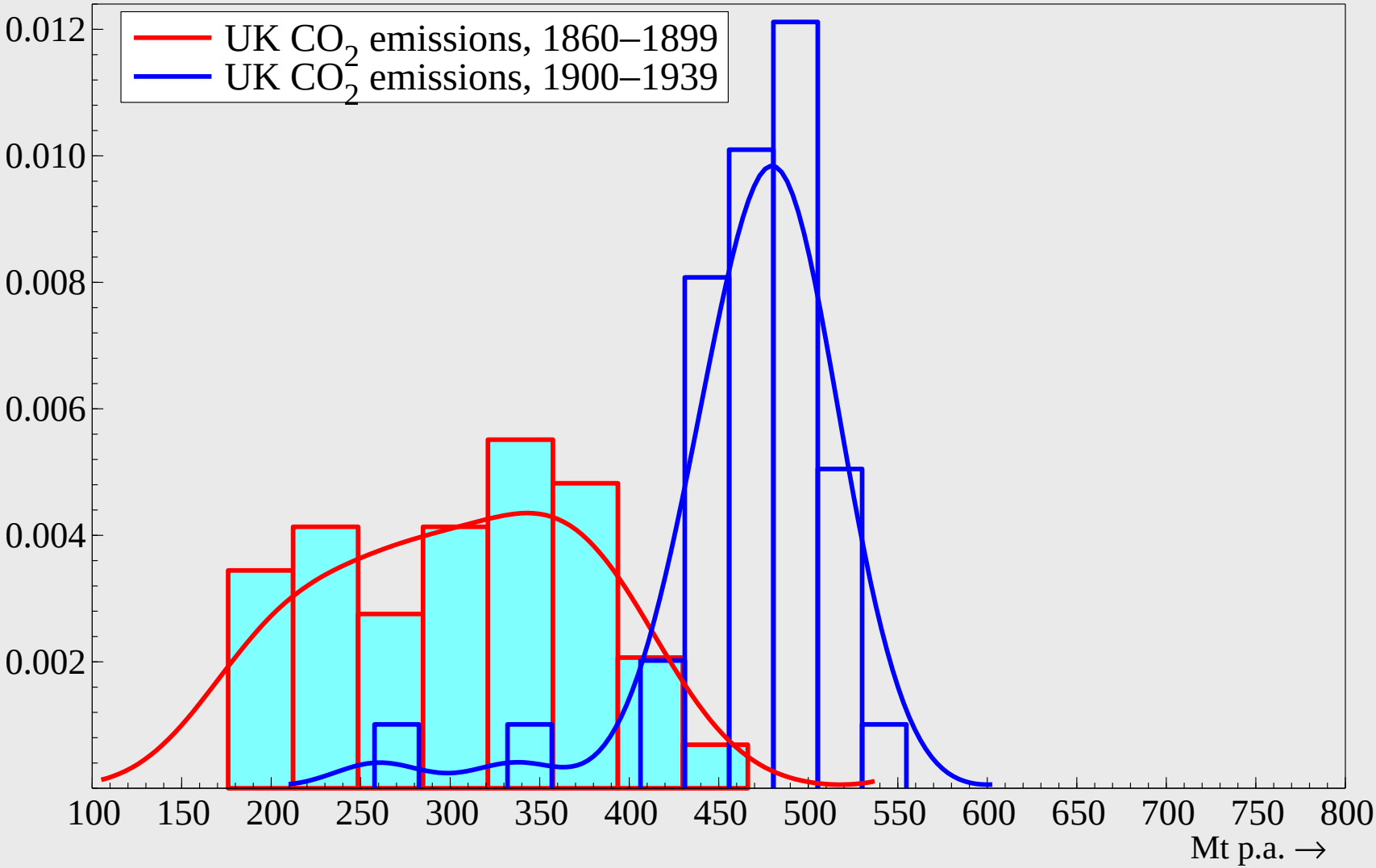

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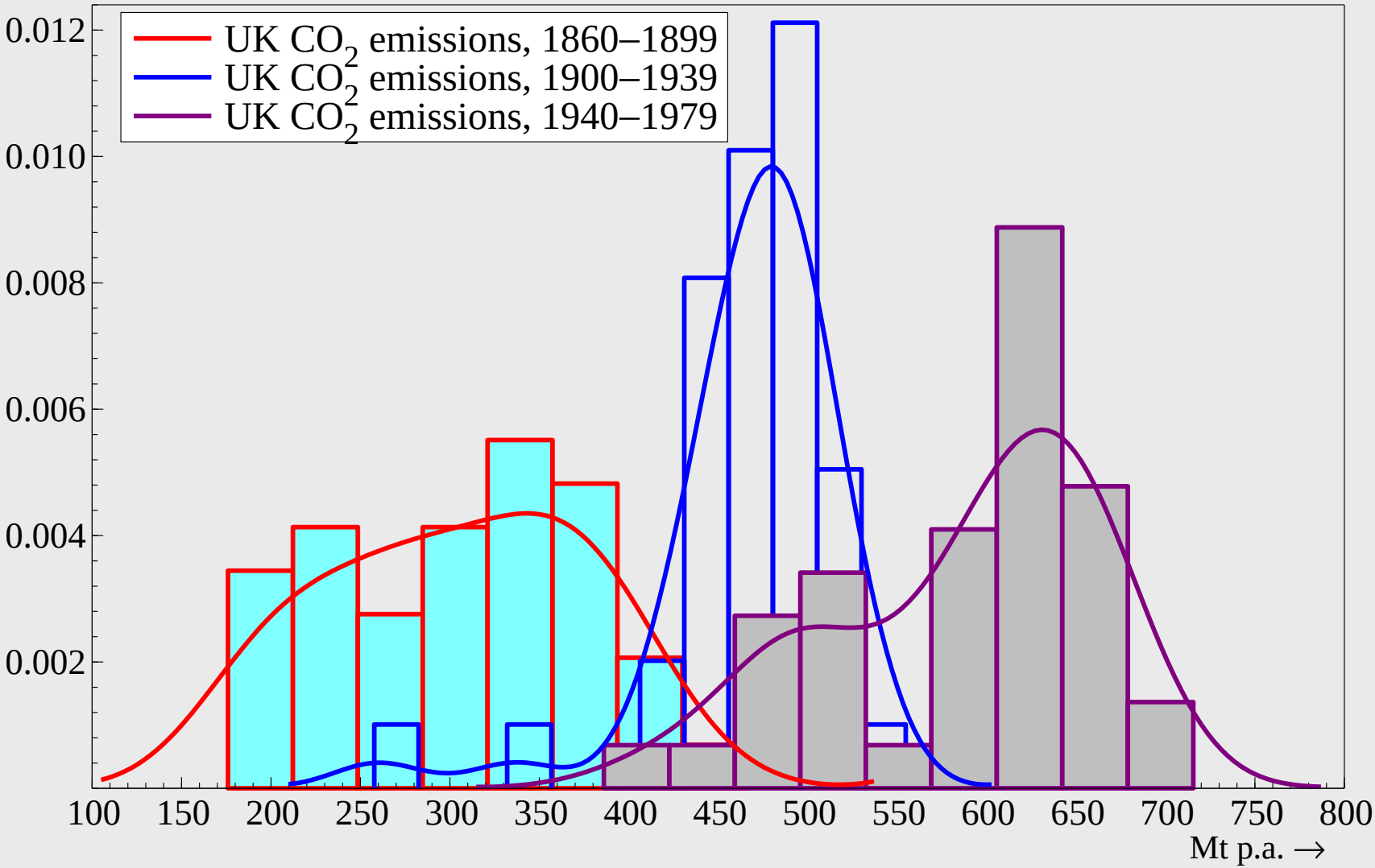

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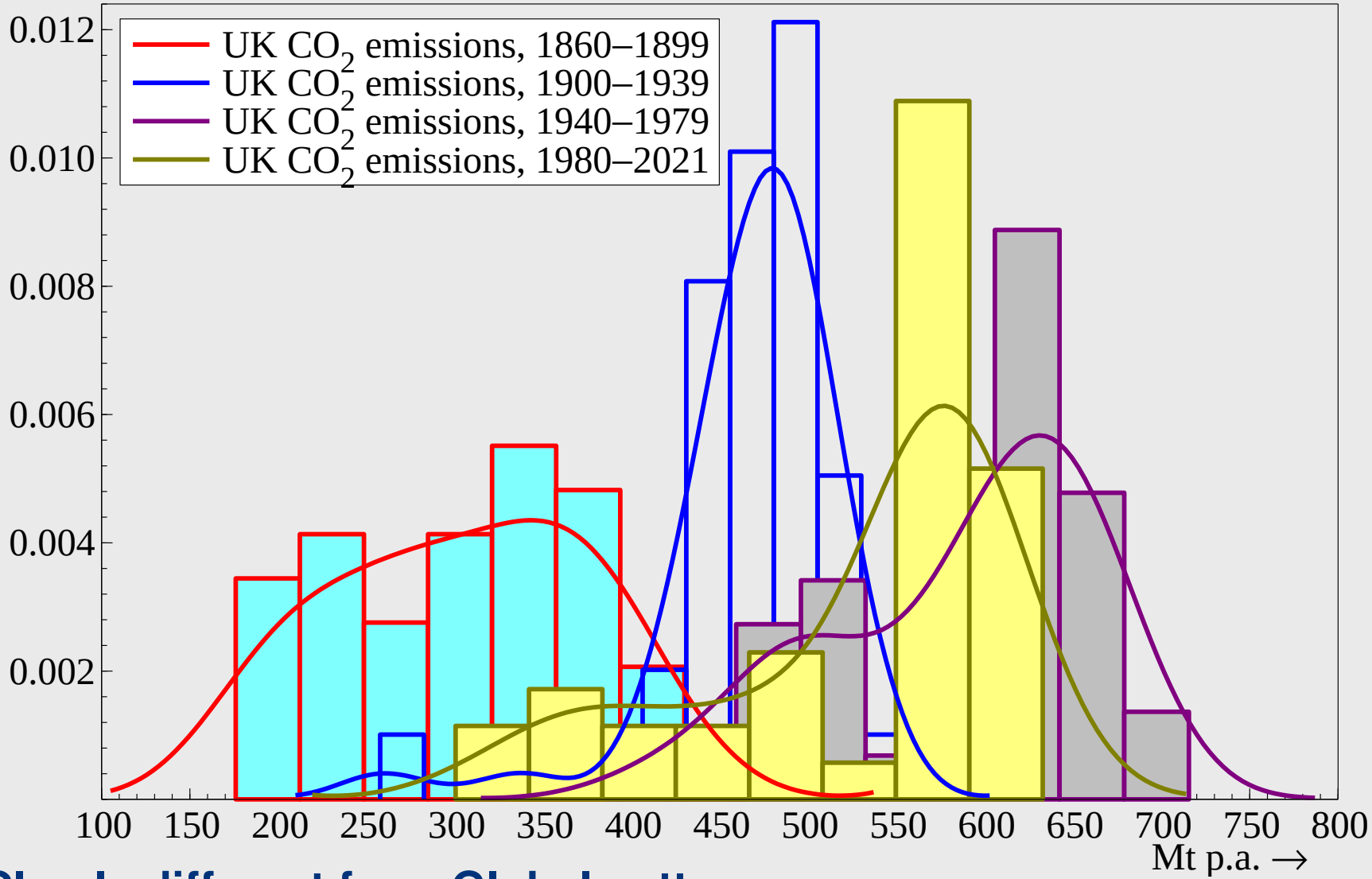
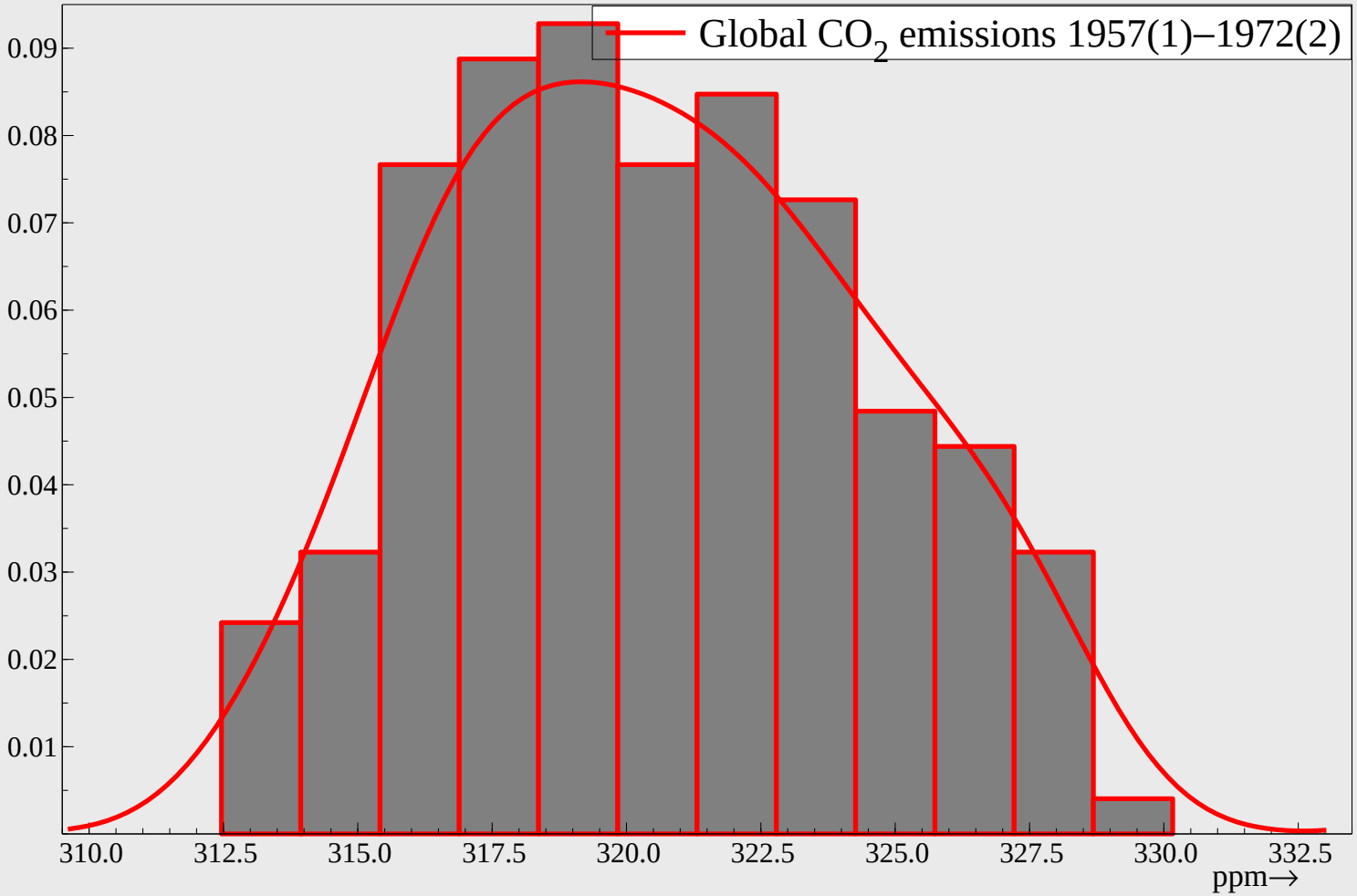


Clearly different from Global pattern.

Distributional shifts in monthly global atmospheric CO_2



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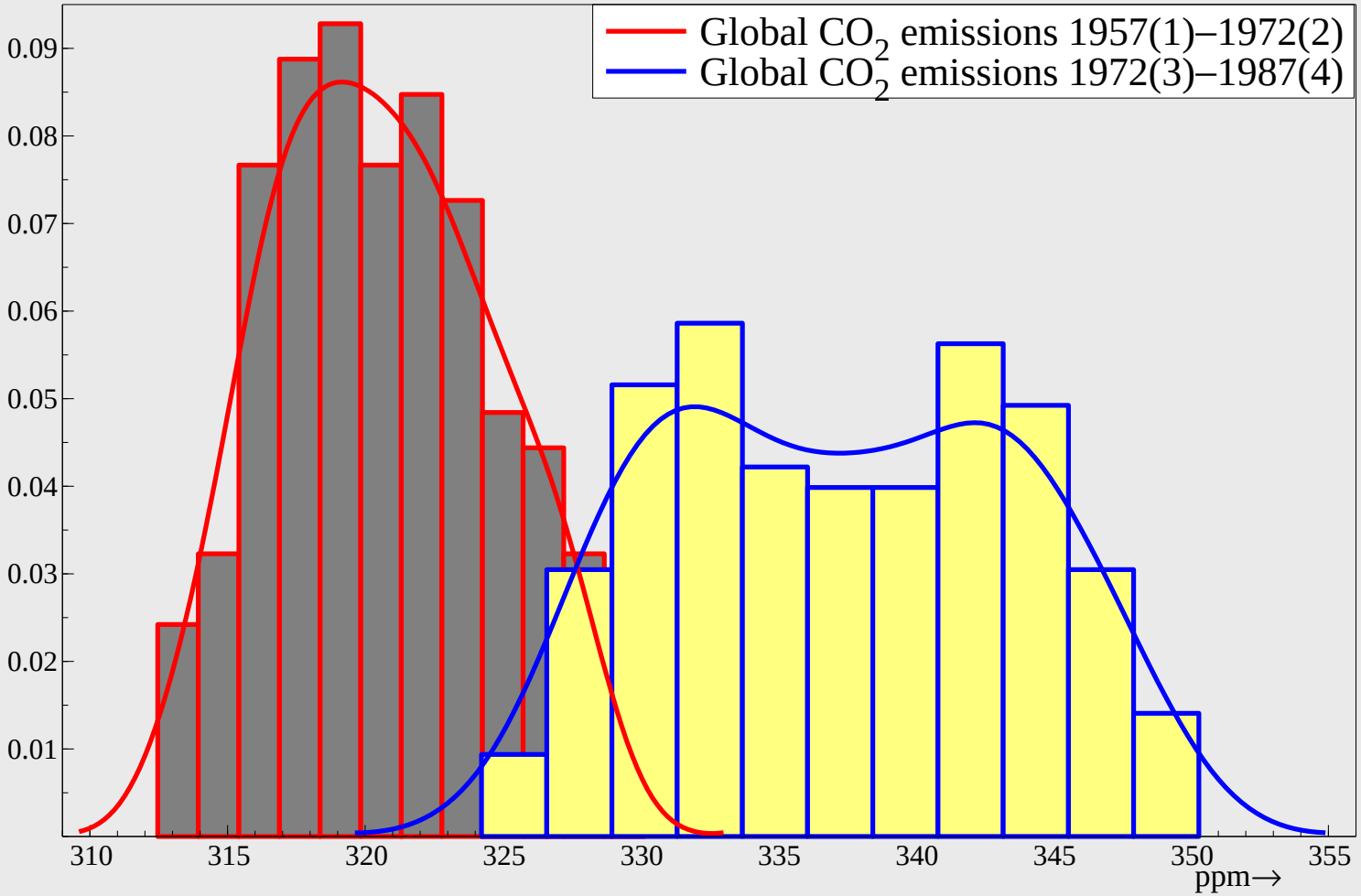

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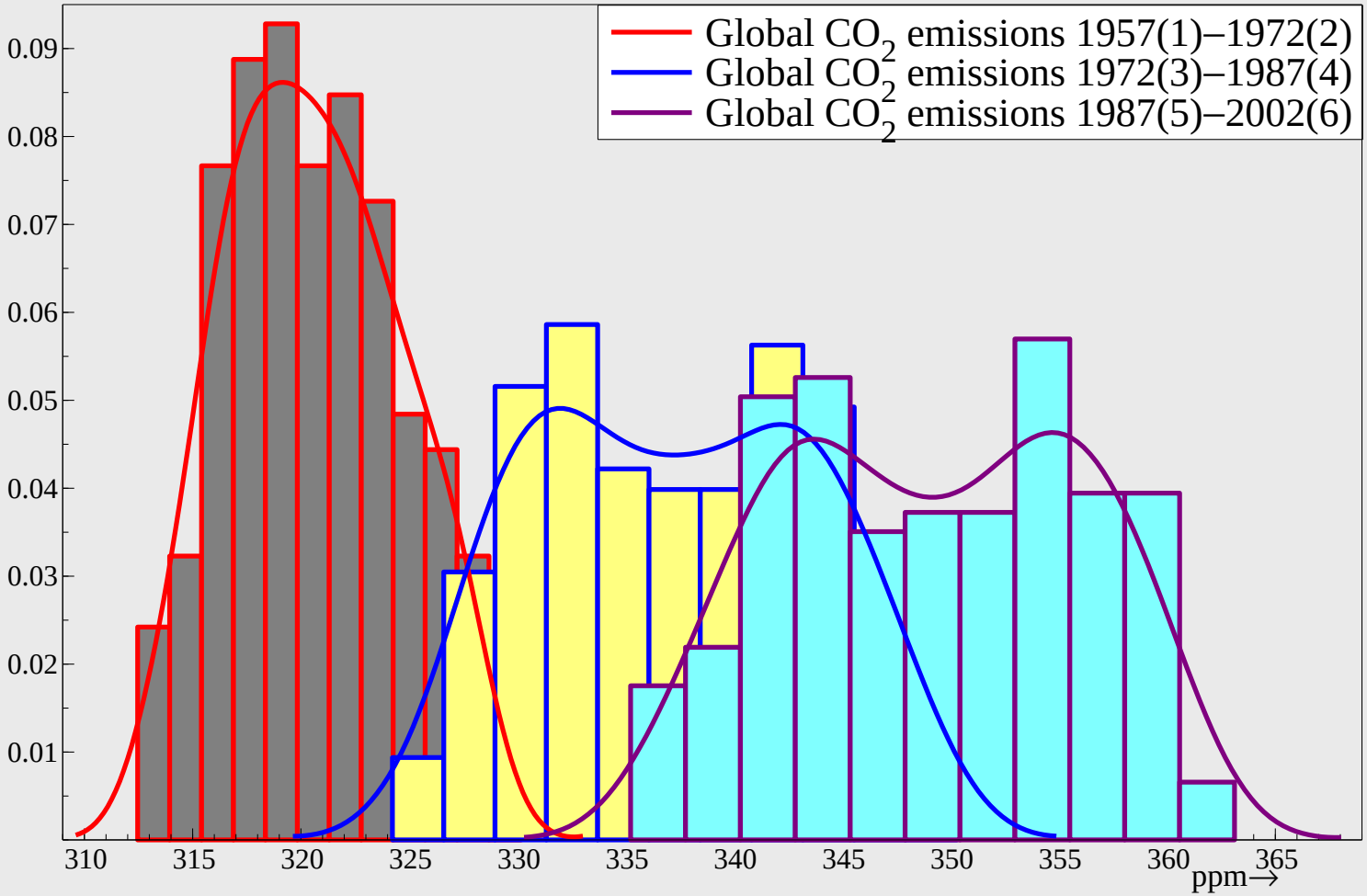

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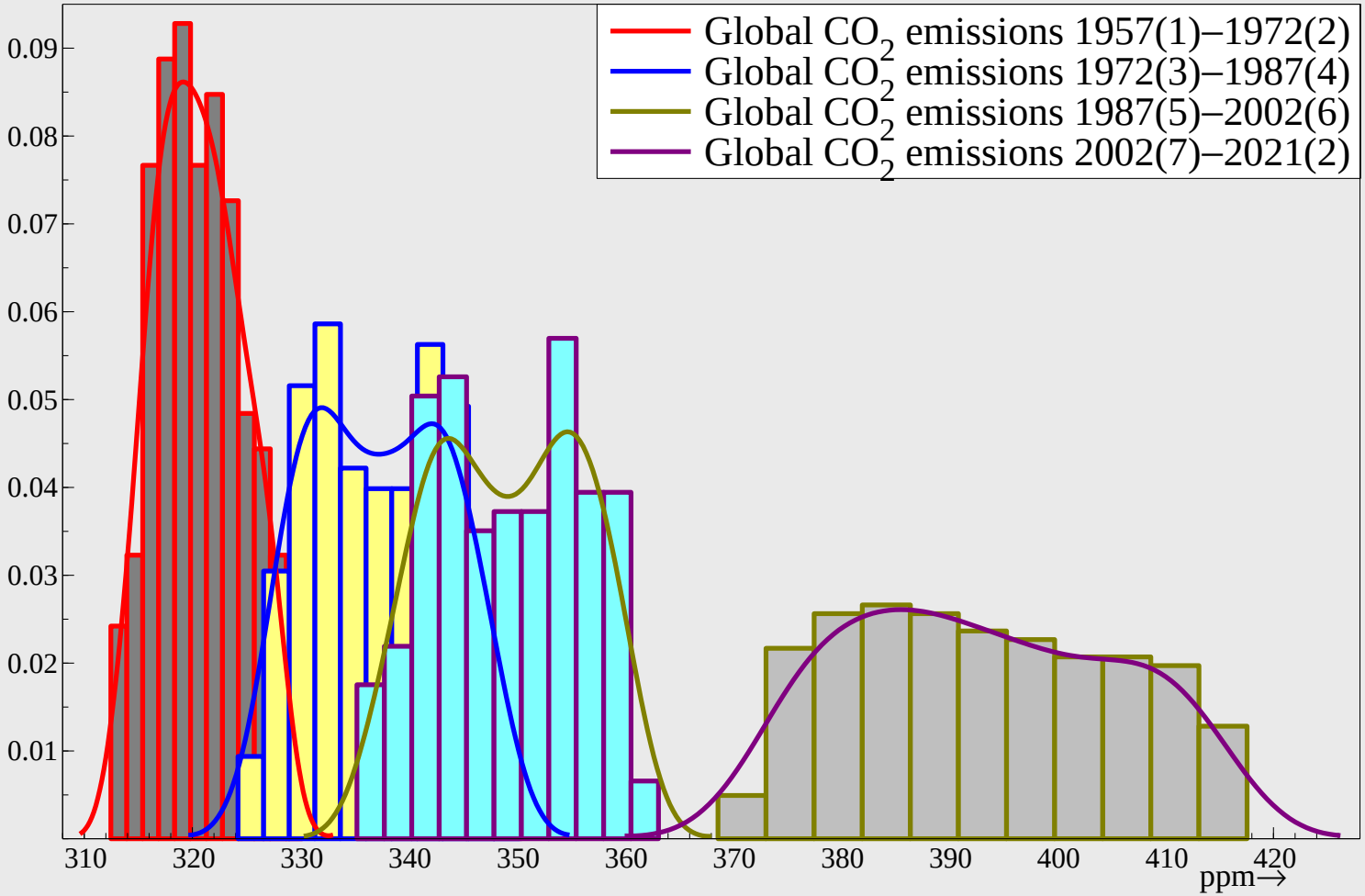
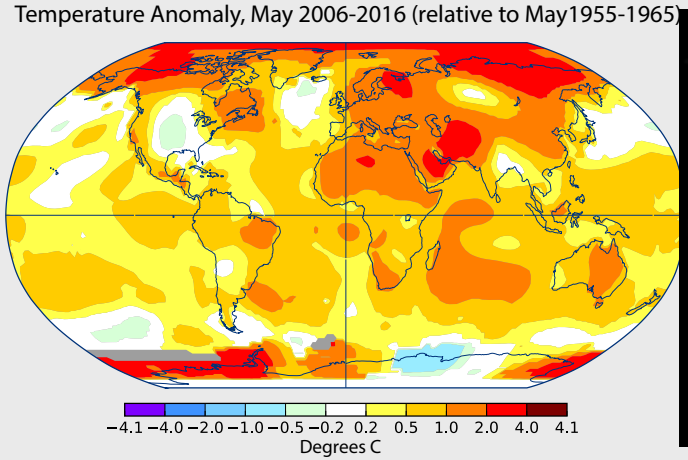
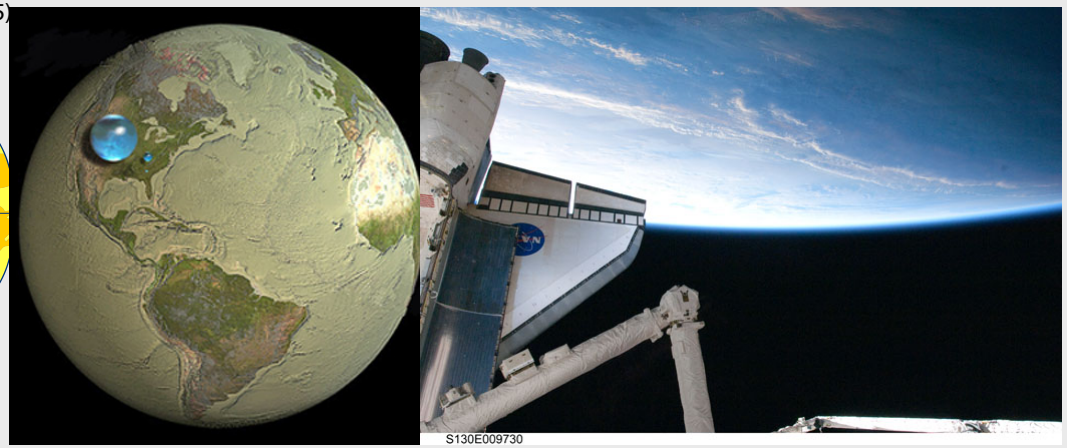


Anthropogenic greenhouse gas (GHG) emissions from energy generation, construction, chemicals, artificial fertilizers, deforestation, animal husbandry & waste.

Route Map





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(6) Reduce GHG emissions from agriculture

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Five sensitive intervention points (SIPs) linked by non-GHG generated electricity

A SIP is when a system is near a critical (or tipping) point so a small change triggers a much larger change that becomes essentially irreversible (see Farmer *et al.*, (2019)).

SIPs can lever policy actions (e.g., CCA08) and technology developments (e.g., cheaper solar photovoltaics & wind energy).

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Five SIPs to reduce GHG emissions given cheaper renewables:

1] Expand green electricity: *Earth* (thermal, bio), *Air* (wind), *Fire* (solar, nuclear) & *Water* (hydro, tides, waves): 10–15 fold increase.
2] Electric-powered vehicles connected to a smart grid (V2G) for short-run backup storage to balance variable renewable supply.
3] Low-cost hydrogen from intermittent 'surplus' renewables;
4] Liquid hydrogen as medium-term storage & high-heat source;
5] Electricity-based agriculture (e.g., grind basalt; biochar; vertical & underground 'farms'; biomethane-based electricity).

Non-GHG ‘green’ electricity generation

To eliminate coal, oil & natural gas from electricity generation needs massive increase, linked grids resilient to adverse weather & storage to balance supply facing greater variability in renewables (V2G), & for still, cloudy periods (‘power-to-X’: hydro pump & store, batteries, flywheels, supercapacitors, liquid hydrogen, ocean battery on sea bed etc.).

As oil produces 30% more CO_2 per kWh than methane, expand electricity for electric vehicles before replacing natural gas in electricity generation, but disrupted by Ukraine war.

Non-GHG energy

Wind turbines & solar PVs offer lowest cost alternatives if CCS is enforced.

Floating wind turbines: easier to install & dismantle offshore given 100 meter-long blades & allow under-water high-pressure energy storage.

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Energy from waves near Orkney and tides off Shetland: twice daily ebb & flow $\rightarrow$ predictable energy from underwater turbines.

Background renewable electricity from safe small modular nuclear reactors (SMRs) from well-developed nuclear engines in submarines, probably $+$ large 'conventional' nuclear reactors.

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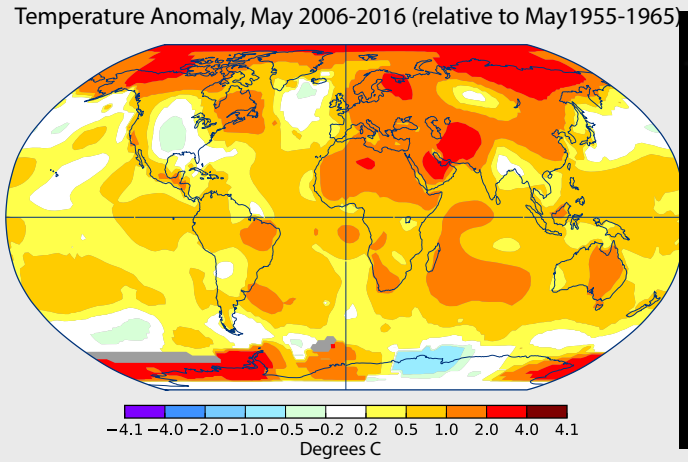

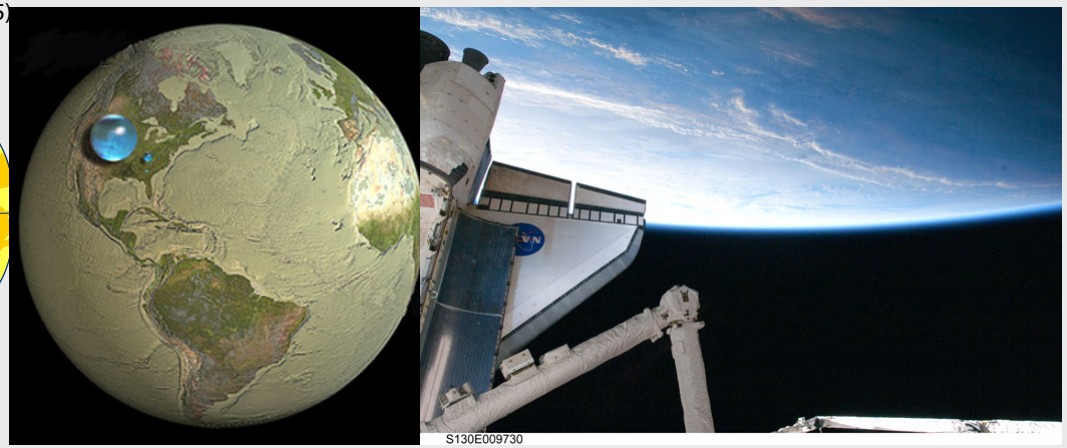

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Decarbonize ground transport cutting both CO_2 and nitrous oxide (N_2O)

Natural replacement of internal combustion cars (UK average life $<$9 years) with electric vehicles;
fuel cells & hydrogen drive-trains for large trucks & UK railways.

Vehicle-to-grid (V2G) could provide low-cost-investment short-term electric storage system. Vehicles plugged into intelligent grid when parked paid peak prices if discharged.

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Batteries rapidly improving. Graphene based carbon nanotubes (CNTs) are electrode supercapacitors: store electricity in vehicles for recharging batteries.

If viable, CNTs offer sufficiently light electric power to advance developments in electric-powered aircraft.

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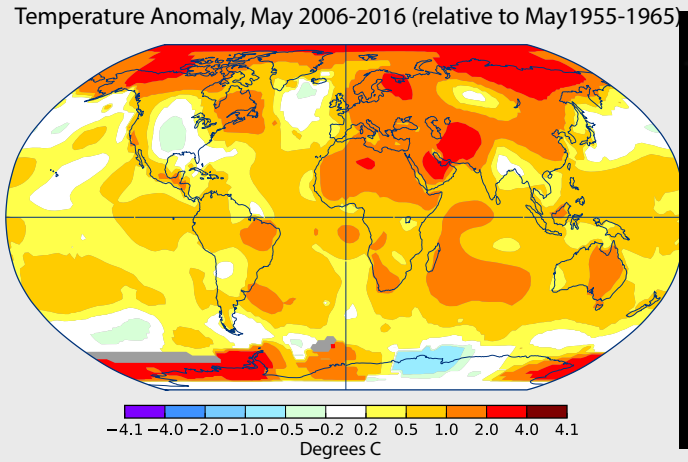

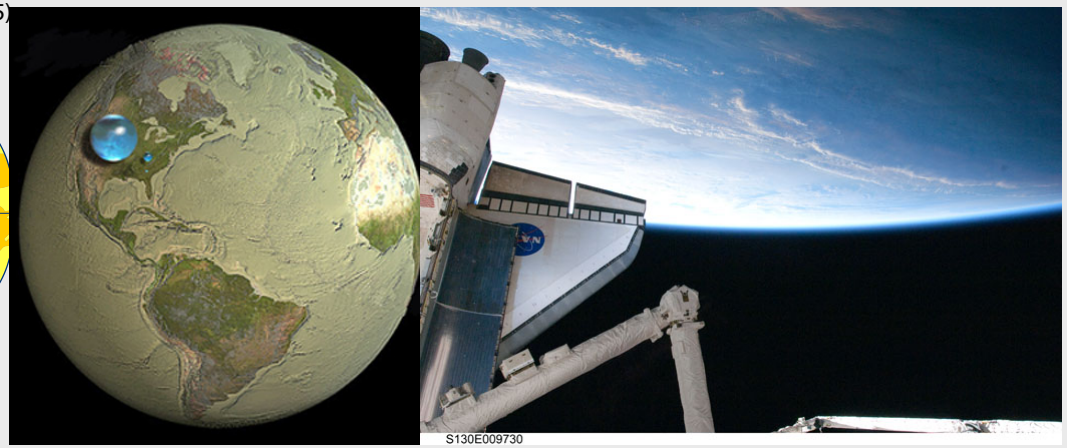

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Decarbonize households and construction

Retrofit old buildings by improved insulation & triple glazing

Then heat pumps are effective, even for entire villages.
Install LED lighting and solar PV panels and evacuated tube solar collectors on roofs.
Retrofitting a Glasgow tenement shows what can be achieved.
But Government has backtracked on insulation standards for rental properties.
Raise fridge & freezer insulation standards (Chu's law in action).

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New buildings need zero GHG materials like laminated wood

Prefabricate highly-insulated dwellings. Add graphene to strenghten concrete, magnesium oxide for carbon eating cement, & hot mixing lime for longer life; glulam can replace some steel.

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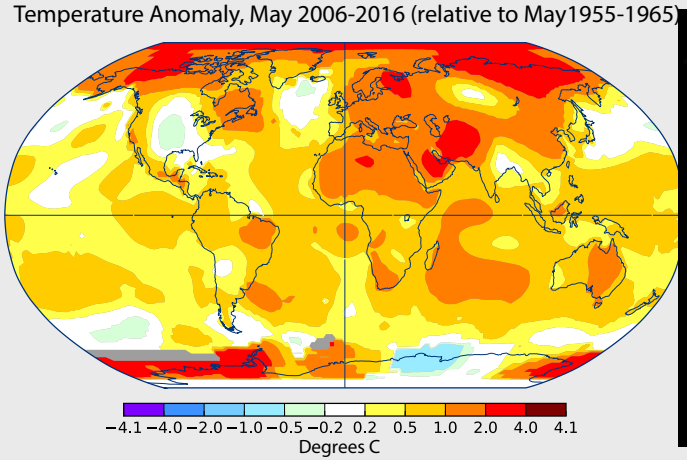

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Decarbonize industry, chemical manufacturing and waste

Liquid hydrogen as potential high heat source for industry

Also electric arc methods and direct waste heat from nuclear. Require non-GHG electricity generation: self-defeating to use natural gas based electricity to make hydrogen.

CCS and CO_2 extraction may remain essential as chemical manufacturing uses some coal, oil and natural gas.

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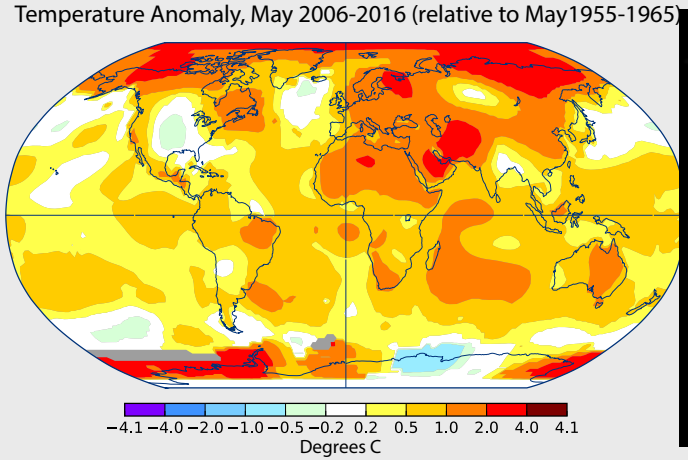

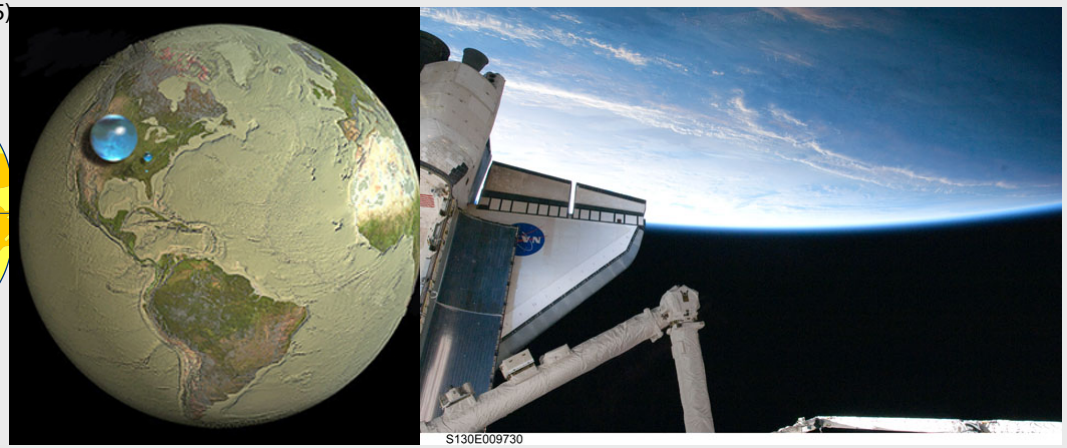

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Essential to reduce GHG emissions from agriculture: get down to *Earth* for a lower 'foodprint' with less food waste!

Climate Econometrics

UNIVERSITY OF OXFORD

Reduce CO_2 emissions: stop deforestation & peat use

Plant appropriate trees; restore wetlands & mangroves.

Reduce nitrous oxide emissions by less artificial fertiliser

Use basalt dust (absorbs CO_2) + biochar; cut cropland by more efficient crop production; vertical & underground farms cost effective with LED lighting.

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Improve aquaculture production by marine protection areas

Seaweed (kelp, seagrass, asparagopsis) cuts NoX pollution; off-shore wind farms are marine reserves & mix ocean layers.

Sheep on the island of North Ronaldsay in the Orkneys

Reduce methane from ruminants by dietary changes & mix:

Fumaric acid, *asparagopsis taxiformis* and selective breeding.
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Ancient local breed of sheep forced to live off seaweed on the beach by a dry stone dyke around the island. Eating the seaweed controls methanogenic bacterial activity & saves sheep energy.

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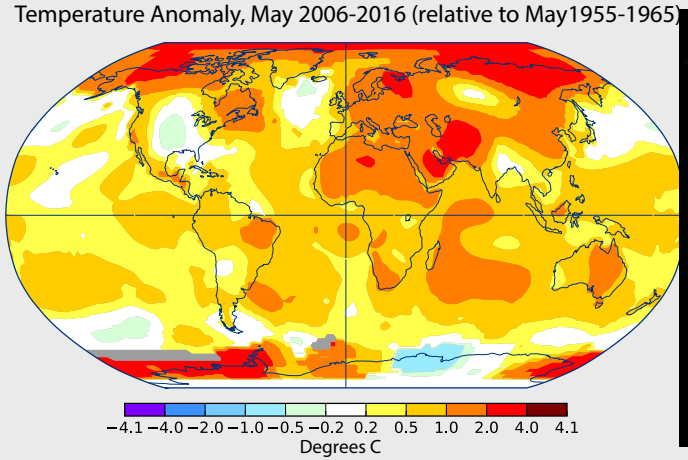

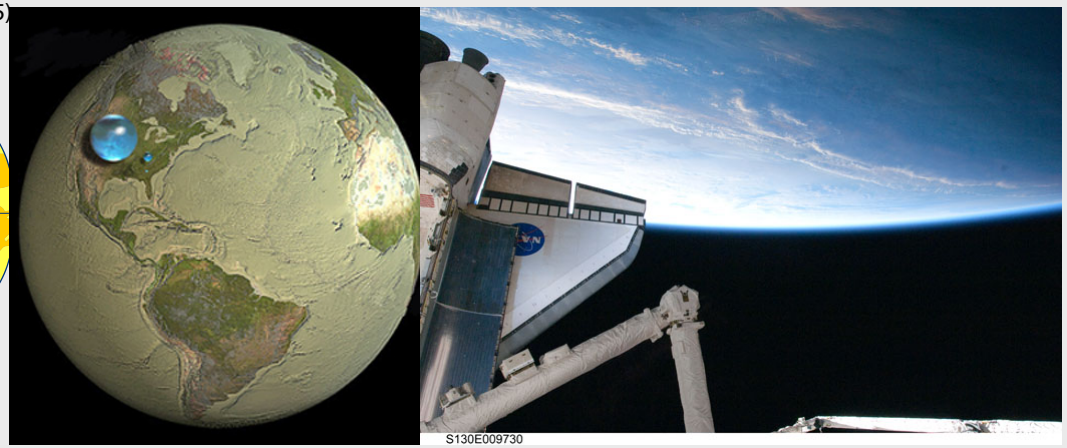

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Policy implications: creating virtuous circles using SIPs

Five key sensitive intervention points (SIPs) from green electricity

1] **Vastly expand non-GHG electricity**: no coal so much less CO_2

2] **Decarbonize ground transport**: no oil, & store electricity in V2G

3] **Decarbonize households & construction**: no natural gas

4] **Decarbonize industry**: less of all fossil fuels

5] **Reduce agriculture GHG 'foodprint'**: less CO_2, N_2O & CH_4

UK's total CO_2 higher as some embodied in net imports. To reduce, impose import tariffs on countries not reducing their GHG emissions (Nordhaus, 2020) or deforesting, threatening species extinctions (Leaf).

Cap and trade like the EU Emissions Trading System could help facilitate GHG reductions where coal still widely used.
Also increase taxes on oil and gas as prices fall to maintain shift to all electric.

Policy implications: creating virtuous circles using SIPs

Total atmospheric accumulation of GHGs determines temperature increases, so trajectory getting to net-zero faster matters greatly.

Replacing oil by non-GHG electricity entails huge expansion: hence vast storage requirement to balance supply and demand (batteries, V2G & liquid hydrogen from 'surplus' electricity).

Further large non-GHG increase needed to remove natural gas from electricity generation, and make hydrogen when 'surplus'. Liquid hydrogen then also available for industrial use.

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Insulate homes, replace gas boilers, zero-GHG construction, climate resilient local environments, low GHG 'foodprint', recycle. Green electricity facilitates basalt grinding, as well as vertical and underground farms.

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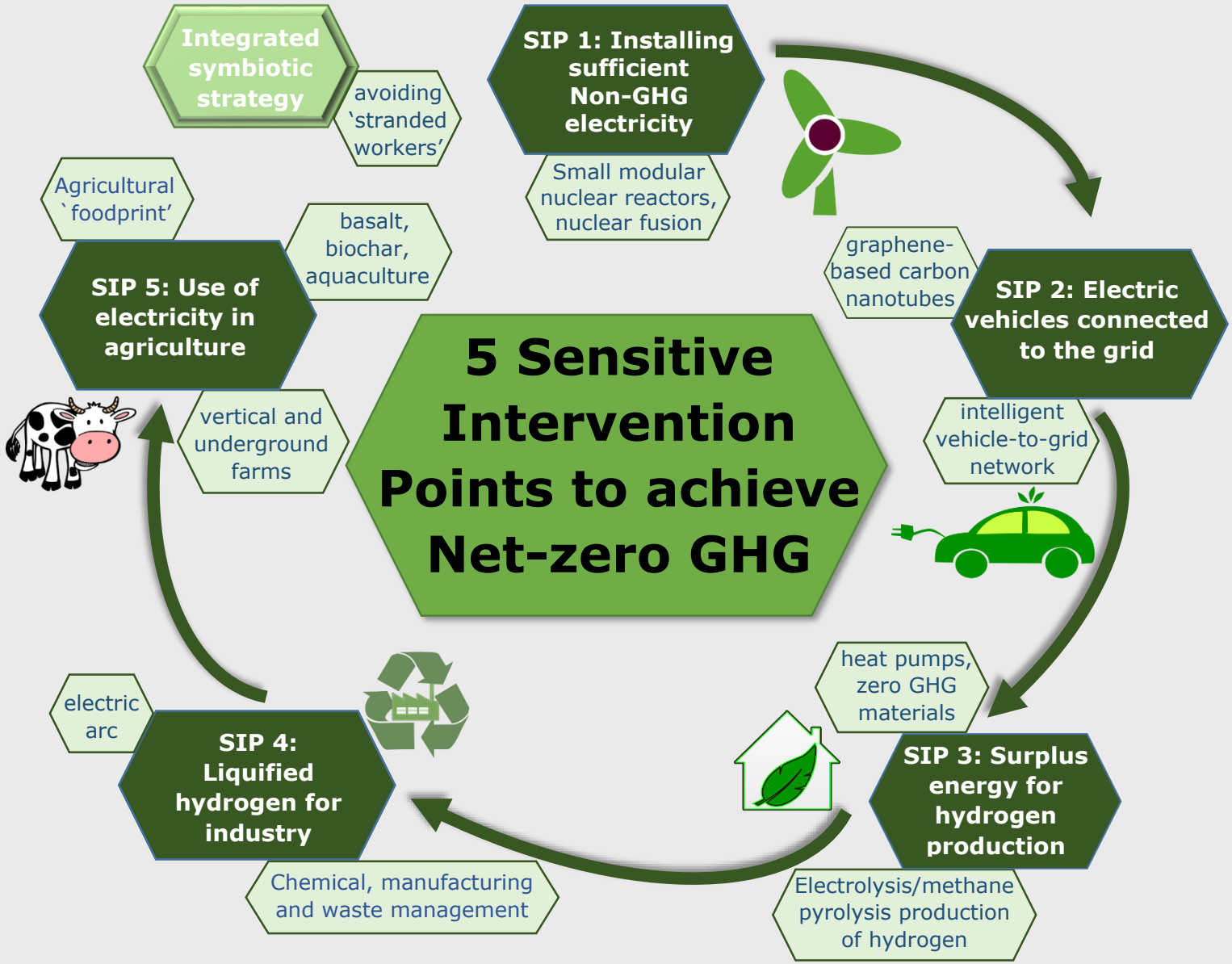
Could achieve net zero at relatively low cost, but unclear will.

SIPs linked by non-GHG electricity



Thank you! **https://www.climateeconometrics.org/**

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