The role of Carbon Capture and storage in Achieving Net Zero

- **Myles Allen:** some harsh truths about what it is going to take to stop global warming.
- **Stuart Haszeldine:** a positive vision for decarbonizing fossil fuels at an affordable cost.
- **Margriet Kuijper:** How The Netherlands is pioneering the way forward.
- **Tim Kruger:** How UK industry is ready to go – in more senses than one.

Achieving Net Zero by decarbonizing fossil fuels

How we will eventually stop global warming

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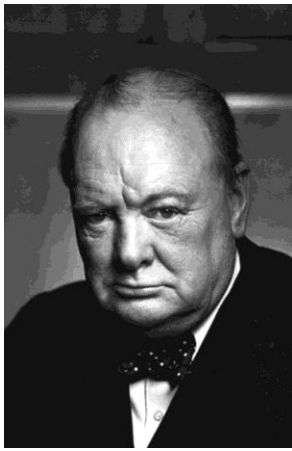
Achieving Net Zero by decarbonizing fossil fuels

How we will eventually stop global warming having tried all the alternatives…



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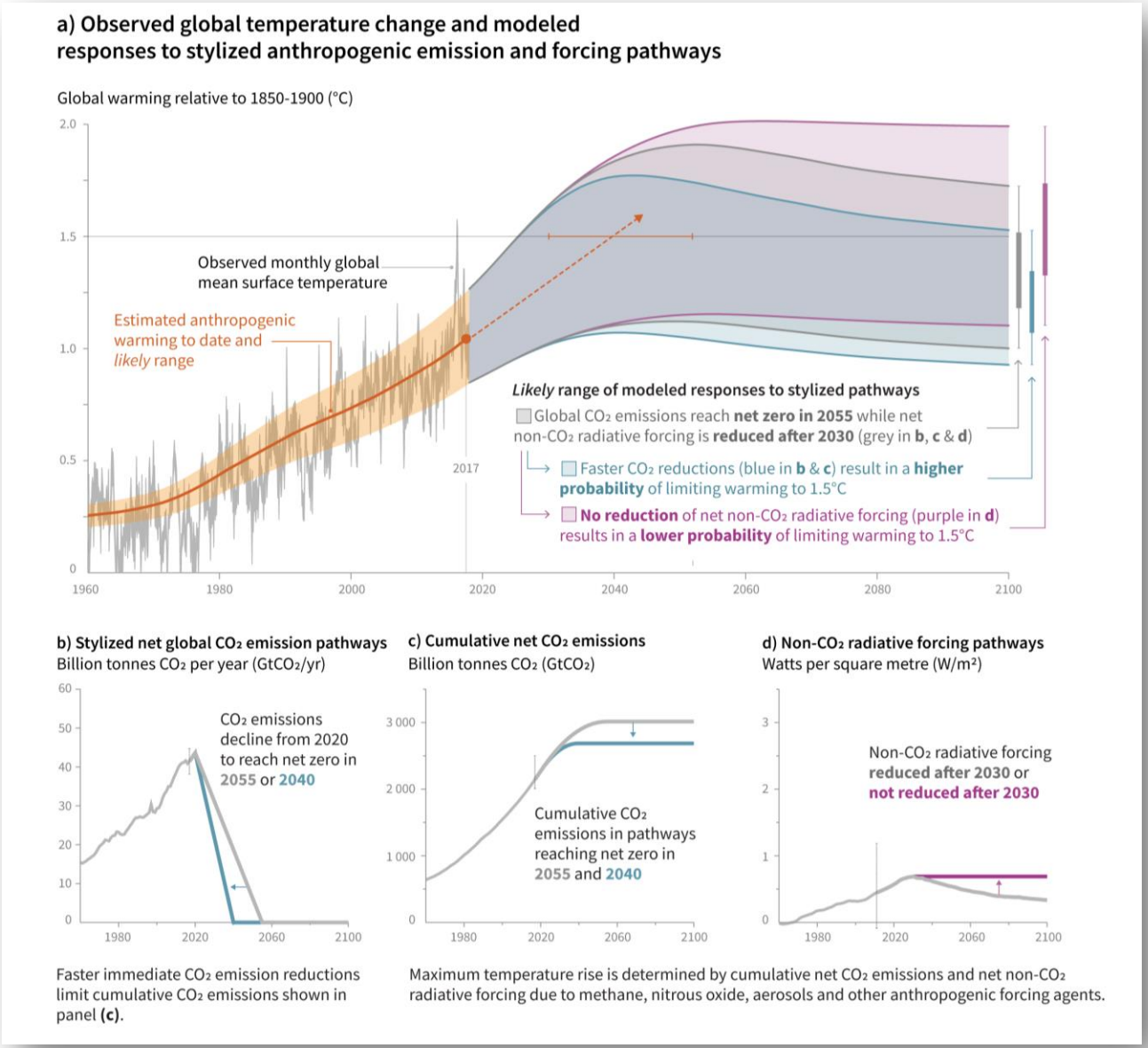
Key findings from the IPCC Special Report on 1.5°C



Now at 1.1°C, warming at 0.2°C/decade, primarily due to fossil fuel emissions, heading for 1.5°C by 2040.

Limiting warming to 1.5°C requires net zero CO_2 emissions from fossil fuels and industry by or before mid-century.

Other climate drivers and land-use change can affect peak warming by a few tenths of a degree: very useful IF fossil CO_2 emissions are already approaching net zero.

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

To stop global warming…

- …we need to stop dumping fossil carbon dioxide into the atmosphere.
- And there are only two ways to stop dumping fossil carbon dioxide into the atmosphere:

➢ An effective global ban on fossil fuel extraction and use, *or*

➢ An alternative, safe and permanent means of disposing of CO_2.

Putting a price on carbon will not stop global warming

Lignite mining in Anthochori, Greece, 2007

Nor can we rely on trees to offset fossil carbon emissions indefinitely

Fires in Brazil, a major recipient of carbon storage credits, 2019

Hoping renewables will simply out-compete fossil fuels is not a strategy

Imagining a ban on the extraction and use of fossil fuels: Cambridge's "Absolute Zero" report

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	2020-2029	2030-2049	2050 Absolute Zero	Beyond 2050
Road vehicles	Development of petrol/diesel engines ends; Any new vehicle introduced from now on must be compatible with Absolute Zero	All new vehicles electric, average size of cars reduces to ~1000kg.	Road use at 60% of 2020 levels - through reducing distance travelled or reducing vehicle weight	New options for energy storage linked to expanding non-emitting electricity may allow demand growth
Rail	Growth in domenstic and international rail as substitute for flights and low-occupancy car travel	Further growth with expanded network and all electric trains; rail becomes dominant mode for freight as shipping declines	Electric trains the preferred mode of travel for people and freight over all significant distances,	Train speeds increase with increasing availability of zero emissions electricity
Flying	All airports except Heathrow, Glasgow and Belfast close with transfers by rail	All remaining airports close		Electric planes may fly with synthetic fuel once there are excess non-emitting electricity supplies
Shipping	There are currently no freight ships operating without emissions, so shipping must contract	All shipping declines to zero.		Some naval ships operate with onboard nuclear power and new storage options may allow electric power
Heating	Electric heat pumps replace gas boilers. and building retrofits (air tightness, insulation and external shading) expand rapidly	Programme to provide all interior heat with heat pumps and energy retroifts for all buildings	Heating powered on for 60% of today's use.	Option to increase use of heating and cooling as supply of non-emitting electricity expands
Appliances	Gas cookers phased out rapidly in favour of electric hobs and ovens. Fridges, freezers and washing machines become smaller.	Electrification of all appliances and reduction in size to cut power requirement.	All appliances meet stringent efficiency standards, to use 60% of today's energy.	Use , number and size of appliances may increase with increasing zero-emnissions electricity supply
Food	National consumption of beef and lamb drops by 50%, along with reduction in frozen ready meals and air-freighted food imports	Beef and lamb phased out, along with all imports not transported by train; fertiliser use greatly reduced	Total energy required to cook or transport food reduced to 60%.	Energy available for fertilising, transporting and cooking increases with zero-emissions electricity
Mining material sourcing	Reduced demand for iron ore and limestone as blast furnace iron and cement reduces. Increased demand for materials for electrification	Iron ore and Limestone phased out while metal scrap supply chain expands greatly and develops with very high precision sorting	Demand for scrap steel and ores for electrification much higher, no iron ore or limestone.	Demand for iron ore and limestone may develop again if CCS applied to cement and iron production
Materials production	Steel recycling grows while cement and blast furnace iron reduce; some plastics with process emissions reduce.	Cement and new steel phased out along with emitting plastics . Steel recycling grows. Aluminium, paper reduced with energy supply.	All materials production electric with total 60% power availability compared to 2020	Material production may expand with electricity and CCS, CCU, hydrogen may enable new cement and steel.
Construction	Reduced cement supply compensated by improved material efficiency, new steel replaced by recycled steel	All conventional mortar and concrete phased out, all steel recycled. Focus on retrofit and adaption of existing buildings.	Any cement must be produced in closed-loop, new builds highly optimised for material saving.	Growth in cement replacements to allow more architectural freedom; new steel may become available.
Manufacturing	Material efficiency becomes promiment as material supply contracts	Most goods made with 50% as much material, many now used for twice as long	Manufacturing inputs reduced by 50% compensated by new designs and manufacturing practices. No necessary reduction output.	Restoration of reduced material supplies allows expansion in output, although some goods will in future be smaller and used for longer than previously.
Electricity	Wind and solar supplies grow as rapidly as possible, with associated storage and distribution. Rapid expansion in electrificiation of end-uses.	Four-fold increase in renewable generation from 2020, all non-electrical motors and heaters phased out.	All energy supply is now non-emitting electricity.	Demand for non-emitting electricity drives ongoing expansion in supply.
Fossil fuels	Rapid reduction in supply and use of all fossil fuels, except for oil for plastic production	Fossil fuels completed phased out		Development of Carbon Capture and Storage (CCS) may allow resumption of use of gas and coal for electricity

Allwood, J. et al, 2019: https://doi.org/10.17863/CAM.46075

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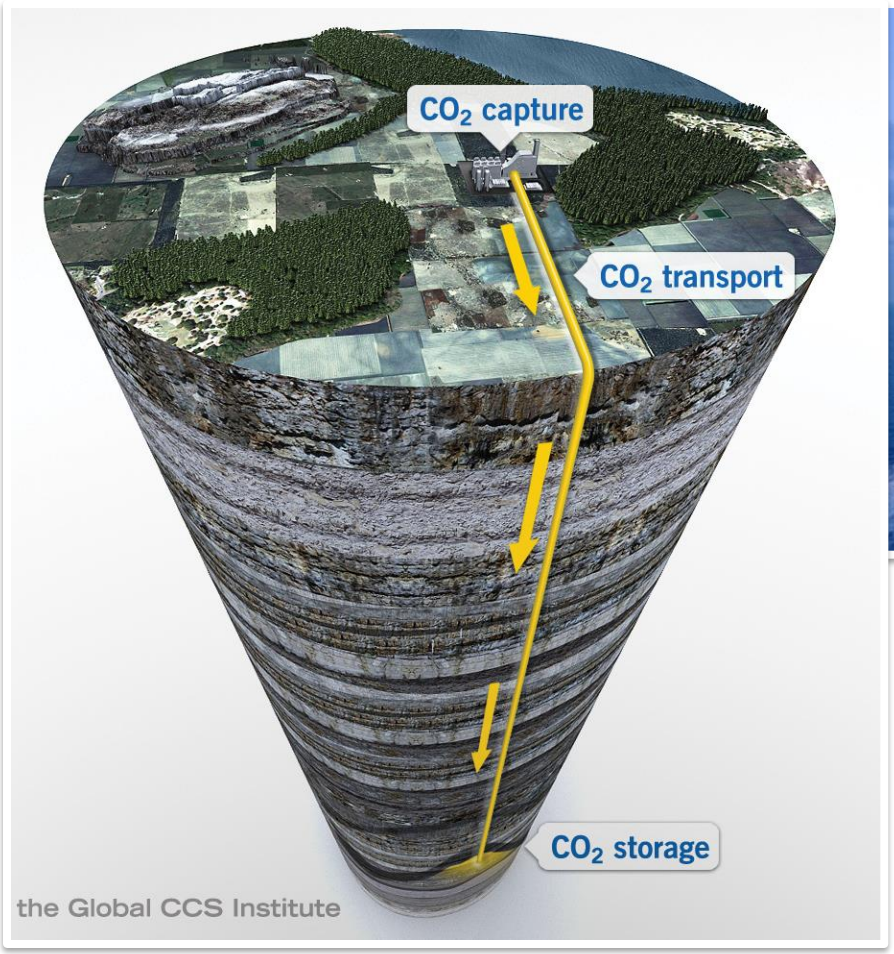
If we cannot ban fossil fuels or price them out of existence, we need to decarbonize fossil fuels

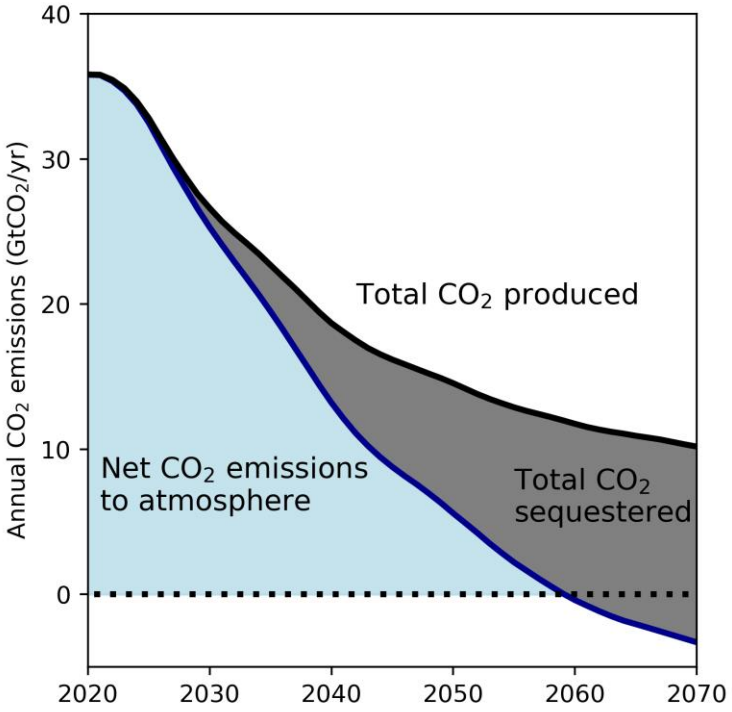
- Net decarbonization: one tonne of carbon dioxide is permanently disposed of (*not* in the atmosphere) for every tonne generated by fossil fuels or industry.
- It doesn't have to be the same tonne: some carbon dioxide, such as aviation emissions, will need to be recaptured from the atmosphere (Tim Kruger's talk).
- The rate of disposal needs to account for any losses or any extra carbon dioxide generated in the disposal process.
- Storage must be effectively permanent over timescales of 10,000+ years.

The simplest proven permanent option is geological storage



- Pure CO_2 becomes liquid under very high pressure.
- Reinject into Earth's crust under impermeable rock.
- Long-term behavior similar to natural oil and gas reserves.

In IPCC 1.5°C scenarios, we decarbonize fossil fuels by mid-century, but we don't stop using them

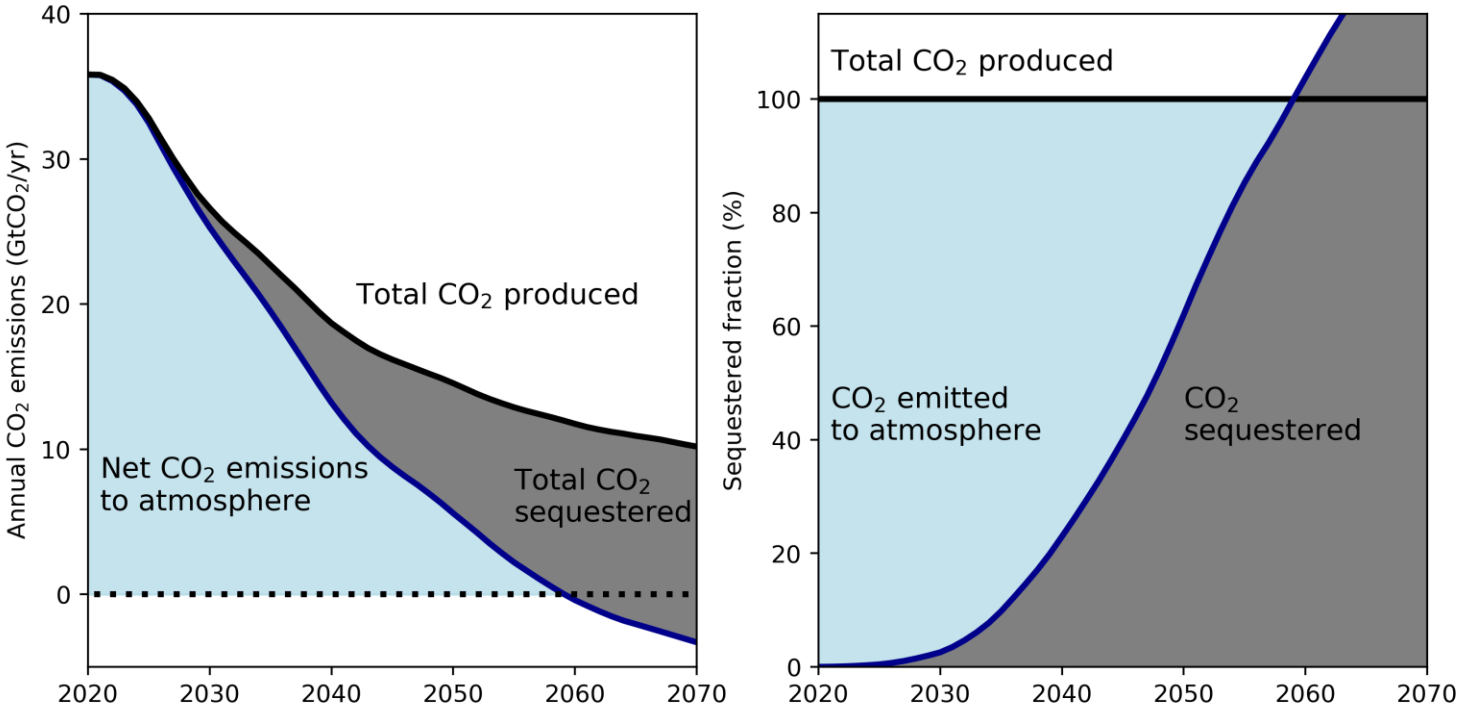


Median 1.5°C-consistent scenario from the IPCC database

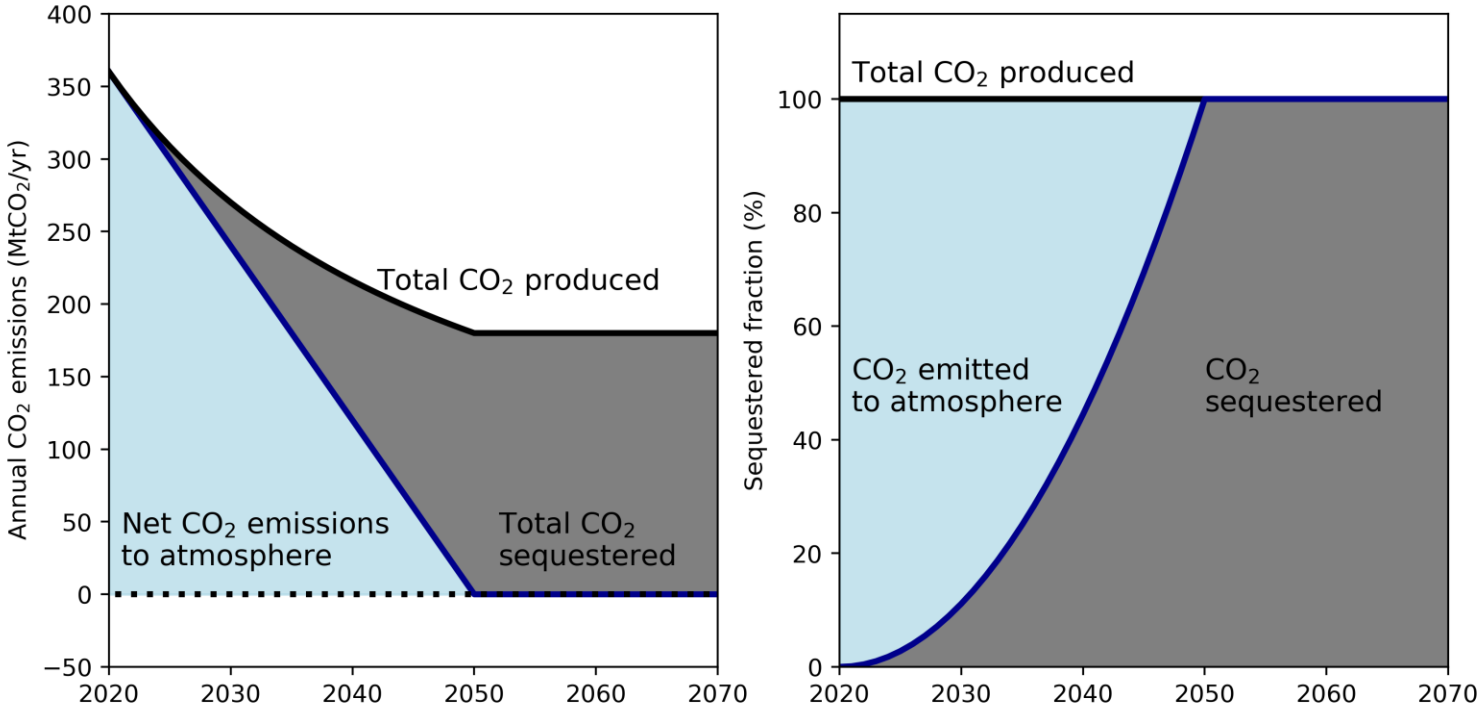
Black: Total CO_2 produced from burning fossil fuels, industrial bio-energy & industrial processes

Blue: Net fossil fuel, industrial bio-energy and industrial process emissions

Another way of showing the IPCC 1.5ºC scenarios: smooth transition to 100% sequestration & beyond



A stylized scenario meeting the UK goal of net zero by 2050



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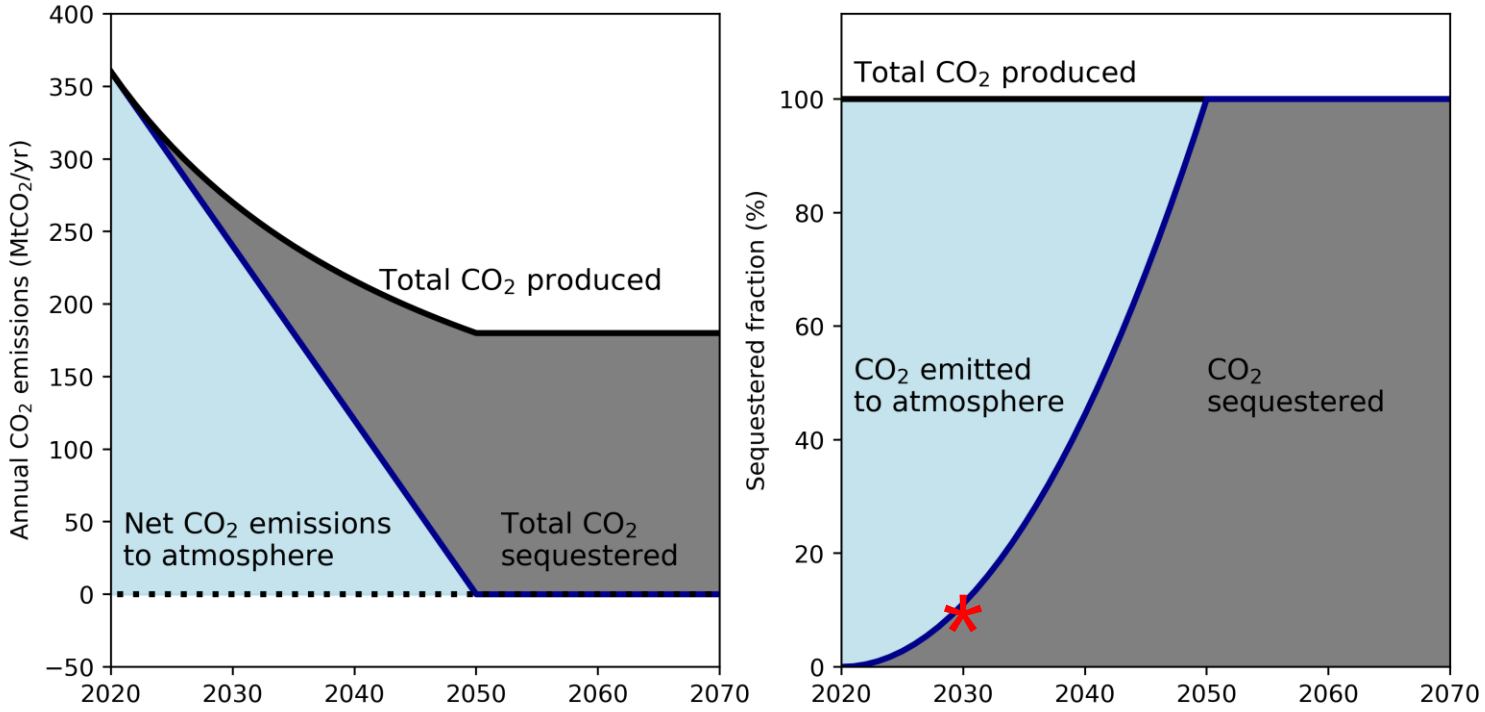
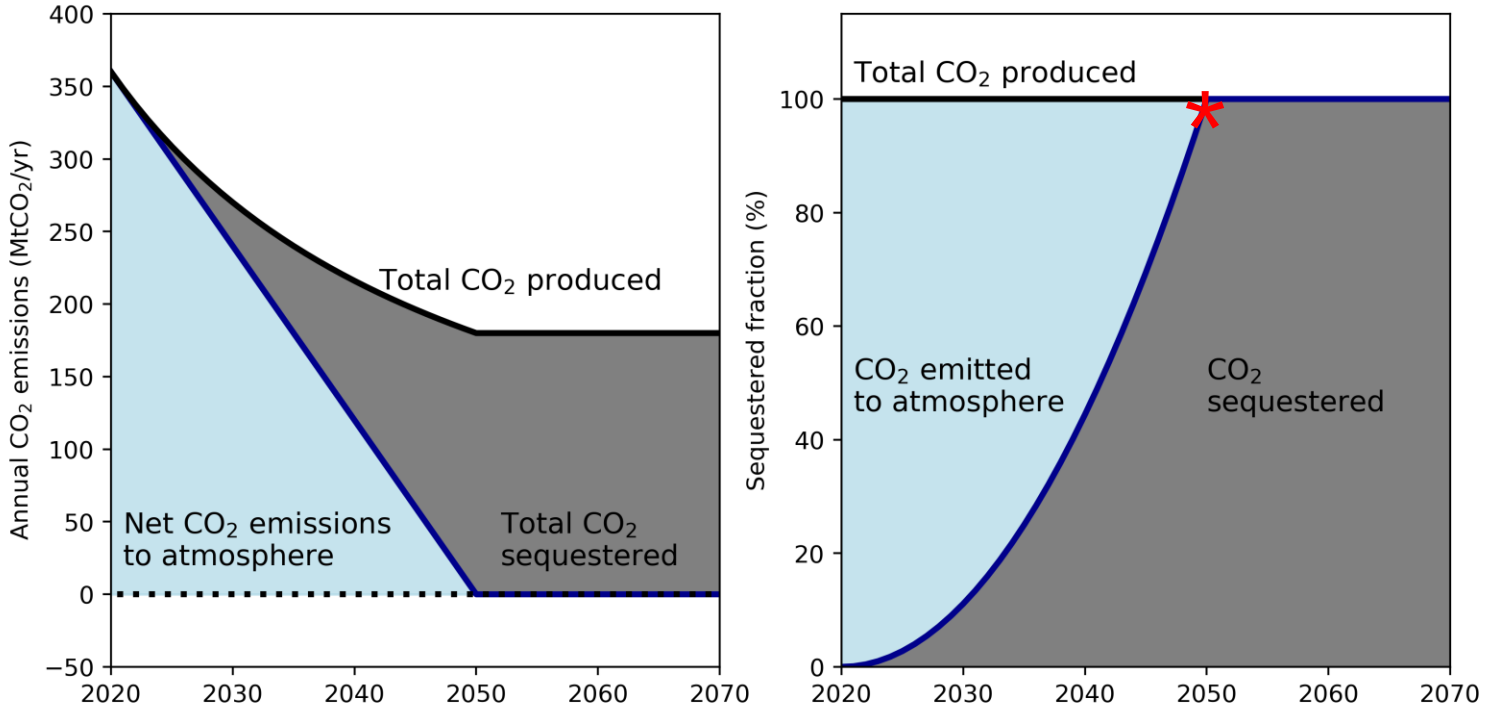


* A 10% sequestration requirement ("Carbon Takeback Obligation") would cost less than the current UK carbon floor price.

A stylized scenario meeting the UK goal of net zero by 2050



* A 100% Carbon Takeback Obligation would add about 50p to a litre of petrol at current costs for direct air capture.

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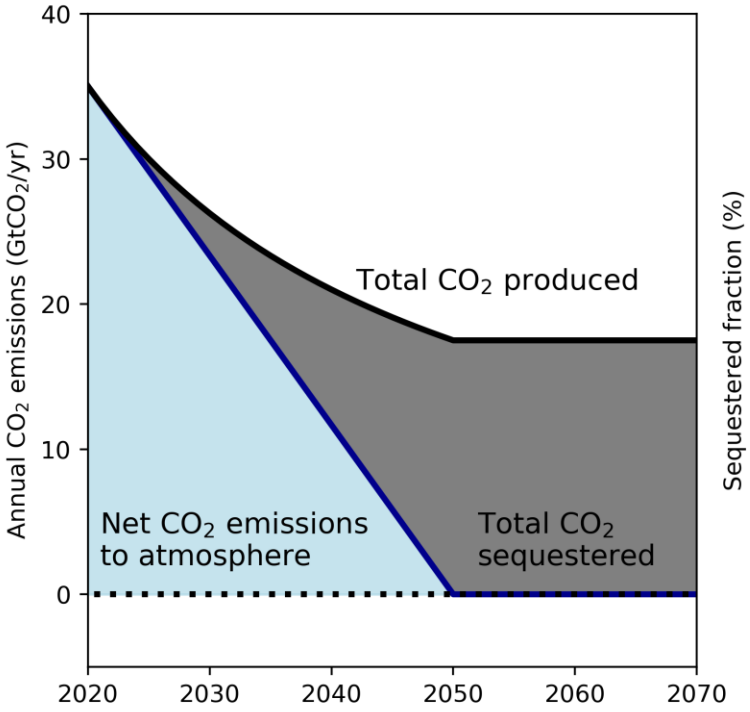

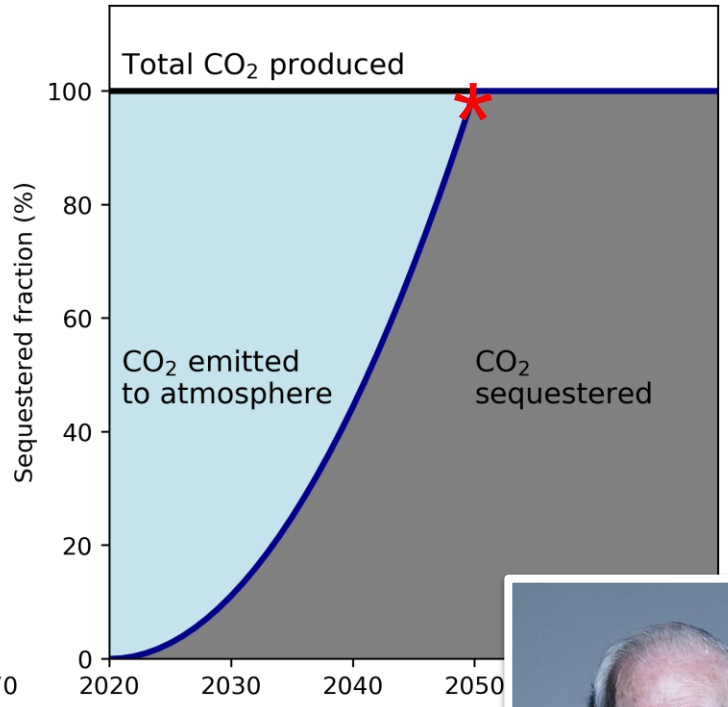

* A 100% Carbon Takeback Obligation would add about 50p to a litre of petrol at current costs for direct air capture.
See Amendment 34a of the Energy Bill, 2015

Some facts to remember

- Climate change is fixable.
- But we have to get on with it.
- We can't ban fossil fuels, so we need to decarbonize fossil fuels, which means a safe and permanent means of disposing of the CO_2 they generate.
- There is only one institution in the world with the engineering capability, the cashflow & the access to capital to decarbonize fossil fuels:

➢ The global fossil fuel industry.

- So how can we get them to do it?