What is carbon capture and storage (CCS)?

Briefly, the idea of carbon capture and storage is to capture carbon dioxide (CO_2) emissions from high-emitting industries or power stations that burn fossil fuels, compress the CO_2 and send it through a pipeline (or by vehicle) to be injected into a storage site, deep under the ground or the sea bed (as is the intention in the UK)

> **Pre-combustion CCS** accounts for most existing CCS (about 94%). The CO_2 is captured before a product is burned, eg in gas processing the CO_2 is removed from the natural gas stream
>
> **Post combustion CCS** refers to capturing CO_2 from flue gases produced by burning fossil fuels, biomass or waste for heat or power.
>
> **Direct air capture (DAC)** technologies extract CO_2 directly from the atmosphere, which is much more difficult due to the very low concentration of CO_2 in air.
>
> **Carbon Capture, Utilisation and Storage (CCUS)** means captured CO_2 is used in another product.

About 80% of captured CO_2 is actually used for enhanced oil recovery (EOR), that is, injected into oil wells to make the oil easier to extract. A proportion of the CO_2 remains trapped underground, enabling the producer to claim the oil is lower carbon; however, the vast majority of the emissions from oil are from its final combustion - and increasing the supply of oil also increases its use globally.

No plans have been announced to use EOR in the UK, but it is significant that EOR has been a key part of the business model for most CCS. Alternative business models would almost certainly rely on long-term public subsidy, very high carbon taxes levied on high emitting industries or both, in order to be financially viable..

Captured CO_2 can also be used (eg by combining with renewably-produced hydrogen) in synthetic fuels or plastics normally made from oil; however this would not be low carbon if the final product was itself burned and the emissions released!

A note on hydrogen

Hydrogen can be produced from a variety of fossil fuels, but in the current context we are discussing “blue” hydrogen, that is, hydrogen produced by splitting (or “reforming”) methane, the main component of natural gas, into hydrogen and CO_2, with the CO_2 supposedly captured and stored. Hydrogen produced by this method but *without* carbon capture is termed “grey” hydrogen.

Hydrogen can also be produced by passing an electric current through water (electrolysis), splitting it into hydrogen (H_2) and oxygen. If the electricity comes from renewable sources, this is termed “green” hydrogen. Confusingly, the government terms both these types “low carbon hydrogen”, and plans to support both with large subsidies.

Producing blue hydrogen in fact results in particularly high emissions (see below); however hydrogen, regardless of how it’s produced, is itself a potent *indirect* greenhouse gas, as it prolongs the life of methane in the atmosphere, and increases the production of ozone - both powerful greenhouse gases.

Producing green hydrogen is a very inefficient use of renewably-produced energy, so it should be reserved for uses where there is currently no alternative, such as for certain industrial processes - definitely not for home heating or road transport, where direct electrification is far more efficient!

What are the UK "low carbon" clusters?

About a third of UK industrial emissions are produced within six "clusters" - locations where a large number of industrial sites are concentrated. The largest of these is the Humber cluster which, combined with Teesside, forms the East Coast cluster. These are industries like oil refining, chemicals and glass which have high CO_2 emissions from burning fuel for high temperature processes, and in some cases (eg cement) from the process itself. The idea is that industries and power plants across a cluster can capture their CO_2 and share common CO_2 pipeline and undersea storage infrastructure.

To be completely accurate, most UK cement manufacture is not located within an industrial cluster, but cement manufacture in the Peak District, for example, is intended to be linked by pipeline to the storage infrastructure in the HyNet project (see below).

Government policy

In brief, the government has announced plans to spend £21.7 billion of public money over 25 years to support CCS in two industrial clusters, with more expected to follow. These initial projects (Track One of the subsidy programme inherited from the last government) are in the Teesside part of the East Coast Cluster, with storage beneath the North Sea, and the HyNet Cluster incorporating carbon storage in Liverpool Bay and industries across a region including West Cheshire and North Wales. Projects expected to follow, and to be allocated further funding, are in Scotland, South Wales, the Humber and the "Black Country" (West Midlands). In addition to the £21.7bn announced for infrastructure, the government also intends to subsidise hydrogen for 15 years to make it "competitive" with natural gas.

Projects in Track One include:

East Coast Cluster
- Net Zero Teesside Power (gas power plant with carbon capture)
- bpH2 Teesside
- Teesside Hydrogen CO_2 Capture

HyNet Cluster
- Hanson Padeswood Cement Works Carbon Capture and Storage Project
- Viridor Runcorn Industrial CCS
- Protos Energy Recovery Facility (ie, waste incinerator with CCS)
- Buxton Lime Net Zero
- HyNet Hydrogen Production Plant 1 (HPP1)

If the idea is to capture industrial emissions, why are so many of the projects for new gas power or hydrogen?

One answer to this is that the fossil fuel industry has lobbied hard for gas and oil to be retained as part of the UK's energy mix, and convinced the government that it is necessary - despite scientific agreement that fossil fuel extraction and burning must be wound down as fast as possible. There is strong evidence that fossil fuel producers have promoted CCS to policymakers deliberately for this purpose, and to benefit from the large public subsidies being made available. In the United States, for example, generous tax credits applied to CCS projects have already led to an increase in high-emitting industrial projects.

Their argument is that an energy system based entirely on renewable electricity will not be possible for decades to come, because energy sources like wind and sun are intermittent, and do not follow the patterns of energy use by households and industries. To make sure there is enough energy available for peak times or periods of low wind/little sun, and to provide stability for the grid, natural gas or hydrogen are said to be needed to provide a reliable energy source that can be stored and dispatched rapidly when needed. The Climate Change Committee (the government's advisory body) has stated that the UK could phase out "unabated" gas from electricity generation by 2035, and build an (electrical) power system with 75% to 90% share of variable renewable generation by 2050. This would give a continuing role for natural gas and hydrogen, even within a near-completely electrified energy system.

However, a review of independent studies on 100% renewable energy states that "the main conclusion of the vast majority of 100% renewable energy systems studies is that such systems can power all energy in all regions of the world at low cost" and that, "as such, we do not need to rely on fossil fuels in the future". Promoting work on 100% renewable energy is, of course, a threat to a fossil fuel industry which is keen to position itself as indispensable not only to the current transition to renewables, but for the foreseeable future.

The reality is that the proportion of energy coming from renewables is growing rapidly, and remaining reliant on fossil fuels as part of the mix, with or without CCS, makes a fully decarbonised power system impossible. Even so, we are not yet close to a position where 100% renewables would be possible (either in the UK or globally). Retrofitting *existing* gas power stations with CCS (rather than building new ones) does make sense as part of a transition away from gas, but CCS can never *substitute* for a genuinely fossil free energy system, and must be strongly opposed wherever it has the effect of slowing that transition.

Hydrogen is also argued to be a "clean" fuel (because it produces no CO2 when burned) which can replace natural gas for high temperature processes in industry. It is argued that this can eventually be replaced with green hydrogen, as that technology becomes cheaper. There is also talk of using hydrogen, or a mix of hydrogen and natural gas, in power stations or in the gas supplied to homes. These arguments must be opposed for the reasons stated above.

Will the announced projects reduce UK CO2 emissions?

Absolutely not!

Firstly, CO2 is only one of the greenhouse gases produced when fossil fuels are used. Another very potent greenhouse gas is methane, the main component of natural gas. Measured over 100 years, methane has a GWP (Global Warming Potential, or impact on global heating of a given weight of methane compared with the same weight of CO2) between 28 and 32 times that of CO2. But whereas CO2 persists and accumulates in the atmosphere over a very long period of time, methane is a relatively short-lived greenhouse gas; most of its warming impact occurs in the first two decades after it is emitted. Over a 20 year timescale methane has a GWP around 83 times that of CO2.

Secondly, not only does measuring CO2 captured at a plant ignore other greenhouse gases that are *not* captured, but it doesn't include all the emissions that are produced along the supply chain, from first extraction when high rates of methane leakage are common, through processing and transportation of the feedstock (gas or biomass) for burning, or gas for producing blue hydrogen. In the case of gas, methane emissions along the supply chain are so high that the final emissions of CO2 may account for a relatively small proportion of the lifetime emissions of the whole project (normally expressed as CO2e or "CO2 equivalent", meaning the amount of CO2 which would have to be emitted to have the same warming impact).

New gas-fired power stations and new hydrogen plants (ie, *not* replacements, in the current policy scenario) will create additional demand for gas, but since supplies of natural gas from the UK continental shelf are in sharp decline, it is likely that a large proportion of the additional demand will be in the form of imported liquified natural gas (LNG) from the USA and elsewhere. This is likely to be from fracked shale gas (with particularly high extraction emissions of methane), to which can be added the emissions from the energy needed for liquifying and transporting the gas.

One study has estimated that blue hydrogen produced *in* the US from shale gas had a greenhouse gas footprint greater than just burning gas or coal, due to the increased demand for natural gas to power the carbon capture. A further study estimates that when US-UK LNG imports are burned, upstream emissions (from extraction, processing and transport rather than combustion) account for almost half (48%) of the total greenhouse gas footprint when CO2 and methane are compared over 100 years. This figure rises to 63% if the impact of methane is assessed over a 20 year period.

Is CCS a proven technology?

Based on the above, it is clear that building power stations or hydrogen plants with CCS will not cut emissions (and retrofitting existing ones will not cut them much), but it is still worth asking questions about the efficiency and reliability of the CCS itself.

The chemical process which captures the CO2 works, and has actually been used for decades for EOR (see above). But getting CCS to work at full plant or power station scale, consistently, and at high enough efficiencies to be really relevant to cutting atmospheric emissions, is another story.The history of CCS is one of repeated technological problems, underperformance and massive cost overruns.

No CCS installation, regardless of whether for power stations or for industry, has ever cut CO2 emissions by more than about 65% over its lifetime, when the extra emissions from powering the carbon capture are included (or about 80% if they are excluded). Many have far worse capture rates.

Post combustion capture (from power stations or high temperature industries) is more technically difficult (and far more expensive) than pre-combustion capture such as in natural gas processing, because the density of CO2 within the exhaust stream of a power station is far lower. The majority of the CO2 used for enhanced oil recovery is actually from natural underground sources and not captured from industry or power plants at all.

Only two power stations with carbon capture currently exist (Petra Nova in Texas and Boundary Dam in Canada); both are coal-fired, and both have consistently underperformed and experienced lengthy outages and ballooning costs due to technological problems. Petra Nova shut down for a lengthy period due to a fall in the price of oil in 2020, demonstrating the vulnerability of a business model dependent on enhanced oil recovery.

As yet there are *no* full-scale gas-fired power stations with carbon capture in operation, although many are planned around the world. Emissions from burning gas are harder to capture than from coal, as the exhaust stream contains a lower proportion of CO2.

Transportation by pipeline (land and sea)

Standards for this are relatively undeveloped but despite the fact that many pipelines and storage sites are repurposed fossil fuel pipelines and gas/oil fields, it is clear that the engineering specifications for CO2 pipelines are not the same. A US site reports that since 2010 there had been one “incident” (eg a release of gas) for every 73.5 miles of CO2 pipeline, compared with one for every 405.4 miles for all pipelines combined. CO2 is an asphyxiant, and being heavier than air does not disperse readily.

What about the CO2 storage?

Only two projects using undersea storage currently exist. These are the Norwegian Sleipner and Snohvit sites, both associated with gas processing (not power). Both are frequently held up as proof of the safety of undersea storage, yet in one case (Sleipner) the CO2 moved into a previously undetected rock layer, and in the other (Snohvit) the porosity of the layer into which the CO2 was injected was less than expected, leading to rapidly increasing pressure in the store, so that the injection well had to be capped and a new location found.

Feeding in CO_2 from multiple industrial sources will make it more complex to monitor and control pressures and levels of contaminants inside the pipeline, which may increase the risk of corrosion and a consequent leak. Engineering work offshore is more complex than on land, with increased risk of corrosion of pipelines due to ingress of water during construction.

When CO_2 is injected into saline aquifers (layers of porous rock filled with salt water, as in the Northern Endurance field, the store for the Teesside project), not only is there a risk of leaks contributing to ocean acidification, but the salty water from the aquifer can be pushed out into the surrounding areas, harming creatures in sea-bed habitats.

High pressures can even crack the rocks capping the layer holding the CO_2. Recent experimental work shows that monitoring and detecting unintended CO_2 leaks is technologically feasible, but this provides no assurance that such leaks will be preventable or can necessarily be stopped if they do occur - especially when CO_2 injection is at the vast scale being proposed.

The Sleipner and Snohvit projects store no more than 1.7 million tonnes of CO_2 per year, and even these have behaved in unpredicted ways, Yet Drax power station alone is proposing to capture and store up to *8 million* tonnes of CO_2 a year, and it is claimed that by 2035 the East Coast Cluster as a whole will store up to 23 million tonnes a year on average. Clearly any suggestion that there is precedent for this is untrue; on the contrary, the cluster projects amount to a huge gamble, with £22bn of public money as well as with our climate.

Are there any legitimate uses for CCS?

Currently, it can be argued that any existing gas power stations that are not yet able to be retired should be retrofitted with carbon capture. In the world of industry, it may be that cement works need to be retrofitted until substitutes for cement in concrete can be found, although such substitutes *are* in development, and the main effort needs to go into recycling, plus reduction and re-use of materials.

There may be an argument for some smaller-scale capture at sites producing their own energy or requiring very high temperatures for chemical reactions, but again fossil technologies may soon be superseded by direct electrification - a far lower-regrets option - in the timescale needed to apply carbon capture

However, the majority of effort and investment should be directed not towards technologies that enable fossil fuel use to continue, but towards *removing the barriers* that currently stand in the way of moving rapidly to a fully renewables-based energy system. These barriers include:

- Insufficient *non-fossil* energy storage capacity. This requires research, development and deployment of things like pumped hydro, sustainable and recyclable batteries, non-fossil chemical storage, and other technologies.

- Bottlenecks in the supply chain for building out renewables - requiring far more support for supply chain manufacture.

- Inadequacy of the grid - needing huge amounts of new capacity and upgrading to support multiple inputs from widely distributed renewables and storage on multiple scales.

- *Serious labour and skills shortages* - which the government needs urgently to directly address with funding for well-paid jobs for trainers, courses for new entrants to the labour market, and support for existing workers to upskill and transfer out of high emissions sectors.

- Neglect of measures to cut energy demand - without which it will be impossible to meet all our energy needs from renewables. The single biggest impact would come from funding a mass buildings retrofit programme - the very thing the government has slashed relative to its earlier promises.

- The emphasis on carbon capture itself is a barrier, diverting funding from where it is needed and instead sending industry and energy down a path that locks in fossil fuel use. The scale of CCS envisaged for the clusters is especially problematic as unlike small individual projects it will be impossible to reverse when it proves ineffective or outmoded..

Finally, a note on jobs

The government says that their £22bn investment will create 4,000 jobs and “support” 50,000 in the longer-term. This is a transparent and insultingly unconvincing attempt to get workers on side whilst stoking antagonism towards critics of the fossil fuel/CCS pathway.

It is worth stressing that the 4,000 jobs would mostly be short term and exist only at the height of the construction phase. Highly-skilled workers, largely (given the current skills shortage) poached from other projects or sectors, tend to move around to where projects are located, so their spending doesn't form a reliable basis for a local economy. More routine construction work is rife with poor employment practices such as “bogus self-employment”, with no employee benefits and no guarantee of further work once a project is finished. Importantly for communities where projects are located, the jobs in other sectors which are dependent on the spending of workers employed on the projects are also vulnerable to the drop-off in labour needed once the construction phase is over.

Though the government seems vague on this point, the 50,000 jobs “supported” longer-term are perhaps essentially those that currently exist in the high-emissions industries, and which are claimed to be at risk if those industries fail to decarbonise. This means that getting the transition pathway wrong will place those jobs at greater risk in the long term, not less!

It is absurd to claim that the only alternative to carbon capture and hydrogen is leaving the market to dump workers in polluting industries onto the scrap heap, even whilst skills shortages mount in sectors essential to decarbonising the economy. The best way to protect jobs is not by seeking to prolong the life of polluting technologies and energy sources, but to ensure properly planned and supported pathways for workers to transition to these important new sectors.