Carbon capture and storage: An upcycled solution to climate change?

With the Intergovernmental Panel on Climate Change (IPCC) now concluding that the Paris Climate Change Agreement stretch target — to limit the rise of global average temperatures in 2050, from pre-industrial levels to 1.5°C — must be achieved to avoid significant and irreversible harm to the planet (Ref. 1), the challenge of reducing carbon dioxide (CO_2) emissions is becoming more and more pressing. Carbon Capture and Storage (CCS) is expected to play a crucial role in meeting this target, but what is it, what risks does it present, and how should they be managed?

LESS IS MORE

Power generation, where CO_2 is produced as part of the combustion process, is a major source of global CO_2 emissions. There are three ways we can reduce emissions from power stations, as illustrated in Figure 1.

CARBON CAPTURE AND STORAGE

Carbon Capture and Storage (CCS) is the name given to the industrial-scale process of capturing CO_2 before it is released into the atmosphere and transferring it into deep subsurface rock formations, such as depleted oil and gas reservoirs, where it can be safely and permanently stored (see Figure 2).

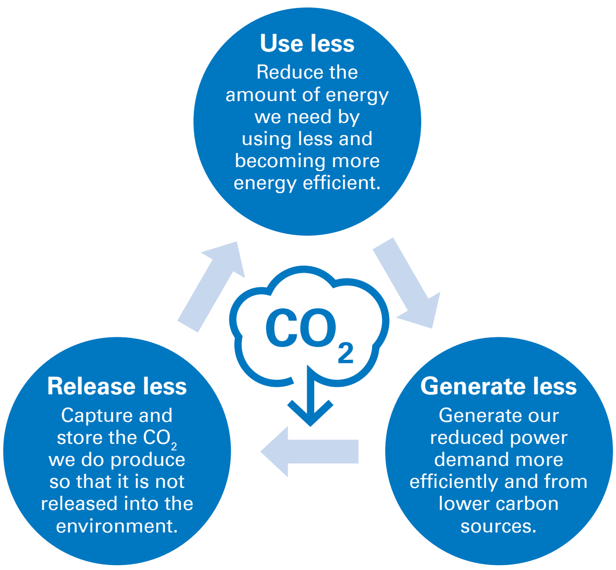

Figure 1
Opportunities to reduce CO_2 emissions from power generation

But the benefits of CCS stretch well beyond the power generation industry. It can be used to capture the CO_2 produced from other industrial processes and when integrated into an overall carbon capture network, as depicted in Figure 2, it can play a highly cost-effective and efficient role in reducing global carbon emissions.

SIGNIFICANT REWARDS

It is predicted that CCS can deliver 17% of the UK's 2050 CO_2 reduction target (Ref. 2), while its inclusion within a mix of low-carbon technologies is seen as the lowest cost route to decarbonisation. Without CCS, the cost of meeting the target would increase by 40%.

WHAT ARE THE RISKS?

CO_2 is not harmful to health at low concentrations. It is not flammable and will not support combustion. However, at high concentrations it can cause headaches, dizziness, confusion and loss of consciousness. With CO_2 being heavier than air, fatalities from asphyxiation have occurred when it has entered confined spaces and displaced oxygen. As such, CO_2 has been recognised as a significant workplace hazard for over a century; and highly effective standards and legislative controls have evolved to manage today's risks effectively.

CCS, however, will involve CO_2 being handled in quantities many orders of magnitude greater than today. Whereas in existing facilities, an inadvertent release of CO_2 may

1. CCS technology captures the harmful CO_2 emissions from a power station before they are released into the environment. The CO_2 is then compressed to liquid form for temporary storage at the onshore collection hub.
2. CO_2 captured from other industrial facilities is compressed to liquid form and temporarily stored ready for transportation to the onshore collection hub.
3. Liquid CO_2 is transported via road, rail, sea or (most efficiently) pipeline to an onshore collection hub.
4. Onshore collection hub stores the liquid CO_2 from all sources ready for onshore or offshore injection.
5. Liquid CO_2 is pumped to an existing repurposed offshore oil and gas platform through an existing subsea pipeline.
6. A repurposed and refurbished offshore oil and gas platform injects the CO_2 into deep geological formations below the seabed, in gaseous form.
7. Alternatively, CO_2 is injected into deep geological formations via an onshore injection facility.
8. The integrity of storage resevoirs is monitored to ensure permanent sequestration (trapping).
9. When combined with bioenergy technologies for power generation, CCS has the potentialto generate 'negative emissions'. The bioenergy feedstocks absorb CO_2 from the atmosphere and, when burned, the CO_2 emissions are captured.
10. Coal, oil and gas provide a rich fuel source that traditionally generates significant quantities of CO_2 when burned to generate power. However, when combined with CCS, the CO_2 can be captured and stored in depleted reservoirs, delivering a convenient, sustainable solution to greenhouse gas emissions.

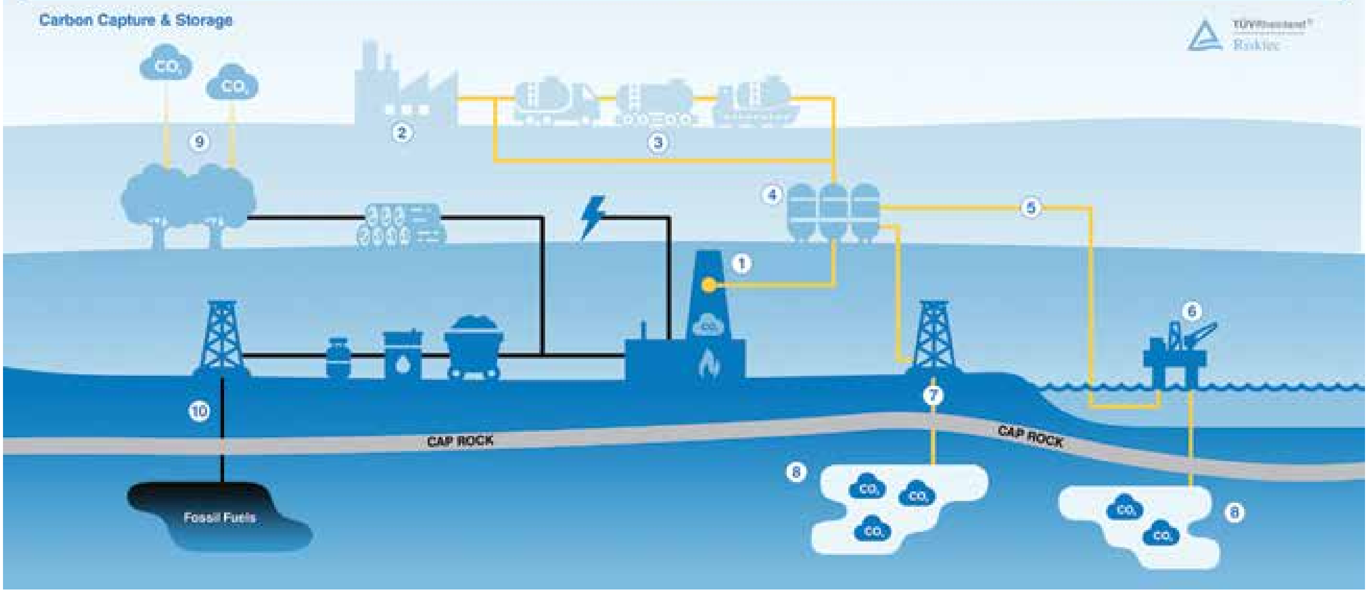

Figure 2 - The CCS process

create a small-scale hazard only affecting those in the local vicinity, a very large release of CO_2 from a CCS facility has the potential to produce harmful effects over a wide area affecting many more people and the environment.

There are engineering challenges too. CO_2 is corrosive in wet and impure conditions; therefore careful consideration is required in the design and material selection for storage, transport and injection facilities.

Geological security is clearly paramount to the success of CCS. Unless the long-term integrity of underground storage can be ensured, the environmental benefits of CCS will not be achieved and public health and environmental protection could be compromised.

SOMETHING OLD, SOMETHING NEW, SOMETHING BORROWED…

Perhaps the greatest risk to the sustainable proliferation of CCS is in treating it as something entirely new and innovative. Whilst clearly a novel concept with significant new challenges, it will rely on many existing systems and processes. Granted, these will often be used in reverse (e.g. using an offshore platform and subsea pipeline to inject CO_2 rather than extract oil and gas) and will accommodate a different medium, but many of the tools and techniques required to assess and manage these risks will be very similar; and much of today's offshore design and operating experience can also be brought to bear.

'Upcycling' may be defined as "Creative reuse - the process of transforming by-products, waste materials, useless or unwanted products into new materials or products of better quality or for better environmental value" (Ref. 3). By this definition, CCS is upcycling on an industrial scale and the approach to managing the associated risks should be tailored to suit. We must innovatively rework and repurpose existing infrastructure, knowledge, experience, processes, tools and techniques to learn from the past and benefit from the tried and tested, whilst developing solutions to the new challenges presented.

CONCLUSION

CCS can play a starring role in the fight against climate change, but comes with a range of technical, geological, health, safety, environmental and ethical challenges. However, by repurposing the old, borrowing the proven and innovating the new, CCS can meet these challenges and achieve its full potential in a safe and sustainable way.

Contact: Gareth Ellor
gareth.ellor@risktec.tuv.com

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