CARBON CAPTURE & STORAGE

What's in store for CO_2?

Carbon capture and storage (CCS) has lots of potential worldwide but also faces significant challenges, explains *Roberto Bencini*, Chartered Petroleum Geologist, and *Greg Coleman*, Managing Director, PetroMall consultancy.

Petra Nova CCS project, Texas, US
Photo: NRG Energy

Excessive anthropogenic carbon dioxide (CO_2) emissions from the use of fossil fuels are contributing to global warming and climate changes, according to the Intergovernmental Panel on Climate Change (IPCC) and other leading experts. Anthropogenic CO_2 is the single largest contribution to greenhouse gas (GHG) levels and is responsible for about 64% of global warming.

Nevertheless, no science-based forecast of future energy needs suggests that fossil fuels will provide less than 50% of primary energy sources for the next 50 years at least.

BP's latest *Energy Outlook* points out that improved living standards are distinctly targeted by many governments, and will demand increasing energy consumption, particularly in Asia, Africa and South America. However, as a society we should aim to abate CO_2 emissions despite the prospect of a rise in energy consumption.

Indeed, all practical methods for limiting and reducing CO_2 emissions should be implemented worldwide as a matter of urgency and national priority, including energy saving and efficiency, use of renewable energy sources, reforestation, and carbon capture and storage (CCS). The latter, in particular, has the potential to maintain sustainable energy consumption at current levels and improve living conditions globally.

Powerful solution

CCS and its variations – carbon capture, usage and storage (CCUS) and bio-energy carbon capture and storage (BE-CCS) – represent a powerful solution to the problem of excessive anthropogenic CO_2 emissions, acting as a bridging technology for the energy transition to a decarbonised world.

CO_2 capture is the more costly element of the CCS chain. It has been shown that CO_2 storage can be carried out safely and relatively cost effectively in suitable subsurface sites, with many potential storage reservoirs identified and tested worldwide. However, CO_2 storage is impossible without CO_2 capture at the same scale. Carbon capture can be done using established technologies such as post-combustion CO_2 scrubbing from fumes, pre-combustion CO_2 separation from a hydrogen-rich gasification stream and oxy-combustion.

While solid fossil fuel gasification is currently the cheapest option for capturing CO_2, oxy-combustion has the best chance of gaining industry favour in the near future. Besides the power generation sector, CCS is of particular use to other high CO_2 producers such as the steel, cement, chemicals and petrochemicals sectors.

CCUS is a technological scheme where the CO_2 is used in an economic way in an industrial process. For example, large amounts of CO_2 can be used for enhanced oil recovery (EOR; using CO_2 to get more out of oil reservoirs) at many sites in the US and could be deployed elsewhere.

BE-CCS is a clever idea. If the source of carbon for CO_2 capture is vegetable material, the geological storage of the captured CO_2 will implement the incremental removal of CO_2 from the atmosphere. Such integrated technology is more efficient than direct capture from air, an energy intensive technology currently being studied, and is an attractive

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solution relative to simple CCS from use of fossil fuels.

BE-CCS, however, is likely to be applicable at a smaller and more local scale than fossil fuel CCS. The vegetable carbon source for BE-CCS can be fuel crops (sorghum, maize, etc) or managed forestry, *spirulina* group algae (biofuel, biodiesel) or other types of algae (*chlorella*, *dunaliella*, *scenedesmus*, etc). Such bio-energy sources can be grown in many parts of the world, and the CO_2 captured and stored, to offset CO_2 emissions elsewhere.

The challenge

The key challenge of CCS is reducing the capture cost, which represents two thirds or more of the total cost of CCS.

The current anticipated CCS cost, measured pro-rata per tonne of CO_2 avoided, is likely to be less than the European penalty that is currently set at €100/t of CO_2 for emitting CO_2 above the given (and ever reducing) threshold. The CCS cost is, however, still higher than the current cost of the European Union Emission Trading Scheme (EU ETS) emission certificates.

Until it is cheaper to buy CO_2 emission certificates to avoid heavy penalties, CCS is unlikely to take off as a new industry. On the other hand, if capturing, transporting and storing CO_2 underground steadily becomes cheaper than buying standard CO_2 emission certificates, there is a strong chance that CCS can develop worldwide.

It should be noted that verified CO_2 underground storage can generate tradeable CO_2 emission allowances for the same amount that is documented to be permanently stored, according to EC Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of CO_2.

The challenge is to lower the CO_2 capture cost, and therefore create better return on investment. This can be done by capturing the CO_2 at plants that are most suited to have low capture costs, such as coal or tar gasification applied to power generation. Alternatively, it is possible to adapt the oxy-combustion technique, which has the extra advantage of avoiding entirely the formation of nitrogen oxides (NO_x).

Currently, according to StorageData, there are 19 large scale CCS plants in operation (nine in the US, three in Canada, two in Norway, one in Australia, Brazil, China, Saudi Arabia and the United Arab Emirates), and a further four are under construction (two in Canada, two in China). One plant completed its operative life in 2011 at In Salah, Algeria.

Another 20 plants are at different stages of development worldwide. With reducing carbon capture costs, more and more projects become economical under today's market conditions.

Of course, if the CO_2 emission certificate prices climb steadily above the current capture cost per tonne then there will be a strong economic incentive to capture and permanently store the CO_2 underground.

Many fundamental factors are currently changing. The economic crisis that started hitting the western world in 2008– 2010 is relenting, and energy generation and consumption from fossil fuels is resuming its growth despite the rocketing rise of renewable power generation (particularly photovoltaic and wind power). Consequently, the gradual reduction of CO_2 allowances on the market is pushing the emission certificates price higher and higher.

Since early 2018, after some 10 years of stagnation, the ETS CO_2 emission certificate price has been growing with moderate oscillations from approximately €5/t to some €29/t more recently. It is likely, therefore, that the two curves, lowering capture cost and rising certificate price, will cross in the near future, allowing CCS to progress and grow worldwide.

Erik Reinhardsen, Chairman of Equinor, speaking at the opening session of the European Association of Geophysicists and Engineers (EAGE) annual meeting in June 2019, sees a carbon tax as a very important measure to drive change in emissions. 'From an international perspective we don't have a legislative framework. But we do have the Paris Agreement and UN sustainable development goals,' he said. 'Both accords have become widely accepted among societies, investors and companies as targets to strive for improved climate.'

The opportunity

Discovering suitable CO_2 storage sites is much like discovering oil or gas fields, and requires the same set of tools, techniques, knowledge and technical know-how. Safe CO_2 underground geological storage can be done in depleted or semi-depleted oil and gas fields, deep coal seams unsuitable for mining and deep saline aquifers (with or without structural closures). This will require comprehensive risk mitigation and monitoring to reassure the public that the CO_2 will not 'leak' from the underground storage site.

There is wide agreement in academic and industrial circles that the largest CO_2 underground storage capacity by far is located in deep saline aquifers that are unsuitable for other human use.

It is estimated that there is more CO_2 underground storage capacity worldwide than CO_2 that can be generated by burning all the past, present and future fossil fuel reserves until their compete depletion.

We are at the very beginning of a new CO_2 storage era, and trying today to calculate the total world CO_2 storage capacity is like trying to calculate the total amount of producible oil in the years following first oil production from the Colonel Drake well at the end of the 19th Century. The opportunity is highlighted by the abundance of CO_2 storage capacity located somewhere in the shallowest few kilometres of the crust of this planet.

In conclusion

Every industrial product consumes materials and energy. If the materials are entirely recycled and the energy comes from renewable sources, there is no CO_2 emission problem to take care of. If, however, new raw materials are inserted in the productive cycle and non-renewable energy is used, as most commonly is the case for years to come, then a full lifecycle CO_2 emission can be calculated for every single industrial item sold worldwide.

Producers of industrial products should calculate a total life-cycle CO_2 emission allowance for that item and offset such CO_2 quantity with CO_2 emission certificates that will increasingly come from permanently storing CO_2 underground in a certificated way.

There is an opportunity for the leading oil and gas companies to evolve into leading CO_2 storage companies due to the similar toolbox and challenges entailed. Equinor is an example of this, as it operates the oldest CCS project (the Sleipner gas field, which involves producing a CO_2-rich gas stream) and promotes the technique in other projects (eg Snøhvit, In Salah, as well as the Mongstad test facility for CO_2 capture).

We also predict the birth and rise of dedicated CO_2 underground storage companies that could prosper selling guaranteed CO_2 emission certificates to whoever needs them, from service stations to power suppliers or food retailers. ●