Submission - “CCUS and Hydrogen” - 14/12/2021, E. Dalhuijsen

Carbon Capture, Usage and Storage

Including Acorn CCS, UK Government decision on Scottish Cluster, and technology development and innovation in the sector.

Erik Dalhuijsen, Principal Petroleum Engineer, OceanValley Ltd, Aberdeen

CCUS and/or Hydrogen?

The title of this session states CCUS/CCS. However, “blue” or “low carbon” Hydrogen are also part of the discussion: both the Acorn project and the Scottish Cluster are specifically focused on such fossil-fuel based hydrogen.

Both in a Climate Emissions and in an Energy Transition context CCUS and Hydrogen require separate, independent consideration; doing otherwise obfuscates important issues and may lead to incorrect conclusions and unsound decisions. Such issues include GHG emissions, achievable timelines, technical and economic uncertainties and risks, scalability, capacity and areas of application, emissions targets and even non-technical factors such as energy security and jobs.

Carbon Capture, *Usage* and Storage (CCUS)

Contrary to much of the public discourse, CCUS is not proven or “oven-ready” technology. Regardless several decades of related history including study, near-implementation and partial implementation, at present only two definite conclusions may be drawn from the experiences: it is costly to implement; and big drawbacks, uncertainties and risks remain with regards to both viability and implementation. Some of these are detailed in the following.

Time line for implementation, speed of implementation

CCUS for the purposes of achieving (net-) zero emissions is not a quick project with known challenges. While the above-ground (surface) aspects of CCUS seem a relatively straightforward (if complex) industrial project, boundary conditions for the sub-surface part are highly challenging: ensuring sufficient CO_2 residence time for mineralisation -of the order of 10,000 years- is not something for which current engineering tools are adequate. For comparison: this period is roughly twice the age of the famous Giza pyramids. Any trial -no matter how elaborate and costly the data gathering- must have a substantial duration to be of relevance for such a long-term aim.

Following on from possible multiple future trials covering either saline aquifer (the apparent UK preference) or depleted gas and oil fields (the apparent Netherlands preference), and incorporating the learning, and if technical, economic, ecological and sociological outcomes were indeed positive, then a first implementation could be initiated. I would consider this timeline-to-first-implementation in decades. The requirements are, and must be, very different from earlier short-term small-scale economics-driven installations.

The climate change timeline and agreed emissions targets do not allow for such delay before significant energy decarbonisation is needed; residual emissions may remain within scope.

Risks for scaling up

Current estimates for potential total storage capacity for CCUS are determined by regional studies. These studies do not cover the detail required to avoid every possible leak-path, which must be completed for each potential implementation. It is likely that many specific structures and fields will not be able to achieve a leak-free status; whether the site-screening success rate is 1 in 10 or 1 in 1000 is unknown and cannot be determined quickly. Once screening has been successful, any remaining oversights still need to be detected during implementation (plume-monitoring), adding further delay to any scaling up.

These risks may be of the kind encountered in Sleipner (1996), where an EU requested survey post-implementation (2011) discovered a surface penetrating leak-path, some 25km beyond the Sleipner CO2 store. Sleipner is an oft cited poster child of (so-far) successful implementation of dedicated CCS, but might equally have been its most visible failure. Gorgon, another oft-used example, failed its moderate performance expectations of 80% capture. Both of these examples extract CO2 entrained in produced natural gas, and in doing so emit extra greenhouse gases from the additional energy required to separate and inject the CO2. The installations also remain responsible for the entire emissions contained in the natural gas produced.

Long term integrity of storage, future generational exposure and monitoring burden

Guaranteeing leak-rates substantially below 0.01%/annum for a 10,000+ year life span may be neither easy to achieve nor to prove. Failure to guarantee the store integrity may contribute to future climate failure and/or environmental shock, and future generations may not even be aware of leakage: maintaining skills (monitoring, remediation) across many generations is an unprecedented challenge, and passing on both concern and burden to future generations is equally unprecedented.

Energy consumption increase

The CC*U*S process requires substantial energy, in the order of 25% of the fossil fuel energy for which emissions may be captured. Therefore, large scale implementation of CC*U*S will make the energy transition yet more challenging by increasing the total demand for energy.

Carbon Capture efficiency

The capture technology, much of it proven at industrial scale, is not proven at the required capture efficiency: average capture rates of what is generally considered (by the CC*U*S industry) as “track record” are in the order of 60%, nowhere near the 98% to 100% capture efficiency required to achieve net-zero emissions when dealing with fossil carbon.

The suggestion of upscaling lab-conditions (95%) to industrial scale with no loss of efficiency is unlikely to universally materialise. It is also important to note that capture efficiency figures do not include any emissions upstream of the flue-gas. In the case of fossil-fuels, such upstream emissions are considerable.

Non-CO2 emissions

Other pollutants present in the emissions from which CO2 may be extracted will typically still be emitted. Due to the increased energy requirement, this level of pollutants may increase compared with a non-CC*U*S scenario. This effect steers any potential health benefits of energy decarbonisation in the opposite direction.

Opportunity Cost

It is important to consider whether CC*U*S is the most efficient way to invest substantial funds and effort from limited supplies. For applications where still no alternatives to emissions exist, such as cement manufacture, CC*U*S might be of value, and due to the long lead time (as described) of any possibility of operational CCS at a relevant scale and efficiency, trials are likely to add value over time. From an overall economic perspective, reducing energy wastage and removal of fossil fuels from the energy equation are likely to be much more cost- and climate-effective.

Specific Applications

CC*U*S remains a potential solution for specific applications in the future, for a small fraction of emissions for which there are no alternative approaches available. Currently cement manufacture would lie in this category, though developments with alternative materials are afoot and show some potential.

BECCS (Bio Energy with CCS), the capture and storage of short-cycle biomass emissions, might in the future contribute to the achievement of negative emissions. As this refers to carbon recently extracted from the atmosphere, capture efficiencies of less than 100% are acceptable here.

For capturing fossil fuel emissions, whether from burning natural gas or from the conversion of natural gas into hydrogen, CCS is not a valid emissions reduction solution. (Some detail for hydrogen, the technically easiest of these, is given further on.)

Hydrogen, emissions, skills and investment

Hydrogen has excellent potential for the zero-emissions world which must materialise in the coming few decades. However, the UK’s current approach towards a fossil-fuel driven “hydrogen economy” is misguided and has every potential to annihilate all net-zero intentions.

Hydrogen is not a Clean “Fuel” - An Important Misunderstanding

Unlike often suggested, hydrogen is not a fuel source but only an energy carrier, just like electricity: how it is made - “sourced”- determines its climate impact.

For example: make electricity with wind power and it is clean, make it with coal and it is not. Make hydrogen with wind power and it is clean, make it with natural gas and it is not.

Make hydrogen with natural gas and add on CCUS, and all the emissions in the entire chain must be counted. It is certainly not clean, and according to recent analysis little better than natural gas in terms of emissions, and far less efficient than renewable energy sources.

This simple concept is extremely important. Comparing energy *sources*, a “zero emissions hydrogen economy” merely becomes an “inefficient electricity economy”. Due to hydrogen’s different storage, use and transport characteristics substantial convenience value exists for specific applications.

Green Hydrogen

Green Hydrogen is produced with renewable energy sources such as wind and solar with no GHG emissions. It is generally accepted that green hydrogen is the only hydrogen adequate to achieve net-zero and true-zero-emissions. It is also generally accepted that direct electrification (with renewable electricity) is a more efficient way to reduce emissions where energy is concerned.

This leaves green hydrogen as an important alternative energy carrier where direct electrification is not possible; in these cases the efficiency penalty -the energy loss during hydrogen production and compression- is compensated for by hydrogen’s physical characteristics.

For Scotland, with Europe’s joint-highest excess potential for green hydrogen, a short distance from Europe’s regions with the greatest future green hydrogen deficit, this may also offer an export opportunity.

Non-green hydrogen

Blue hydrogen, “low carbon” hydrogen and grey hydrogen are all the same hydrogen made from fossil fuels. In the case of blue or “low carbon” hydrogen (as referred to by the UK government and the oil industry), part of the emissions of the conversion process are hypothetically captured and stored through CC*U*S.

From an emissions perspective, the two critical concepts are “partial emissions capture” and “hypothetically stored”.

From the perspective of the fossil fuel industry, the critical concept is “made from fossil fuels”.

In the current climate and emissions crisis, with universal agreement that phasing out fossil fuels is the only valid path to avoid climate disaster, it is relevant to note that many fossil fuel companies maintain a growth strategy for natural gas and are seeking government support for new long-term fossil fuel infrastructure. The growth strategy is in part built on the concept of a “hydrogen economy”, specifically with an abundance of non-green hydrogen. This is concerning for several reasons.

A Hydrogen Economy?

Green hydrogen has an important role to play as an alternative energy carrier in the transition away from fossil fuels, towards zero emissions. Many technical aspects around manufacture, use and storage would benefit from ongoing development.

The concept of a “hydrogen economy” however has little merit from an emissions perspective. Where decarbonisation and minimisation of energy use are the aim, conversion to hydrogen where this is not essential has the opposite effect, increasing fossil fuel demand and associated emissions.

Risks to Scotland’s Climate Response

The UK Government’s current emphasis on fossil-fuel-sourced hydrogen, with or without CC*U*S, carries a substantial risk of emissions increase, stranded and misplaced investment and negative climate impact. Specifically:

Emissions risk – fossil-based hydrogen

Analysis of whole-chain emissions for “blue” or “low-carbon” hydrogen shows that GHG emissions for such an outcome are greater than of simply burning natural gas, due to both methane and CO2 emissions of the natural gas feedstock and non-captured CO2 emissions from the gas-to-hydrogen conversion process. (Green hydrogen avoids all of this.)

Price risk – investment mis-allocation

Green hydrogen is generally expected to achieve price-parity with fossil-fuel based hydrogen by 2030. Due to the continuing downward cost trend of green hydrogen, any residual investment in fossil-fuel hydrogen facilities beyond this date will have been mis-allocated.

Price risk – hydrogen versus electricity

Switching to hydrogen where electricity is more appropriate will end up costing more: renewable energy is in many cases cheaper than fossil-fuel based energy, and this trend will continue. For example, domestic heating and rail transport with hydrogen are in most cases inefficient use of energy in a decarbonising world.

Emissions risk through increased energy demand

The excess energy required for producing green hydrogen (~15%) or blue hydrogen (~30%), when used at large scale will require more renewable energy, causing full renewables penetration to be achieved later, raising cumulative emissions.

Social: Climate Risk and Just Transition Job-Risk

Ongoing investment in fossil fuel linked technology will delay investment in renewables and green-tech, postponing the energy transition, increasing cumulative emissions and reducing the availability of “green jobs”, which in turn prevents mobility of essential skills required to achieve the immense effort the transition entails.

Technology Development and Innovation – some considerations

CCUS is currently not a feasible decarbonisation tool: capture can work (but can be optimised), transport and injection can work (but can be optimised), short term CO2 flow behaviour modelling underground can work (but can be optimised), but there appears to be a gap concerning the “keeping it in the ground until harmless” phase of CCUS. On the technical side there is scope for improvement of monitoring and (cross-generational) remediation options, but an important uncertainty is primarily non-technical: how to guarantee store integrity, how to ensure store failure does not occur, how to ensure the storage process cannot be inadvertently reversed by accident or intent, at any point in the 10,000+ years ahead. Until store integrity can be guaranteed, at least for a predetermined fraction of any CO2 stored, CCUS cannot be regarded as a feasible emissions solution. Due to its open-ended nature CCUS is a “weakest link” project: if one aspect fails to deliver all is lost. This might be resolved by targeting CO2 “transformation” rather than “storage”, through processes which efficiently and effectively make CO2 harmless on an acceptable timescale.

For green hydrogen technology and more generally for decarbonisation there is a need for further developments both for application and innovation; a specific focus on application could be of great positive impact, especially if subsequent implementation were adequately financed.

In addition to hydrogen and CC*U*S, there is a broad area of integrated decarbonisation technologies where improvement would help both in concept and implementation, where the positive impact on Scotland’s climate goals will be greater, and where a just transition will become achievable.

Overall, a more systems-based cross-discipline approach is required to maximise the probabilities of whole-system-success for greenhouse gas reduction overall.

Ir. E. Dalhuijsen
Aberdeen