Technical background on Enhanced Hydrocarbon Recovery using CO_2 accompanied by permanent CO_2 storage

1 The process of Enhanced Hydrocarbon Recovery using CO_2

1.1 Enhanced Hydrocarbon Recovery (EHR) is a generic term used to describe a range of techniques that allow more oil or gas to be recovered from a reservoir than would otherwise be possible. Enhanced Oil Recovery (EOR) can be regarded as established in the US but less so in the EU. It is generally more effective than Enhanced Gas Recovery (EGR). Another option is Enhanced Coal Bed Methane Recovery, an option under active consideration in Belgium and Poland. In order to focus on the key issues using a straightforward case, the remainder of this paper addresses EOR.

1.2 CO_2 is one of a number of injection fluids that is used for EOR but is generally held to be the most effective. When CO_2 is injected into an oil saturated geological reservoir formation (an operational or abandoned oil field) during EOR, some of it remains permanently trapped in the reservoir and some of it associates with the oil or gas and is recovered to the surface facilities as part of the petroleum production process. The recovered CO_2 is separated from the petroleum in enclosed conditions in a pressure vessel and is normally recompressed and returned to the oil reservoir. The quantity of CO_2 used is typically substantially larger in terms of mass than the increment in oil produced[1].

1.3 This process would accomplish permanent storage of CO_2 providing that the site and reservoir in question are selected on the basis of suitability for permanent CO_2 storage, and that the appropriate regulatory framework for permanent storage is fully complied with. Most oil field reservoirs by their very nature provide appropriate conditions for such permanent sequestration of CO_2. Provided that the conditions of the CCS Directive apply, the storage of carbon dioxide through EHR is as permanent as if it had been stored through an exclusively storage activity.

2 The economics of CCS combined with EHR

2.1 Carbon capture and storage is not currently economically viable even when stored CO_2 is counted as abated under phase 3 of the EU ETS. In fact the cost of capturing CO_2 from the power plant alone is predicted to be around two thirds of the total cost for CCS on power generation. Current industry estimates range from €25/tonne to €60/tonne of CO2 abated for different technologies and are very dependent on the assumptions made about fuel costs. With the price of CO_2 under the EU ETS around €20, there is currently no incentive for emitting installations to capture their CO_2. Taking into account the cost of transport and storage as well leads many experts believe that the CO_2 price is unlikely to be high enough before 2020 to enable CCS projects without public funding.

[1] At least 2 tonnes of CO_2 are required to produce 1 tonne of oil.

2.2 CO2-EOR is also not currently economically viable in Europe. This is in part because there are no natural sources of CO_2 in Northern Europe that are large enough to enable EOR to take place on a commercial scale offshore[2]. This means that no offshore oilfields in the EU that might have implemented CO_2-EOR have done so because they do not have a sufficiently large accumulation of geologically sourced CO_2 nearby that can economically be accessed. Also, CO2-EOR can require retrofit of the injection and extraction facilities at an oilfield to cope with the corrosive nature of the mixture of CO2 and formation water which is recycled.

2.3 If combined CO_2 storage and EHR were permitted, the income from the EHR would provide an additional revenue stream that would be available to offset the costs of CCS. These are first and foremost the costs of the storage itself: although the EHR income will decline to zero over the course of the project, and there may be a post-EHR period where only storage is conducted, the initial revenue can be used to offset the costs of the storage over time. In exceptional cases, it may even be the case that the EHR would not only offset the costs of storage, but also make a profit. In such cases, the market will lead to a price being placed on CO2 for use in HER, which could partially offset the CO2 emitter's cost of capture and transportation[3]. That is, there will always be a net cost of capture, transport and storage that the emitters would have to bear, but it would be reduced to some extent by the revenue stream coming from the EHR scheme.

2.4 If the EOR scheme is not allowed to obtain a CO_2 storage permit under the CCS Directive, the entire net cost would ultimately have to be born by the electricity market (the customer). In these circumstances there is no incentive for the emitter to make any investment in the capture and storage installation, since from an economic standpoint, the emitter would be better off continuing to directly emit CO_2 to the atmosphere.

2.5 Furthermore, availability of storage is expected to be a key constraint on the deployment of CCS. Allowing for the additional revenue generated from EOR is expected to considerably accelerate the construction of storage sites. It should also be noted that the transport infrastructure requirement for a large-scale EOR project would also reduce investment barriers for the development of the transport networks required for the large number of storage projects which will be required in the longer-term (either by reuse of CO_2 transport facilities when the EHR project is finished, or by securing economies of scale for transport by aggregation of storage and EOR projects).

2.6 There are some 200 oilfields in the North Sea, a significant proportion of which would be potentially suitable for EOR[4]. There are at least six

[2] Some on-shore fields might be feasible sites
[3] McKinsey Report "The Economics of Carbon Capture and Storage" estimates the cost of capturing CO_2 to be in the range EUR 25-32/tonne CO2 abated, and the cost of transportation offshore to be around EUR 6/tonne CO2 abated.
[4] Any potential reservoir would require detailed study to appraise its suitability in the first instance, as required under the draft CCS Directive. Most sandstone reservoirs and many

potential projects in the UK, Denmark, and the Netherlands. If sufficient volumes of anthropogenic CO_2 were economically available then many of these could produce oil for an extended period[5]. An EOR project could also be optimised to use a much larger proportion of CO_2 to maximise the storage benefits[6].

2.7 The increased production of oil in Europe from EHR could offset imports from outside of Europe, with two main consequences. The first is to increase security of energy supply. The second is to reduce the impetus to produce oil from new exploration or from tar sands, which are likely to have significant environmental impacts.

3 Regulatory considerations

3.1 CO_2 to be used during the EOR process can be delivered from the following sources:

- i) Predominantly, CO_2 brought to the platform from industrial sources
- ii) Minor quantities of CO_2 produced by a gas turbine on the platform

This CO_2 would be recycled into the reservoir and permanently stored during EOR operations in a continuing storage program after the EOR phase was complete. It would be measured according to the monitoring plan in the storage permit issued under the requirements of the CCS Directive.

3.2 Minor quantities of CO_2 emitted into the atmosphere from such production facilities would arise from:

- iii) Leakage (minor/trivial) and
- iv) Deliberate venting for process or emergency purposes.

3.3 The Monitoring and Reporting Guidelines (MRGs) produced for CO2 storage projects under the Emissions Trading Directive, which include MRGs for storage combined with Enhanced Hydrocarbon Recovery, will ensure that an operator must monitor any release of CO2 as part of EOR with permanent storage, and inclusion in the ETS means that any release must be covered by

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carbonate reservoirs are likely to be found to be satisfactory storage sites. Other factors such as location and accessibility would also require detailed appraisal before a field could be accepted as suitable, but it is likely that a significant number will be suitable in the right economic and fiscal circumstances and that the resulting CO_2 storage capacity will be strategically significant.

[5] For example, a typical EOR field operation would require at least the equivalent amount of CO_2 to that which would be captured from a industry typical1600MW power station or a cluster of closely situated industrial point sources, i.e. c.6 to 8 million tons CO_2 /year which could ultimately give rise to an oil production stream of c.50,000 bbl/d.

[6] Descriptions of the projects so far proposed suggest that the mass of CO_2 stored could be 5 times, or more, that of the additional oil produced (see https://www.og.berr.gov.uk/information/papers/IEA_CO2Optimisation_Paperincfigs.pdf). In those cases, there would be a substantial net gain to the storage of carbon, irrespective of the use made of the additional oil.

the purchase of ETS allowances. The new recital 15a in the proposal for a Directive on geological storage reflects this situation[7].

3.4 All the requirements of the proposed geological storage Directive would apply for a combined project. Just as for any non-EOR (e.g. saline aquifer) site, the initial choice of site would have to respect the provisions of Article 4, that under the proposed conditions of use there is no significant risk of leakage, and no significant environmental or health risks exist. The same monitoring techniques would be employed. In practice, the oilfields in question have the advantage of having a proven seal which has already retained the oil contained over millions of years, and thus have a good chance of meeting the criterion for permanent storage.

4 Conclusion

4.1 The combination of CO2 storage with EHR would not pose any additional environmental risks to pure CO2 storage, because all the requirements of the proposal for a Directive on geological storage would have to be met by any combined project.

4.2 At present, neither CCS nor EHR is economically viable on its own. However, the combination of the activities will allow a revenue stream which could partially offset the costs of CO2 storage, and in certain cases perhaps also of the transport and capture of CO2, thus making CCS cheaper than would otherwise be the case and so enhancing the possibility of early CCS deployment.

4.3 The extra hydrocarbons generated in Europe by CO_2 EHR would offset imports of hydrocarbons, thus increasing security of energy supply and reducing the pressure to engage in other, potentially more environmentally damaging, means of hydrocarbon production.

[7] In practice, the CO_2 would be extremely valuable to the EOR/storage operation and would be carefully safeguarded, and so the process would be designed and operated so as to minimise losses.