Enabling CO_2 reuse value chains: the importance of geographical conditions

Strategies for capturing CO_2 from existing industrial processes are considered important in the transition to low carbon economies. CO_2 reuse offers the possibility of making different contributions to the mitigation of overall emissions. To enable re-use at different scales, knowledge on the practical logistics of capture, treatment and transport is essential before establishing whether a final conversion process would be viable. In addition to knowledge about the individual stages of the value chain, the implications of each stage must be adapted to the processes of subsequent and preceding stages in the local context. This understanding helps stakeholders to search for partners and explore business cases according to the composition and scale of the source, feasible distances and final application requirements.

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Introduction

Carbon capture and utilisation (CCU) is an attractive option for abating CO_2 and displacing primary hydrocarbon use. CO_2 is already used as feedstock in some processes and is produced in high purity by others. Previous research has focused on the individual stages of a CCU value chain. This work examines the pre-conditions for joining the stages. It systematises the technical choices for discrete CO_2 emitters and receivers. Sources are classified to enable consolidation and the factors and thresholds for the choice of transport mode are laid out. The Value Chain Analysis project of the EnCO$_2$re programme[1] provides a framework to support the preparation of CCU business cases.

Evaluating CCU value chains

Ideally, large mass flow and high concentration are sought as requisites for considering a CCU scheme. These two parameters, as well as the impurities present in the flow, influence the cost of capture and treatment. Impurities are the least tractable parameter. They can vary widely due to, amongst others, variations in reaction ratios and feedstock quality. The resulting range of possibilities and implications complicates their categorisation.

1 http://enco2re.climate-kic.org/

The classification of sources starts with the mass flow. Sources that emit more than 0.1 MtCO$_2$ per year (Mtpa) are considered “large scale” (IPCC 2005); it is estimated that sources emitting less than 0.1 Mtpa together account for less than 1% of the emissions from all stationary sources. Our stakeholder engagement revealed four sensible scale categories:

- Micro: 0.035-0.075 Mtpa
- Small: 0.075-0.1 Mtpa
- Moderate: 0.1-0.5 Mtpa
- Large: $\geq$0.5 Mtpa

The concentration of CO_2 in the effluent depends largely on whether or not the source involves combustion. In processes such as hydrogen or ammonia production, the levels of concentration are higher, mostly reaching over 95% (Element Energy et al. 2014). Sources have been classified in four bins by (Jin et al. 2012), based on the impact of the CO_2 concentration on the energy required for separating the CO_2. Our stakeholder engagement resulted in a practical classification of three bins based on the number of sources in each category and the technologies suitable for treating them:

- High Level: >90%
- Moderate Level: 20-90%
- Low Level: <20%

Capture and treatment technologies have been reviewed extensively by (Styring et al. 2011) and (Global CCS Institute 2011). The work in EnCO$_2$re synthesises the most applicable combinations for promising value chains. Three categories of capture technologies, i.e. (i) post-combustion capture, (ii) pre-combustion capture, and (iii) oxy-fuel combustion, were analysed in combination with the sources for which they are suitable. Based on their technology readiness level (TRL), companies interested in providing or receiving CO_2 can select options for further cost analysis. Cost curves were generated for promising technical combinations reflecting the influence of scale. This allows individual nearby sources to estimate the cost of reaching a particular level of purity and scale by consolidation. The participants of a new CCU scheme could assess the collective cost of offering a large, uniform CO_2 stream.

Potential CO_2 providers need to estimate the radius in which they can search for CO_2 receivers. The choice of transport means and the maximum suitable distance depend on: (i) the purity of the CO_2 stream, (ii) the scale of the flow, (iii) terrain morphology, and (iv) existing infrastructure. Although configurations with the lowest number of steps, such as storage, uploading and unloading, are preferred, the main pre-condition is to find demand points with matching purity

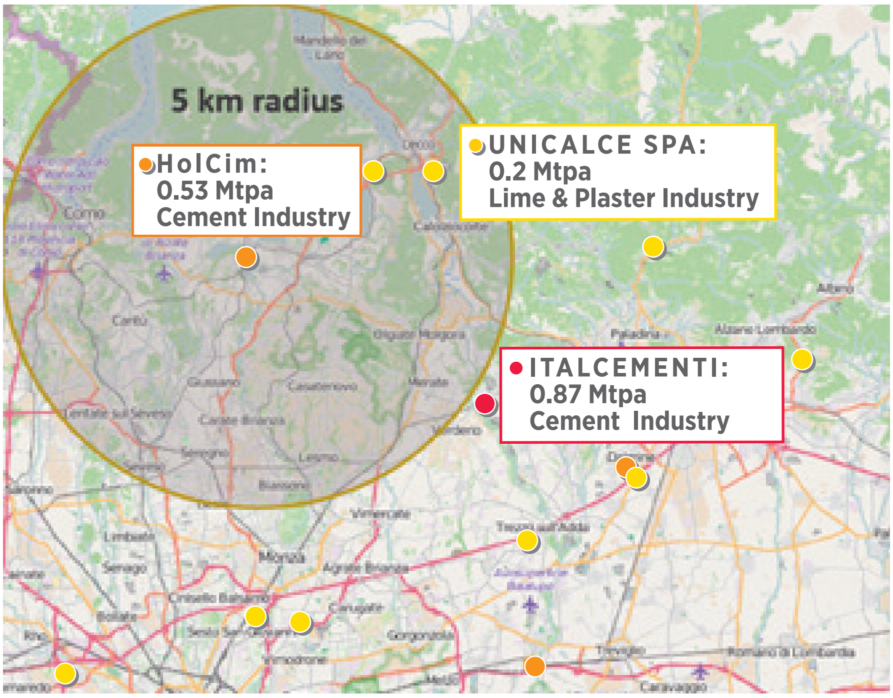

Fig. 1: Viable range for seeking CO_2 receiving processes -
Source: Own figure based on openstreetmap.org

requirements, mass flow uptake capacity and willingness to pay for the captured CO_2. Calculations including assumed values, for example for the sale of emission permits and CO_2 market prices, illustrate cost trends for various CO_2 streams using all transport means across a range of distances. CO_2 providers can visualise the geographical areas they could serve, as shown in **Figure 1.**

Conclusions

To explore the full CCU potential of a region it is necessary to coordinate the specifications of the different value chains. Understanding how to consolidate sources and the requirements, location, scale and TRL of the sinks, can constructively inform the choice of capture, treatment and transport technologies. The EnCO_2re programme can help stakeholders to define a CCU scheme by performing the calculations presented in this Value Chain Analysis framework using their local requirements. The ability to find the right partners is unlocked by the ability to identify the right technologies at the right scales.

References

Element Energy; Carbon Counts; Process Systems Enterprise; Imperial College London; University of Sheffield (2014): Demonstrating CO_2 capture in the UK cement, chemicals, iron, steel and oil refining sectors by 2025: A Techno-economic Study. Final Report for DECC and BIS. Cambridge, UK. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/311482/Element_Energy_DECC_BIS_Industrial_CCS_and_CCU_final_report_14052014.pdf

Global CCS Institute (2011): The global status of CCS: 2011. Canberra, Australia: Global CCS Institute. https://hub.globalccsinstitute.com/sites/default/files/publications/22562/global-status-ccs-2011.pdf

IPCC (2005): IPCC special report on carbon dioxide capture and storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, USA: Cambridge University Press.

Jin, H.; Gao, L.; Li, S.; van Sambeek, E.; Porter, R.; Mikunda, T.; et al. (2012): Supporting early Carbon Capture Utilisation and Storage development in non-power industrial sectors. No. 12. Shaanxi Province, China: The Centre for Low Carbon Futures.

Styring, P.; Jansen, D.; de Coninck, H.; Reith, H.; Armstrong, K. (2011): Carbon Capture and Utilisation in the green economy: Using CO_2 to manufacture fuel, chemicals and materials. No. 501. The Centre for Low Carbon Futures 2011 and CO_2Chem Publishing 2012.