IEAGHG Information Paper 2018-IP35; Results from the CEMCAP Project

The CEMCAP project has recently released their last techno-economic evaluation of carbon capture technologies in the cement sector. As in previous reports, CEMCAP shows their assessments transparently, giving the opportunity of comparing those with available literature and IEAGHG results. Four different CO_2 capture technologies were investigated in CEMCAP: oxyfuel, chilled ammonia, membrane-assisted CO_2 liquefaction, and calcium looping. CEMCAP modelled those technologies for one reference plant.

As we commented in our recent report "Cost of CO_2 capture in the industrial sector: cement and iron and steel industries", the economic evaluations are dramatically influenced by the selected economic parameters, the process design and the source of steam/electricity. We presented in GHGT-14 the differences found between the cost methods included in the available literature, which will impact on the final results. The results from the CEMCAP project are showed as Total Plant Costs, calculated through an aggregation method. The selected key economic parameters are: the specific primary energy consumption for CO_2 avoided (SPECCA); cost of clinker; and cost of CO_2 avoided. The inputs for the economic calculations are from simulations validated with experimental results.

Comparing the parameters used in CEMCAP and IEAGHG reports, firstly, it must be considered carefully that the first is showing results in €$_{2014}$ while the second one is using \$$_{2016}$ as currency. The capacity factor varies from 91.3 to 85% and discounted cash flow rate from 8 to 10%, in CEMCAP and IEAGHG reports respectively. The raw meal price is slightly different, and the natural gas price varies from 6 to 9 €/GJ. The price of electricity is lower in CEMCAP, 58.1€/MWh compared to 90 \$/MWh in the IEAGHG report, while the cooling water is slightly more expensive, 0.39€/m^3 compared to 0.25\$/m^3. The maintenance cost is slightly different, 2.5 compared to 2.4% of TPC, and the maintenance labour cost is 40% of the maintenance cost (1% of TPC) compared to the 1.6% of TPC in the IEAGHG report.

A common topic of discussion when assessing the CO_2 capture technologies is the contingencies, both process and project contingencies. In IEAGHG (2018), the process contingencies were considered zero, based on the assumption of assessing a Nth-of-a-kind plant (NOAK). The project contingencies were a function of the level of detail on the design of the technology, dependent also on the maturity level. In the CEMCAP report, the process contingency has been divided in two sections, one dependent on the maturity of the technology and another one dependent on the level of detail of the equipment list. There are differences between the assigned process contingencies between the technologies. For example, while oxyfuel, chilled ammonia process and calcium looping-tail-end technologies have been tested at small pilot plant scale, the process contingency due to maturity is 30, 20 and 20% respectively. Similar difference is observed for membrane-assisted CO_2 liquefaction and calcium looping integrated EF, both concept at bench-scale data but with 40 and 60% of process contingency respectively. Moreover, in the CEMCAP analysis, few subsystems and associated process add contingency cost depending on the technology status. For the project contingencies, CEMCAP includes a factor as a function of the Total Direct Costs (TDC). In their previous report (Deliverable 3.2 CEMCAP framework for comparative techno-economic analysis of CO_2 capture from cement plants) this factor was 19% of EPC.

In the CEMCAP project, the steam is imported from a gas boiler, and waste heat can be recovered (with an added cost) from the manufacturing plant to use in the capture system. Additionally, it is possible to sell the energy surplus (if any) to the electricity grid. From the IEAGHG report, we concluded that those integrations have an important impact on the economic evaluation, and mainly when assessing the chemical looping processes.

Regarding the CO_2 emissions, the emissions factor of the electricity grid is slightly higher compared to the IEAGHG report. While the CO_2 emissions from the cement production were fixed in the CEMCAP document, the IEAGHG report, due to its nature, was different, as it was considered a reference case per study selected. Consequently, the emissions varied per case.

In the CEMCAP report, five capture configurations were evaluated for each technology. Those are: Lower air leak in the mill; different capture rate; CO_2 prepared for transport by ship; and steam imported from a near coal CHP plant. For further information in those scenarios, we recommend to see the CEMCAP report.

Some conclusions were extracted, as included in the table below. As CEMCAP pointed out, it is difficult to select the best capture technology without a site-specific study with evaluation of heat, energy and steam integrations, available space, electricity grid, amongst other factors. Moreover, economic evaluations are still dependent on the maturity level of the capture technology.

Conclusions from CEMCAP	Related comments in the IEAGHG report
Steam consumption is the main cost in the chemical absorption process (30%MEA)	In the cases evaluated in this review, capital costs were the highest contribution in most of the cases. Perhaps, the review of the CEMCAP case showed that the capital costs and energy contribution were comparable. In the scenario of absence of waste heat to recover for the capture process, energy costs became more significant.
Oxyfuel is the cheapest technology	It was difficult to extract which technology was the cheapest configuration. The IEAGHG document is a technical review to homogenise cases from the literature. Calcium looping appeared promising but also based on selling electricity to the electricity grid. In the scenario where there is no waste heat available for the capture process, membranes and oxyfuel were promising. Perhaps, as CEMCAP also concluded, it still depends in many factors and the evaluation must be site-specific.
The membrane-assisted liquefaction technology is the most expensive	The membrane-assisted liquefaction technology was not included in the IEAGHG review. The most expensive configuration was the hybrid arrangement (indirect calcination combined with traditional chemical absorption with MEA) but very little information is included in the literature. More cases and experience are needed.
Both calcium looping arrangements generate a significant amount of electricity, providing some revenue to the entire process and decreasing the CO_2 avoidance cost	The costs of CO_2 avoidance in calcium looping arrangements was found to be dependent on the heat integration and revenue from selling electricity to the electricity grid. As also CEMCAP indicated, it would be site-specific.

In conclusion, CEMCAP is a good source of information, not only from an economic but also from a technical perspective. We are looking forward to seeing the next steps of this consortium.

Reference: Information about the CEMCAP project and deliverables can be found here: https://www.sintef.no/projectweb/cemcap/

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