2019-IP04: CCT2019- Session on hydrogen production with CO_2 capture

The interest on cutting down CO_2 emissions in coal power plants is growing and, if combined with hydrogen production, that could result in an improved business case.

During the CCT-2019, I enjoyed attending a couple of presentations linked to hydrogen production in integrated configurations with CO_2 capture: a presentation given by Yoichi Takahashi on the NEDO's IGCCS demonstration project, and the results showed by Ruby Ray on a comparison of storage options for two arrangements of IGCC with carbon capture. The information presented and further references are included below.

NEDO's IGCC Demonstration Project

The New Energy and Industrial Technology Development Organization (NEDO), along with Osaki CoolGen Corporation is carrying out a demonstration project on a coal power plant based in Osakikamijima-cho in the prefecture of Hiroshima.

This project is carried out in three phases. The first phase aimed to demonstrate an oxygen-blown integrated coal gasification combined cycle. It operates a 1,300°C-class gas turbine by converting pulverized coal into gas in a gasifier and simultaneously operate a steam turbine using the heat generated from the gas turbine and the gasifier to generate electricity. As seen in previous IEAGHG technical studies, flexibility is key to integrate new systems in the electricity grid (for further information, see IEAGHG study 2017-09 "Valuing flexibility in CCS power plants"). During the first phase of the NEDO's IGCCS project, flexibility tests were carried out, based in loading changes. The successful results included: a net thermal efficiency of 40.8%, low emissions of pollutants (SO_x, NO_x and particulate), flexibility on the coal type, and stable operation. More than 5,000 hours of operation time were accumulated, with more of 2,000 at continuous operation.

The second phase combines that technology with a CO_2 capture facility for then, in the third phase adding a Solid Oxide Fuel Cell (SOFC, for further information on this technology, please see the IEAGHG study 2019-03 "Review of fuel cells with CO2 capture for the power sector").

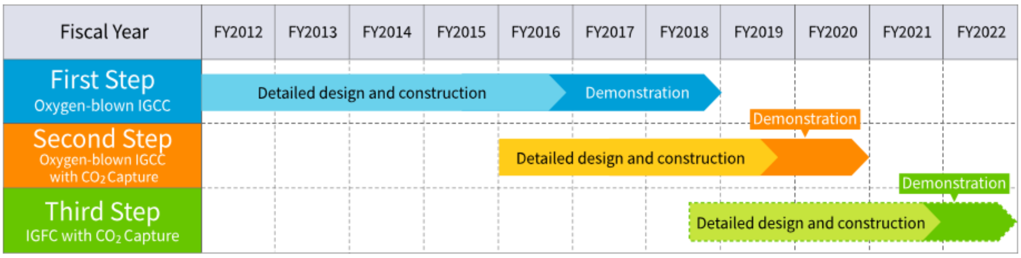

Figure 1 Timeframe of the NEDO's demonstration project [1]

The figure above shows the timeframe of each phase. The first phase ended at the end of 2018 with the demonstration of the oxygen-blown integrated coal gasification combined cycle. The construction of the CO_2 capture system has been finalised and tests will start soon. Regarding the capture system (see figure below), a physical absorption (low temperature catalyst) was selected to capture 90% of the CO_2 contained in the syngas produced in the IGCC facility. The goal is to maintain a 40% efficiency (net HHV).

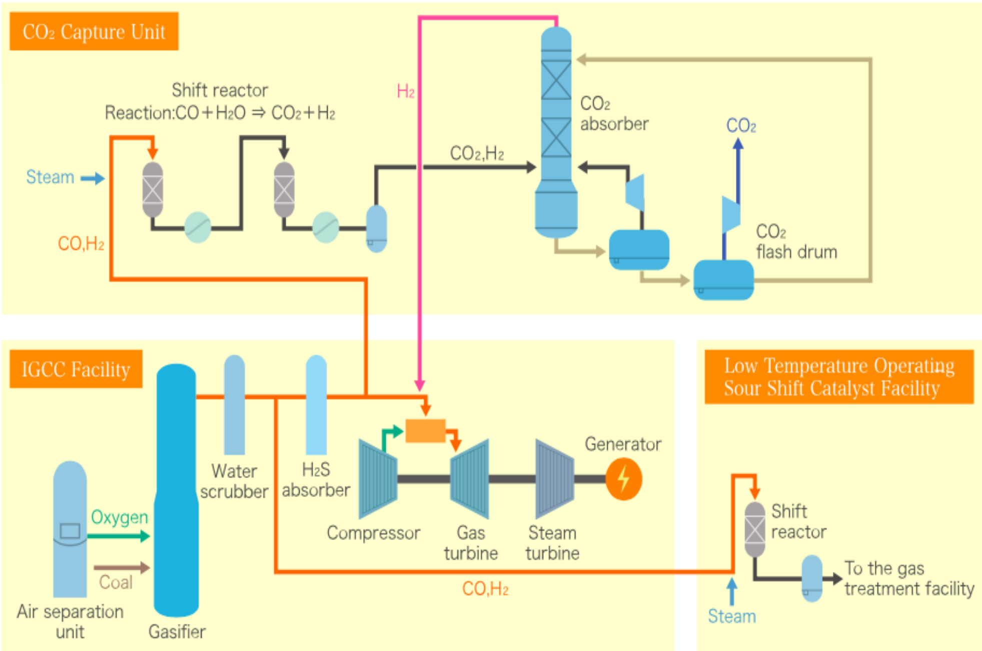

Figure 2 Configuration of the IGCC and CO_2 capture units [1]

The final target of this project includes reaching a 47% efficiency (net HHV) while capturing 90% of the emitted CO_2 (obtaining a 99% pure CO_2) in a 500 MW class commercial unit.

We are looking forward to seeing the results soon.

References:
[1] https://www.osaki-coolgen.jp/
[2] https://www.nedo.go.jp/english/news/AA5en_100195.html

A Comparative Assessment of the Techniques Available for the Underground Storage of Hydrogen- and Methane-Rich Gases for Power Generation

Following the NEDO's presentation, Ruby Ray, from WOOD, presented the results from their comparative study on producing fluegas in an IGCC with carbon capture, and storage it in underground salt caverns for flexible power generation.

Two cases were considered: methane-rich gas production through the VESTA process, and hydrogen-rich gas production via gasification. The first option, based on the VESTA process, results in the production of a methane-rich gas with similar composition and energy density to substitute natural gas (SNG). Using SNG, it is expected an easy integration on the IGCC because it can be used in any gas turbine, and it is not needed to include a dilution step or NO_x cleaning. However, the capture rate is lower than in the hydrogen production case via coal gasification with oxygen and shift reactions, and acid gas removal through physical absorption.

It is interesting to analyze the gas composition of the resulting gases in both arrangements. In hydrogen option, a H_2 purity of 92.4% (mol/mol) is reached, with a 4.6% CO_2 concentration. Regarding the SNG option, a CH_4 purity of 95.4% (mol/mol) is obtained, with a 3.3% of N_2 content. The SNG has an energy density of 35.6 MJ/m^3, compared to the 9.6 MJ/m^3 of the hydrogen-rich gas.

The next step within this analysis was to review the underground storage in salt caverns, solution-mined cavities within salt domes or salt beds. This practice is common, for example, for H_2 storage in the Teeside in UK, and SNG storage worldwide. The buffer storage will support the flexibility of the IGCC. The thickness and depth will be key to define the salt cavern size, which will impact on the storage pressure, operating pattern and the gas volume to be stored.

Three operation schemes were studied for both options, hydrogen and SNG: steady state operation, diurnal operation regime, and seasonal operation regime. The results indicated that the SNG option had a higher plant efficiency, with a lower capture rate, 67% compared to the 90% showed by the hydrogen scheme. Under steady operation, the SNG system cost (as total plant cost) is approximately 14% higher than that in the hydrogen scheme, but its exportable MW cost is lower. This difference increases in the diurnal regime. However, the total plant cost in the seasonal regime is lower in the SNG scheme than in the hydrogen case due to the significant difference on the construction of additional salt caverns (85 compared to 13 in the SNG case).

In conclusion, the conversion of coal to SNG seems a cheaper option than gasifying coal to obtain hydrogen, comparing both cases for gas storage in gas caverns for flexible operation. However, it is important to keep in mind the capture rate for a complete evaluation of the value of each option instead of focusing only on the energy production cost. In this regard, the gasification scheme captures a 23% more CO_2 than the SNG case, what could impact under specific financial structures.

References:
[3] Ray, R., and Skinner, G., "IGCC with Carbon Capture: a comparison of the storage option", Modern Power Systems, Vol. 34, p 16-20 (2014).
[4] VESTA process: https://www.woodplc.com/news/2016/successful-pilot-for-amec-foster-wheelers-vesta-once-through-methanation-technology

Hydrogen, if produced through low carbon processes, can become an alternative to fossil fuels. We have predicted a fast advance on fuel cells in the coming years and, based on two large demonstration projects, that can become a reality soon. Flexible operation is key to integrate new energy production systems in a complex electricity grid, and the value of new technologies must be assessed covering not only cost but also the CO_2 reduction potential, integration and flexibility. Those studies provide additional options to decrease CO_2 emissions in coal power plants, which can offer a viable solution for countries with high dependency on coal.

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