Sinopec Zhongyuan Oil Field Company Refinery CCS-EOR Project

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Abstract

1. Introduction and background

In recent years, China has made significant progress in the development and demonstration of carbon capture and storage (CCS) technology. The number of pilot projects and the number of planned large scale projects have been on the rise. The Chinese government has included CCS as an important emission reduction technology in many of its policy documents.

Sinopec, as China’s largest refiner and a Fortune Global 500 company (ranked No.2 in 2015),¹ has made extensive efforts in CCS development and demonstration. Zhongyuan Oil Field Company is a wholly-owned subsidiary of Sinopec. In recent years, oil production has become increasingly difficult with conventional oil production technologies. CO₂-EOR has been proven as an effective measure to increase oil production for this oil field. With more stringent requirements on carbon emissions and the needs of CO₂ for enhanced oil recovery in the oil field operations, Sinopec approved the CCS-EOR project in October 2013. The CO₂ is captured from the fluidized catalytic cracker (FCC) flue gas at the company’s refinery in Liutun, Puyang, He’Nan Province in China.

2. Capture process description

The Zhongyuan refinery has a crude oil processing capacity of 1.20 million tonne per year. Its fluidized catalytic cracking process includes an air compression unit, catalyst riser, regenerator and other auxiliary units. The regeneration of FCC catalyst produces large amount of CO₂.

The capture system has a capacity of 100,000 tonne CO₂ per annum (tpa). It uses an amine-based solvent process to capture CO₂ from FCC flue gas. The project started construction in September 2014, and it was successfully commissioned on 30 June 2015. The carbon capture system includes:

- 1 x Absorber (51 m in height)

- 1 x Stripper
- 2 x CO₂ Compressor
- 2 x Ammonia Refrigerator
- 2 x Spherical storage 650m³
- Loading dock

The flue gas coming out from the FCC unit has a flow rate of 65,000 Nm³/hr. This gas stream goes through De-NOx, dust removal, and De-SOx processes before entering the carbon capture unit. The capture unit employs a conventional amine-based solvent process. Captured CO₂ (12.50 tonne per hour liquid CO₂) is liquefied and stored in special tanks. Liquid CO₂ is then transported for EOR by cryogenic trucks and storage in nearby oilfield.

3. Project cost

The total investment in the project to date has been RMB150 million (around US$22.76 million, assuming 1 USD = 6.59 Chinese Yuan). By comparison, the 120,000 tpa carbon capture project of Huaneng Group in Shanghai Shidongkou No. 2 Power Station had a budget of RMB159 million back in 2009.² The Petra Nova Project (CCS-EOR) in the United States has a budget of US$1 billion and the project captures 1.6 million tpa CO₂. It should be noted that these numbers are for total project investments, and are not just for capture the system.

Table 1 CCS project cost comparison

<table>
<thead>
<tr>
<th>Project</th>
<th>Gross Investment, million USD</th>
<th>Capture capacity, tonne per year</th>
<th>Capture capacity tonne per day, (TPD, assuming 350 days operating)</th>
<th>Specific capital (USD/(TPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petro Nova</td>
<td>1,000</td>
<td>1,000,000</td>
<td>4,571</td>
<td>218,750</td>
</tr>
<tr>
<td>Huaneng Shanghai Shidongkou</td>
<td>22.13</td>
<td>120,000</td>
<td>343</td>
<td>70,372</td>
</tr>
<tr>
<td>Sinopec Zhongyuan FCC</td>
<td>22.76</td>
<td>100,000</td>
<td>286</td>
<td>79,660</td>
</tr>
</tbody>
</table>

Note: the scope of the gross capital investment is not clear and thus the capital cost can only be used as an indicative parameter, instead of an accurate costing.

Industrial capture, due to its higher CO₂ concentration and higher technology maturity, often incurs lower capital investment. Unsurprisingly, this has proved to be true for this project. It is noted the converted currency value may not truly reflect the actual purchasing power and certain project cost items are relatively lower in China.

4. Performance & Challenges

Based on the operation data since commissioning, the project has achieved significant environmental, social and economic benefits.

The project resulted in a SO₂ reduction of 90%, NOx reduction of 70%, and substantial dust reductions. The emissions meet the high standards established by China Environment Protection Act 2015 revision. Further, the project achieved permanent storage of CO₂ and thus greatly reduced the FCC unit carbon footprint which carries significant environmental and social benefits.

In terms of economic benefits, revenue comes from the oil field as the captured CO₂ is sent to nearby oilfields for EOR. Without the CO2 captured as a result of this project, Zhongyuan Oil Field Company needs to purchase CO₂ at RMB390 per tonne. This project generates a saving of RMB39 million per year (based on 100,000 tpa injection). A few assumptions were taken for the calculation:

- 1 tonne oil requires the injection of 3 tonne CO₂
- Crude oil price of US$40/barrel,³
- Exchange rate: US$1=RMB6.59
- Oil tonne to barrel: 1 tonne = 7.33 barrel

Revenue from increased oil output may then be readily calculated as follows:

- Oil production: 33,000 tonne oil per year
- Revenue: US$9,675,600 (RMB63,762,204)

5. Conclusions

This Sinopec project has demonstrated that carbon capture for FCC flue gas can be both technically and economically feasible. It is important for early mover CCS projects to identify the social, economic and environmental benefits of CCS projects. The experience gained from this large pilot project improves the expertise and confidence of stakeholders so as to accelerate the implementation of larger scale CCS projects in the future.

³ The Chinese government sets a price floor of US$40/barrel as of 12 January 2016.