INITIAL CCS IMPLEMENTATION IN CHINA: SCHEMES DESIGNING AND ASSESSMENT

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Overview

As a new means of CO_2 emission reduction, carbon dioxide capture and storage (CCS) has receiving more and more attentions, especially in EU and US. These countries took CCS as an important part of their future energy strategy and carbon reduction portfolio. As the largest producer and consumer of coal in the world, China is facing tremendous pressure in CO_2 mitigation. Due to China has huge geological storage potentials and abundant coal reserves, combining coal-fired power plants with CCS has been considered as one way to solve the paradox of soaring energy demand and environment protection by Chinese government and academics. CCS consists of three parts, which are CO_2 capturing, CO_2 transportation and CO_2 storage respectively. Moreover each part has several alternative technologies in varies stages of maturity. Thus a fully integrated CCS system is the combination of CCS technologies of the three parts. However, there is still little experience in whole process CCS chain implantation, and CCS has yet to reach the stage of commercialization. In order to find the optimal combination, some developed countries have proposed several CCS schemes and carried out some pilot and demonstration projects. But for China, CCS is still in the initial stage, and the integrated implementation schemes and technology roadmap are unclear. For the purpose of figuring out the most suitable integrated CCS schemes for China, we designed four CCS chains according to China's reality and assessed each chain from the aspects of economic benefits, net life-cycle emission reductions and extra energy consumptions.

This paper is organized as follows: firstly by analyzing China's energy structure and CCS technology reserve, four CCS integrated implementation schemes were designed. Secondly, we developed a system dynamic model to determine system behaviors in an integrated CCS system, as well as to calculate the net life-cycle emission reductions, NPV and extra coal consumptions of each CCS chain. Thirdly, based on the simulation results, by dynamic MAUT model, the above four CCS implementation schemes were ranked in different climate policy scenarios. Finally, the conclusions were discussed.

Methods

System dynamics approach, dynamic MAUT ranking model.

Results

First, according to China's energy structure and generation technology, super-critical pulverized coal (SCPC) plant is proved to the best type for CCS retrofitting, and integrated gasification combined cycle (IGCC) plant is the best choice for new building CCS. On the other hand, deep saline aquifer (DSF) has the greatest storage potential and enhanced oil recovery (EOR) has extra business profits, so DSF and EOR are considered to be the main options for CO_2 storage. Therefore four CCS chains were designed, which are SCPC+DSF, IGCC+DSF, SCPC +EOR and IGCC +EOR.

Second, as Fig 1 showed, the net life-cycle emission reductions of different schemes varied. For those using DSF storage, they can avoid about 70%-80% of total chain emission. For those using EOR storage, they can only avoid only about 35% due to CO_2 breakthrough and additional CO_2 emissions in oil production. Fig.2 and Fig.3 showed that without subsides or revenues from oil production, the NPV of CCS schemes using DSF storage is fall from -5.8 billion yuan to -1.9 billion yuan, and the cost of CO_2 avoidance is around 35 yuan/t -100 yuan/t. Moreover, in life span (25 years) of a CCS chain, the total extra coal consumption will reach 5-6 million tones, which means reducing one tone of CO_2 will consume 0.1-0.2 tons of coal.

Third, as a result of learning curve effect, the energy loss of the power plant will decrease gradually with the operation of CCS. Among these schemes, SCPC+ DSF has the largest learning potential (Fig. 4).

Fourth, through scheme ranking (Fig.5), IGCC+DSF is proved to be the best scheme for China's CCS implementation, especially when climate policy becoming stricter. Moreover, in terms of CCS source-sink matching, IGCC is more suitable for matching with DSF, and SCPC is more suitable for EOR. Because in CO_2 capture sector, the cost of IGCC is much cheaper than SCPC, so in storage sector IGCC can afford DSF which has good performance in storage but has no extra profits.

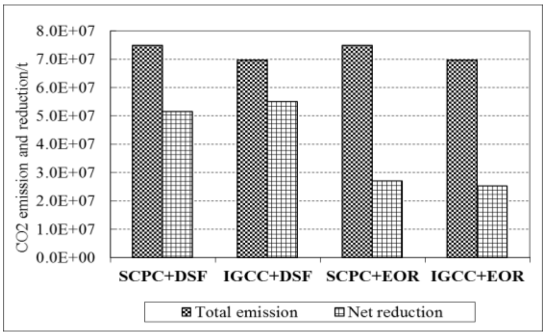


Fig. 1. Net emission reductions of each scheme

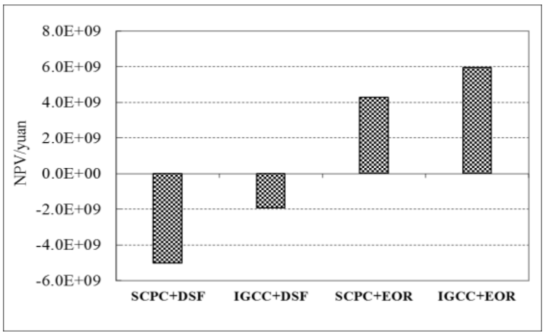


Fig. 2. NPV of each scheme

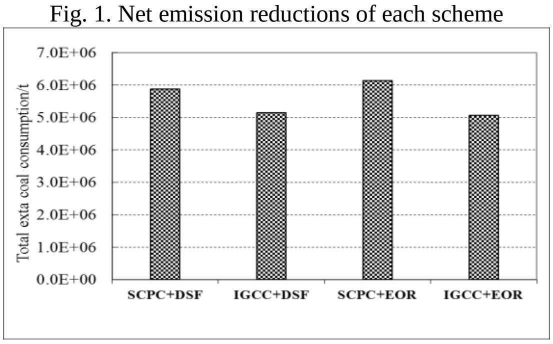


Fig. 3. Total extra coal consumption of each scheme

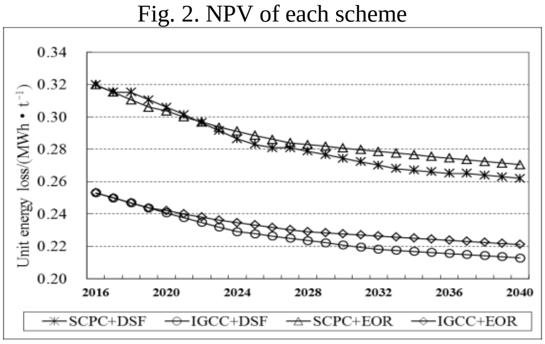
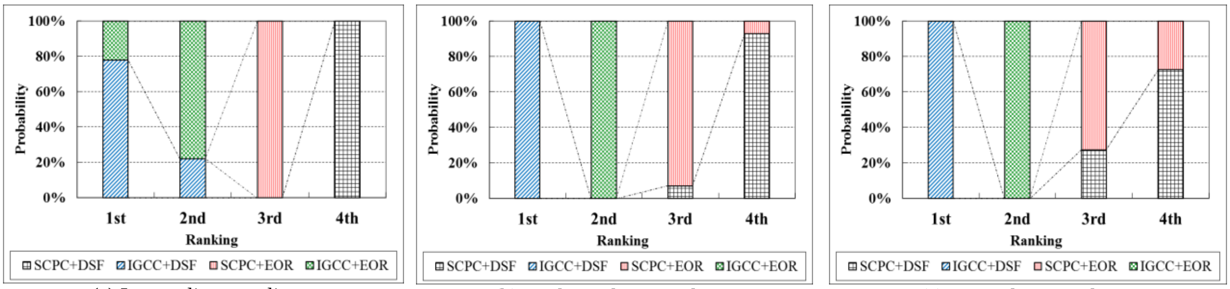


Fig. 4. Unit energy loss of each scheme



(a) Loose climate policy (b) Medium climate policy (c) Strict climate policy

Fig.5. Ranking situation of each scheme in different climate policies

Conclusions

In this paper, we designed four CCS chains as the alternative implantation schemes for CCS deployment in China and found out the optimal schemes in different climate policy scenarios. The results showed that IGCC+DSF is the optimal scheme. In addition, for source-sink matching, IGCC is more suitable of DSF and SCPC is more suitable for EOR. Moreover, the schemes using DSF storage contributed a lot to CO_2 reduction, but the cost of CO_2 avoidance is very high. Those schemes using EOR storage were economically feasible, but their reduction effects were poor. Therefore in the initial stage of CCS deployment, China should consider combining DSF and EOR to reach a balance between cost and effect.

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