The Critical Role of Economic Assumptions in Cost-effectiveness Analysis of Power Plant CO_2 Capture and Storage

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Introduction

Decarbonization of fossil fuel power plant has been identified as a key enabler on the 2DS climate change trajectory; Carbon Capture and Storage (CCS) is an important technology for such fossil fuel power plant decarbonization. Although the technology readiness level of CCS has become mature, successful demonstration projects are quite limited. Low Cost-effectiveness has been the main reason for the low uptake of power plant CCS applications. Recently, many studies conduct cost-effectiveness evaluation of fossil fuel power plant CCS; interestingly, the results differ a lot. A closer examination would find that these studies deploy divergent assumptions, such as fuel price, CO_2 transportation cost; the following question is how these parameter uncertainties influence the power plant cost-effectiveness evaluation results and how could these analyses based on different assumptions be adapted to a consistent framework for comparison? In other words, global sensitivity of fossil fuel power plant CCS cost regarding to key economic parameters should be researched. Starting from here, we present a systematic analysis of the impact of key economic parameters on power plant CCS cost in this paper and point out how such impact should be addressed in future study.

Methods

Process flow sheet of typical Pulverized Coal (PC) and Natural Gas Combined Cycle (NGCC) power plant with CCS is simulated in the study, then surrogate model is established based on the simulation results of techno-economic model. Surrogate model is an approximation model that mimic the behavior of the simulation process as closely as possible while being computationally cheaper to evaluate. As a result, the cost of a CCS power plant under different parameter uncertainties could be quickly and accurately assessed. Through literature review, we obtain a parameter uncertainty range for the key parameters, see Table 1; seven key parameters are inspected, including fuel (i.e., coal and natural gas) price, bioenergy price, bioenergy heating value, CCS CPLEX, CCS OPLEX (CO_2 transportation and storage cost), capacity factor. Firstly, single-factor sensitivity analysis is conducted to inspect how one single factor change the overall CCS cost; then Latin hypercube sampling method is used to select representative points from the variable design space to conduct global sensitivity analysis. Finally, the CCS power plant generation cost is normalized based on global sensitivity analysis results.

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Results

The generation cost of typical PC and NGCC power plants with CCS are analyzed in the study. As shown in Fig.1, the generation cost of PC plant with CCS is 82$/MWh when all parameters are at baseline levels in Table 1. When there are uncertainties for all key parameters, the generation cost varies between 72-108$/MWh, the high end of PC CCS plant generation cost happens when carbon price is at its high end (i.e.100$/ton) whereas the low end happens when coal price is at its low end (i.e.20$/ton). Similarly, the generation cost of NGCC CCS plant varies from 87 $/MWh to 75-110 $/MWh, NGCC CCS power plant generation cost is highest when carbon price is highest (i.e.100$/ton) and is lowest when natural gas price is lowest (i.e.1.8$/MBTU). In terms of percentage variation, PC CCS plant generation cost is sensitive to the change of the aforementioned seven parameters in Table1 at 22%, 9%, 8%, 14%, 9%, 12%, 18% respectively whereas NGCC CCS plant generation cost is sensitive to same parameters at 19%, 8%, 8%, 16%, 10%, 11% and 20% respectively. Such results clearly show that the cost-effectiveness of fossil fuel CCS power plant depends on various parameters and it seems that no single parameter plays dominant role. As a result, if we desire to decrease the generation cost of a CCS power plant, all mentioned parameters should be deliberately set up to favorable levels as shown in Table 1, which is a non-

	500MW subcritical PC	600MW NGCC	Uncertainty range
Fuel price	42$/ton	2.6$/MBTU	20-60$/ton for coal; 1.8-3$/MBTU for gas
Bioenergy price	0.05$/ton	0.05$/ton	0.01-1.5$/ton
Bioenergy property	16.25MJ/kg	16.25MJ/kg	5-50MJ/kg
CCS CPLEX	1200$/kW	600$/kW	700-1500$/kW for coal; 400-800$/kW for gas
CO_2 transportation cost	2.2$/ton	2.2$/ton	0.5-10$/ton
CO_2 storage cost	3$/ton	3$/ton	0.5-10$/tom
Capacity factor	75%	75%	40%-90%

Table 1. Detailed configuration of typical PC and NGCC power plant models in the paper.

trivial task because the values of these parameters depend on many different factors which are not only technological, but also related to societal, political and behavioral factors.

Moreover, the impact of technology learning on the future PC and NGCC CCS plant is explored in the study. Technology learning rate could reflect the impact of technology learning on performance improvement of CCS technology. If there is carbon price at 10 $/ton, the generation cost of PC power plant with CCS would become 68 $/MWh, 65 $/MWh and 61 $/MWh when CCS learning rate is low, middle and high respectively, whereas the average fossil fuel power plant generation cost would be 64 $/MWh in 2050 (Fig.2). In such case, PC power plant with CCS would be economically feasible if the CCS technology learning rate is middle or high; however, the generation cost of NGCC power plant with CCS (e.g. 72 $/MWh at high learning rate) remains higher than the average generation cost, which means CCS integration with NGCC power plant is still economically infeasible at such carbon price.

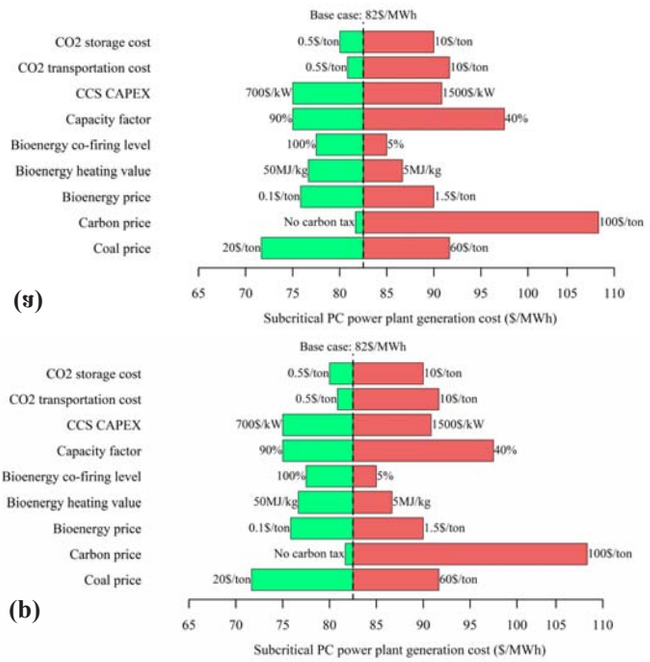

Fig.1 Effect of key parameters on power plant generation cost. Shown here are the generation cost of a typical (a) PC power plant and (b) NGCC power plant regarding to key parameter uncertainties.

Conclusion and future work

This study presents sensitivity analysis of fossil fuel CCS power plant generation cost regrading to key parameter uncertainties, including fuel price, bioenergy price, carbon tax, CCS CPLEX, CO_2 transportation and storage cost, capacity factor etc. We find that the generation cost of PC and NGCC CCS power plant could vary from 82 $/MWh to 72 $/MWh up to 108 $/MWh, from 87 $/MWh to 75 $/MWh up to 110 $/MWh respectively when key parameters change. The high end of PC and NGCC plant generation cost happens when carbon price is at its high end whereas the low end happens when fuel price is at its low end. The results show that making fossil fuel CCS power plant economic is nontrivial because it is related to various factors which are not only technological, but also related to societal, political and behavioral factors.

Opening Session Overview

By Machiel Mulder

The conference started with a welcome and opening remarks by Machiel Mulder (general conference chairman), Nienke Homan, Executive of the Province of Groningen, Gertjan Lankhorst (chairman New Energy Coalition, Groningen) and David Knapp (president of the IAEE).

The conference was kicked off by a concise opening session in which the delegates where welcomed on behalf of the organizers, sponsors and the IAEE. Machiel Mulder, as general chairman, explained why the organizers have chosen the conference theme "transforming energy markets'. Energy systems have to change in order to reduce the emissions of carbon, but in order to do this in an efficient way, markets also need to be transformed. In the conference the transformation of energy markets is being discussed in a large number of various types of sessions. He also mentions the contribution of many people and sponsors in the organisation of this conference.

Mr. Gertjan Lankhorst, chairman of the Energy Academy Europe, stressed the fact that economists need to contribute to the field of energy as we cannot leave this to engineers.

Mrs. Nienke Homan, regional minister of energy, said that policy makers are in need of careful economic scientific analysis to underpin their decisions.

Finally, Mr. David Knapp, president of the IAEE, thanked the organizers for all the effort they have put in to make this conference to a success.

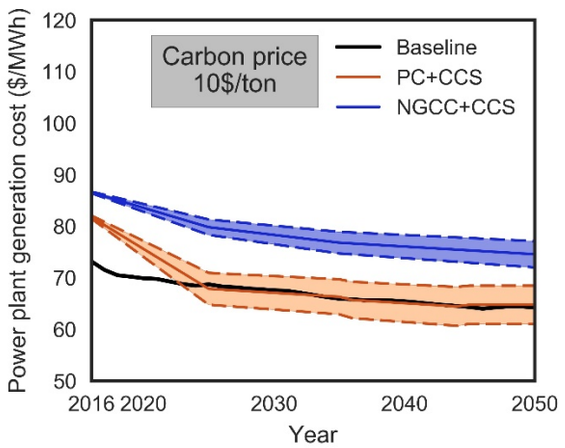

Fig.2 Impact of technology learning on the future cost of PC and NGCC CCS power plant under 10$/ton carbon tax.