INDUSTRIAL USE OR STORAGE OF CO_2? A COMPOUND REAL OPTIONS VALUATION FOR THE RETROFITTING OF COAL-FIRED POWER PLANTS

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Overview

In addition to fuel switching and energy efficiency improvements, carbon capture and storage (CCS) is expected to play an important role in achieving deep cuts in global CO_2 emissions. This efficient technology captures CO_2 from large emitters and transports it to a suitable geological reservoir (e.g., saline aquifers, salt caverns, and depleted gas fields) for permanent storage. Thus, it is worth considering CCS retrofitting, given the enormous amount of CO_2 emitted by power plants during their long lifespan. Although savings on CO_2 allowances from stored CO_2 incentivizes CCS retrofitting, the heavy investment burdens, geographical restrictions, and social acceptance issues challenge a widespread implementation.

Captured CO_2 can have many uses in various industries, from sparkling beverages to urea production, and thus does not necessarily have to be permanently stored. In light of recent breakthroughs in catalysts, methanol (MeOH) synthesis using hydrogen (H_2) and captured CO_2 as feedstock is drawing growing attention as a carbon capture and utilization (CCU) case (Ravikumar et al., 2020). On the one hand, as a versatile chemical with high economic values, MeOH has the potential to generate profits that offset the investment costs of CCS retrofitting. On the other hand, MeOH synthesis provides a possible intersection for CCU and power to gas (PtG), if the H_2 used is produced from renewable energy via water electrolysis. Moreover, liquid MeOH serves as a better medium for energy storage and fuel for transportation than gaseous H_2. Several pilot plants have been put in place to demonstrate the economic feasibility of CCU MeOH production. The largest of these is the MefCO_2 project in Germany, which produces one ton of methanol per day.

Since neither CCS retrofits nor CCU MeOH production has been deployed on a large scale to date, the question is how they would interact with each other once they both become commercially available. Real options analysis (ROA; see Dixit & Pindyck 1994), which considers price uncertainties and management flexibility, is an appropriate method to investigate this question. Several authors have conducted ROA to study the profitability of investment in CCS retrofits. Heydari (2010) analyzes a coal-fired power plant that has the discretion to invest in a full or partial CCS unit, modeling the CO_2 allowance price and the coal price as correlated geometric Brownian motion (GBM) processes. She concludes that investment in either technology is optimal under current market conditions. Wang and Du (2016) further account for the learning effect and conclude that even a total subsidy is insufficient to induce an immediate investment in a CCS retrofitting project. Chen et al. (2016) study the effects of a governmental subsidy using least square Monte Carlo simulations. They show that subsidies ranging from 10 \$/MWh to 50 \$/MWh would put forward CCS investment in China. However, the existing literature has not determined whether the possibility of using captured CO_2 for CCU MeOH production can be expected to accelerates CCS retrofits and thus serves as a stepping stone to permanent storage.

Methods

In answering our research questions, we consider an opportunity for a power plant owner to sequentially invest in both CCS and CCU MeOH production facilities. The investor has managerial flexibility in (i) how to proceed with the investment decisions and (ii) the subsequent real-time optimization, either selling MeOH at the market price or storing CO_2 for carbon credits after acquiring such a hybrid system. We apply Bertsekas' (1978) dynamic programming (DP) framework to tackle such a sequential investment problem.

Results

We find that CCS investments will be desirable in 2025 assuming there are low levels of uncertainty in the CO_2 price, given the currently high CO_2 price. Furthermore, we show that investments in CCU MeOH are economically unfavorable in the current environment. However, we provide some evidence that CCU MeOH has the potential to fully outshine CCS due to the high methanol price. Notably, we focus only on the economics of carbon capture, utilization and storage (CCUS) and MeOH production and neglect aspects of regulatory issues and technological progress. Nevertheless, we contribute to the existing literature by modeling a complete CCUS MeOH production system based on ROA.

Conclusions

In this paper, the profitability of CCUS and MeOH production for an existing coal-fired power plant is scrutinized using real options analysis. It is assumed that the investor has the discretion to decide whether and when to retrofit the power plant with a capture unit and store the captured CO_2 or use it for MeOH production. Uncertainty in electricity prices, CO2 permits, and methanol prices is taken into consideration as correlated stochastic processes. The expected value of investment opportunities is determined by employing a backward recursive DP algorithm.

First, the individual options to invest in CCS and CCU MeOH production is investigated separately. The option values, as well as the optimal investment thresholds, are determined using current market data and price scenarios provided by Öko-Institut (2014). Under the assumed model parametrization, we find that the critical threshold is $P_{(CO2)}* = 41$ €/t, indicating that the current high CO_2 price level already makes investments in CCS technology attractive. However, the investment opportunity is very sensitive to changes in volatility and investment costs. Policymakers should, on the one hand, reduce the uncertainty in the CO_2 price through consistent and rigorous climate policy, if they render to reduce CO_2 emissions through CCS retrofits. On the other hand, financial support should be provided. Otherwise, CCS would remain recommended only for geographically well-positioned power plants.

The individual option to invest in CCU is, unsurprising, deep out of money. The price of methanol and hydrogen are identified as the most important factors that influence the profitability of CCU MeOH production. Investment costs and the opportunity costs of the losses in electricity sales caused by the retrofit are trivial compared to the huge profits that methanol sales are liable to generate. Also, the base case study reveals that the critical threshold for investing in CCU is P_{me}*=680 €/t. Otherwise, the price of hydrogen ought to drop below 1250 €/t to prompt investment in CCU. Also, we assume that the power plant owner can invest in CCS and CCU MeOH production in a sequential manner. After the owner invests both, the power plant can operate in two modes, namely storage and utilization. The main conclusion is that combining CCS with CCU MeOH production increases the overall investment probability and the potential for larger profits. However, the additional value is debatable as it stems from the uncertainty in the price of methanol. Since methanol is far more valuable than CO_2, it is very likely that CCU will dominate the value of the compound option once the market conditions become favorable (e.g., the price of hydrogen falls dramatically).

In summary, we conclude that CCU MeOH production will only accelerate CCS retrofits if the price of hydrogen decreases sharply. However, in that case, MeOH production, with its vast revenues, may outstrip carbon storage. It is therefore questionable whether CCU methanol production is a stepping stone to the permanent mitigation of CO_2 emissions.

Future work could aim at relaxing some of the assumptions adopted in this study. Decommissioning of the facilities, for instance, including the power plant itself, is an important aspect but disregarded in our analyses. Another caveat is that we only considered the price uncertainty and used a constant hydrogen price throughout the planning horizon. The technical specifications and the cost parametrization used reflect the current state of knowledge, and we did not consider learning factors for emergent technologies. Finally, the model used in this paper can be applied to similar investment problems faced by other CO_2 producers, or it can be extended to include market competition.

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