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INFLUENCE OF CO_2 CERTIFICATES ON THE INVESTMENT IN COAL-FIRED POWER PLANTS WITH CARBON CAPTURE AND STORAGE: A REAL OPTIONS ANALYSIS

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OVERVIEW

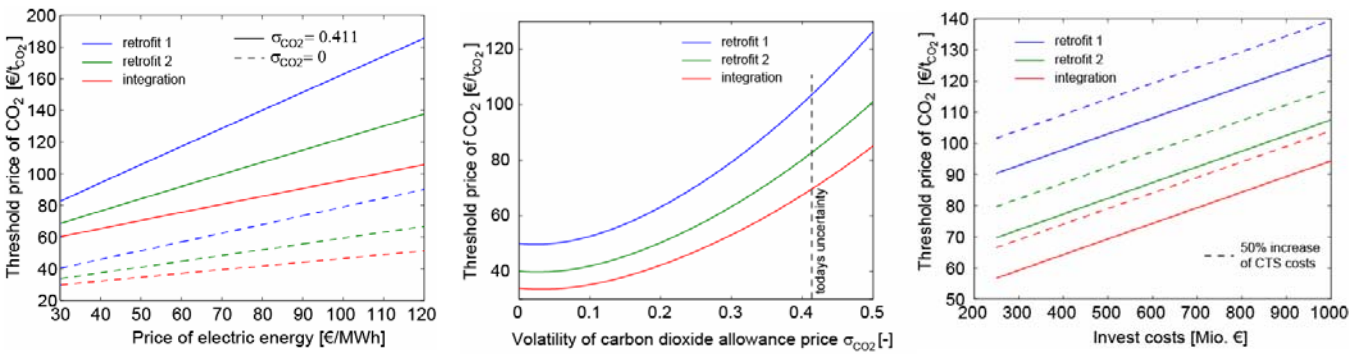
The increasing demand for electrical energy, the nuclear power phase-out, and the age pattern of the German power plant portfolio provoke investments in new electricity generation facilities within the coming years. Today, hard coal and lignite provide a major part of electricity supply because of their moderate electricity production costs but at the expense of high carbon dioxide emissions. The introduction of a price for these emissions influences investment decisions. Carbon capture and storage (CCS) is widely seen as a major opportunity to continue fossil fuel-based generation, providing an option for investors to avoid the acquisition of CO_2 certificates but at the expense of higher specific investment costs and lower net efficiencies. The IEA's World Energy Outlook 2008 [1] predicts 160 GW of worldwide CCS coal capacity in operation by 2030, even in the conservative 550 ppm CO_{2e} scenario. This ambition can only be realized if CCS is technically mature, economically sound, and socially accepted. Recent power plant designs [2] show a decrease in the net efficiency loss to only 7.8% for a post combustion process, reducing the efficiency of state-of-the-art plants from 46.9 % to 39.1 %. Furthermore, the opportunity to retrofit existing power plants allows the postponing of CCS investments causing lower net efficiencies and higher investment costs compared to greenfield CCS power plants. From an economic point of view, the revenues gained from the saved CO_2 certificates must exceed the costs of capturing, transporting and storing CO_2 and the opportunity cost of the unsold electrical energy caused by the reduced net efficiency. Previous studies [3] predict that a certificate price higher than 45 €/t_{CO2} in 2015 is required to run CCS cost-effectively. The focus of our study [9] is the influence of uncertainty in the certificate price, indicated by the wide spread of CO_2 price scenarios given in the literature [1], on the investment decision regarding CCS technology. The project's uncertainty calls for a risk premium that increases the threshold value of the certificate price at which investments are conducted. Furthermore, we investigate the economic advantage, expressed by the expected rate of return, for pre-investments needed to make a power plant 'capture-ready'.

METHODS

To analyze the capital asset of CCS, we use a real options approach in continuous time [4], based on the option to wait [5], with a fictitious investment constructed from the difference of a CCS and a conventional coal-fired power plant. The model considers three assets: the certificates, the electric energy and the variable costs of capturing, transporting and storing (CTS), eventually aggregated to one single asset. All assets are afflicted with different levels of uncertainty and weighted by the technology used. Assuming Geometric Brownian Motion processes for all prices an analytical solution for a three-factor model is given, allowing not only individual escalations and volatilities, but also correlations between the assets as it is observed for the electric energy and the CO_2 certificate price [6]. This model formulation leads to a three-dimensional stochastic process, where the threshold value P^*_{CO2} at which an investment should be undertaken depends on the two other variables. The border between the regime of waiting and investing becomes a plane within the three-dimensional space. Parameters for the certificate and electric energy price estimated from historical data [6] are used to represent current market conditions. The asset-dependent discount rate is calculated by means of the Capital Asset Pricing Model (CAPM) and using the German stock market (DAX) as a reference. The DAX is also used to determine the market price of risk. Initially, we performed parameter variations, varying the certificates escalation and volatility as well as the price of electricity and the correlation between the two assets. Here three different CCS options [2] with different losses in net efficiency (retrofit 1: 16 %, retrofit 2: 11% and integration: 7.5 % points) are compared. The variable costs of capturing, mainly caused by degeneration and volatilization of the washing agent, sum up to 4.8 €/t_{CO2} (MEA). For pipeline transport [7] and storing in Deep Saline Aquifers in Europe [8] we assume 7 €/t_{CO2}. Because increasing certificate costs go along with increasing prices for the electric energy, the threshold value P^*_{CO2} changes towards higher prices over time. To estimate the expected date when CCS becomes economical we simulated the tree-dimensional price development in time.

RESULTS

The simulation results show in case of certain certificate prices (σ_{CO2}=0) and an integrated post-combustion carbon capture process that CO_2 prices between 32 €/t_{CO2} and 35 €/t_{CO2} are necessary, if the price of electrical energy is in the range of 40 €/MWh to 50 €/MWh (Figure 1). For retrofit options the threshold value is higher because of an increased loss in net efficiency. In case of retrofit 1, with the same assumed efficiency loss as in [3], 45 €/t_{CO2} to 50 €/t_{CO2} are required. Incorporating risk (σ_{CO2}=0.411), we observe more than a doubling of the CO_2 threshold price. Figure 2 demonstrates the influence of the certificates' price volatility, measured by σ_{CO2}. Low volatilities, at about σ_{CO2}=0.1, do not increase the threshold value significantly, but instead might even reduce it. However, a further rise in volatility leads to strongly increasing certificate prices. The dependency of the threshold price on the investment costs is calculated incorporating risk. Additionally, we investigated the influence of a 50% increase in the CTS costs. All curves show the same dependence on the investment costs: For all options, decreased investment costs of €300 million are worth about 16 €/t_{CO2}. The increased CTS costs (+5.3 €/t_{CO2}) require certificate prices that are about 10 €/t_{CO2} higher. Finally, we investigated a three-dimensional price development showing that investments in CCS might be realized in the next 20 years only if the certificate price is known a priori (no price risk).



CONCLUSIONS

In addition to the cost of CCS, caused by the loss in net efficiency and the variable cost of capturing, transporting ans storing, we found major costs of uncertainty. The carbon dioxide market over the last few years was characterized by a high volatility that - if it continuous like this, prevents investment decisions in favour of CCS. The aim of the established certificate market to achieve CO_2 abatement at the lowest economic costs does not seem to be accomplishable with the high level of uncertainty actually observed in the market. Furthermore, a positive impact of uncertainty on the investment decision is seen in the range of $\square_{CO2}<0.05$ that is caused by the correlation between the electric energy and the certificate price. Here, uncertainty lowers the value of waiting and reduces the threshold value. The fact that increased CTS costs require disproportionately higher certificate prices is also caused by the high uncertainty in the CO_2 price.

Additionally, the results point out that the value of facilities with enlarged net efficiencies increases not only by higher electric energy prices but also by excessively high levels of uncertainty.

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