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Assessment of clean-coal strategies: The questionable merits of carbon capture-readiness

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ABSTRACT

In this paper we investigate the value of capture-readiness by modeling the cost effectiveness of various alternative technological options and focusing on different clean-coal technology pathways. The modeling framework developed is based on stochastic net present value calculations. It allows for consideration of path-dependent and technology-specific risk combinations inherent in the input and output commodities that are relevant for operating the plant. We find that capture-readiness competes with alternative options of power plant replacements and that capture-readiness is not necessarily preferable from an economic perspective.

1. Introduction

Carbon capture and storage (CCS) is seen by many international organizations [14,38], the European Commission [6], and on national levels [26] to play a major role in reducing carbon dioxide emissions. In recent years, many performance and cost studies of new coal- and gas-fired power plants have been conducted [1–3,19,34]. However, the technology is either not yet commercially available or not economically reasonable for the large-scale coal-fired power plants that are built today. At the same time, many new coal-fired power plants of this kind are being built, and they will emit large amounts of carbon dioxide in the future. China, for instance, is expected to increase the capacity of its coal-fired power plants by 485 GW from 2008 to 2035 [4], which is an increase of about 150 percent compared to the estimated 557 GW of operating coal-fired capacity. Therefore, capture-ready power plants seem to be an attractive solution, enabling a later retrofit. This capture-readiness may include different investments, such as extra space for large utilities, a modified turbine with a throttling valve at the intermediate pressure/low pressure crossover pipe of the steam turbine section, additional foundations, cable trays, and pipe racks. The costs for those modifications are found to be less than five percent of the total investment cost of a coal-fired power plant [9].

The economic value of such capture-ready investments has to be investigated cautiously, because a modest increase in the investment cost translates directly into a few hundred million Euro. The major parameter influencing the value of capture-readiness is the time of CCS-retrofitting and the discount rate applied to the future cash flows. In order to determine the optimal time of retrofitting, it is important to account for alternative technical options available for switching from conventional coal-fired power plants to coal-fired CCS power plants. Such options compete with the retrofit of a capture-ready power plant and might be preferred, further delaying the necessity of retrofits of CCS-ready power plants and reducing the option value of capture-readiness. The lock-in of four specific retrofits (non-capture-ready and three different technical capture-ready configurations) were investigated in a recent study [17]. The authors found a non-significant impact of capture-ready pre-investments on the probability of a later retrofit (estimated to be around 50 percent). Another study investigates the economic value of retrofitting four Portuguese fossil fuel power plants with CCS [7]. Interestingly, they found a 50 percent higher break-even price of CO_2 (where the cost of electricity is equal for plants with and without CCS) for a power plant whose remaining lifetime is 30 years, compared to an old power plant whose remaining lifetime is only 17 years. This-at first sight-surprising result is caused by the very low efficiency of the old power plant that results in high

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specific carbon dioxide emissions. However, the authors do not account for an early closure of the power plant. Although the first-mentioned authors did account for an early closure of the power plant, neither studies accounts for the option of replacing existing plants by new CCS power plants.

For our analysis, we use an advanced net present value (NPV) modeling approach. In particular, we are interested in the optimal investment timing for the investment in alternative coal-fired power plants, given specific situations regarding the age of existing power plants and whether or not they were built as CCS-ready. Options considered in this study for investments after 2020 are (cf. Fig. 1): First, retrofitting a modern ($\eta = 47\%$) coal-fired power plant (capture-ready or non-capture-ready). Second, the replacement of older power plants with an efficiency of between 35 and 40 percent (including an early shut-down) and the construction of a new CCS power plant. Third, the early shut-down of a modern power plant ($\eta = 47\%$) and construction of a new CCS power plant. Although the third option seems at first sight pathetic, multiple serious justifications for this option do exist. The penalty in terms of a net efficiency loss of a new CCS power plant is, in general, less than the penalty in net efficiency of a retrofit. The attractiveness of a CCS retrofit decreases with the lifetime of the plant. Generally, just like with energy retrofits of buildings, the retrofit of the entire coal-fired power plant can sometimes be expected to be more expensive than a demolition and subsequent new build.

The fact that multiple alternatives to a capture-retrofit are preferred will delay the need for retrofits, further reducing its probability. In this study we do not consider more cost-effective alternatives to reduce CO_2 emissions, such as nuclear power plants for low-emissions base-load electricity [25] or renewable energies which also compete with electricity generation from fossil fuels [31]. The renewable technologies with fluctuating supply reduce the full-load hours of base-load power plants and render them less attractive [20].

The economic modeling is challenging, because of path- and technology-dependent risk stemming from the high price uncertainty of the underlying assets (e.g. electricity price, CO_2 permit price) as well as the correlation of those assets with each other. By describing the various investment options as combinations of those assets, the resulting investment risk becomes endogenous and technology-dependent.

The original contribution of this paper is twofold: On the one hand, we develop a new modeling framework that enables a comparison of different investment options by using endogenous, technology-specific, and risk-adjusted dynamic discount rates. On the other hand, the application of this modeling framework enables the determining of a merit order for the investment in clean-coal technologies in terms of (cumulative) probabilities of adoption.

In the analysis we show that the value of capture-readiness is highly questionable due to the competing investment options. We also demonstrate that in many situations it is preferable to shut down a modern coal-fired power plant ($\eta = 47\%$) and construct a new CCS power plant rather than to retrofit a CCS-ready power plant.

The remainder of this paper is structured as follows. Section 2 provides an overview of technical specifications and design requirements for capture-readiness, and reviews the existing literature on this topic. Section 3 introduces the modeling framework, while Section 4 reports on the underlying data and assumptions used. Section 5 presents the results and Section 6 concludes.

2. Aspects of capture-readiness

Capture-readiness is a term increasingly used, but often without clarity of meaning [5,22]. Studies and statements of various groups and organizations, such as the International Energy Agency Greenhouse Gas R&D Programme [15], the Global CCS Institute [8], and the European Power Plants Suppliers Association [5], have proposed definitions and technical requirements for capture-readiness. Moreover, the German technical inspection association TÜV has developed criteria with respect to the current state of knowledge and put together the so-called TÜV NORD Climate Change Standard TN-CC 006 [37].

Apart from definitions and legislative issues, the studies comprise technical specifications for new-build power plants that allow for and facilitate a later retrofit. Those specifications should lower the effort and the cost associated with a later retrofit of the power plant, reducing the overall CO_2 mitigation costs. The technical requirements, which aim at a reduction of the plant outage time during the retrofit and a high flexibility (e.g. by allowing to take advantage of technical improvements in CCS), concern among others the following (cf. [8,15]):

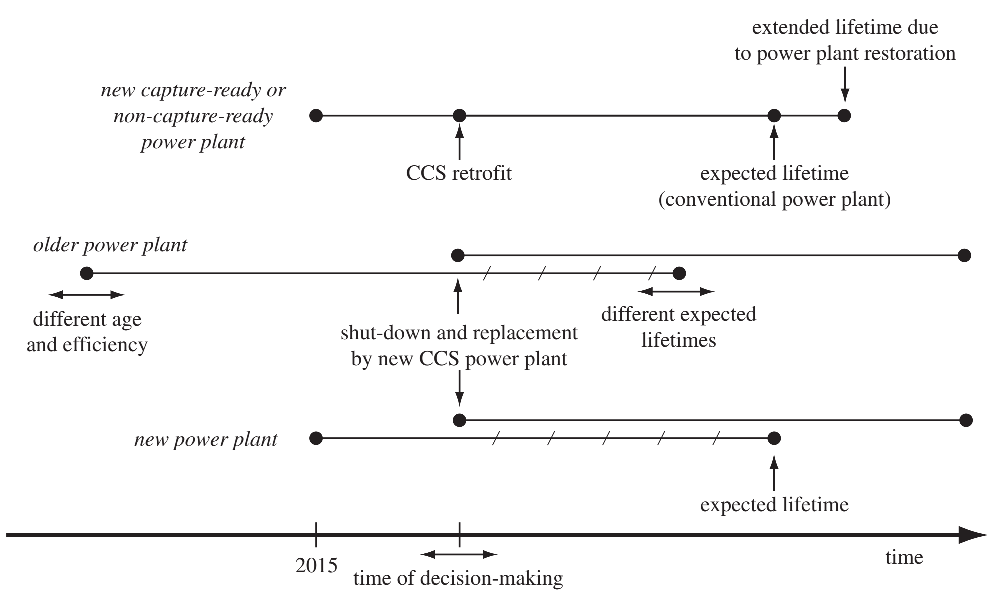

Fig. 1. Pathways from conventional coal-fired power plants to a clean-coal technology.