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Economic viability of biomass cofiring in new hard-coal power plants in Germany

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ABSTRACT

Biomass cofiring in coal power plants (with thermal contributions of typically 5–20%) is an interesting option to mitigate CO_2 emissions, since the additional costs are relatively minor and a secondary benefit is provided by the increased fuel flexibility. Worldwide, about 150 cofiring plants are in operation. In Germany, the electrical power potential for biomass cofiring in coal plants is about 28 TWh per annum, assuming a 10% replacement of coal combustion by biomass. In this paper, we study the economic potential of biomass cofiring in hard coal power plants in Germany. To this end, we identify suitable biomass input fuels, investment and operating costs, and the profitability of cofiring investments. In a sensitivity analysis, we check for the robustness of the results gained, and in a Monte Carlo simulation (MCS) uncertainties are explicitly taken into account. We find that both regional and international biomass supplies are relevant, and that the cost effectiveness of cofiring is strongly affected by the prices for biomass, coal and CO_2 permits, while investment and operating costs only have a modest influence. According to our calculations, electrical power generation costs attributable to biomass combustion for a plant put into operation in 2020 are between 70 and 75 € MWh^{-1}, while the average costs of biomass fuel from various sources and markets are calculated to be around 4.1 € GJ^{-1}.

1. Introduction

While coal is globally still very important for power generation it is also very CO_2-intensive. Biomass cofiring in coal power plants, with thermal contributions of typically 5–20%, depending on the technology involved and the type of biomass used, is an in many cases cost-effective option to substitute coal for biomass in electricity production, and thus to mitigate CO_2 emissions [1]. Another benefit of cofiring is the increased fuel flexibility. In Europe, cost-effectiveness has been enhanced further by the introduction of the EU Emissions Trading Scheme (EU ETS) [2].

Whereas typical conversion efficiencies of biomass-fired power plants are around 25%, average conversion efficiencies of conventional (sub-critical pulverized) coal-fired power plants are about 36% in OECD countries (state-of-the-art plants: ca. 46%). Hence biomass cofiring is an interesting way to convert biomass into electricity with high conversion efficiency. Worldwide, about 150 cofiring plants are in operation. In Germany, the electrical power potential for biomass cofiring in coal plants is about 28 TWh per year, assuming a 10% replacement of coal combustion by biomass (in 2008, some 280 TWh of electricity were produced from coal, cf. [3]). Economic studies are still quite rare – e.g. [2] investigates the

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economic potential for the EU-27, [4] studies the effects of biomass cofiring subsidies on the heat and electricity markets, [5] the impact of different operating and logistic schemes on the economic viability of biomass cofiring, and [6] reductions in fuel side costs.

In Europe, biomass cofiring is much more widespread than elsewhere in the world. About two thirds of all cofiring plants are located in Europe alone ([7], p. 10). The technology is present especially in Northern Europe, Germany and Austria, since large amounts of relatively low-cost biomass are available and because bioenergy is popular and politically supported. In *Germany*, for example, there were some 30 cofiring plants in operation in 2007, of which thirteen were permanently operated with mixed fuels ([7],p. 176–8). The most frequently used fuel is sewage sludge, which is utilized in 50% of all plants. Sewage sludge can be co-fired up to 3% of thermal contribution without significant plant modifications. This is attractive, because sewage sludge is a resource that is available all year round and typically has negative costs [8]. Further fuel materials are waste wood, straw and organic residues. Important barriers in Germany are the limited security of biomass supply (lack of suppliers, seasonality etc.), high requirements regarding the operating license for waste-cofiring plants and the increased competition in liberalized power markets after deregulation, which has led to a less investor-friendly climate due to the additional risks involved in cofiring. Moreover, the feed-in tariffs stipulated in the German Renewable Energies Act (EEG) do not apply to biomass cofiring, in contrast to other technologies using renewables. Hence a plant that is fired 100% by biomass receives higher tariffs and can thus also pay higher prices for the biomass. Reviewing also the situation in other European countries (cf. [7]), it becomes evident that biomass use for cofiring is either enabled by favorable availability of biomass resources or by promotion policies. For Germany, hence, political support is necessary to push this technology, e.g. through the EU ETS.

In the remainder of this paper, we study the economic potential of biomass cofiring in hard coal power plants in Germany, with a particular focus on the power plants owned by the energy provider E.ON. In Section 2 we identify fuels suitable for biomass cofiring, and important influencing factors determining their contribution to overall investment and operating costs. Section 3 contains the analysis of the cost-effectiveness of biomass cofiring, and profitability calculations for cofiring investments, a sensitivity analysis for checking the robustness of the results obtained, and an MCS for taking uncertainties explicitly into account. Section 4 concludes.

2. Biofuel cost analysis

Biofuel input costs vary significantly by the type of biomass and its origin. Whereas obtaining certain biomass types locally (e.g. straw, energy crops) can be favorable in some cases, international supply of refined biomasses (namely pellets) traded over long distances lends itself to applications with a high fuel input demand. Transportation costs and plant location (inland, coastal region) can become decisive factors. In this section, the determinants of fuel supply are further expounded. These considerations form the basis for the price scenario definition and profitability analysis provided in Section 3. Fuel supply costs for selected plants in Germany and regional fuel supply are investigated in Section 2.1, whereas the fuel prices for international trade are quantified in Section 2.2. The combined results yield a qualitative synthesis over the fuel prices for different types of biomass.

2.1. *Fuel supply costs in case of regional supply*

International trade of biomass enables the use of biomass resources also from other regions. Electrabel, for instance, has found that international pellet suppliers can provide less costly pellets for their power plants than local suppliers ([9],p. 725). Fig. 1 shows the span of prices for different types of biomass. It becomes evident that the biomass fuel costs calculated for Germany in various studies (e.g. "Leitstudie Bioenergie", cf. [10]; "RENEW", cf. [11]) (see price levels A, B in Fig. 1) are mostly higher than current market prices. In contrast, in the study of [12] (see C in Fig. 1) the costs are below the market prices.

2.2. *Fuel supply cost in case of European/international supply*

Biomass is increasingly traded internationally. Often biomass from overseas is less costly than regional biomass, due to economies of scale in production and transport, e.g. in South America. Since economies of scale in ship transport are not very distance-dependent, the production cost differences are the main relevant factor. These are in Western Europe markedly higher compared to countries with lower costs of land and labor. For intra-European trade the situation is different. As production is more expensive than in Latin America, and since transport has to be effected by railway or via often long detours on waterways, cost reductions due to scale effects are often minor (Fig. 2).

Due to their favorable transport characteristics wood pellets are particularly well-suited for international trade. Their costs are sometimes at 5 € GJ^{-1}, and thus lower than for pellets produced in Germany. Fig. 3 shows the total supply costs of wood pellets for a representative onshore power plant location compared to an inland location (approx. 800 km off the sea port) and supply from different regions. The onshore location benefits from the easy access to shipping routes, so that heat prices when using wood pellets are similar to those from using coal. In contrast, the higher shipping costs compared to coal for the inland location lead to somewhat less favorable conditions when pellets are provided by an international supplier.

A comparison between international and regional supply shows the strong dependency of the fuel supply costs by type of biomass and origin due to their different energy density and transport characteristics. Straw and energy crops are best procured from regional suppliers. For long distances transport costs rise markedly and render this unattractive. Fresh wood chips are, due to the high moisture contents, also unfavorable if transported over long distances. Log wood can be transported over medium distances (e.g. from Sweden) at prices comparable to those of pellets. For longer distances, however, pellets are superior.