Electrification and coal phase-out in Germany: A scenario analysis

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***Abstract*—The electrification of fossil fueled processes and applications is frequently quoted as an essential component for the deep decarbonization of the German energy system. A prerequisite for decarbonization through electrification is low-emission electricity. In the German case, this leads to the so-called "electrification dilemma", as both a reduction of the emission-intensive conventional power plant park and the significant increase in electricity consumption are driving the demand for RES and guaranteed capacities drastically. In a simulation-based scenario analysis, two measures to reduce emissions in power generation in a high electrification regime are compared: CO_2-allowance pricing and a lignite phase-out. Using the DC power flow formulation, the effects on the German transmission grid are determined. The results show that both the coal phase-out and an increase in the CO_2-prices lead to a significant reduction in the average CO_2-coefficient of power generation. Simultaneously the capacity gap increases significantly, but only for a few hours per year.**

***Index Terms*— Electrification, Energy consumption, Power generation planning, Power system planning, Power transmission**

I. Introduction

Recently published energy scenarios such as [1]-[3] show that a variety of pathways to deep decarbonization in Germany exist [4]. In all three scenarios the electrification of final energy consumption (FEC) is considered a key enabler for the reduction of greenhouse gas (GHG) emissions by 95 %, compared to the level of 1990.

Previous work by the authors of this paper [5] analyzes the effects of increased demand-side electrification in combination with high shares of variable renewable energy sources (vRES) on the German energy system in 2030. [5] shows that electrification in combination with a high share of vRES can pose a barrier to the phase-out of emission intensive coal fired power plants, leading to a so-called "electrification dilemma". The latter describes the effect by which the combination of high electrical load and installed vRES capacities result in stronger fluctuations of the residual load. The consequences are an increased need for guaranteed capacity and dispatch of fossil power plants in times of low feed-in from vRES. This in turn, prohibits the phase-out of fossil power plants and a further reduction of the CO_2-coefficient of power generation, thereby restricting the decarbonization effect of increased electrification. To unfold the full decarbonization potential of electrification measures, the implementation of strategies aimed at reducing the dispatch of emission-intensive power plants are required.

This paper builds on the scenarios and findings in [5] and analyzes the effects of a politically forced lignite phase-out and variations of CO_2-prices on the German energy system, in a high electrification and high RES scenario, in 2030. The focus hereby lies on the analysis of the following parameters: capacity gap, curtailment, redispatch, the CO_2-coefficient of power generation, the generation mix and the electricity export balance. Through the analysis, a contribution to answering the following questions is made:

1. *What are the energy system effects of a lignite phase-out or an increasing CO_2-price in a high electrification and high RES scenario?*
2. *What role do Germany's neighboring countries play with respect to the procurement of supply security and emissions?*
3. *What are the operational characteristics and transmission grid repercussions of future peak-load generation units in a electrification regime?*

Furthermore, this work builds the basis for further analyses of the effects resulting from the integration of flexibility measures (e.g. demand-side-management, storage systems) in high electrification and high RES scenarios.