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Combining Life Cycle Assessment and Energy System Optimization to Model Sustainable Power Systems Transformation#

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ABSTRACT

We link the highly flexible Energy System Model Backbone with Life Cycle Assessments of energy system technologies to optimize various environmental impact indicators in addition to system costs. Additionally, we perform a multi-objective optimization of costs and environmental impacts and determine a pareto front to investigate interrelationships and trade-offs even further. We apply this to the power system of twelve central european countries with a special focus on the Rhenish Mining Area, a structural change region in western Germany, in the year 2040. This reveals a decrease in electricity generation in the region for all objective functions compared to 2020, as well as a strong preference for gas power for cost minimization and onshore wind power for minimization of environmental indicators.

Keywords: Energy System Model, Life Cycle Assessment, Multi-objective Optimization, Energy Transition, Structural Change, Rhenish Mining Area

NOMENCLATURE

Abbreviations	
ESM	Energy System Model
GAMS	General Algebraic Modeling System
GWP	Global Warming Potential
LCA	Life Cycle Assessment
MDP	Metal Depletion Potential
PHS	Pumped Hydro Storage
RMA	Rhenish Mining Area
ULOP	Urban Land Occupation Potential

1. INTRODUCTION

Since hard coal mining was ended by the end of 2018, lignite along with minor amounts of natural gas is the last fossil energy carrier exploited in Germany [1]. Power plants in the Rhenish Mining Area (RMA), the largest lignite mining area in Germany, currently cover about one tenth of Germany's electricity demand [2]. The core area of the RMA, located in western Germany, includes the opencast mining areas, lignite-fired power plants and refinement plants, and some locations of energy-intensive industry. The immediate surrounding area, however, is also impacted by the lignite industry through strong economic and social ties. This so-called impact area is regarded as the RMA and includes seven counties and cities (Fig. 1) [3].

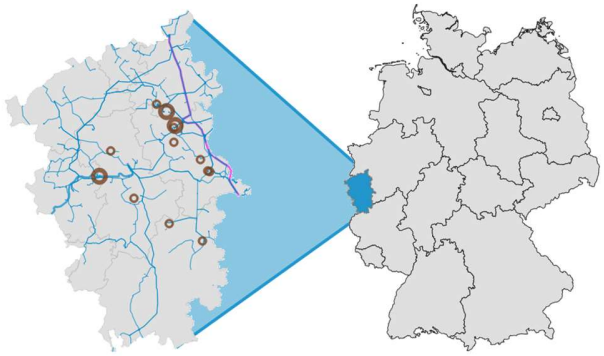

Fig. 1 Location of lignite-fired power plants (brown) and high-voltage power lines (blue, pink: project EnLAG15) in the RMA in 2020 and location of the RMA in Germany.

Since the existing lignite-fired power plants will be shut down by 2038 at the latest and lignite mining will be stopped, the RMA is affected by another substantial structural change [4]. The central reason for the political decision to phase out coal-fired power generation is to reduce greenhouse gas emissions and the climate change caused by these emissions. Currently, the energy sector also causes a large share of the total potential environmental impacts (beyond climate change) globally [5]. Therefore, in the course of the coal phase-out, in addition to limiting production and shutting down lignite-fired power plants, sufficient renewable power plants and capacities must be expanded in order to meet the energy policy objectives of environmental compatibility, economic efficiency and security of supply

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