RETIREMENT DURATIONS OF EUROPEAN COAL-FIRED POWER PLANTS: BUILDING AN EMPIRICAL FOUNDATION

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Overview

The phase-out of CO_2-intensive infrastructure is vital to climate change mitigation scenarios as envisioned in energy-economic and integrated assessment models. Out of 1500 publicly available scenarios generated by more than 30 integrated assessment models to understand pathways limiting global warming to below 2°C, 80% reduce coal rapidly or gradually (Minx, 2024). In reality, retirements are complex, multi-year, multi-stakeholder processes that result in various outcomes, ranging from plant conversions (e.g., coal to natural gas) to adjacent new builds that leverage existing grid connection points (e.g., solar PV) to complete demolitions and idle infrastructure in the form of retired plants with no further steps taken towards conversion or secondary plant usage. Yet, while such information is available for individual retirement cases, past phase-out experiences at 2,782 retired coal-fired units globally have yet to be systematically documented and analyzed.

Past research has shown that countries achieving early plant retirements succeeded in three ways: top-down changes to plant operating licenses, compensation payments to companies and regions affected by early retirements, and leveraging market dynamics to render plants economically unattractive (Brutschin, 2023). Historically (i.e., in coal transitions since the 19th century), policies inducing both demand- and supply-side have been most successful at reducing coal usage (Diluiso, 2021). Yet despite much historical progress, constraining coal retirement rates to rates observed in the past would make climate goals harder to achieve and require a much faster reduction in global oil and natural gas production to offset CO_2 emissions from slower coal retirements (Muttitt, 2023).

One area that has not been addressed in past research on coal phaseouts is the duration of retirement processes from the point in time where a decision is made to shut down a plant to the actual disconnection of that plant's generation units from the power grid and the subsequent dismantling, demolition, and secondary plant usage. Similarly, the extent of secondary plant usage in retired coal plants has not been analyzed, leaving many questions unanswered about whether and how quickly high-carbon infrastructure can be repurposed or removed. Mapping such multi-step phase-out processes is critical to identifying conditions that make successful retirements more likely and easier to replicate across locations and developing more realistic projections of future retirement timelines. This paper takes the first crucial step toward this goal by constructing a database of historical coal phase-outs and their characteristics (e.g., unit-level retirement durations) in Europe.

Methods

We examine retirement timelines and post-retirement plant uses in European coal-fired power plants, covering 20 European countries (Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom), 231 units, and a total capacity of 76.4 GWe. Specifically, we define the "retirement duration" of a coal-fired power generation unit as the period from the public announcement of the intended retirement to the shutdown of that same unit (i.e., the point in time when the unit is disconnected from the power grid) and study this duration as a metric for how quickly targeted retirement timelines are realized in practice. Retirement durations are reconstructed for 231 retired units in Europe using web searches to determine announcement dates and drawing on data from the Global Coal Plant Tracker to identify actual retirement dates. The units were selected based on their retirement date (after 2010) and public availability of the announcement date (e.g., in electric utility press releases). We compute mean and capacity-weighted average retirement durations for all units in our dataset and study the time evolution of these retirement duration metrics. We also collect data on the degree of secondary plant usage, as in whether plants retired after 2010 are retired and otherwise unchanged, converted to lower-emission sources, or dismantled and demolished (i.e., prepared for land re-use).

Results

Retirement durations. Retirement durations vary significantly across countries and power plants in the same country, with a mean retirement duration of 24.9 months and a standard deviation of 19.4 months. The countries with the lowest mean retirement duration are Greece (12 months) and Hungary (3 months), although the cumulative number of retired units is much smaller than in countries with higher mean retirement durations, like the UK and Germany. Overall, the shortest retirement durations in our dataset are below 6 months and are observed in Austria, Germany, Hungary, and the UK. The longest durations are eighty to ninety months and are observed in Finland, Germany, and Poland.
Overall, about one-third (33.5%) of units in our dataset retired relatively soon after the retirement announcement (within two years or less after the announcement), and 60% of units retired within 3 years of the announcement date. The other 40%, however, take much longer to retire. 87% of those slower retiring units completed the retirement process within 3-6 years, and 13% retired within more than six and less than 9 years. Larger units tend to retire slightly faster, with considerable differences between simple average country-specific retirement durations (which range between 3 and 38 months across countries with more than four units retired since 2010) and unit capacity-weighted average retirement durations (which range between 0.6 and 6.9 months across countries with more than four units retired since 2010).

Secondary plant use. Conversion rates to lower-carbon fuels are relatively low. Only 6% (5.6) of coal units retired between 2010 and 2024 have been converted to biomass or natural gas. The most significant fraction, 62% of units retired after 2010, remains unchanged, with no publicly traceable steps taken towards secondary plant or land usage. The remaining 32% of units have been dismantled or demolished, preparing the power plant infrastructure and land for other uses.

Conclusions

Coal plant retirements are intricate processes that involve top-down deadlines set by policymakers, negotiations with plant operators, owners, and local populations, and complex regulatory, administrative, and engineering processes. These processes ought to be better documented, both qualitatively and quantitatively, to extract lessons for future retirements and calibrate energy-economic models using empirical data to estimate coal phaseout timelines realistically. Our dataset and initial analysis constitute a crucial step towards a better understanding of on-the-ground phaseout processes, demonstrating the significant duration of retirements, the considerable variability across locations and plants, and the role of unit capacities. Our data can be used in future research to identify best practices in plant retirement and better represent timelines associated with climate policy changes in models. For example, a collective announcement date could be assigned to all plants in a country implementing a stricter coal phaseout policy, and the timeline for actual plant shutdowns and resulting emissions reductions could be constrained to historically observed durations.

References

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