Thermal Storage Power Plants to decarbonize the globally existing coal-fired power plants: Techno-economic analysis

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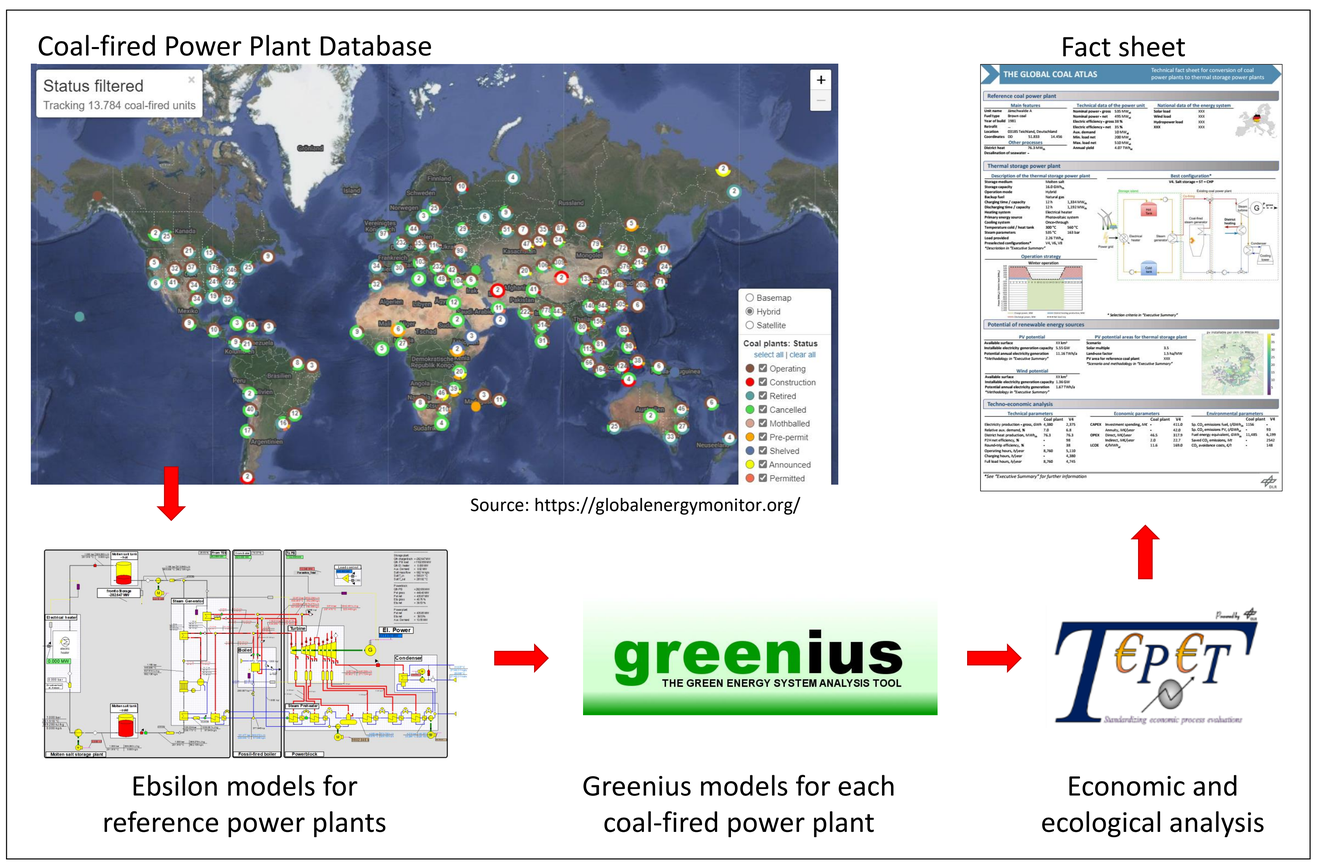

Figure 1: Methodology for the Techno-Economic Analysis of Worldwide Coal Power Plants in the "Global Coal Atlas" Project

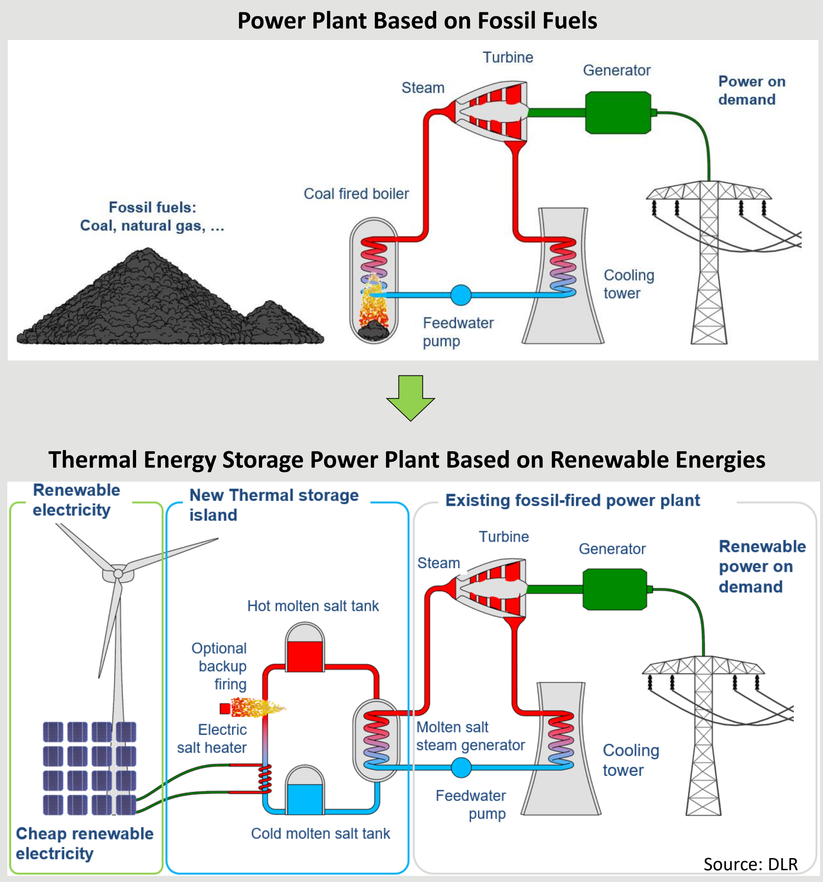

Figure 2: Conversion of a Coal-Fired Power Plant to a Thermal Storage Power Plant with Electric Heater

Motivation and objectives

The Paris climate agreement has the main goal of limiting global warming to 1.5 degrees compared to the pre-industrial era. Achieving this target requires a significant reduction in global CO_2 emissions. **Coal power plants contribute substantially to these emissions, accounting for approximately 15 Gtco2 annually**. The European Union is committed to achieving climate neutrality by 2050, with Germany aiming to reach this goal by 2045. To this end, Germany plans to close its last coal-fired power plant by 2038 at the latest.

Many coal-fired power plants around the world are still operational, and some are relatively new, with components and sites that **could be repurposed into Thermal Storage Power Plants (TSPP)**. In a TSPP, a high-temperature thermal storage is charged using renewable energy (Power-To-Heat). Optionally, additional firing with CO_2-neutral fuels can be used. For discharging, the heat from the storage is converted into electricity and fed into the grid using the existing power block and grid connection (Heat-To-Power). TSPPs can convert fluctuating renewable electricity generation into reliable power on demand.

This study presents a techno-economic analysis of converting existing coal-fired power plants into TSPPs with electric heaters. **The analysis covers approximately 7,000 coal-fired power plants worldwide.** This work is part of the "Global Coal Atlas" project, which aims to create a collection of data that includes a forecast of decarbonization costs and CO_2 avoidance costs for each of the existing coal-fired power plants worldwide [Figure 1].

Methodology

Various concepts for converting coal-fired power plants to TSPPs with high-temperature molten salt storage were defined. This study focuses on a system using a electric heater as the power-to-heat unit [Figure 2]. The operation mode involves a daily cycle with 12 hours of charging and 12 hours of discharging of the thermal storage [Figure 3].

The techno-economic analysis was first conducted for the reference power plant, Angamos (Chile), using a simulation model based on EBSILON®Professional for technical results and the DLR-internal tool TEPET+ for the economic and ecological analysis. The results for the coal-fired reference plant were compared with those for its conversion to a TSPP.

Subsequently, **a global analysis of coal power plants was carried out using the Global Plant Tracker database** [1]. A technical model was created for each power plant using the DLR tool greenius, and economic and ecologic results were calculated with TEPET+. Fact sheets summarizing the most relevant information of the conversion to a TSPP were generated for all the power plants.

Results and discussion

Key technical results, such as round-trip efficiency and annual yield, along with economic indicators like capital expenditure (CAPEX), operating costs (OPEX), and levelized cost of electricity (LCOE), were calculated for the global fleet of coal-fired plants converted to TSPPs. CO_2 avoidance potential and associated costs were also estimated.

For the reference plant Angamos (Net Capacity 251 MW_{el}), based on costs assumptions for 2022, thermal storage accounts for approximately 40% of the investment, while the electric heaters contribute around 20%. **The LCOE is highly sensitive to the cost of PV electricity.** For example, with a PV LCOE of 20 €/MWh_{el} in Chile [GIZ Chile], the resulting TSPP LCOE is 116 €/MWh_{el} [Figure 4]. In contrast, **with a global average PV LCOE of 46.5 €/MWh** [2], **the TSPP LCOE rises to 184 €/MWh**. **CO_2 avoidance costs**, calculated under the global PV LCOE assumption, **amount to 159 €/tCO_2 for a fully depreciated plant** and 147 €/tCO_2 when financing is considered.

For the global analysis, results were calculated for each power plant, revealing a significant dependence of LCOE values and CO_2 avoidance costs on plant capacity [Figure 5].

This data aims to provide a robust foundation for decision-makers in industry and politics, serving as an objective resource for evaluating the potential global conversion of existing coal-fired power plants into CO_2-free TSPPs.

Conclusions and outlook

Globally, around 7,000 coal power plants remain operational, many of which are set to be decommissioned in the near future. Some of these plants, still relatively new, can be repurposed as thermal storage power plants.

TSPPs store renewable energy (e.g., PV, wind) in high-temperature thermal storage systems (Power-to-Heat), which can then be used to generate electricity on demand (Heat-to-Power). This allows renewable energy to be dispatched in a "base-load" manner, improving supply security.

The techno-economic analysis conducted demonstrates that **electricity generation and CO_2 avoidance costs are largely site-dependent**, with the cost of charging power being a critical factor.

The "Global Coal Atlas" project is set to publish its comprehensive data collection by early 2025, including a detailed assessment of the LCOE, CO_2 avoidance potential, and investment costs for converting coal power plants into CO_2-free TSPPs. Future work will also explore alternative TSPP concepts, such as using heat pumps instead of electric heaters, to further optimize the conversion process.

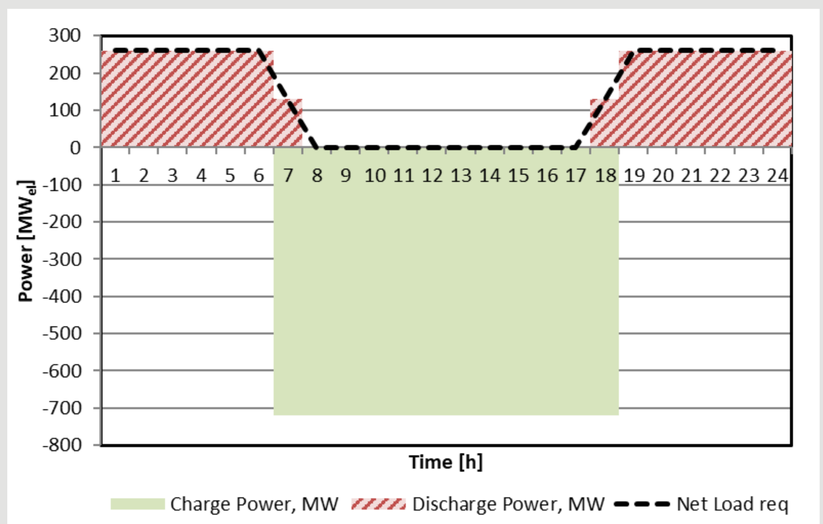

Figure 3. Defined operation mode based on a daily profile

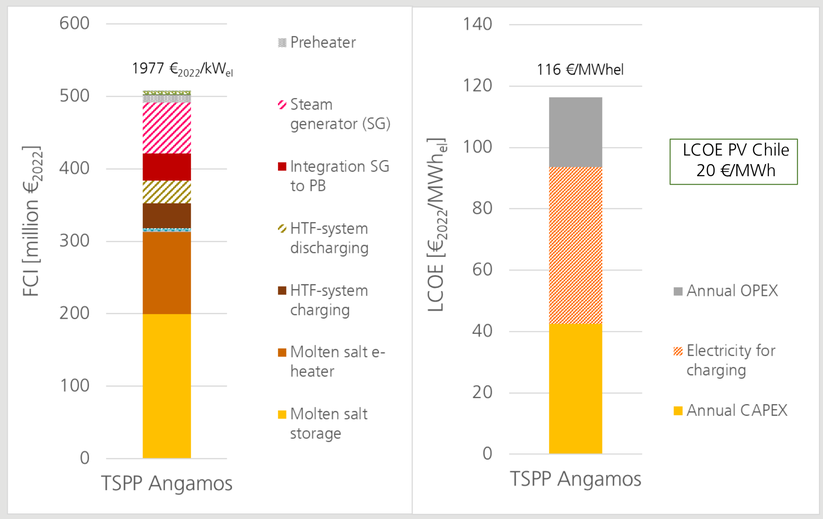

Figure 4. Reference Power Plant: Investment costs and LCOE for Angamos Thermal Storage Power Plant with electric heater and power block net capacity of 251 MWel

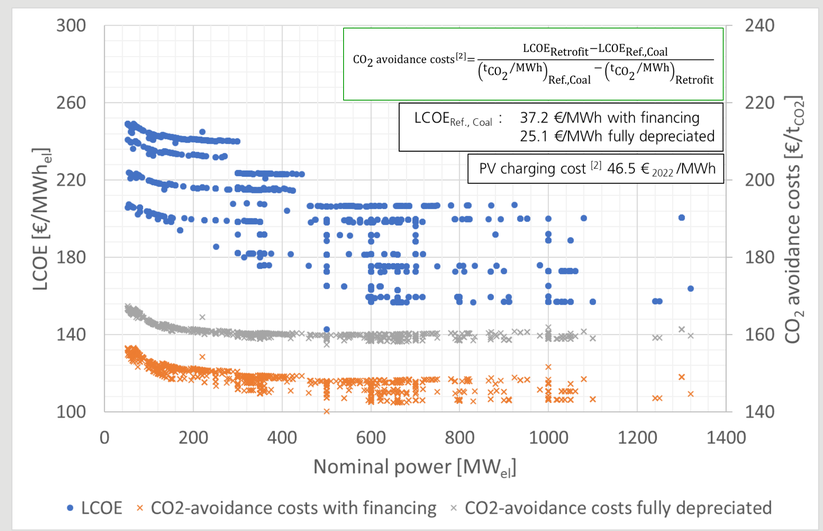

Figure 5. LCOE and CO_2 avoidance costs for the conversion of approximately 7,000 Coal-Fired Power Plants worldwide into Thermal Storage Power Plants based on their capacity

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[1] Global Coal Plant Tracker, Global Energy Monitor, July 2024 release. Available online: https://globalenergymonitor.org/projects/global-coal-plant-tracker/
[2] IRENA (2023) Renewable power generation costs in 2022, International Renewable Energy Agency, Abu Dhabi