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Time-Series Aggregation in Energy System Models: Navigating the trade-offs between short-term and long-term dynamics

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It is widely acknowledged that relying on a single energy source is not viable and a mix of energy sources and carriers is required to achieve carbon neutrality [1]. Hydrogen has come to the forefront of discussion, particularly due to its potential for long-term storage.

Computational models based on mathematical optimization have been widely used in the literature, to better understand the role of hydrogen in energy systems with high shares of variable renewable energy sources (VRES). These models optimize dispatch and investment decisions for multiple energy sources and carriers over several decades. However, to maintain a holistic view of the system with reasonable complexity, it is common to decrease the temporal resolution.

Clustering hourly VRES time-series to a reduced set of representative periods is a particularly popular method in the literature. However, there is an inherent trade-off between short- and long-term dynamics: For example, clustering days enables a more accurate representation of diurnal features compared to clustering hours, although at the expense of considering seasonal trends. In the optimization problem, these features can have a direct impact on investments in short- or long-term storage, and, ultimately in VRES. Moreover, the clustered data suffers from a loss of chronology which is important for modeling long-term (hydrogen) storage and providing accurate operational and investment signals.

To address the research gap raised by [2], the approach of this modeling exercise is to analyze the performance of clustering hours (1) versus clustering days or weeks (2) in the context of storage and VRES investments. The analysis is based on different scenarios for VRES optimized in the energy system model GENeSYS-MOD co-developed by TU Berlin. To improve the shortcomings of (1) and (2), chronological clustering [3] and additional storage constraints [4] are tested and evaluated. Ultimately, the goal is not to derive normative conclusions for time-series aggregation methods and (hydrogen) storage modeling, but instead highlight different configurations and their performance under various settings.

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