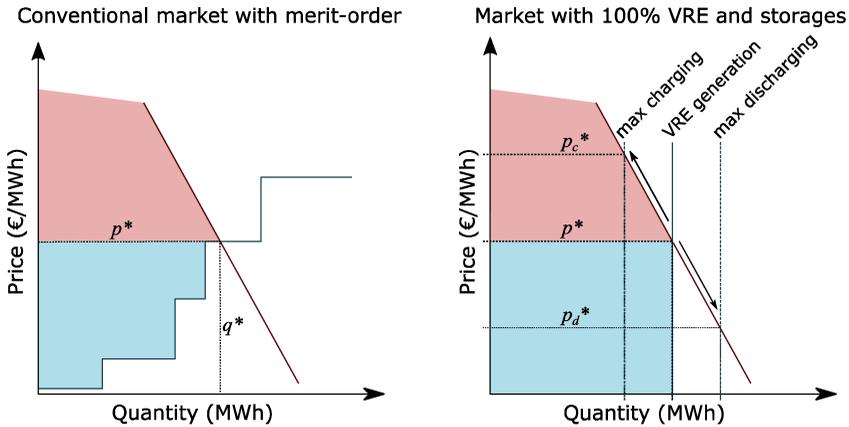


# Pricing and Competition with 100% Variable Renewable Energy and Storage

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Electricity production is a key sector in global decarbonization efforts, and variable renewable energy (VRE) technologies are a primary way to produce carbon-free electricity. The challenge with VRE, however, is that matching fluctuating demand with intermittent VRE production requires notable investments in flexibility, such as electricity storage. We study an electricity market where electricity generation is 100 % VRE, while energy storage and elastic demand resolve the temporal supply-demand imbalances. We model the hourly equilibrium to assess how prices are settled in such a market. We also study how imperfect competition (Cournot) with varying levels of ownership concentration (Herfindahl-Hirschman index) can distort the market. This market power is exerted either with storage-only or with both VRE and storage.

In the studied setting, electricity price formation differs profoundly from the static logic of merit-order curves. As VRE production is not dispatchable, price is determined by the demand side and the charging and discharging decisions of storages, as depicted below. Decisions on storage use are intertemporal, making price formation inherently a dynamic problem.



Market power with storage operations has a relatively minor effect on prices and social welfare (market efficiency). However, once the electricity price reaches zero, curtailment by price-taking VRE capacity provides additional flexibility for storage operators. This allows storage owners to extend periods of zero prices when generation is high, which benefits consumers but decreases VRE revenues considerably. VRE owners can exert market power by curtailing production, which has far larger welfare impacts. However, it could be more readily observed by a regulator, e.g. by a comparison of forecasted (weather-based) production to actual VRE sales.

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