INTEGRATING PROSUMERS INTO A FULLY DECARBONIZED EUROPEAN WHOLESALE ELECTRICITY MARKET

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Overview

Decarbonizing the European energy system requires a massive expansion of renewables, particularly solar energy (Child, Kemfert, Bogdanov, & Breyer, 2019). Besides large-scale solar capacity, a large share of new power plants will have to be built on the rooftops of residential and commercial buildings. The impact of these new decentral capacities on wholesale electricity markets will highly depend on their degree of system integration, namely the share of rooftop solar energy fed into the grid in contrast to self-consumed energy. While a high share of rooftop solar energy fed into the grid is likely to cause decreasing wholesale electricity prices and cannibalization, a high degree of self-sufficiency could mitigate these effects (Hirth, 2013). The degree of system integration, in turn, will be influenced by the regulatory framework in place for prosumers, particularly feed-in and end consumer tariffs. Typically, optimization models of future European energy systems assume all generation to be fed into the public grid. In our work, we optimize the future European energy system under different scenarios and explicitly model prosumer invest and unit commitment. Particularly, we allow a certain share of electricity demand to be served by self-produced electricity from new rooftop solar capacities or electricity from the public grid at the costs of two types of end consumer tariffs. To the best of our knowledge prosumers have not been integrated into an optimization model in this manner before (Chen, Alsafasfeh, Pourbabak, & Su, 2018; Correa-Florez, Michiorri, & Kariniotakis, 2019).

Method

We apply the flexible energy system modelling framework Backbone to carry out a cost-minimizing investment and operation planning of fully renewable European power system scenarios for a full year (Helistö, et al., 2019). Based on our scenarios, we model two reference systems with non-thermal renewable shares of 85% and 95%, respectively, which we enforce by adding corresponding constraints to our minimization problem. Furthermore, we assume our system to be fully decarbonized by excluding fossil technologies. We build our model based on data collected by the Horizon2020-project TradeRES (Helistö, Kiviluoma, Similä, Nienhaus, & Serna, 2020). Similar to Böttger & Härtel (2022) and Finke et al. (2022), we analyze the reference system results with a focus on profitability of variable renewables as well as wholesale electricity prices, for which we use the model's marginal system costs. Subsequently, we introduce prosumers into the model. Particularly, we add an additional prosumer electricity grid, whose load can either be served by new rooftop-solar capacities or electricity from the public power system, i.e., the general electricity grid in the model. Power supply to prosumers from the public system happens via an explicitly modelled supplier unit that transfers electricity from the general to the prosumer electricity grid. The operating costs incurred by the supplier unit represents end consumer tariff elements, such as levies and network tariffs, added to the wholesale electricity price, which are passed through to prosumers in real time in one specification of the model (see Figure 1). Another specification additionally includes a trader unit, which passes through the wholesale electricity price as a fixed-price-element to prosumers. The two specifications allow us to distinguish between a dynamic- and a static-price-tariff regime. Finally, the rooftop-solar power plants are also able to feed their energy production into the public grid. Furthermore, our model set-up allows the introduction of renewable feed-in tariffs and the addition of prosumer-owned battery storage.

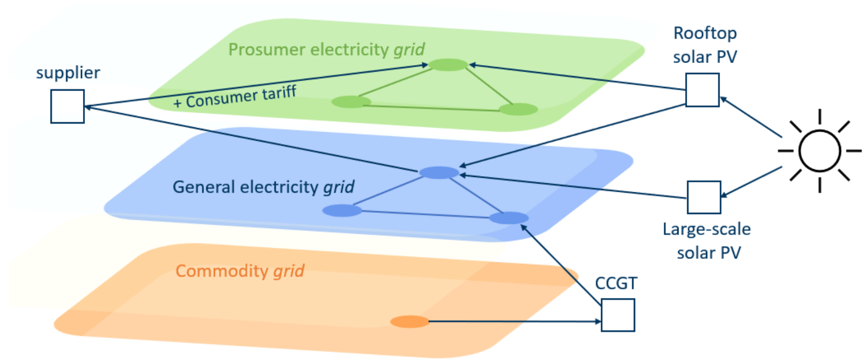

Figure 1: Simplified representation of our model set-up within Backbone

Results

Our reference systems are characterized by 100% carbon-free generation by assumption and a high-share of non-thermal renewable energy by constraint. Since the dominant sources of power, namely solar, wind and hydro energy, incur very low marginal costs, resulting wholesale electricity prices are near zero in more than half of the hours per year across all European countries (see Figure 2). Consequently, across all European countries, non-thermal renewable power plants as enforced by our constraint are not profitable within our model. We expect our modelled prosumers to have the following effects on wholesale electricity prices and investment shares: since for a certain load share, we add costs to general electricity production by modelling end consumer tariffs, we expect to see an increase in investments in rooftop solar PV. Ceteris paribus, this increase will lead to a higher merit-order effect and therefore, higher cannibalization of all solar power production units. However, investments in large scale-solar PV are likely to decline, since load to be served by the general electricity grid decreases due to self-consumption. Our results will shed light on the net effect of these two dynamics in terms of wholesale electricity prices and profitability of solar PV investments. Future work will also cover the additional effects of feed-in tariffs and prosumer-owned battery storages.

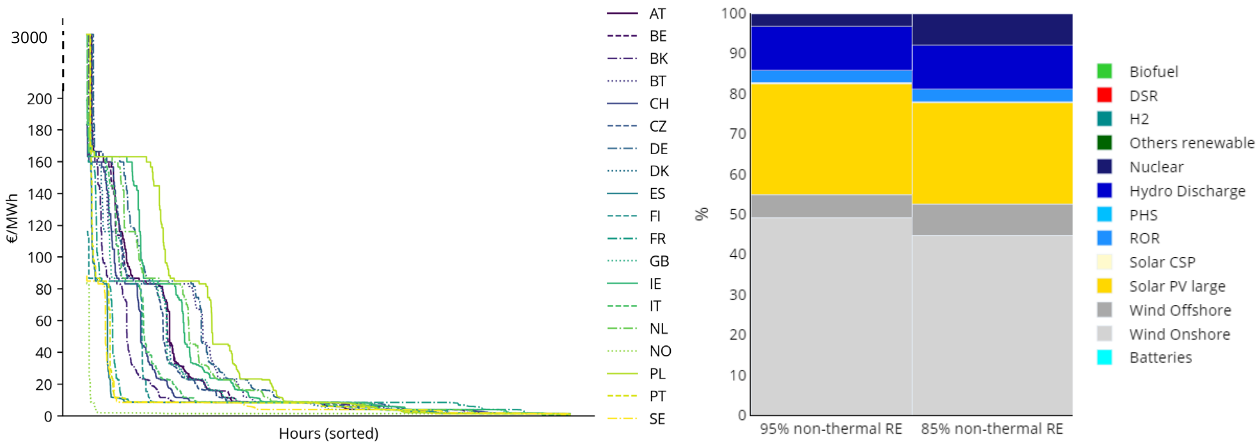

Figure 2: Price duration curves by country in the 85%-non-thermal renewable scenario (left) and overall energy generation shares by technology in both reference scenarios (right)

Conclusion

Our reference systems of a fully decarbonized European electricity market are characterized by high generation shares of low-marginal-cost technologies. After wind onshore, solar power constitutes the prevalent future source of power. Typically, optimization models of European energy systems assume all solar power to be fed into the public grid. We explicitly model prosumers with the ability to self-consume the energy generation of their endogenously installed rooftop solar capacity under two different tariff schemes. Our results will be able to shed light on the effect of prosumers on the future decarbonized European wholesale electricity market.

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