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Impact of small-scale storage systems on the photovoltaic penetration potential at the municipal scale

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The yearly cumulated technical energy generation potential of grid-connected roof-top photovoltaic power plants is significantly larger than the demand of domestic buildings in sparsely populated municipalities in central Europe. However, an energy balance with cumulated annual values does not deliver the right picture about the actual potential for photovoltaics since these run on a highly variable energy source as solar radiation. The mismatch between the periods of generation and demand creates hard limitations for the deployment of the theoretical energy generation potential of roof-top photovoltaics. The actual penetration of roof-top photovoltaic is restricted by the energy quality requirements of the grid and/or the available storage capacity for the electricity production beyond the coverage of own demands.
In this study we evaluate in how far small-scale storage systems can contribute to increment the grid-connected roof-top photovoltaic penetration in domestic buildings at a municipal scale. To accomplish this, we calculate, in a first step, the total technical roof-top photovoltaic energy generation potential of a municipality in a high spatiotemporal resolution using a procedure that relies on geographic information systems. Posteriorly, we constrain the set of potential photovoltaic plants to the ones that would be necessary to cover the total yearly demand of the municipality. We assume that photovoltaic plants with the highest yearly yield are the ones that should be installed. For this sub-set of photovoltaic plants we consider five scenarios: 1) no storage 2) one 7 kWh battery is installed in every building with a roof-top photovoltaic plant 3) one 10 kWh battery is installed in every building with a roof-top photovoltaic plant 4) one 7 kWh battery is installed in every domestic building in the municipality 5) one 10 kWh battery is installed in every domestic building in the municipality. Afterwards we evaluate the energy balance of the municipality using a series of indicators. These indicators include: a) the total photovoltaic installed capacity, b) the total storage installed capacity, c) the output variability, d) the total unfulfilled demand, e) total excess energy, f) total properly supplied energy, g) the loss of power supply probability, h) the amount of hours of supply higher than the highest demand in a year, i) the number of hours, when supply is 1.5. times higher than the highest demand in a year, and j) the additional storage energy capacity and power required to store all excess energy generated by the photovoltaic installations.
The comparison of the proposed indicators serves to quantify the contribution that household-sized small-scale storage systems would make to the energy balance of the studied municipality. Increased installed energy storage capacity allows a higher roof-top photovoltaic share and improves energy utilization, variability and reliability indicators. The proposed methodology serves also to determine the amount of storage capacity with the highest positive impact on the local energy balance.