Reducing the carbon footprint of mini-grids in Africa: the value of solar PV.

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Ensuring a universal access to a reliable, affordable, and sustainable energy by 2030, would require electrifying around 600 million people in Sub-Saharan Africa. The International Energy Agency estimates that one third of the future electricity connections would be met by mini-grids (MG). This electrification must be compatible with the objective of the Paris agreement and global pathways expected to limit warming to 1.5°C have to reach net-zero CO2 emission as soon as 2050. Autonomous MGs based on solar PV are there a promising solution to electrify rural areas. They have a low cost and allow to significantly reduce greenhouse gases (GHG) emissions compared to diesel generators.

Many different MG configurations hybridizing solar PV, diesel genset and batteries can supply the production required for a given community, and the sizing of MG is usually done by minimizing criteria such as the levelized cost of electricity (LCOE) and/or the carbon footprint (CFP) of the system. The goal of this study is to quantify the distance between the CFP optimum and the LCOE optimum configurations, and the potential to find compromising configurations between.

To do so, we consider fictitious hybrid MG for a large range of configurations (PV and diesel share, storage capacities) to supply typical load profiles for 93 different locations over Africa. The solar PV production is simulated using meteorological data at a 15min resolution (ERA5, Heliosat SARAH2) and we ensure that the electrical consumption is fully supplied with simple dispatch rules for the batteries and the genset.

We show that the least LCOE (LCOE*) and the least CFP (CFP*) configurations and values are mainly driven by the mean capacity factor of the solar resource and by its co-variability with the electric load profile. The larger the capacity factor, the lower the LCOE and the CFP, and the nighttime energy consumption strongly influences the CFP values for both configurations.

We show that, even in a configuration where all the production is obtained from solar, the CFP of a MG is non-negligible. If the CFP of a MG is obviously determined by the direct greenhouse gases (GHG) emissions related to fuel combustion, it indeed also results from the indirect GHG emissions obtained for solar PV and batteries production. For the studied locations, the CFP* values cannot go below a minimum threshold between and depending on the climatic zone and the load profile considered.

For almost all locations, the least LCOE configuration LCOE* is obtained with a hybrid MG. We also show that this configuration usually allows a CFP reduction by more than 50% compared to a genset only configuration, and that, relatively high increases (often >20%) of the LCOE are needed to reduce further MG emissions at the level of the CFP* configuration. We however also show that significant CFP reduction can be obtained at low cost by choosing a configuration between the CFP* and the LCOE* configurations.