Title: Productive Use of Energy: Role of Demand in Integrated Energy Planning, Yuezi Wu

Stakeholder: Winch Energy

Theory of Change: If one can understand the upfront and recurrent costs of a transition from diesel-operated productive uses to electric machines powered by solar, this understanding can in turn clean energy (either grid, mini-grid or off-grid) allow governments to create suitable policy and private sector to create suitable business models for a large-scale shift away from expensive fossil fuels.

Winch installed electric grinding mills in their mini-grids, an example of a diesel to electric conversion of a productive use of energy (PUE). By February 2024, Winch provided a full year of load data. In general, these PUEs in minigrids not only boost overall demand but also alter the load profile, enhancing solar and battery utilization and improving the economic viability of minigrids.

After cleaning the data, we analyzed electricity consumption for 2124 domestic customers and 21 PUE customers, across 25 minigrids. There is a strong contrast in electricity demand between these two groups. Domestic customers typically have relatively low electricity usage, with average and median monthly consumptions of 7.0 kWh and 3.2 kWh respectively. In comparison, the PUE customers have much higher usage, with average and median monthly consumptions of 353.4 kWh and 298.4 kWh, respectively. The figure below shows the average monthly consumption by minigrid for both groups, illustrating that the demand from just a few PUE customers is comparable to the combined demand of domestic users.

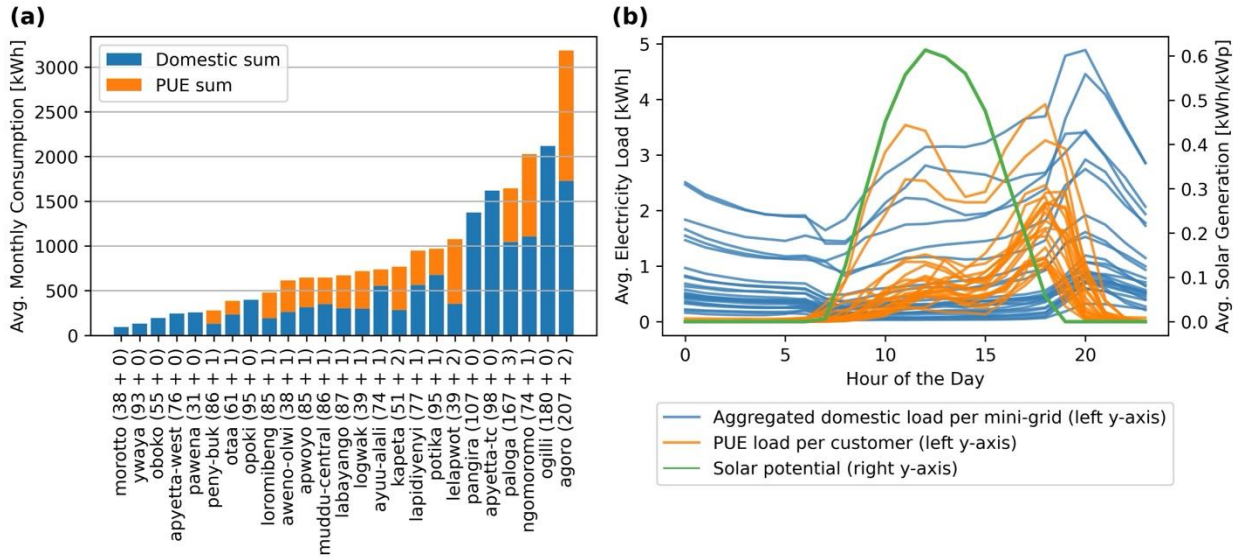

Figure – (a) Average monthly electricity consumption by aggregated domestic customers and aggregated Productive Use of Energy (PUE) customers across villages. The village name with domestic and PUE customer numbers are presented on x axis. **(b)** Hourly average of diurnal load patterns for per minigrid domestic customers aggregated and per PUE customer (left-side y-axis), compared with the pattern of solar generation potential (right-side y-axis).

Moreover, subplot (b) shows the average daily load profiles for aggregated domestic customers by minigrid and for each PUE. From the load timing perspective, both domestic and PUE load peaks occur in

the late afternoon to evening. Comparing the 16 minigrids with PUE customers, we observed that the daytime load ratio (the ratio of daytime load from 9am to 5pm to the total load) increased from 22% to 34% after incorporating the PUEs. With more daytime load, more electricity is used directly from solar sources, lowering the need to shift electricity usage to night hours using battery storage.

We have found that the peak-to-average daily load ratio is crucial for minigrid economics. Higher ratios require increased solar and battery capacity to supply peak demands but lead to lower utilization on typical days. Incorporating PUEs has been shown to reduce this ratio. One reason is that PUEs generally maintain a more constant load day-to-day. Another reason is that PUEs increase the average demand. Our findings suggest that minigrids with smaller demand can be affected by occasional high-demand events from domestic customers. A higher average daily demand ensures that equal consumption spikes have a lesser overall impact.

Lastly, our project installed 35 three-phase grinding machines in these minigrids. However, 14 of them lack complete annual data, so the current analysis focuses only on the remaining 21 machines.