

# **Which customers belong together? An enhanced off-grid clustering algorithm for cost-effective rural electrification**

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## **Abstract-**

**With 750 million people lacking access to electricity, cost-effective rural electrification is essential. A critical challenge for rural electrification projects is determining whether to cluster consumers to best serve them with standalone systems, mini-grids, or grid extensions. While state-of-the-art models offer advanced solutions, current clustering algorithms often rely on simplified cost estimators and rigid, bottom-up approaches, limiting their accuracy and adaptability.**

**This paper introduces a clustering algorithm that advances the state of the art by thoroughly evaluating the space of potential off-grid clustering solutions (i.e., the algorithm excludes extensions of the power grid as alternatives) and enhancing the accuracy of cost estimations. Applied to the Cajamarca region in Peru, it reduced electrification costs by 6.16% compared to a traditional state-of-the-art clustering method. Qualitatively, the method produced smaller, better-sized mini-grids and more appropriate allocations of standalone systems, demonstrating planning accuracy for sustainable energy access. An additional sensitivity analysis was performed, demonstrating the algorithm's ability to consistently deliver more cost-efficient and flexible electrification solutions, thereby contributing to sustainable energy access.**

**Index Terms- Rural electrification; Large-scale planning; Clustering; Mini-grids; Off-grid systems**

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