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Mini-Grid Innovation Lab

Innovation Insight

Grid Densification

June 2023

Proactively installing the distribution network in a mini-grid community drives down capex per connection significantly, and could account for an average IRR increase of 1.2%

Grid Densifications tests whether **proactively installing distribution[1] network infrastructure to connect a community to a mini-grid leads to higher project IRRs** than installing the same infrastructure reactively.

Two scenarios of grid densification have been **tested with 5 developers over 10 sites:** (i) Network saturation includes installation of all overhead distribution and customer connection accessories required throughout a community, and (ii) Network expansion includes installation of all overhead distribution throughout a community. Analysis of data from 2020 to 2023 shows that adoption of grid densification positively impacts grid economics, customer acquisition and grid utilization:

1. **On the average, grid economics results improve by an average of 1.2% in project IRR, from a base case of 5%**. Network saturation and expansion cost per connection were 15% and 1.4% cheaper than control sites at $778/connection and $905/connection respectively, as compared to $918/connection at control sites. Average revenue per user and average consumption per user do not seem to be related to grid densification in any way
2. **Grid densification results in faster customer acquisition.** Network saturation and expansion sites had higher community penetration, over 80% of the community connected in less than a year[2], compared to control sites (~51% penetration by year 1)
3. **More customers mean more utilization, sooner.** Network saturation (27%) and expansion (27%) have the higher average utilization compared to control site (13%) after 1 year

These findings indicate **grid densification should be incorporated into developers' mini-grid construction best practices**. All of the developers participating in this study have already adopted grid densification into their standard construction operations.

The Mini-grid Innovation Lab continues to test technologies that could capture the benefits of network saturation but require less upfront capex. We are testing different combinations of network saturation, distributed mini-grids, and mesh grids, with the aim of determining the approach that yields the most optimal benefit. Findings will be shared with the sector.

1 Proactively installing distribution network is refers to the practice of deploying distribution lines to all parts of a community that are planned to be connected from the point of construction, and not waiting for customer to ask to be connected before connecting them. 2 Over 100% suggests new households migrating to the community after mini-grid deployment

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Grid economics improvements result in 15% reduction in capex per connection

Grid densification tests the impact of proactively building distribution infrastructure and installing connections before customers make a financial commitment

We tested grid densification on 2 sets of treatment sites – network expansion and network saturation – and compared results to control sites

Network expansion

- Network expansion is a scenario of grid densification where the **installation of all[2] overhead distribution line is done throughout a community up to the droplines**
- Customers that require connection later only require a drop line, smart meter, and in-home wiring

Network saturation

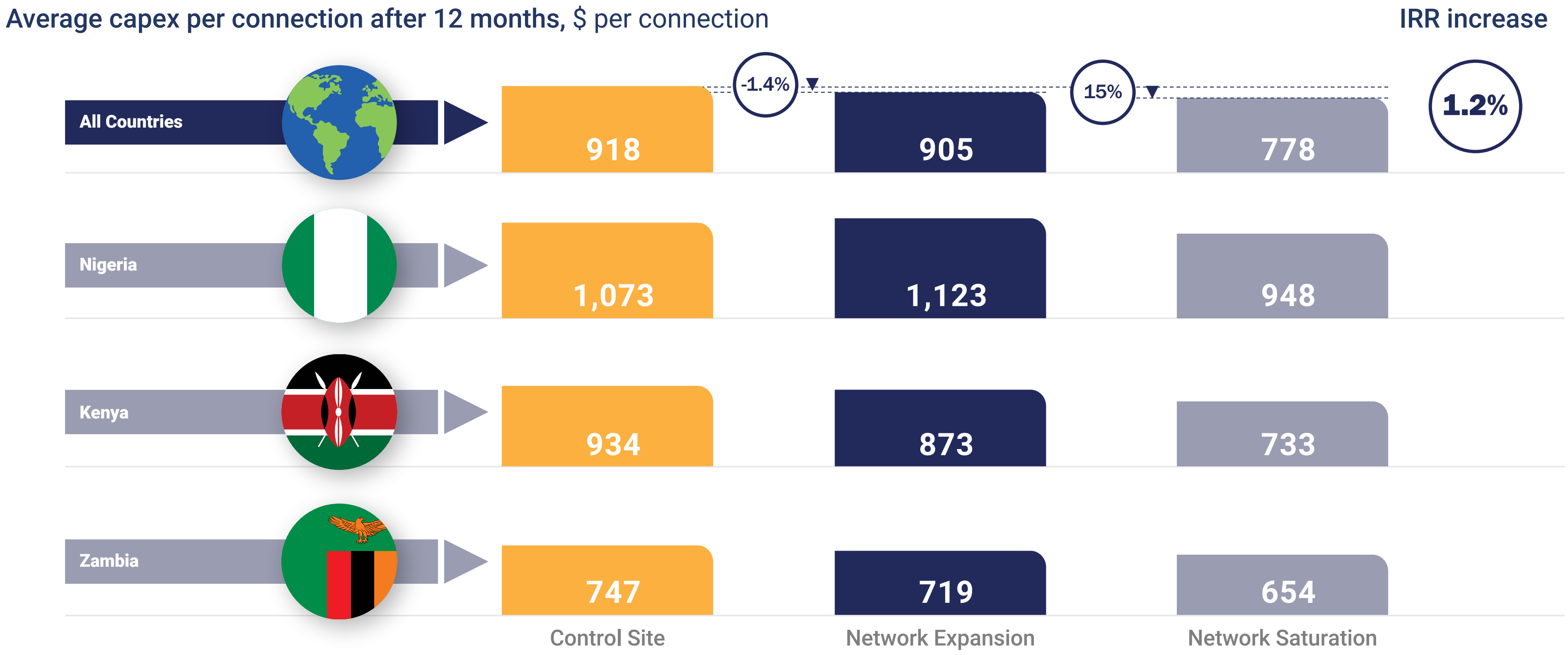
- Network saturation is another type of grid densification where the installation of all **overhead distribution and customer connection accessories (including in-home wiring)** is done proactively throughout the community
- New customer are connected by "turning on a switch" which in some cases could be done remotely

Control sites

- These are business-as-usual (BAU) sites where developers build out distribution line and customer connections **only after individual customers indicate interest**

1. Data from a total of 15 sites are shown in this insight – 10 treatments/grid densification sites (made up of 5 network expansion and 5 network saturation sites) and 5 control sites.
2. "all" refers to all of the customers the deployed systems were sized for

Using network saturation is 15% cheaper than BAU at $778/connection, and can increase IRR by up to 1.2%



What we're seeing

On the average, the total cost per connection for control site is the highest, followed by test expansion sites, and test saturation sites have the cheapest cost per connection by far

What it means

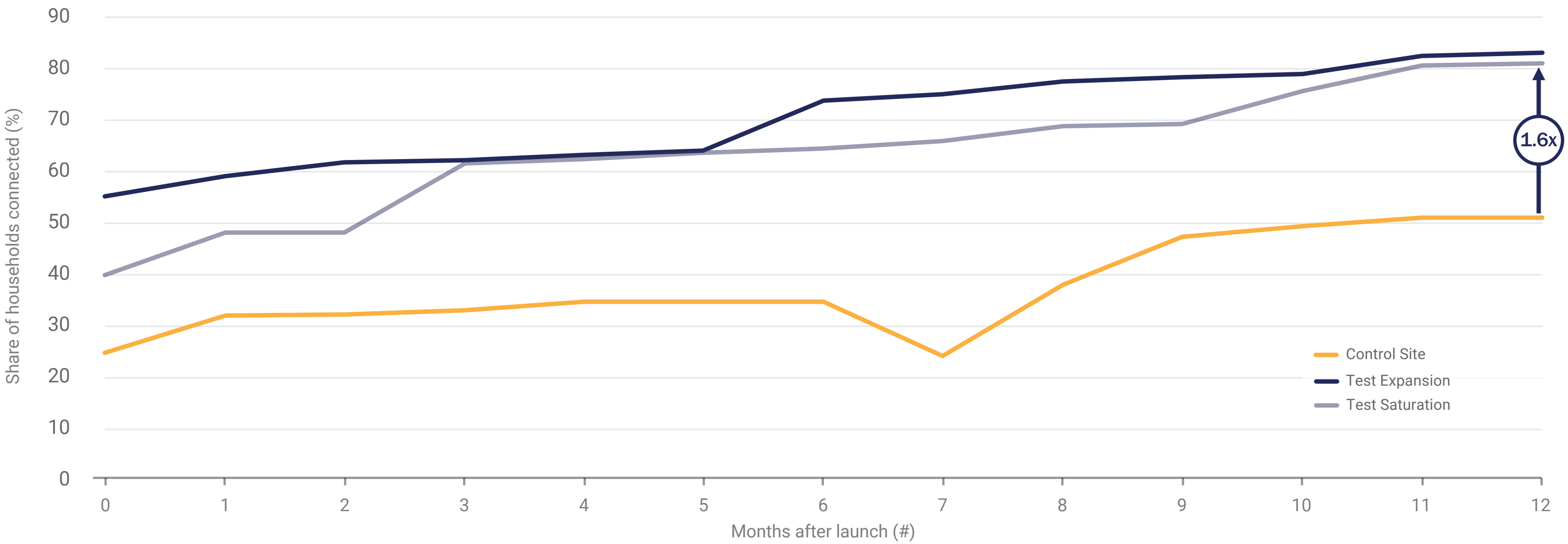
Grid densification using network saturation works. The unit savings realized are attributable to logistics, labor and bulk purchase of materials, which help to minimize capex per connection. These savings are highest in saturation, translating to an average of 1.2% increase in IRR, and realized to a lower extent in expansion

Note: (1) The impact of inflation on the cost over time was not accounted for (we expect impact to be minimal). The IRR increase quoted is based on the average capex per connection difference observed for network saturation compared to control. The penetration, or speed of connections are not included as observed trends may not be sustained, and control sites may eventually catch up

2 Grid densification results in faster customer acquisition

Network saturation has connected the highest share of households in communities, moving us closer to SDG 7 up to 1.6x faster…

Community penetration by site type (%) across months after launch (#) across all countries



What we're seeing

Network saturation has the highest community penetration rate, followed by network expansion and then control sites. At the observed rates, saturation could help achieve SDG 7 access targets up to 1.6x times faster than BAU

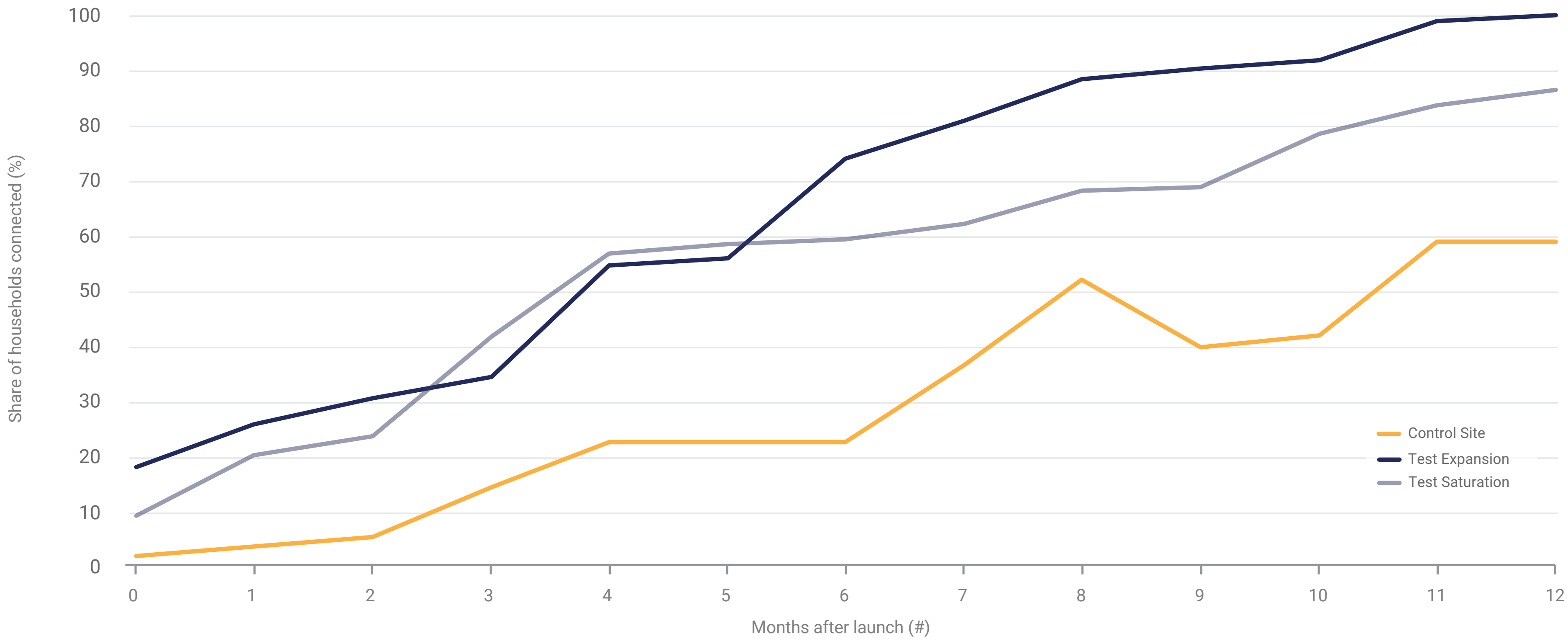
What it means

The availability of the distribution network and household electrical wiring across entire sites signals developers' willingness, capacity and ease of connecting new customers under network saturation, which drives faster and more expansive reach across the communities. The same effect can be observed, to a lesser effect in comparing network expansion to control sites.

1. Chart shows data for 5 control sites, 10 treatment sites (5 network saturation, and 5 network expansion)
2. Community penetration is defined as number of households connected, divided by the total number of households identified and recorded in the community before prototype launch

… and has connected these households at a much faster rate than control sites

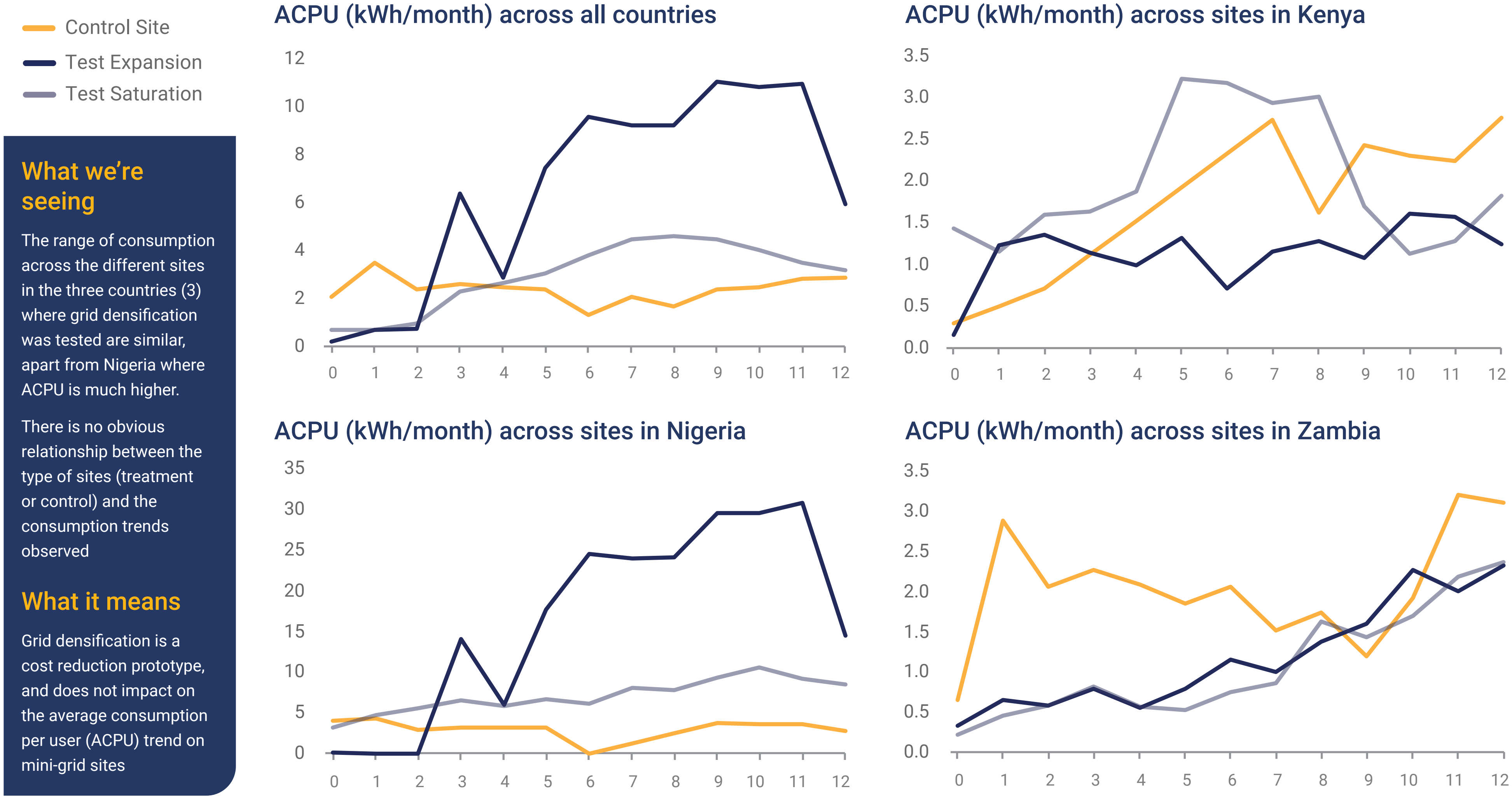
Ratio of relative meter count to maximum site meter count (%) across months after launch (#) - all countries



1. Chart shows data for 5 control sites, 10 treatment sites (5 network saturation, and 5 network expansion)
2. Relative meter count is calculated by dividing number of meters divided by site capacity (kWp) to discount the effect of site size

3 More customers mean more utilization, sooner

Grid densification is a cost reduction innovation. It does not affect ACPU directly, hence it may need to be paired with demand stimulation interventions



What we're seeing

The range of consumption across the different sites in the three countries (3) where grid densification was tested are similar, apart from Nigeria where ACPU is much higher.

There is no obvious relationship between the type of sites (treatment or control) and the consumption trends observed

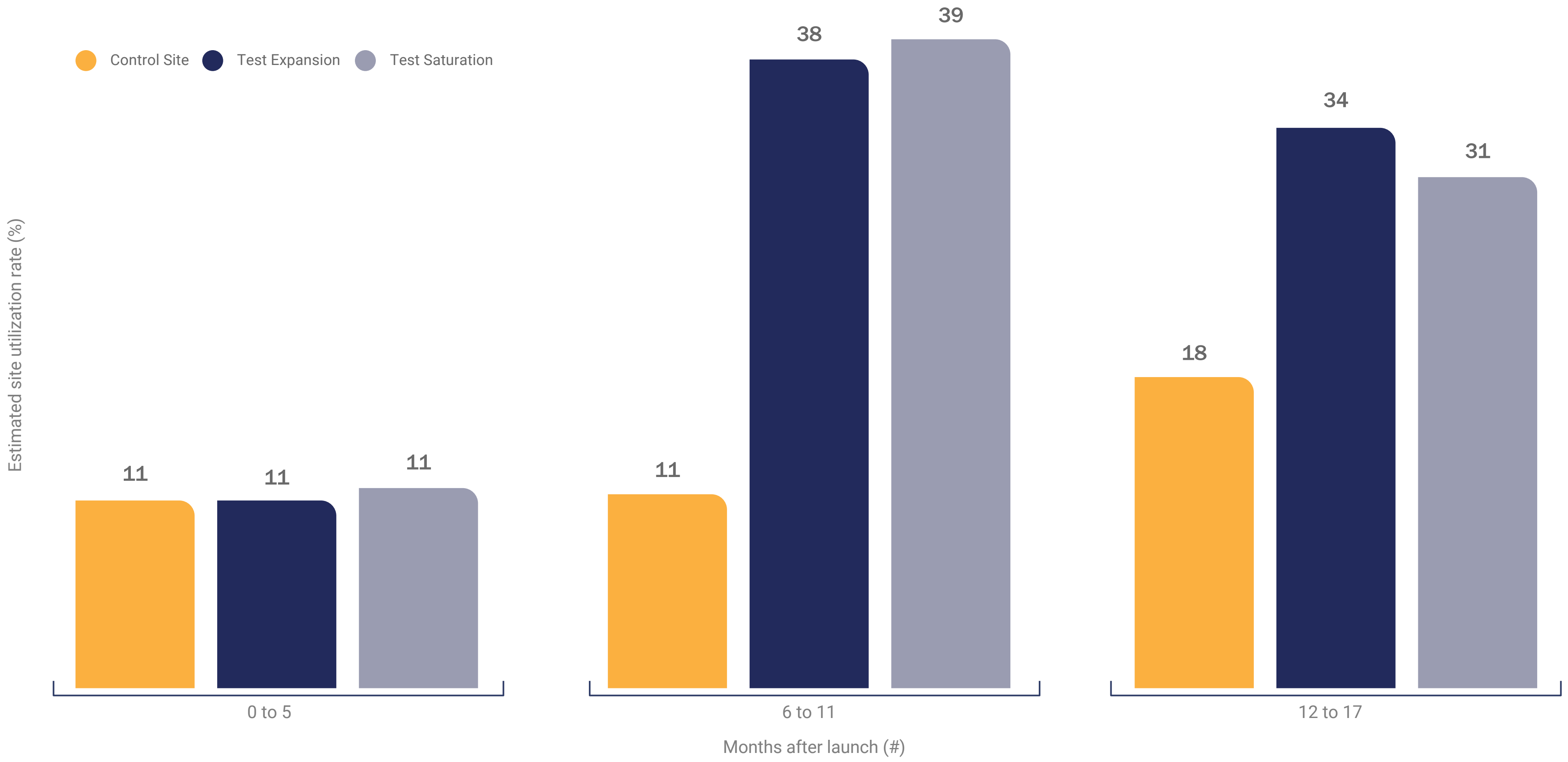
What it means

Grid densification is a cost reduction prototype, and does not impact on the average consumption per user (ACPU) trend on mini-grid sites

Note: showing data for 5 control sites, 10 treatment sites (5 network saturation, and 5 network expansion)

However, connecting customers quicker, as is the case in network saturation and expansion, leads to higher average site utilization rate

Estimated site utilization rate by site type (%) across months after launch (#)



1. Chart shows data for 5 control sites, 10 treatment sites (5 network saturation, and 5 network expansion)
2. Capacity utilization is defined as total consumption divided by the expected generation (based on irradiation data) over the same time period

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Grid densification should be incorporated into construction best practices

All 5 developers participating in this study have already confirmed the adoption of grid densificationn into their standard operations

For all mini-grids we deploy, we construct the entire distribution network, customer drop lines and in-house wiring of customers premises at the same time during the construction phase of the project. We do that for the ***cost efficiency, enhanced customer satisfaction, and improved site capacity utilization****.*

- West African Mini-grid Developer 1

Our electricity generation systems are designed with the electrification of the whole target communities in mind. Hence, grid densification will continue to be ***our standard grid construction approach****.*

- East African Mini-grid Developer 1

Customers tend to respond more favourably to the payment of connection fees at sites utilising the Network Saturation model. This positive reception can be attributed to ***the visible installation of wiring into their premises, which provides a tangible representation of the service being offered****. In contrast, models that require reactive connections after payment of connection fees may not elicit the same level of enthusiasm from customers.*

- West African Mini-grid Developer 2

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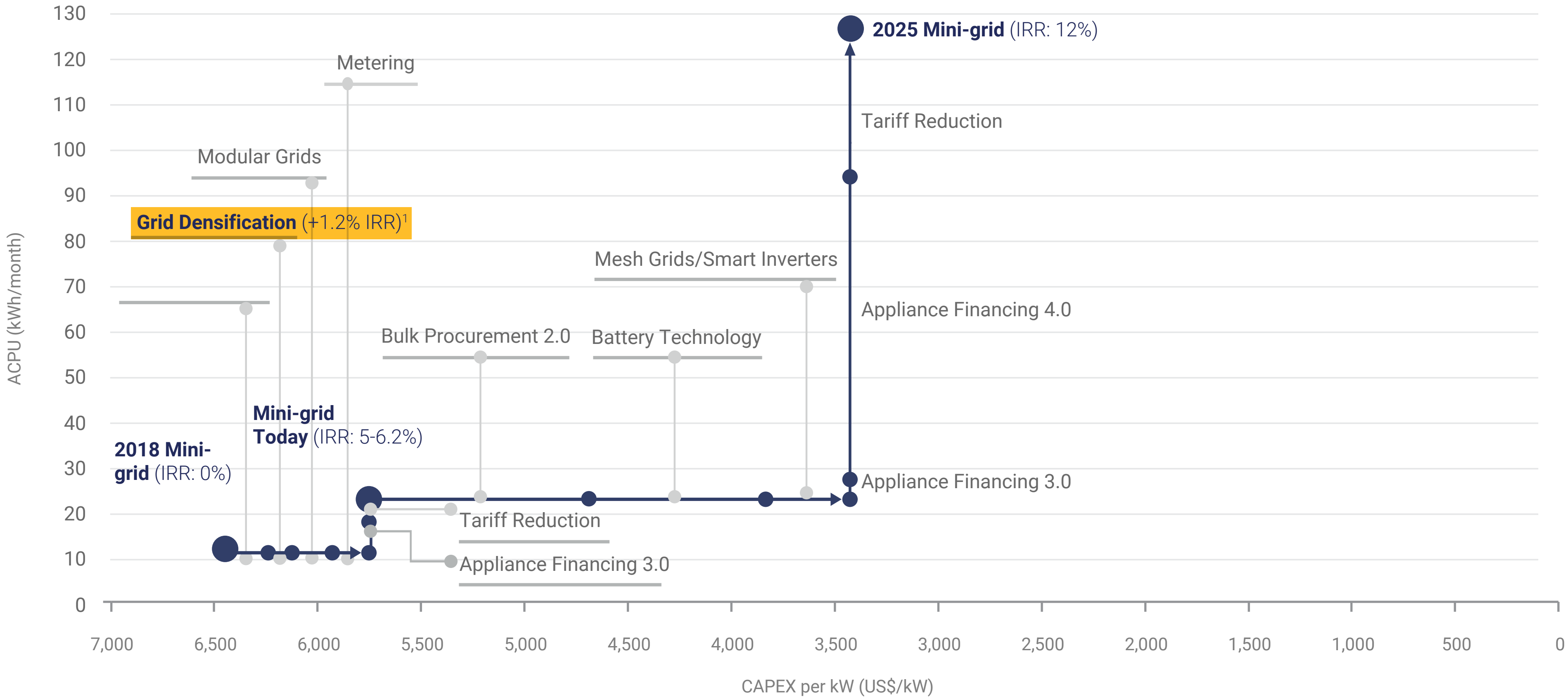
The Lab continues to test other innovations that reduce cost per connection

Based on results from the prototype, network saturation increased mini-grid IRR by an average of 1.2%. We are testing other innovations to reach our target of 12% IRR



Note: Modular Grids consists of two distinct innovations (Increasing Capacity and Extending Reach). A grid would, however, only be eligible for one of the two innovations at any given time. Increasing capacity was used in this chart. The Tariff Reduction prototype subsidizes a mini-grid's tariffs to test the impact on customer consumption and developers' revenues. MEM of 1,000kWh per person per year broken down into household (300kWh) and non-household electricity consumption (700kWh). Household consumption of 300kWh per person per year translates to 125kWh per household per month. 1. The IRR increase quoted is based on the average capex per connection difference observed for network saturation compared to control. The penetration, or speed of connections are not included as observed trends may not be sustained, and control sites may eventually catch up

Network saturation generates cost savings but requires a large upfront capex outlay. We are testing technologies that could capture the benefits of network saturation but require less upfront capex

We are also testing different combinations of grid densification (network saturation), distributed mini-grids, and mesh grids, with the aim of determining the approach that yields the most optimal benefit

Distributed mini-grids

We are testing whether building mini-grids modularly in decentralized clusters closer to key customers (i.e., distributed mini-grids), and expanding as needed improves mini-grid developers' profitability, by reducing the initial capacity requirement, minimizing losses, and optimizing distribution network capex

Mesh grids

Mesh grid technology is a technology of decentralized solar home systems that are interconnected for power sharing. They can be deployed alone or alongside mini-grids. We aim to compare the economics of mesh grids to mini-grids, and ascertain conditions where each is optimal

The Innovation Lab's work is made possible by the following funders:

And by the following developers:

Disclaimer and acknowledgements

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The Lab's Innovation Insight series provides ongoing, early insights on the prototypes so mini-grid developers, governments, and funders can act on the results as they emerge. All results and analysis in these series is therefore shared as actionable business intelligence rather than scientific evidence.

While these series are not intended to meet the standards of an academic paper, the Lab will publish more complete reports at the end of each prototype, and has partnered with University of Massachusetts Amherst, Rochester Institute of Technology, and Duke University to publish academic papers on certain prototypes.

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