AFRICA

A model for better electrification planning

Off-grid electrification systems can be the best option to provide electricity access in areas where the central grid is too expensive or the incumbent distributor is unable to extend the grid, for whatever reason. Researchers supported by the MIT Energy Initiative's Tata Center for Technology and Design in collaboration with IIT-Comillas in Madrid have built a computational tool called the Reference Electrification Model (REM) that can improve electrification planning in developing countries with low electricity access and help increase the success rate of off-grid projects.

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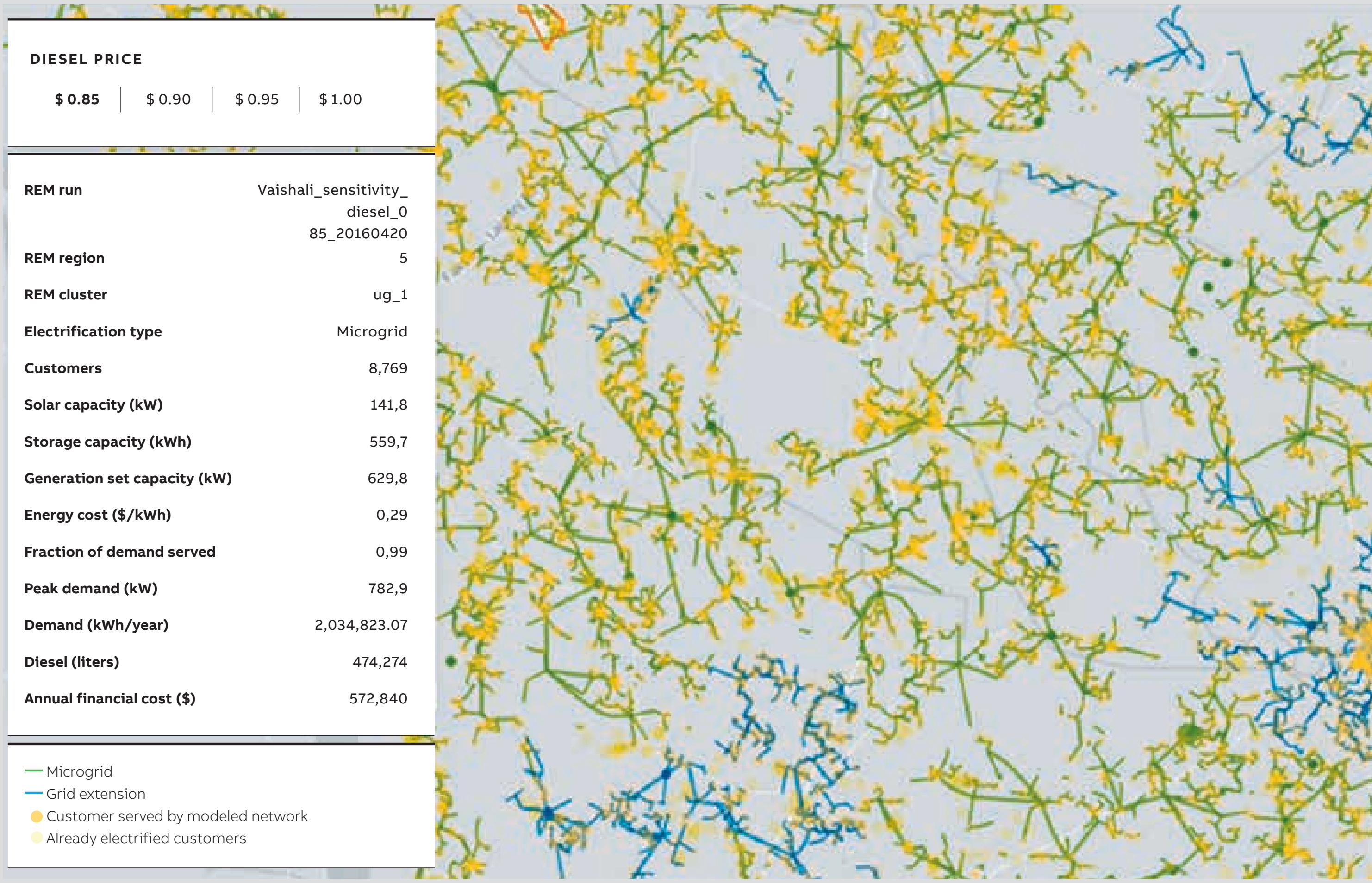
Over half a billion people in sub-Saharan Africa live without electricity, mostly in rural areas that may be years away from receiving reliable, centralized electricity (if it happens at all, considering the potential expense). A substantial portion of the rural population in the developing world could be served by off-grid systems – 70%, according to the International Energy Agency. But determining where off-grid systems such as microgrids would be the best solution (let alone building and operating those systems) is easier said than done, and it is here where the REM model can help. REM can also estimate the costs of electrification and potentially illuminate solutions to a serious financial viability problem: the cost of supplying scarce and disperse demand is more than what many of the customers that lack service can afford.

Developing low-cost, standalone systems to provide a small amount of lighting and phone charging has been the recent trend, but those solutions tend to do little to enable families to rise up the income ladder and realize the additional benefits that electricity can provide. The lack of "anchor loads" in rural areas – industrial or commercial – which could increase the total level of consumption, makes it challenging to design economically viable systems. The diversity of contexts in which microgrids hold promise create scalability challenges that tend to drive up engineering costs.

EDITOR'S NOTE:

With three decades experience in numerous projects around the world, ABB is a leader in off-grid and microgrid solutions. Whether powering whole islands, remote villages, or isolated industrial sites, ABB knows how to customize and right-size systems, agnostic to the generation source, and with the aim to drive maximum reliability with low cost. Most recently, the group introduced a new set of "plug and play" modules based on a number of pre-designed variants, which are scalable, expandable, and easy to install.

This guest essay from MIT's Tata Center for Technology and Design, which is part of the university's Energy Initiative, is an example of how such projects can be identified and scoped. MIT is a participant in ABB's Technology Forum.



REM run	Vaishali_sensitivity_diesel_0 85_20160420
REM region	5
REM cluster	ug_1
Electrification type	Microgrid
Customers	8,769
Solar capacity (kW)	141,8
Storage capacity (kWh)	559,7
Generation set capacity (kW)	629,8
Energy cost ($/kWh)	0,29
Fraction of demand served	0,99
Peak demand (kW)	782,9
Demand (kWh/year)	2,034,823.07
Diesel (liters)	474,274
Annual financial cost ($)	572,840

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Among other uncertainties, the possibility that the grid could eventually arrive makes investments in off-grid systems seem risky.

These obstacles – along with the regulatory challenges associated with upsetting the electricity sector status quo – mean that the decision about where to extend the grid, deploy microgrids,

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or use standalone systems is worthy of serious consideration. Existing approaches to this sort of hybridized electrification planning in developing countries range from politically motivated decisions to extend the grid, to other software tools, like Columbia University's electrification planning software, Network Planner.

REM provides the maximum degree of granularity in electrification decision-making (i.e., individual building level) that until now has been unattainable in such data-constrained environments.

REM is a robust optimization tool designed to process data about any size region, be it a village, a county, or an entire country, in order to make cost comparisons between different combinations of electrification modes (grid extensions, microgrids, or standalone systems) and identify areas better suited to on- or off-grid electrification →6. The tool also produces first-pass technical designs for recommended grid extensions and is capable of doing detailed system designs for grid extensions or microgrids that contractors, governments, and investors can rely upon for scenario planning and budgeting.

How It Works

In order to assess these tradeoffs and determine least-cost plans, REM requires two categories of inputs:

- Geospatial and resource information — Location of buildings, existing electricity distribution grid (if any), administrative or other context-relevant boundaries (including topography and geological features that the network cannot cross or at higher cost) →2, and the availability and prices of different energy resources.
- Electricity demand and costs – Classification of building types, characterization of the electricity demand for each building type (based on data such as hourly demand profile of similar buildings in similar contexts, census data about appliance ownership, or existing demand targets) →4, electrification status of buildings, reliability of the existing grid, cost of non-served energy (CNSE), generation and network equipment/technical requirements, and a discount rate to determine the net present value of a project.

The foundational input is the location of the buildings in the study region, since the ability to make decisions at such a granular level is what enables REM to do both large- and small-scale planning. This information is still rarely available from governments or local utilities (although significant progress has been recently observed), so REM employs an algorithm capable of extracting building locations from satellite imagery →5. With this data, REM uses a series of processing steps to organize the buildings into clusters, design systems for those clusters, and compare the costs of the viable options.

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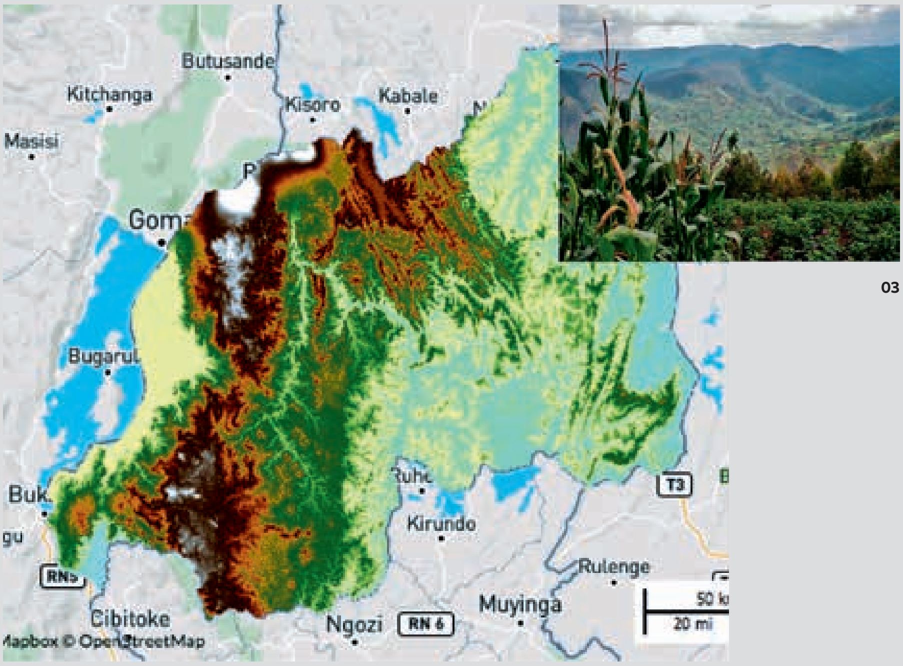
REM outputs information about the set of least-cost options for all consumers in a region in two formats: One, a table of information about each cluster or isolated building, including the type of system assigned to it, the estimated cost of the system, the type of generation and a detailed cost breakdown; two, a set of files that can be visualized using GIS software so that a full map of the study area can be evaluated →1.

01 A mock-up of how REM output might be presented to the end user.

02 A topographical map of Rwanda used as an input to REM.

03 View of the mountainous terrain in Rwanda as seen from the village of Karambe (Photo by Ignacio Pérez-Arriaga).



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Project planners (public or private) can use these results to ask a wide variety of "what if" planning questions, and study possible outcomes of various policy or regulatory interventions. At the individual system level, the goal is that REM can provide a reliable basis from which to conduct follow-on feasibility studies and community engagement.

Status & Availability

REM's development process has been facilitated through early stage on-the-ground projects that have enabled improvements to various capabilities of the model as well as highlighted some key lessons. In Rwanda, for example, where the REM team has been interacting with the Ministries of Infrastructure and Education, it has become clear that the country's mountainous geography lends itself particularly well to microgrids →3, since it is costly to extend the grid to these villages or to link them electrically. These communities place a high value on electricity since it alleviates the need to travel frequently down the mountain to the capital to purchase batteries or services, such as phone charging.

In addition to running REM, extensive community surveys have been employed to obtain reliable load estimates, reducing the risk of over-sizing systems and incurring unnecessary costs.

In Vaishali, a district in Bihar (one of India's poorest states) REM has been used to model a wide range of electrification scenarios that have led to

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other robust conclusions. Most interestingly, REM analyses here suggest that areas in which there is already grid distribution infrastructure may still be good candidates for microgrids if grid reliability is poor and grid extension is not progressing quickly.

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04 An example of how loads were characterized in Karambe, Rwanda.

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05 Two examples of early results obtained using an object extraction algorithm designed to locate buildings in satellite imagery.

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06 A graphical example of how costs change under different assumptions about demand and generation mix.

Additionally, the lack of load diversity gives rise to a demand curve that peaks in the evening and requires substantial battery storage, driving up microgrid costs. REM uses rigorous system optimization to minimize the costs of investment plus operation for a prescribed reliability target, while taking into account the expected demand profiles as well as historical weather and insolation patterns.

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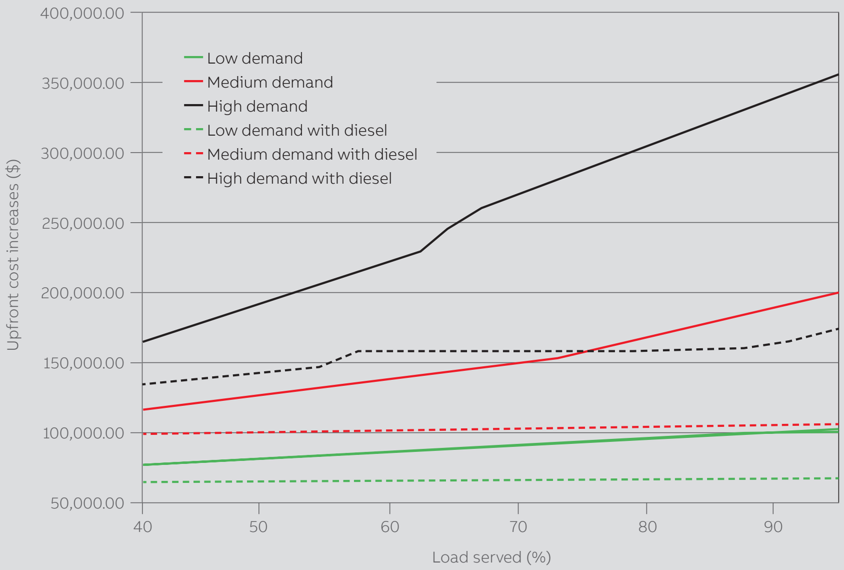
REM will be critical to studying and producing insights about the best mix of solutions in countries considering hybrid electric power systems.

REM is already helping users better understand the enormous role for both private and public dollars in closing the so-called “viability gap” between what people who lack access to electricity can pay and what it costs to improve their electricity access. As it is necessary to consider a diversity of large-and small-scale projects, REM will be critical to studying and producing insights about the best mix of solutions in countries considering hybrid electric power systems. ●



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