The Reliability-Adjusted Cost of Electricity (RACE): A new metric for the fight against energy poverty

Report of the Energy Metric Working Group

The Energy for Growth Hub

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Summary

Adequately tracking progress against energy poverty requires a metric that is more closely tied to income and employment than the commonly-used household access rate. The working group proposes the creation of the *reliability-adjusted cost of electricity* or RACE. This metric estimates the actual costs faced by private firms by capturing both tariffs from the grid plus the additional costs borne by backup generation when grid power is unavailable. RACE can be used as an indicator for the relative depth of energy poverty and of the dysfunction within electricity systems. RACE can be used by countries to compare against competitors, track progress against benchmarks, identify subnational differentials, and set future targets.

The Problem

Energy is recognized as a necessary input to economic and social development. The United Nations' Sustainable Development Goal 7 (SDG7) calls for "access to affordable, reliable, sustainable and modern energy for all." However, the actual metrics for tracking progress against this ambitious goal leave out significant factors in how energy contributes to poverty reduction, human prosperity, and economic transformation. For example, the principal target and indicator for SDG7 is to reach 100% residential electricity access by 2030. Household electricity is a worthwhile goal that brings valuable benefits to families and communities, but does not have a direct impact on incomes or job creation. The other targets and goals of SDG7 are for clean cooking, renewable energy share of electricity generation, and energy efficiency which are arguably aimed principally at health and environmental outcomes, not employment or poverty reduction.

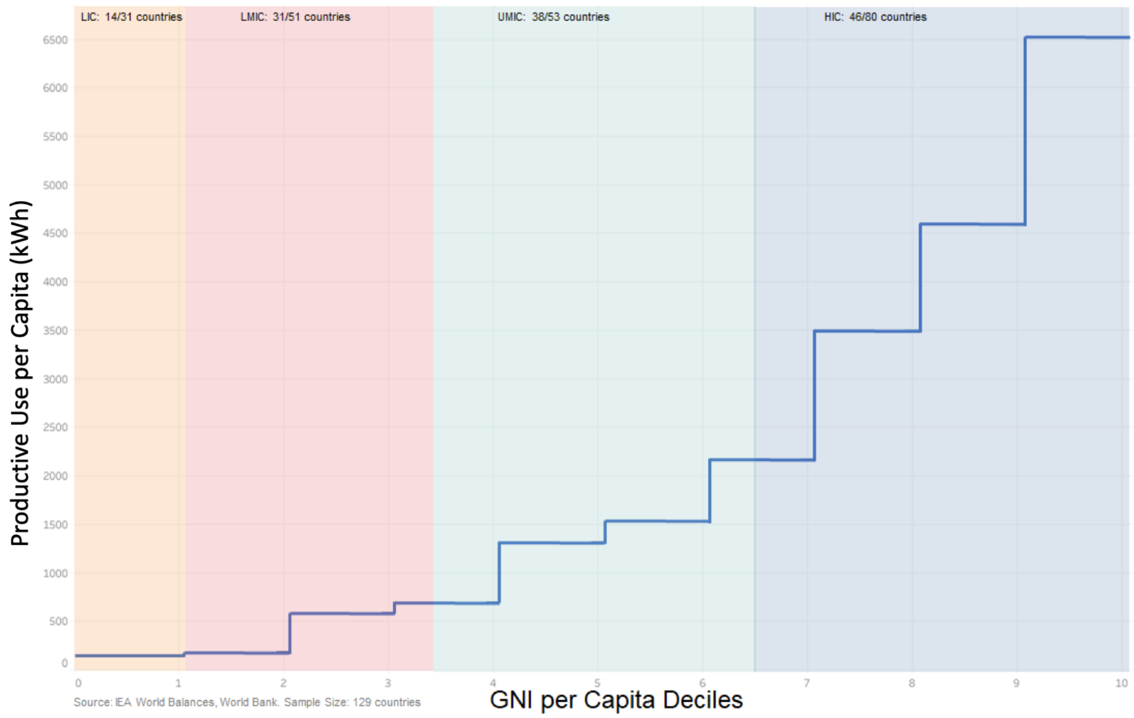
Electricity is fundamental to modern economic activity

No economy has ever reached a high income level without high energy consumption. Electricity consumption is tightly correlated with income; every single high-income country in the world uses at least 4,000 kilowatt-hours (kWh) of electricity per person each year. In the United States the average is more than 12,000 kWh, yet Ghana averages less than 500 kWh

[1] This report is the outcome of a working group convened by the Energy for Growth Hub. Any errors in fact or judgment are solely those of the Hub staff and not of any participants in the working group, funders, nor the Hub's board of directors. The Hub thanks the Rockefeller Foundation, the Spitzer Charitable Trust, and the Pritzker Innovation Fund for financial support that enabled this work. All work by the Hub is conducted with full editorial independence.

while Nigeria is under 150 kWh and Ethiopia is less than 100 kWh. To reach economic prosperity, all countries must climb the steep energy ladder. (Figure A shows all countries by income decile and per capita consumption of non-residential electricity.)

Figure A: The Steep Energy Ladder



The data and evidence consistently point to infrastructure, especially the cost and reliability of electricity, as a leading constraint to firm productivity, employment, and economic expansion.[2] Firms across African markets in particular cannot grow or hire more workers without low cost and dependable power supply. We therefore need additional metrics that more accurately reflect the impact that electricity has on driving incomes and job creation.

The inadequacy of the household access rate as a metric

The dominant metric, the ratio of basic household electrification, is by itself inadequate for measuring progress against energy poverty. It has at least four major shortcomings:

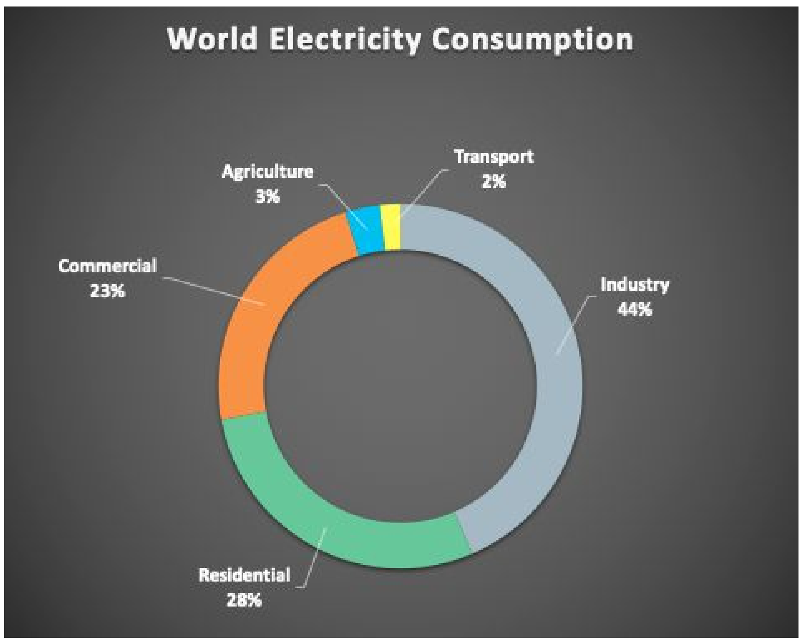
- Binary indicator. A 0/1 access rate only provides information about the ratio of people living above or below a single threshold. It provides no information about consumption, use, or utility of energy above or below that level.
- The threshold level. Any singular consumption threshold is blunt, but the chosen level should in some way be meaningful. The International Energy Agency (IEA) definition

[2] World Bank Enterprise Surveys; See also Moss, Todd, " Job Creation and Energy in Africa," Energy for Growth Hub, 2018.

of ‘modern energy access’ is just 50 kWh/capita/year in rural areas and twice this amount in urban areas. This extremely low level of consumption can provide only the most minimal of electricity services such as basic lighting and phone charging or possibly occasional use of a very low watt fan. The access rate on its own therefore says nothing about the availability, cost, or reliability of electricity for a multitude of uses such as powering machinery, data servers, transportation, or to provide cooling and heating. This minimal level is, in fact, nowhere close to a common understanding of ‘modern energy.’

- Economic sectors covered. Residential electricity accounts for just 5% of world energy consumption -- and only about one-quarter of total electricity (see Figure B). A household access rate includes no information at all about electricity for industry, commerce, agriculture, transportation, or public services -- where the vast majority of electricity is consumed.

Figure B



Source: EIA, 2018

- Rapidly diminishing relevance. The world has already reached 87% access, with 150 countries above 90% and just 50 countries (nearly all sub-Saharan African) below 75%. An access target is therefore irrelevant for most countries, including many economies where the cost and reliability of electricity remains a first-order constraint to development.

In sum, the most commonly-used energy metric for measuring success of SDG7 and the global fight against energy poverty contains almost no information about the contribution of energy to income, employment, or the wider economy. We need metrics that can give a more comprehensive understanding of the challenges.

The existing alternatives are better but also insufficient

While household access is inadequate, two other possible alternative metrics exist.

- *Per capita electricity consumption.* Although not an indicator for the UN's SDG7, the IEA also reports electric power consumption per capita by country, which is an estimate of national generation per year divided by the population. Per capita consumption is highly-correlated with per capita income (R^2=0.84), so it far better captures energy's potential contribution to income growth. While reaching an average consumption level has not become an explicit development goal, governments frequently set targets for national installed capacity in energy planning. Consumption metrics are also only indirectly linked to the utility and economic benefits of electricity use. Further, national averages typically make no distinction between usage in households versus usage in industry and commerce, although IEA data do allow for sector disaggregation in many markets.
- *The multi-tier framework (MTF).* The World Bank's MTF is a relatively new 5-tiered approach for measuring energy access across multiple quality dimensions such as reliability and affordability. Although initially created for household use, the MTF team has created a 'productive uses' version and piloted data collection in three countries (Kenya, Sao Tome, and Nepal). The pilot data are not yet available and widespread regular data collection of this type does not yet appear likely. While much will be learned from this exercise, it is unlikely to provide a regular cross-country metric for tracking ongoing global progress against energy poverty.

An energy metric closely tied to economic activity and job creation

Despite multiple energy-related metrics, none of the current options are sufficient. While no single metric can provide a comprehensive picture, creating one that is directly relevant to how an electricity system may enable rather than constrain economic activity would be a constructive step. To do so, the Energy for Growth Hub convened a working group of academics, industry professionals, and advocates to explore the issue and consider options.[3]

Proposing the *Reliability-Adjusted Cost of Electricity* (RACE)

Goal: The working group collectively agreed that any new metric must be:

- Directly relevant to employment and income.
- Comparable temporally and geographically.
- Useful for benchmarking, policymaking, and target-setting by national and/or municipal/local governments.
- Practical and feasible.

Given these parameters, the working group determined that the most immediate and useful solution was a metric to quantify the effective cost of consistently-reliable electricity for a typical firm in a given location.

[3] See Annex 1 for a list of participants.

Strategy: Create a single price estimate that combines the weighted cost of grid electricity and the least-cost self-generation option for when grid power in unavailable.[4]

Data inputs: A weighted answer only requires three data inputs[5] for a given location:

- *Tariff price*. Depending on the target sector, this can be commercial, industrial, or universal tariffs, and can also vary by monthly consumption levels. For illustrative purposes below, we use an average country-level industrial tariff where available, taken from Climatescope.[6]
- *Reliability measure*. An indicator for how often the grid is available/unavailable. For illustrative purposes below, we use data for the percentage of power from a generator taken from the most recent World Bank Enterprise Surveys.[7]
- *Self-Generation Cost*. An estimate of the cost to firms of providing their own electricity when grid power is unavailable, using the most prevalent or cost-effective option. For illustrative purposes below, we convert the diesel price from Climatescope into an electricity price using plausible assumptions for generator capital costs and efficiency.[8]

With the above data inputs, the following formula was used as the basis for the model:

RACE = (grid tariff * % grid available)+(self-generation cost * % grid unavailable)

Initial Results for RACE: A sample of ten countries for the new metric are shown in Table A and Figure C. The results suggest:

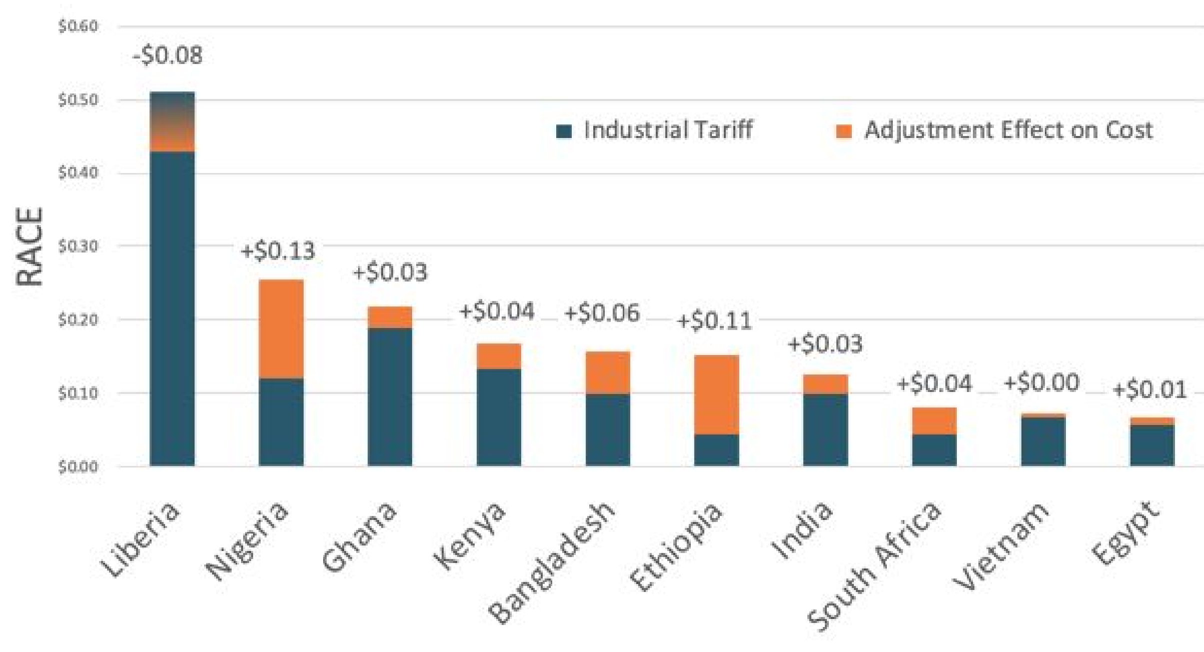
- Nigeria and Liberia have both high tariffs and low reliability.
- High-performing Vietnam has both low tariffs and high reliability.
- Egypt has low tariffs and relatively poor reliability, but cheap diesel mitigates any significant price adjustment for self-generation.
- Ethiopia's exceptionally low tariffs are wiped out by the unreliability or unavailability of its grid.
- Ghana and Nigeria have a similar RACE, but Ghana's rate is driven largely by high base tariffs, while Nigeria's is driven by poor reliability.
- Liberia is an outlier as its RACE is lower than the retail tariff. This is because the extremely expensive electricity tariffs are higher than the estimated cost of self-generation. Generators, as might be expected in such circumstances, are pervasive in the country.

[4] Credit to Anant Sudarshan at the Energy Policy Institute at the University of Chicago (EPIC) for the original suggestion.
[5] See Annex 2 for an explanation of potential data sources.
[6] Climatescope is developed by BNEF. Data available currently only from 2014/2015. The dataset includes 58 countries across Africa, Asia, and Latin America. Climatescope has more recent models which include more expansive country coverage, but the raw input data are not currently public. Data was accessed August 2019.
[7] See Annex 3 for a breakdown of potential options for the reliability input from World Bank Enterprise Surveys.
[8] See Annex 4 for more details.

Table A

Reliability-Adjusted Cost of Electricity (RACE), selected countries				
Country	Generator use	Base Tariff	RACE	Difference
Liberia	54%	$0.52	$0.43	-$0.092
Nigeria	59%	$0.12	$0.25	$0.134
Ghana	22%	$0.19	$0.22	$0.030
Kenya	18%	$0.13	$0.17	$0.035
Bangladesh	26%	$0.10	$0.16	$0.058
Ethiopia	49%	$0.04	$0.15	$0.108
India	9%	$0.10	$0.13	$0.027
South Africa	11%	$0.04	$0.08	$0.037
Vietnam	2%	$0.07	$0.07	$0.004
Egypt	14%	$0.06	$0.07	$0.010

Figure C: Preliminary RACE in Ten Countries



What RACE does well as a new metric

- Conceptually simple and easily understood.
- Clearly shows how baseline industrial tariffs interact with the problem of unreliability.
- Easily comparable across time and geographic space. This makes it a natural fit for benchmarking as a relative measure for comparisons and used as an absolute measure for target-setting.
- Input data are largely available and relatively frequently collected.
- Scalable geographically. RACE could easily be calculated to make comparisons and set targets for geographically specific areas, such as an enterprise zone or a state or city.
- Adaptable to specific sectors. RACE could be used to create comparisons across sectors in a particular place, such as RACE for manufacturing vs RACE for mining.
- Not conceptually limited to specific data sources. Alternative reliability measures could be substituted as better data become available, as long as comparisons use consistent data (See Annex 2). Tariff data also need not be from a single data source as long as it uses the most recently available data. Metric precision could be enhanced as other data or reliability measurements become available, while still maintaining the same conceptual structure.

Limitations of the new metric

- RACE only estimates direct electricity costs faced by firms. It does not quantify opportunity costs or economic losses from outages.
- RACE does not account for non-electricity energy costs.
- Tariff rates and fuel costs may be distorted by government policy, i.e., they may reward implicit or explicit subsidies.

Limitations of the data used to illustrate RACE

- The current RACE data presented do not distinguish between commercial and industrial tariffs which may vary in some locations. Some firms also negotiate special rates directly with the local utility or they contract with their own captive power; none of this data are captured in the illustrative data.
- Current illustrative data are only based on national averages. Fuel prices, tariffs, and especially reliability are likely to vary by geography.
- The reliability data from the Enterprise Surveys are collected only intermittently and only from formal sector firms.

Conclusion: RACE adds an important new tool for the fight against energy poverty

Governments and policymakers who aim to end energy poverty can use RACE as a potential new metric for tracking the effective cost of electricity faced by firms. This is a useful complement to the household electricity access rate, especially for countries or regions where electrification is already at or near universal levels or where energy policy is aimed at supporting business expansion and employment creation.

Institutions such as the IEA, United Nations, or the World Bank should adopt RACE as a new metric in tracking progress of electrification. Individual governments can also use RACE to make comparisons with competitors and to set targets for improvement of electricity costs and reliability faced by firms in their own markets.

The fight against energy poverty should aim not only for lights in every home, but for energy to no longer be a constraint on economic opportunity or a barrier to every human to live up to their full potential. RACE is one measure that can shed light on this eminently solvable problem.

Annex 1: The Energy Metric Working Group

The working group held four meetings between May and August 2019. Participants included:

1. Michael Aklin, University of Pittsburgh
2. Murefu Barasa, EED Advisory
3. Morgan Bazilian, Payne Institute, Colorado School of Mines
4. Moussa Blimpo, World Bank
5. Lauren Culver, World Bank
6. Taryn Dinkelman, University of Notre Dame
7. Emily Huie, ONE Campaign
8. Charles Kenny, Center for Global Development
9. Bryan Koo, ESMAP, World Bank
10. Robyn Meeks, Duke University
11. Vijay Modi, Columbia University
12. James Morrissey, Oxfam America
13. Todd Moss (working group chair), Energy for Growth Hub
14. Rose Mutiso, Energy for Growth Hub
15. Ted Nordhaus, Breakthrough Institute
16. Vijaya Ramachandran, Center for Global Development
17. Manju Shah, Wake Technical Community College
18. Kartikeya Singh, Center for Strategic and International Studies
19. Anant Sudarshan, University of Chicago
20. Jay Taneja, University of Massachusetts at Amherst
21. Catherine Wolfram, Haas School of Business, University of California at Berkeley

Note: Affiliations for identification purposes only. Each working group member participated in a private capacity.

Annex 2: Data Sources

Electricity tariff data

- Tariff rates for industrial and/or commercial customers. For preliminary analysis Climatescope data was used.[9] Africa-only data are also available from the World Bank.[10] Ultimately, a use-specific database would need to be constructed, likely initially a compilation of a variety of data sources.

Reliability data

- Data from World Bank Enterprise Surveys are available for 139 countries, many with multiple years.[11] These include the reported percentage of electricity from a generator, which is used to calculate RACE above. The surveys also include the reported number duration of outages, which provide an alternative measure presented in Annex 3.
- Utility-reported data (such as the annual hours of outage duration per customer, aka the System Average Interruption Duration Index or SAIDI), are an option, though considered far less robust and more subject to manipulation and underreporting.[12]
- Satellite-based estimates of grid stability being developed by Jay Taneja and colleagues should be available soon. These data will likely be most useful for specific urban and peri-urban areas and enterprise zones.
- Computer simulations of 'non served demand' are another option.[13]

Self-generation cost estimates

- Cost of replacement power when the grid is unavailable, using an estimate based on diesel generation costs and/or available solar mini grid tariffs and/or other technologies as they become available and widely used.
- The primary form of self-generation industry and commerce in most countries remains traditional, stand-alone, diesel-electric generators. If mini-grids (whether gas turbine or hybrid) become more commonplace, they could easily be added to the model.[14]
- Cost of electricity using diesel generation is calculated in RACE using (a) fuel cost (b) generator efficiency assumptions and (c) adjustments for capital, operations, and maintenance. Fuel price data are widely available from a variety of sources. We use Climatescope in this proposal but could also use the GIZ database.[15] Generator efficiency can vary somewhat based on size and load. The cost of capital, operations, and maintenance is estimated using Lazard's LCOE model. See Annex 4 for further details and sensitivity analysis.

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[9] Climatescope, BNEF.
[10] Making Power Affordable for Africa and Viable for Its Utilities. The World Bank compiles detailed tariff data for 39 countries in Sub-Saharan Africa.
[11] Enterprise Surveys, World Bank.
[12] Taneja, Jay, "Measuring Electricity Reliability in Kenya," UMass-Amherst, 2017.
[13] Ellman, Douglas, "The Reference Electrification Model: A Computer Model for Planning Rural Electricity Access," MIT, 2015.
[14] Hybrid minigrid (solar/storage or solar/other) costs range in price, but as of today would likely be more expensive than diesel options in most locations in most of our sample countries. Estimated baseline LCOE for hybrid minigrid systems today range between US$0.55-$1.00 according to the World Bank and the Rocky Mountain Institute.
[15] International Fuel Prices 2018/2019. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Annex 3: Two options for reliability measurements derived from World Bank Enterprise Surveys

One of our main data sources for this proposal is the World Bank Enterprise Surveys, with data for various years 2007-2017. From the measures available, the two most plausible options are:

1. Option A: Generator Usage using *If a generator is used, average proportion of electricity from a generator*
2. Option B: Implied Time Out calculated as *number of outages per month * average duration of outages*

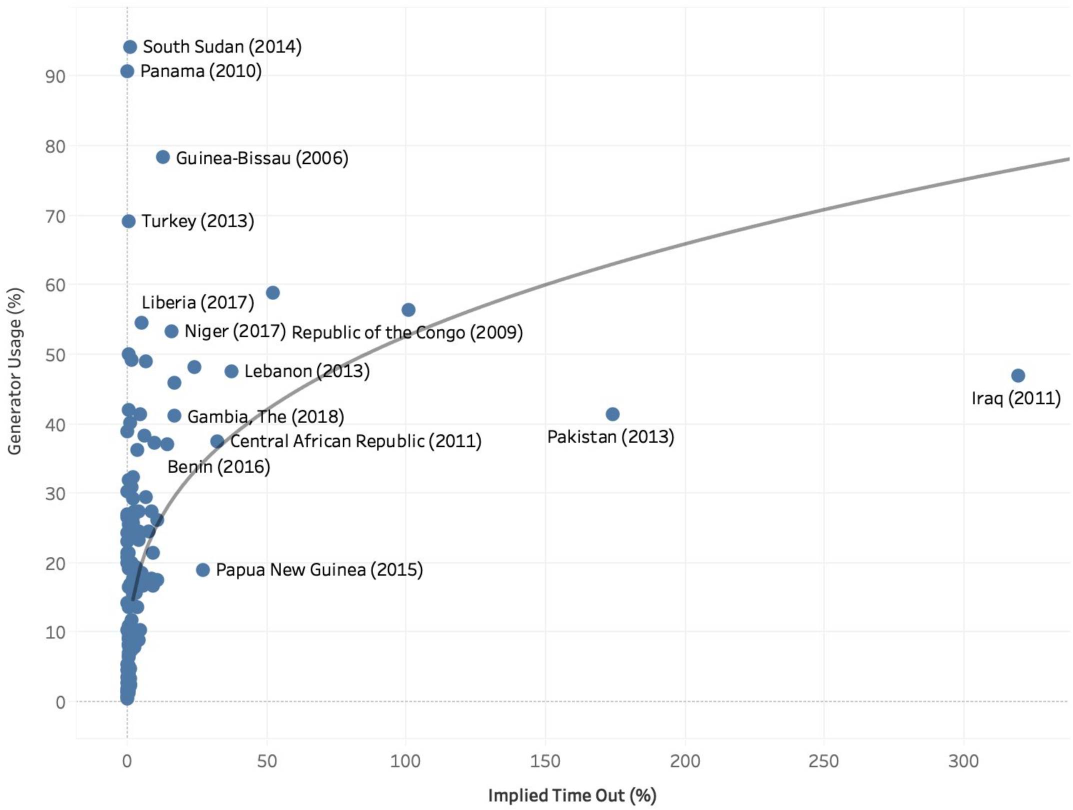
Option A is used above in RACE. For comparison, Option B is shown in Table B using the same sample of countries. However:

- By this measure, some countries (Iraq, Pakistan, Republic of Congo) show calculated totals of outages > 100%. This implausible outcome likely highlights the problem of amplifying measurement inaccuracy by multiplying two noisy indicators. See Figure D for correlation between Options A and B.
- We find ordinally similar results to Option A, but the data overall provide for *substantially* lower total generator usage in all countries.

Table B

RACE, comparing two reliability options					
Country	(A) Generator Usage	(B) Implied Time Out	(A) RACE	(B) RACE	Difference
Liberia	54%	5%	$0.43	$0.51	-$0.083
Nigeria	59%	9%	$0.25	$0.24	$0.015
Ghana	22%	52%	$0.22	$0.20	$0.017
Kenya	18%	3%	$0.17	$0.14	$0.029
Bangladesh	26%	11%	$0.16	$0.12	$0.034
Ethiopia	49%	7%	$0.15	$0.06	$0.094
India	9%	4%	$0.13	$0.11	$0.015
South Africa	11%	<1%	$0.08	$0.05	$0.035
Vietnam	2%	<1%	$0.07	$0.07	$0.003
Egypt	14%	<1%	$0.07	$0.06	$0.010

Figure D: Correlation of the Two Reliability Measures Derived from Enterprise Surveys



Annex 4: Self-Generation Options and Sensitivity Analysis

The base assumption we use in RACE is for a 100 kw diesel-electric generator, running at 75% capacity, and includes an adjustment for capital and operating and maintenance costs using a midpoint assumption from the Lazard estimates that fuel costs account for 65-88% of LCOE.[16] For a US$1 per liter diesel price, this translates into $0.39/kWh. Below in Table C we show the variation if we adjust generator size (100 kw vs 20 kw), load capacity (100%, 75%, 50%), and without capital and O&M adjustment. This provides a range of $0.28-$0.45/kWh.

Table C: Generator electricity costs at $1 per liter under different assumptions ($/kWh)

		Load		
		100%	75%	50%
Excluding capital and O&M	100kw	$0.28	$0.29	$0.31
	20kw	$0.30	$0.33	$0.34
Including capital and O&M	100kw	$0.37	**$0.39**	$0.41
	20kw	$0.40	$0.44	$0.45

[16] Source: Lazard's Levelized Cost of Energy Analysis—Version 11.0; Electrifying the poor: Highly economic off-grid PV systems in Ethiopia - a basis for sustainable rural development).

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