



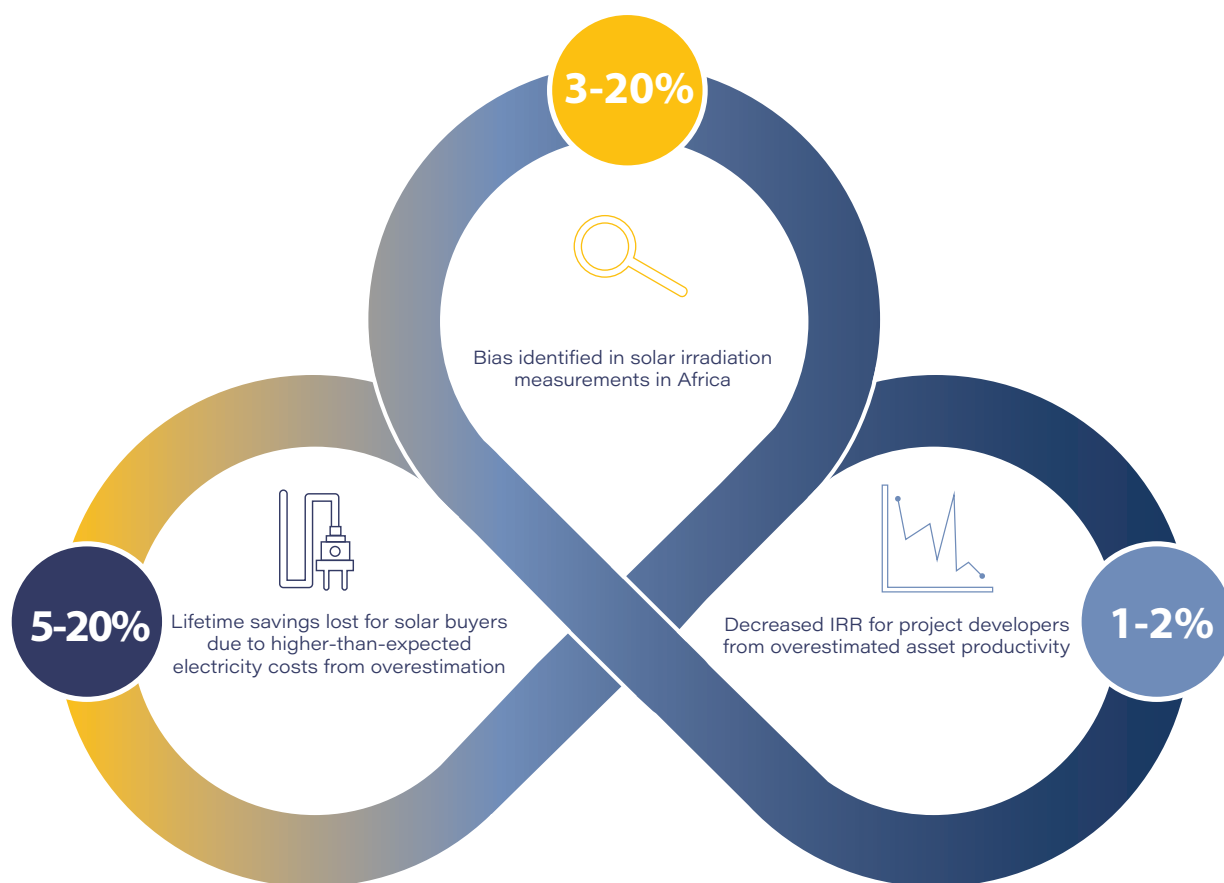
CROSSBOUNDARY
ENERGY



Measuring Solar Irradiation in Africa: *A case for change*

AUGUST 2021 REPORT

Shining a **spotlight** on data irregularities



SOURCE: CROSSBOUNDARY ENERGY

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AUGUST 2021 REPORT

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EXECUTIVE SUMMARY

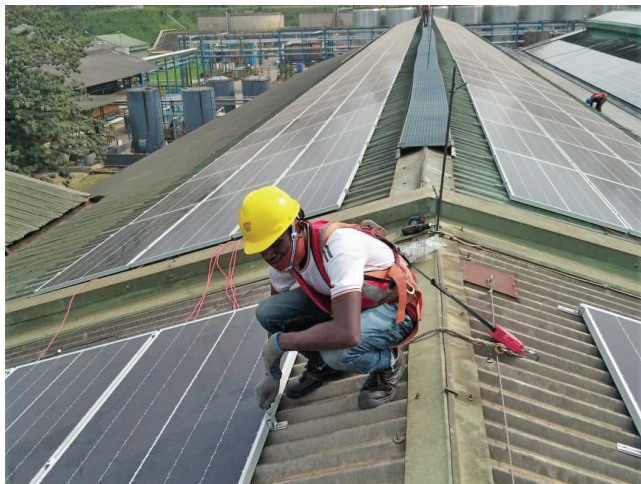
Declining solar equipment costs continue to drive African commercial-industrial (C&I) users toward solar energy solutions. Irradiation – the measurement of how much sunlight shines in each location and therefore how much electricity a solar array can produce – is a key design factor for solar customers, suppliers, and investors alike. But are the industry's current methods of calculating long-term solar production in Africa reliable?

CrossBoundary Energy's (CBE) experience owning and operating one of Africa's largest portfolios of solar plants for businesses suggests that this is not the case. Biases within the datasets commonly leveraged to estimate solar production in Africa cause projections to often overstate solar irradiation. If these biases are not addressed during project development, inaccurate irradiance estimates can result in up to 20% reduction in realized solar savings for C&I solar buyers and a 1-2% reduction in the internal rate of return (IRR) on investment for solar developers and investors.

Careful calibration can mitigate this underproduction risk for a single plant. But the growth of the African distributed solar market as a whole – and its promise to neutralize the carbon footprint of the continent's growing industries – rests on a fractured foundation until we all recognize the shortcomings of current methods for irradiation assessment on the continent.

This report sheds light on how solar production estimates are made, the specific challenges faced in estimating solar irradiation in Africa today, and the negative consequences CBE has seen as a result of inaccurate estimates. By highlighting this issue, we aim to begin a broader conversation about how to raise the C&I industry standard for calculation of long-term solar production to deliver better outcomes for clients.

Improving solar irradiation measurement on the continent is not a single organization's responsibility; collaboration between solar buyers, developers, data providers, installers, and investors is needed to address and ultimately rectify the problems identified in this paper.



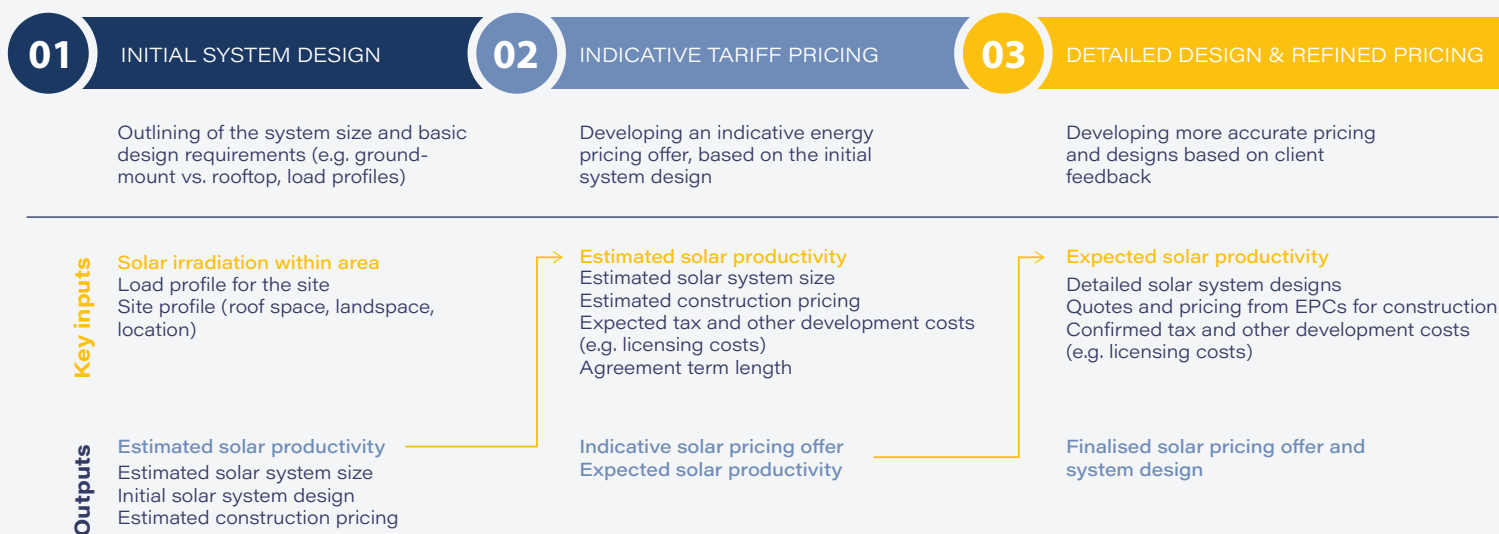
INTRODUCTION

Databases for estimating solar production in Africa overestimate irradiance

Insight 01: Solar irradiation measurements in Africa contain irregularities

Solar developers rely on solar irradiance measurements to predict how much power the plant will produce daily and annually. This affects the solar installation's design, the price for solar charged to C&I clients, and the expected return to investors from solar investments. See below for how irradiation factors into the solar design and pricing process:

FIGURE 1: THE C&I SOLAR PROJECT DESIGN AND PRICING PROCESS



In analyzing CBE's portfolio of operating projects in Africa, we noticed that actual irradiation – measured by our ground-based measurement systems – tended to deviate from the satellite data widely accepted as accurate for making calculations of long-term energy production during solar design. We've observed this deviation between actual measured and estimated irradiation – referred to as 'relative mean bias deviation' – to be 3-5% for two of our operational sites, one in Nairobi, Kenya and the other in Accra, Ghana. This translates into an equivalent deviation of 3-5% in solar power production estimates, all other factors held constant. Looking deeper, the situation worsens. Due to the continent's diverse topography, we found that sites outside of major cities experience even higher biases; satellite solar irradiation estimates for sites nestled in highlands, valleys, or next to lakes can be biased by up to 20%. To put it in commercial terms, this could result in up to 20% lower energy savings for solar customers, with businesses outside of major metropolitan areas most at risk. [1]

So why do such significant gaps exist between estimated and actual solar production in Africa?

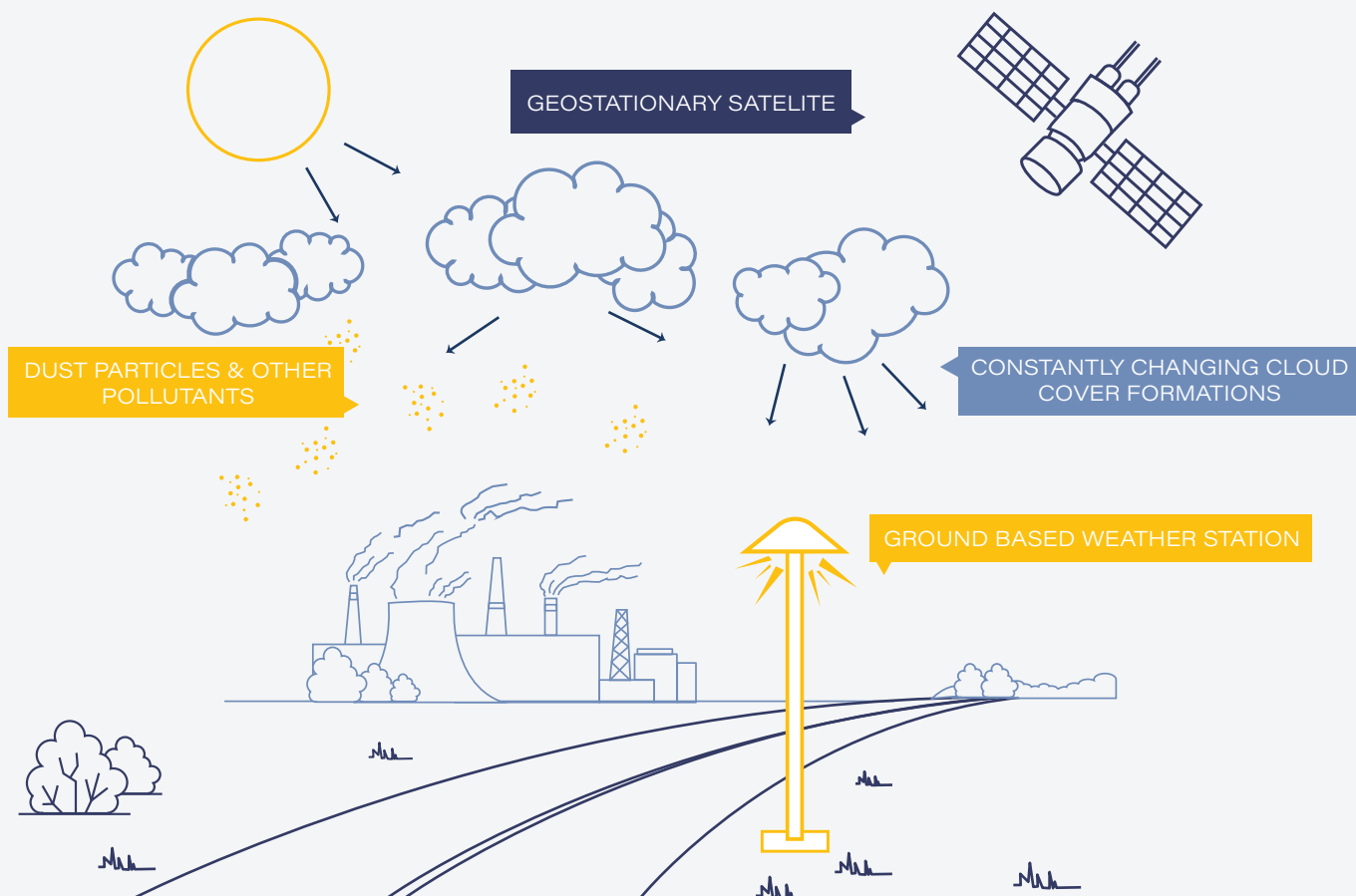
Insight 02: Ground-based measurement stations are few and far between in Africa

There are two main ways to estimate solar irradiation: satellite and meteorological models, and ground-based measurement. With satellite and meteorological model estimation, we obtain data on cloud cover, atmospheric dust concentration, aerosol concentration and water vapor concentration from geostationary satellites and then process it through algorithms to determine the level of solar irradiation expected at a specific point on the earth's surface.

The accuracy of this is limited to the accuracy of the satellite imagery and the ability of the satellite to observe fine details and subtle changes in the parameters under observation. For instance, the U.S. National Oceanic and Atmospheric Administration (NOAA) provides cloud cover data in a grid resolution of 3km, but water vapor data in a 55km grid resolution. By combining climate data captured at varying resolutions, satellites may overlook local microclimatic conditions that deviate from the regional average. [2]

Ground-based measurements, on the other hand, involve the use of instruments such as pyranometers and pyrheliometers that are installed at the surface of the earth and record the actual solar irradiance data on the earth's surface. They can capture both direct irradiance, which is the light that beams down directly from the sun to the earth, and diffuse irradiance, which is sunlight that has been scattered by objects such as clouds and dust particles as it travels through the earth's atmosphere. Satellite data tends to deviate from measured solar irradiance due to the variations in the concentration of particles in the atmosphere, and the inability of satellite imagery and meteorological models to estimate these to pinpoint accuracy. This is where data correlation comes in. Accurate data from ground-based measurement systems is used to validate and recalibrate satellite prediction models to ensure that the disparity between actual and estimated irradiance is reduced. The complementary relationship between these two approaches makes solar irradiation estimation feasible for practically any point on the earth.

FIGURE 2: DIFFERENCES BETWEEN IRRADIATION DATA CAPTURED BY SATELLITES VERSUS GROUND MEASUREMENT TOOLS



INTRODUCTION

There's a catch. In our assessment, we've noted that the distribution of ground-based validation sites is clustered in Europe, South Africa, and overall in temperate regions, with few and sparsely distributed stations serving other parts of Africa, particularly in the tropics. The colored nodes in the chart below represent relative mean bias deviation observed at each measurement station; the satellite models have been shown to underestimate irradiation at blue stations and overestimate irradiation at orange and red stations. Weather stations that do exist in East Africa show high relative mean bias deviation, and satellite model accuracy is unknown for much of the rest of West and Central Africa.

FIGURE 3: PUBLIC GROUND-BASED VALIDATION SITES FOR GHI IN AFRICA [1]



IMPACT

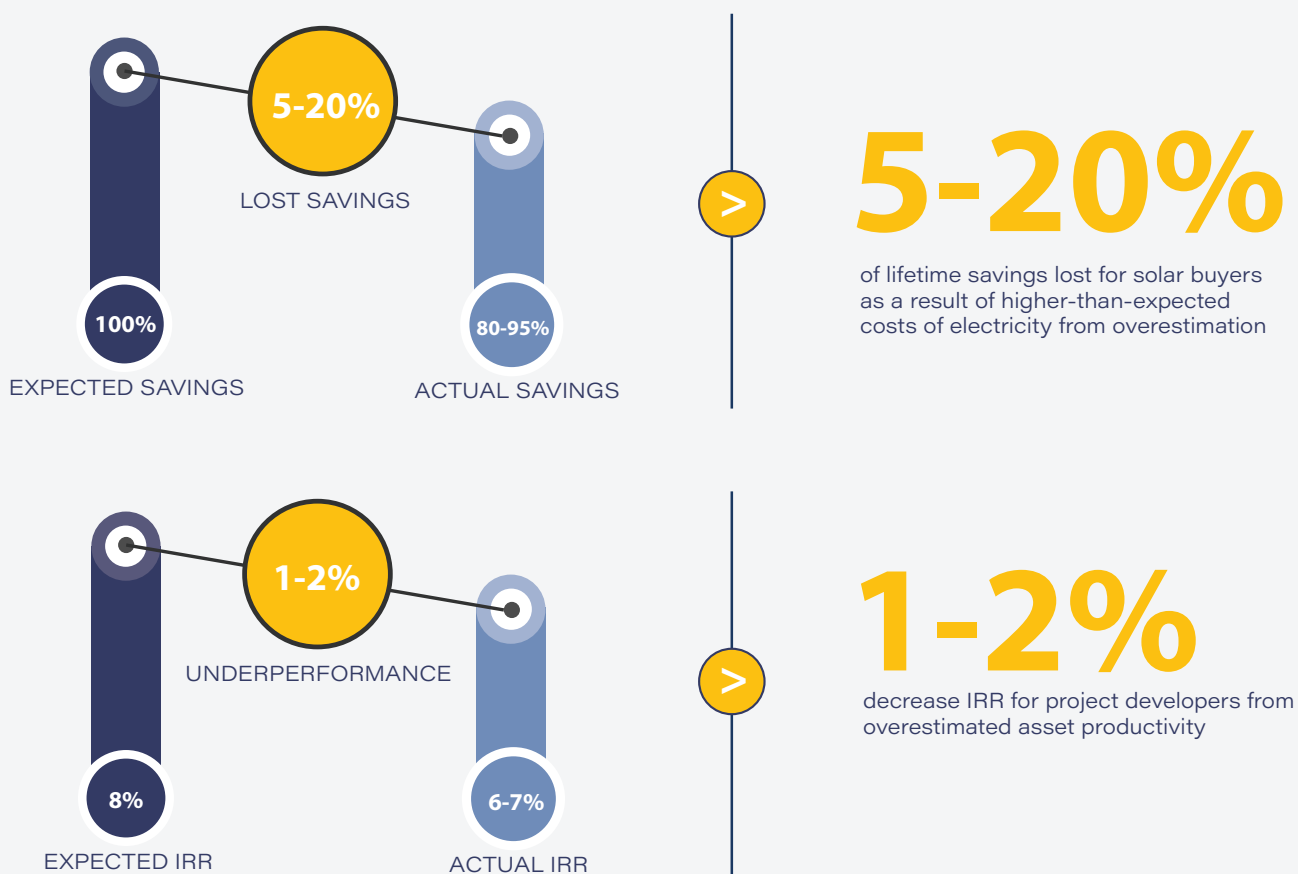
Solar buyers and developers bear the consequences of solar production overestimates

Insight 03: Data irregularities can have significant impacts on both technical teams and solar buyers

As kWh Analytics' inaugural 2020 Solar Generation Index report noted, "If you blindly trust a production estimate, on average, you are likely overestimating a site's production." The U.S.-based research firm recently collaborated with 10 of America's 15 largest solar asset owners to conduct the industry's largest energy validation study to date, analyzing the historic performance of distributed generation and utility-scale solar projects. From 2016-2019, they

found that projects on average underperformed their third-party P50 estimates (target production) by 6.3% on a weather-adjusted basis, with a quarter of the projects missing their production targets by over 10%, even after weather adjustment. Considering the higher irradiation data biases seen in Africa relative to the U.S., African solar developers and their clients could find themselves facing even greater impacts. [3]

FIGURE 4: IMPACT OF IRRADIATION IRREGULATES ON SAVINGS



Note: IRR figures used are illustrative

There are two key risks that solar developers in Africa face as a result of inaccurate solar production estimates: failure to meet portfolio investor returns and under-delivering on the expected savings to solar buyers. A 2020 study by DNV GL confirms that a 3-5% overestimation of a site's solar production is likely to have an equivalent impact (3-5%) on revenues over the life of a project. [3] In turn, the difference in the projected revenues can reduce the projected IRR by up to 1%. The mean solar irradiation biases in major African cities fall within this 3-5% range, though biases in remote areas are greater. Thus, solar developers with diverse portfolios of urban and rural assets could see deviations from their projected IRR of greater than 1%.

A solar developer's failure to meet the modelled solar production output also reduces the effective savings for C&I clients. A solar buyer in a major capital city could lose 4-5% of their projected savings from underproduction, while clients with operations outside of the major cities risk a significant reduction in savings of up to 20% due to system underperformance. The risk to savings is even higher for off-grid mines using solar energy in tandem with diesel gensets, as they will bear additional fuel cost to offset the unmet solar production needs. The commercial consequences of poor data quality are too serious to accept as the status quo.



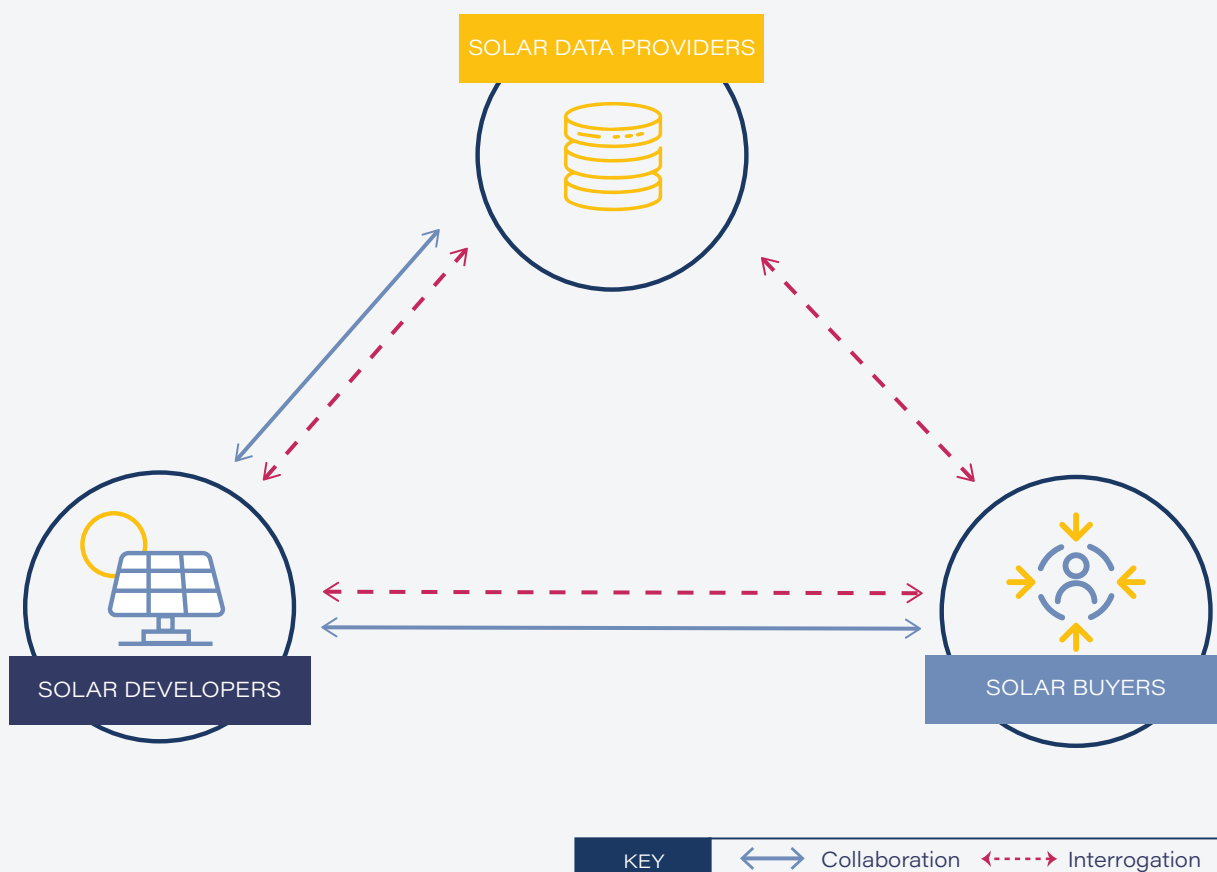
RECOMMENDATION

Through collaborative action the industry can confront the problem of biased irradiation data

Solar irradiation inaccuracy is an industry challenge common across the globe, and something which even the U.S. and European markets still have not perfected. However, in these regions there is a critical mass of solar developers and customers driving a competitive market for solar irradiation data providers. Over time, this has resulted in improvements to irradiation measurement accuracy. The African solar market, however, is growing from a low baseline, has a limited number of data providers and ground-based monitoring stations, and the majority of measurement stations that do exist are concentrated in urban areas.

Pragmatic action is required to secure continued African solar market growth and achieve the critical mass required to improve data diversity. We believe that this approach will require solar buyers, data providers, and developers to better interrogate irradiation data and collaborate on long-term solutions.

FIGURE 5: POTENTIAL SOLUTIONS BASED ON THE INTERACTIONS OF RELEVANT PLAYERS



Insight 04: In the short-term, solar buyers and developers can set a higher standard for solar production estimates during competitive procurement

Given biases are present in solar irradiance data today, solar developers and solar customers can help to mitigate the impacts of these biases through deeper interrogation of estimated long-term solar production figures. It's common for solar developers to rely on a single source of data for estimating the solar irradiation for a given new project. Instead, they should seek to interrogate multiple solar irradiation data sources to evaluate a realistic range of solar irradiation and, where possible, use P90 over P50 values when estimating solar productivity. This will help to ensure that projections are not overly optimistic and avoid misrepresentation of project profitability. While this may require solar developers to pay more for additional database licenses, license fees pale in comparison to the cost of a 1% reduction in IRR, worth tens of thousands of dollars.

Businesses evaluating solar for their facilities should add interrogation of irradiation estimates and expected solar production to their bid evaluation processes. Developers compete on the basis of the electricity tariff and resulting savings offered. Overestimating solar production helps to lower the solar tariff and increase projected customer savings all other factors held constant. Because irradiation and solar production have a strong correlation to the robustness of the savings and tariff proposals, solar buyers should require bidders to submit their solar irradiation and expected production estimates as part of their bid applications. This data can then be compared across all offers, allowing competitors with significantly different projections to stand out. This practice will hold solar developers accountable for using more realistic estimates in their financial models, driving increased demand for high-quality solar irradiation data from databases.

Insight 05: A membership database or unilateral investment in on-site weather stations could offer a long-term solution to improving irradiation estimates

AFSIA's Solar Outlook 2021 identified 2,400 operational solar sites across Africa – 80% are classified as C&I projects. [4] The ongoing irradiance measurements from each of these sites offer an opportunity for solar data providers to sense-check their estimation models, if the data can be collected and consolidated. By anonymously sharing actual on-site irradiance and solar production data from their operational sites, solar developers across the continent could collectively expand the number of ground measurement references by 50x and help to close the irradiance data gap. With solar data providers, a collaborative initiative could be organized by which African solar developers commit to continuously sharing operational data, and information providers – having used this data to train and test their satellite-based irradiation models – offer solar production projections at discounted rates to developer contributors. Developers could also consult the database to explore realized irradiance measurements in new geographies contributed by other members. Such grassroots efforts could complement and potentially accelerate the impact of ongoing, top-down investments in improved African solar resource mapping, such as those led by the World Bank Energy Sector Management Assistance Program (ESMAP). [2]

This is but one example of how closer collaboration between developers and data providers could tackle the high uncertainty factor in irradiance across the continent, offering long-term value for solar developers, buyers, and investors alike.

In the same spirit, the financial burden of ground measurement weather stations should not solely rest with developers and solar data providers. C&I solar buyers have the biggest incentive to invest in accurate solar irradiation data for their sites due to the notable negative impact the overestimation bias can have on their savings (up to 20% reduction). We encourage prospective C&I solar customers to rent weather stations for deployment on their sites, especially ahead of a competitive solar bidding process. This will ensure that all bidders have access to accurate irradiance measurements from the onset, which will enable all participants to deliver their most competitive and robust solar offers. Solar developers could also rent out weather stations as a marginal source of additional revenue, though the primary goal would be to improve the competitiveness and credibility of solar offers based on accurate, site-specific irradiance data.

CONCLUSION

Improving solar irradiance estimates today secures a strong future for African C&I solar

With the number of C&I installations in Africa continually rising, now is the time to build a strong foundation for sustainable industry growth. So long as the biases of African solar irradiation projections and their impacts remain unacknowledged, we as an industry risk reaching an abrupt end to the current boom, as clients achieve less savings and investors realize lower returns than they were sold.

CBE has taken the first step by highlighting the key challenges in Africa to accurate solar irradiation estimation and what solar developers, data providers, buyers, and investors will lose if we do not raise the bar for irradiation assessment. Beyond this, we hope to spark vigorous discussion about potential remedies to this problem across the African C&I solar community, including with solar buyers and investors, who have the most to gain from consistent and robust solar production forecasts. There is a lot of work to be done to raise awareness and find solutions, but the prize is a vibrant clean power sector to drive the economic engine of Africa for years to come.

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