Are we on the path to sustainable health electrification? Lessons from hospital solarisation in Sierra Leone

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- Approximately 15% of healthcare facilities in sub-Saharan Africa (SSA) have no access to electricity, and only half of hospitals have reliable electricity access (WHO, 2023). This electrification gap has broad consequences, impacting the use of healthcare equipment, increasing vaccine spoilage, and limiting health services and quality care provision in already-disadvantaged areas of SSA (WHO et al., 2023).
- Solarisation has become the de facto electrification strategy for both on- and off-grid healthcare facilities in SSA. While recent rollouts of renewable energy sources have provided an increasing number of healthcare facilities with clean electricity access, these sources often fail to provide the stable, constant electricity (i.e. 24/7 availability of uninterrupted power supply) needed to realise the promise of electrified healthcare provision.
- This project leverages a remote monitoring approach to collect minute-by-minute power quality and reliability data for 12 consecutive months at six government hospitals in rural and urban settings in Sierra Leone. This policy brief focuses on these six hospitals retrofitted with solar photovoltaic (PV) and battery storage systems and sheds light on the impact of these decentralised renewable energy solutions on facility-wide electricity supply.
- This policy brief highlights the need for solar electrification initiatives to require remote monitoring systems and reporting – and to provide adequate funding for remote monitoring and verification efforts – in order to ensure reliable, 24/7 electricity for critical care health facilities.

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Policy motivation

High-quality energy access for healthcare delivery

While Sustainable Development Goal 3 (“ensure healthy lives and promote well-being for all at all ages”) and Goal 7 (“ensure access to affordable, reliable, sustainable, and modern energy for all”) have helped drive policy and investment actions at the health-energy intersection in sub-Saharan Africa (SSA), the COVID-19 pandemic demonstrated the need for energy resilience to respond to public health emergencies. Recent evaluations of health electrification projects are beginning to emphasise power quality and reliability (PQR) as fundamental to healthcare outcomes. Healthcare interventions are intrinsically linked to reliable electricity; without reliable electricity, a clinic cannot provide many critical healthcare services (Adair-Rohani et al., 2013). Access to reliable energy enables the provision of quality medical services after sunset, enhances diagnostics, treatment, and surgical capabilities, and bolsters disease prevention and treatment through adequate sterilisation and vaccine and medicine storage (Bhatia and Angelou, 2015).

"Doctors' and first responders' ability to treat infected populations is based on the assumption that clinics, medical equipment, and medicines are fully functioning and that they have access to sufficient, uninterrupted, reliable electricity." - Damilola Ogunbiyi, CEO of SEforALL

Healthcare electrification in Sierra Leone

This project studied healthcare electrification in the context of Sierra Leone, a country with a population of approximately 8.9 million people (CIA, 2024). Only 26% of the country’s population has access to electricity, with rural access estimated at 6% (SEforALL, 2023a). This national energy disparity is mirrored in Sierra Leone’s healthcare system, where health service delivery is directly hampered by a lack of reliable access to electricity. For example, the nation holds one of the highest maternal mortality rates in the world, in no small part due to the absence of electricity, which contributes to the lack of access to high-quality maternal healthcare (Qiao, 2023). Roughly 38% of health facilities lack any access to electricity, and, for those facilities with some form of access, most experience unreliable and inadequate electricity regardless of their combination of energy sources (SEforALL, 2023a). In 2022, Sustainable Energy for All (SEforALL) conducted energy audits at hospitals across Sierra Leone to identify opportunities for the installation of renewable energy solutions that can deliver reliable power (to improve maternal and child health outcomes) and clean power (to reduce diesel generator usage). The Sierra Leone Healthcare Electrification Project – a multi-phase national solar electrification initiative funded by the Foreign Commonwealth and Development Office and in collaboration with the Ministry of Health (MoH) and SEforALL – identified six government hospitals that would be retrofitted with solar PV and battery storage systems during phase one of the initiative.

The unmet promise of "round-the-clock" electricity supply for critical health facilities

One of the primary goals of health solarisation initiatives is to provide health facilities with ongoing access to clean, reliable electricity to ultimately improve healthcare service delivery and, consequently, health outcomes. Despite the glaring impact of PQR on healthcare delivery, solar electrification programs continue to measure electricity access primarily using metrics such as the number of facilities electrified, the number of people served by the facilities, and installed solar capacity. This is problematic because none of these project metrics or key performance indicators (KPIs) measure whether the deployed renewable energy solutions actually ensure constant access to clean electricity for uninterrupted health services at critical health facilities (UNDP, 2024).

"Even when health facilities [have] an electricity connection, there may [be] significant quality-of-supply issues for which data are not collected." (Bhatia and Angelou, 2015, p. 156)

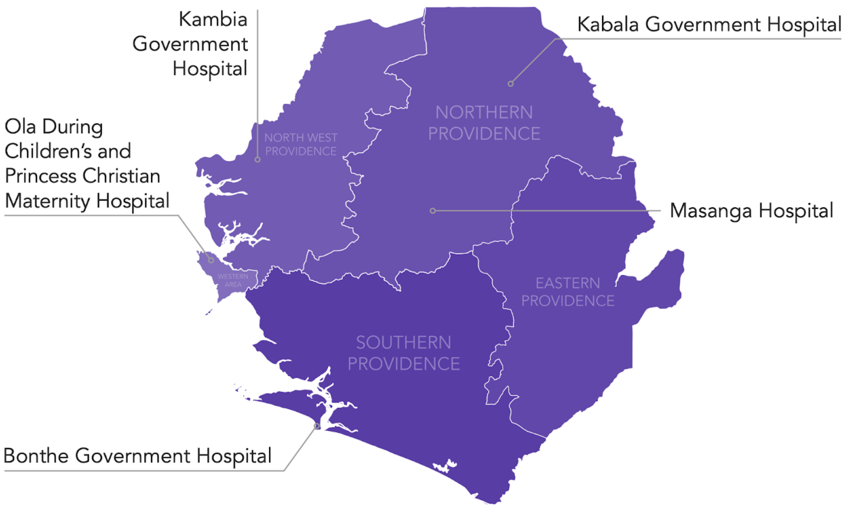
Part of the challenge in assessing the state of electricity access beyond the binary metric of "electrified" or "not electrified" is due to technical and operational challenges, as well as monetary costs associated with remote data collection and system performance verification in low-resource settings and at-scale. Additionally, few utilities – including solar mini-grid providers – are required to report quality and reliability data to investors, donors, or regulators. These challenges have allowed binary measurements of electricity access (i.e., electrified or not electrified) to remain as the status quo and for health electrification funders to affirm project success (for example, "The Sierra Leone Healthcare Electrification Project…is ensuring 24/7 availability of uninterrupted power at six hospitals" (SEforALL, 2024)) without data verification.

Project overview

In 2022, SEforALL issued a tender for the design, supply, and installation of solar solutions at six hospitals and required that systems be "designed using a facility-wide and needs-driven approach" to ensure holistic electrification. This project sought to evaluate to what extent the installation of these decentralised renewable energy solutions (i.e., solar PV and battery storage systems) at under-electrified government hospitals improved existing electricity reliability and resulted in the provision of "round-the-clock" facility-wide electricity supply.

By real-time monitoring electricity reliability at these six hospitals, both before and after installation of the standalone renewable energy systems, we sought to generate critical insights that can inform future solar healthcare electrification initiatives and ensure sustainability and reliable system performance.

FIGURE 1: Six hospitals selected for decentralised renewable energy solutions



Note: A map of the six government hospitals electrified with decentralised solar PV and battery storage systems under SEforALL's "Sierra Leone Hospital Electrification Project". (Source: SEforALL, 2023b).

To measure PQR continuously at the six hospitals, we leveraged Gridwatch, a remote measurement approach that combines quickly deployable wall outlet sensors with cloud algorithms to aggregate sensor data into KPIs of energy system quality and reliability (Klugman, 2021). Over a period of 12 months (August 2023 - July 2024), real-time sensor data was collected on power outages (frequency and duration), voltage and frequency levels at the six government hospitals. These facilities were powered by a combination of on- and off-grid, renewable- and non-renewable energy sources.

TABLE 1: Available electricity sources at hospitals prior to the installation of new solar PV and battery storage systems.[1]

Health Facility Type	Health Facility	Electricity Source		
		Solar	Generator	Grid
Teaching / Tertiary	Ola During Children's Hospital (ODCH)	✓	✓	✓

[1] Energy sources are marked as present (✓) if the source was functional and actively provided power to the health facility (or a subset of departments, rooms or wall outlets in the health facility) at any point during the data collection period.

Hospital	Princess Christian Maternity Hospital (PCMH)	✓	✓	✓
General Hospital	Bonthe Government Hospital	✓	✓	✗
	Kabala Government Hospital	✓	✓	✗
	Kambia Government Hospital	✓	✓	✗
	Masanga Government Hospital	✓	✓	✗

The Sierra Leone Healthcare Electrification Project selected six under-electrified government hospitals for retrofits.

By using a blend of sensor data, site energy assessments, and in-person surveys, the project generated detailed PQR profiles for each hospital and a suite of comparable PQR KPIs. The project specifically explored whether the newly installed renewable energy solutions: i) improved existing electricity supply reliability and ii) provided ongoing access to reliable electricity. The findings are based on data collected from 1 August 2023 through 31 July 2024 (one year).

While this policy brief highlights facility-wide power reliability, GridWatch sensors – which were placed in critical care rooms such as operating theatres, intensive care units, and maternity wards – also monitored power interruptions within each of these areas of the hospital. As a result, power reliability in specific areas of the hospital may vary significantly from facility-wide outages.

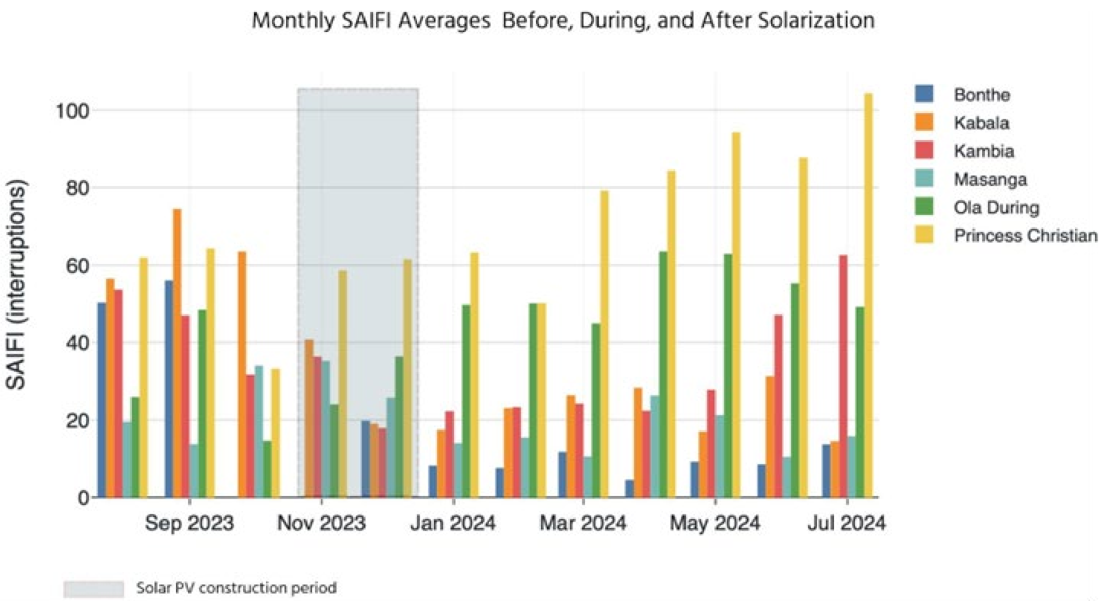
Key findings

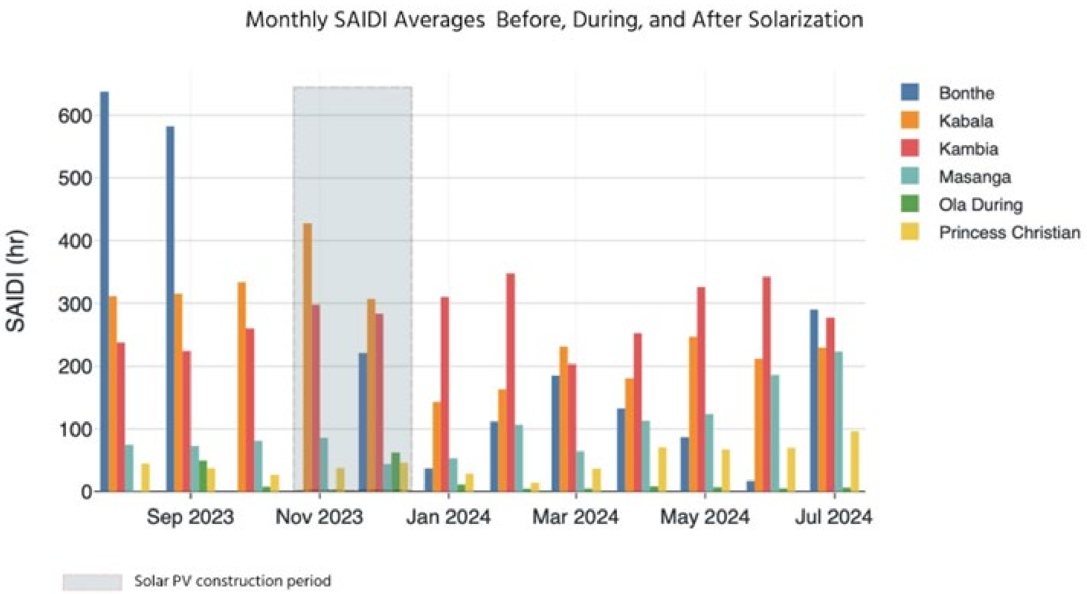
At each hospital, we analyse data from three months prior to solar installation and for seven months afterwards to understand whether the installed renewable energy solutions resulted in improved electricity supply reliability and ensured constant (i.e. 24/7) access to electricity at the facility-wide level.

Decentralised renewable energy solutions resulted in improved, facility-wide electricity supply reliability at some hospitals, but not all

Once the decentralised renewable energy systems began providing power to the hospitals, all health facilities experienced a general reduction in the average monthly number of facility-wide power outages except for ODCH and PCMH hospitals. Further, all health facilities experienced a general reduction in the average hours of facility-wide power outages each month except for Kambia, Masanga and PCMH government hospitals. We conclude that the installation of decentralised renewable energy solutions at under-electrified hospitals does not necessarily and inherently translate into a more reliable electricity supply. Other factors can contribute to a stagnant or even deteriorating level of electricity reliability after system installation. For example, we found that in some of the hospitals where significant improvements were not observed, newly installed systems were not wired to provide power to all departments and rooms (even though initial design plans required facility-wide power supply), which led to poor electricity supply reliability in some areas of a hospital.

FIGURE 2: Monthly average frequency and total duration of power outages before and after solar PV system installation at six hospitals





Note: Construction of the solar PV systems occurred in November and December 2023, and the systems went "live" and began providing power at all six hospitals by January 2024. Top: Average monthly number of facility-wide power outages measured at the six government hospitals over a one-year period. Bottom: Average monthly total hours of facility-wide power outages (for reference, there are approximately 730 hours in one month).

Bonthe Government Hospital (dark blue in Figure 2) experienced a marked improvement in access to reliable electricity. SAIDI (i.e. the average total duration of power outages) and SAIFI (i.e. the average number of power outages) reduced significantly due to an increase in power uptime at the facility-level. For example, the average monthly SAIDI at the hospital decreased from a range of over 600 facility-wide hours of outages to 122 hours after solar PV system installation. Similarly, the average monthly SAIFI decreased from 53 power outages to approximately 9 outages. In contrast, other hospitals, such as Masanga Government Hospital (light blue in Figure 2), experienced no meaningful, consistent increase in access to reliable electricity supply after the solar system was installed. Average monthly SAIFI at Masanga decreased slightly from 22 facility-wide outages to 16 outages, and average monthly SAIDI increased from 75 hours of facility-wide outages to 124 hours.

A base level of service - in terms of supplying power with reasonable reliability - is not provided equally for all critical care health facilities served by decentralised renewable energy systems.

This wide variation in power reliability after the installation of decentralised, renewable energy solutions demonstrates the importance of longitudinal monitoring to ensure reliable, high-quality electricity is provided after an initial connection is made.

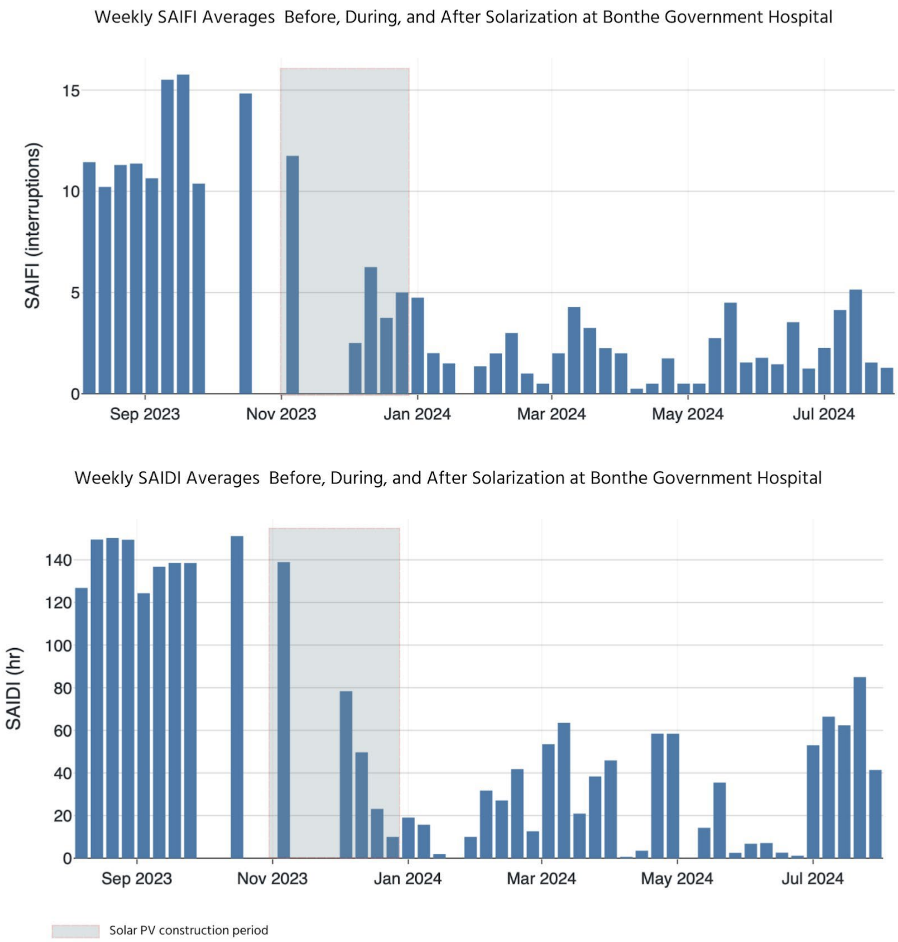
Case study 1: Bonthe Government Hospital

This case study highlights the differences in facility-wide power reliability at two off-grid hospitals after the new solar PV and battery storage systems were installed.

Bonthe Government Hospital is an isolated, off-grid health facility located on Sherbro Island and serves a catchment population of approximately 16,500 people (SEforALL, 2023b). Prior to the new SEforALL commissioned solar PV installation, the hospital relied nearly exclusively on two old generators for power. However, funds for fuel purchases were extremely limited, and the generators were primarily used only in cases of emergencies. An existing, slightly broken small solar power system was connected to the male ward, providing power to critical loads. In 2023, SEforALL funded the installation of a 70.4 (kWp) solar PV generation and battery storage system. System installation began in November, and testing and commissioning were completed by December 2023.

Beginning in mid-December 2023, there was a notable decrease in the frequency and duration of facility-wide power outages (see Figure 3). During the endline measurement period of seven months, there were several weeks when facility-wide power interruptions were minimal (for example, less than two power outages per week) and time spent without power had meaningfully reduced to an average of less than 20 hours each week. It is clear that the new energy system did bring meaningful improvements in overall facility-level power reliability, which can lead to improved health staff satisfaction, health care service delivery, and health outcomes.

FIGURE 3: Changes in facility-wide power reliability before and after renewable energy system installation at Bonthe Government Hospital



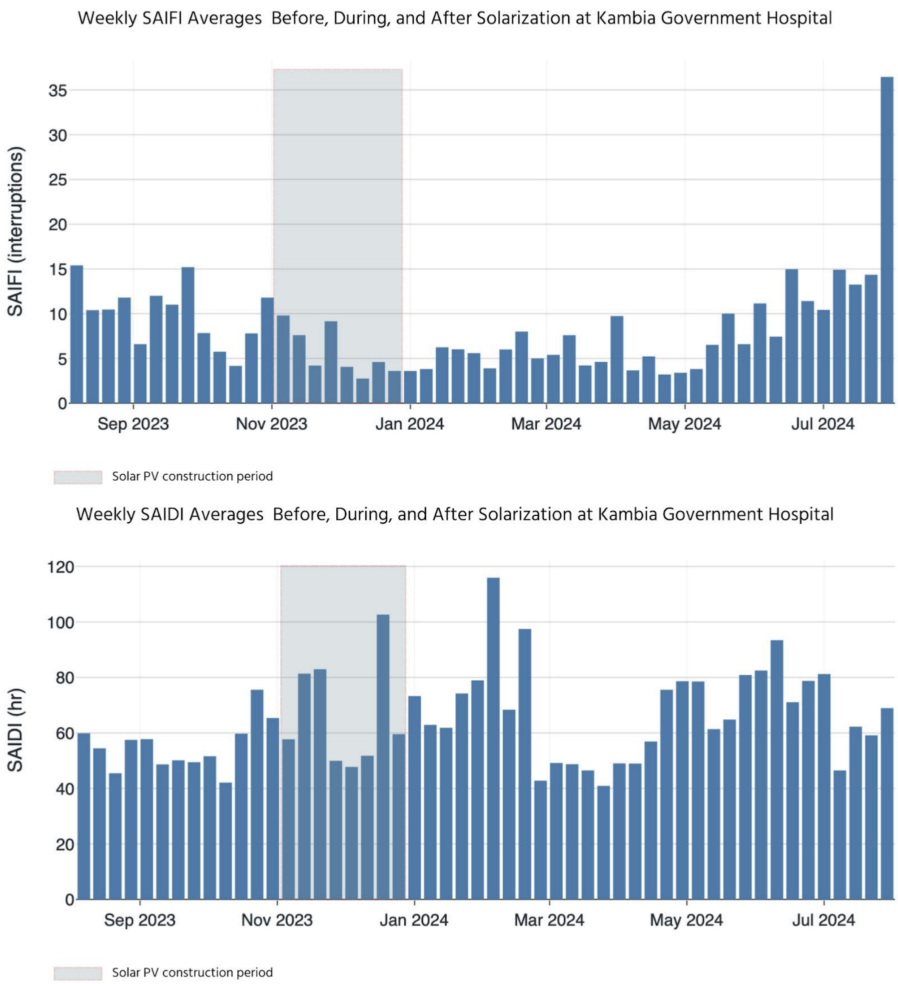
Note: During the 3-month baseline period (August - October), the average weekly frequency of facility-wide power outages (top) and average weekly duration of facility-wide power outages (bottom) were significant due to prohibitive fuel costs for turning on the generators in non-emergency cases. Beginning in mid-December, when the new solar PV system went "live", there was a noticeable decrease – though not elimination – in average weekly facility-wide power outages. Additionally, note that there are several weeks of data gaps in November and December 2023 due to electrical rewiring and disconnection of GridWatch sensors.

Case study 2: Kambia Government Hospital

Kambia Government Hospital is an off-grid health facility that serves a catchment population of approximately 424,000 people (SEforALL, 2023b). Prior to the new solar PV and battery storage system installation, the hospital relied on three generators, a borrowed power line and a small solar system connected to the special care baby unit. In 2023, SEforALL funded the installation of a 61.6 (kWp) solar PV generation and battery storage system. System installation occurred in November and testing and commissioning were completed by December 2023.

There is no notable decrease in the average frequency and duration of facility-wide power outages (see Figure 4) before and after system installation at Kambia. Prior to the commissioning of the solar PV and battery storage system, an average of 10 facility-wide power outages happened each week, with a total average of 55 hours spent each week without power. After the system was installed, Kambia experienced an average of 7 facility-wide power outages each week and spent a total average of 67 hours without power each week. It is clear that the new energy system did not bring meaningful and measurable improvements in overall facility-level power reliability.

FIGURE 4: Changes in facility-wide power reliability before and after renewable energy system installation at Kambia Government Hospital



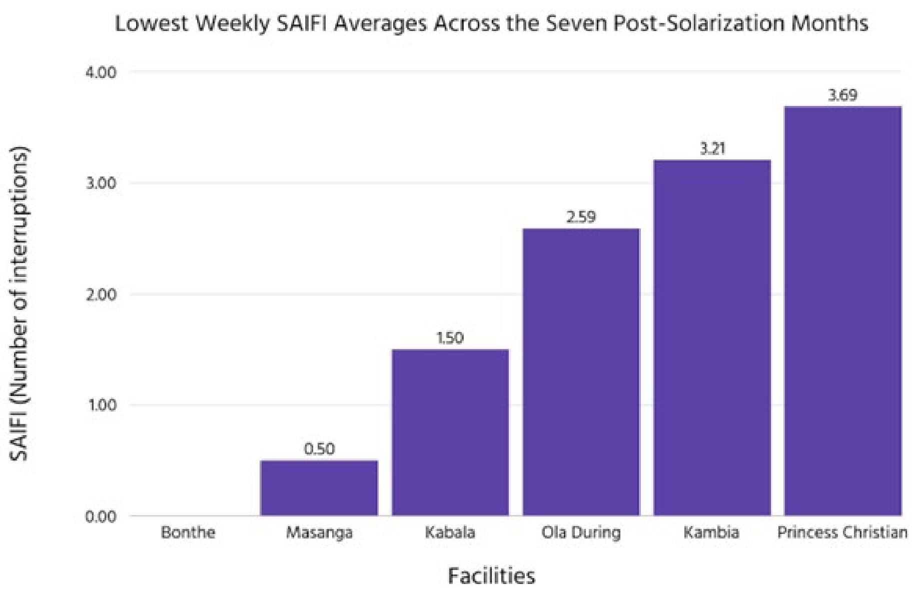
Note: Beginning in December, when the new solar PV system went "live," there was no noticeable and consistent decrease in the average weekly frequency (top) and duration (bottom) of facility-wide power outages.

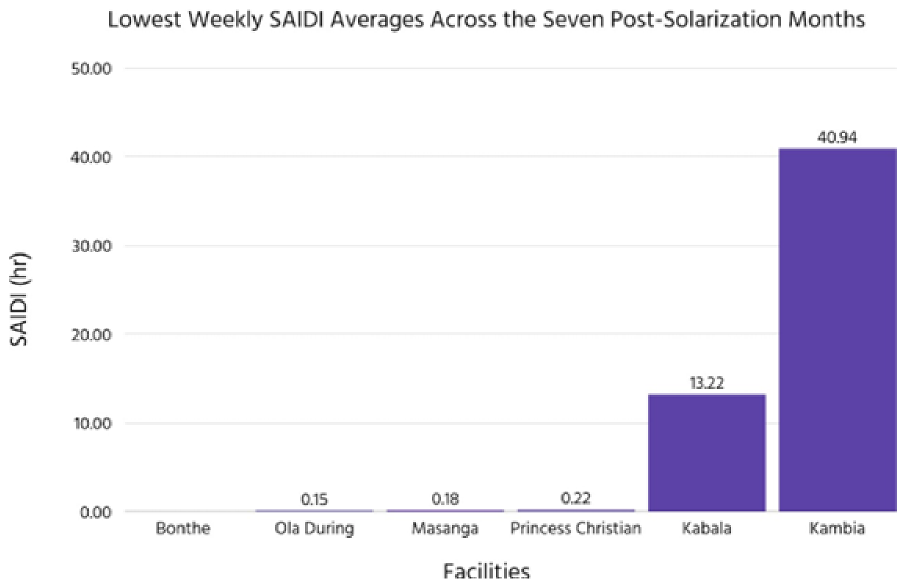
Ongoing "round-the-clock" electricity access was not supplied to any hospital

While we measured a significant improvement in electricity supply reliability at some hospitals after system installation, continued power outages after system installation indicate that ongoing and constant access to electricity (i.e. 24/7 availability of uninterrupted power supply) was never achieved at a facility-wide level at any of the six government hospitals, including at grid-connected facilities (except for a one-week period at Bonthe hospital, as seen in Figure 6).

Figure 5 illustrates the lowest average number of power outages that a hospital experienced at the facility level during the seven-month post-installation measurement period.

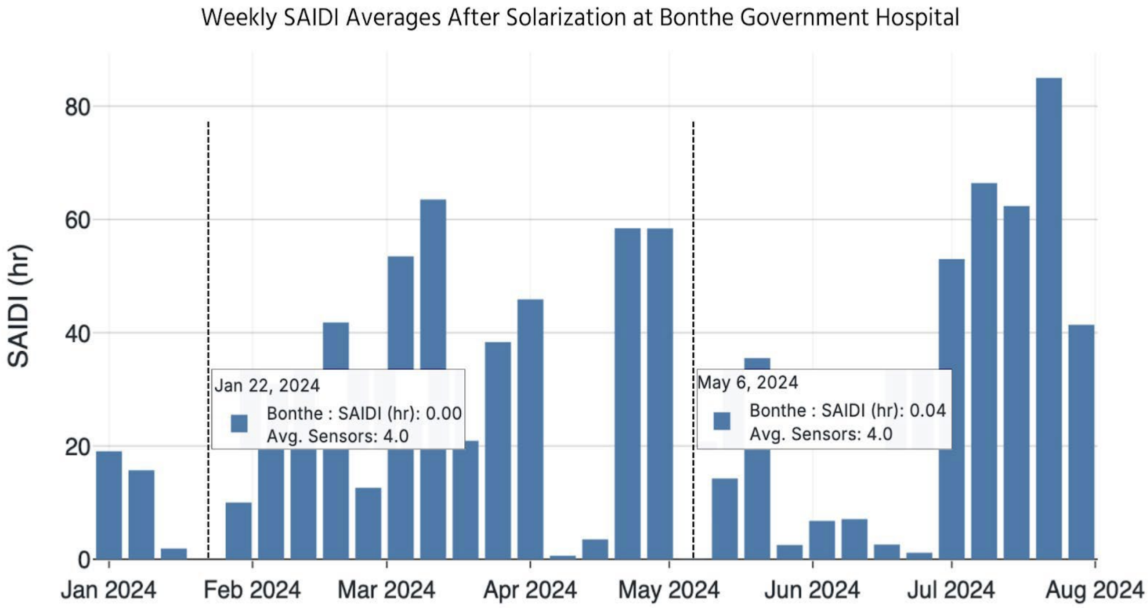
FIGURE 5: Minimum average weekly frequency and total duration of power outages measured after solar PV system installation at six hospitals





Note: Top: The lowest weekly average number of facility-wide power outages measured at the six government hospitals during a seven-month period after system installation. Bottom: The lowest weekly average total duration of facility-wide power outages recorded during the seven-month post-installation period. (For reference, there are approximately 168 hours in one week).

FIGURE 6: Weekly SAIDI at Bonthe Government Hospital.



Bonthe experienced 0 SAIDI in the week of 22 January 2024 and very close to 0 SAIDI in the week of 6 March.

While hospitals like Bonthe experienced at least one week with less than an hour of power outages, this was the exception rather than the norm for all hospitals (see Figure 2 for monthly SAIFI and SAIDI values at each of the hospitals after solar PV and battery storage system installation).

In other words, power outages are still regularly occurring and the renewable energy solutions did not fully ensure 24/7 access to facility-wide electricity for uninterrupted health service delivery.

Case study 3: Kabala Government Hospital

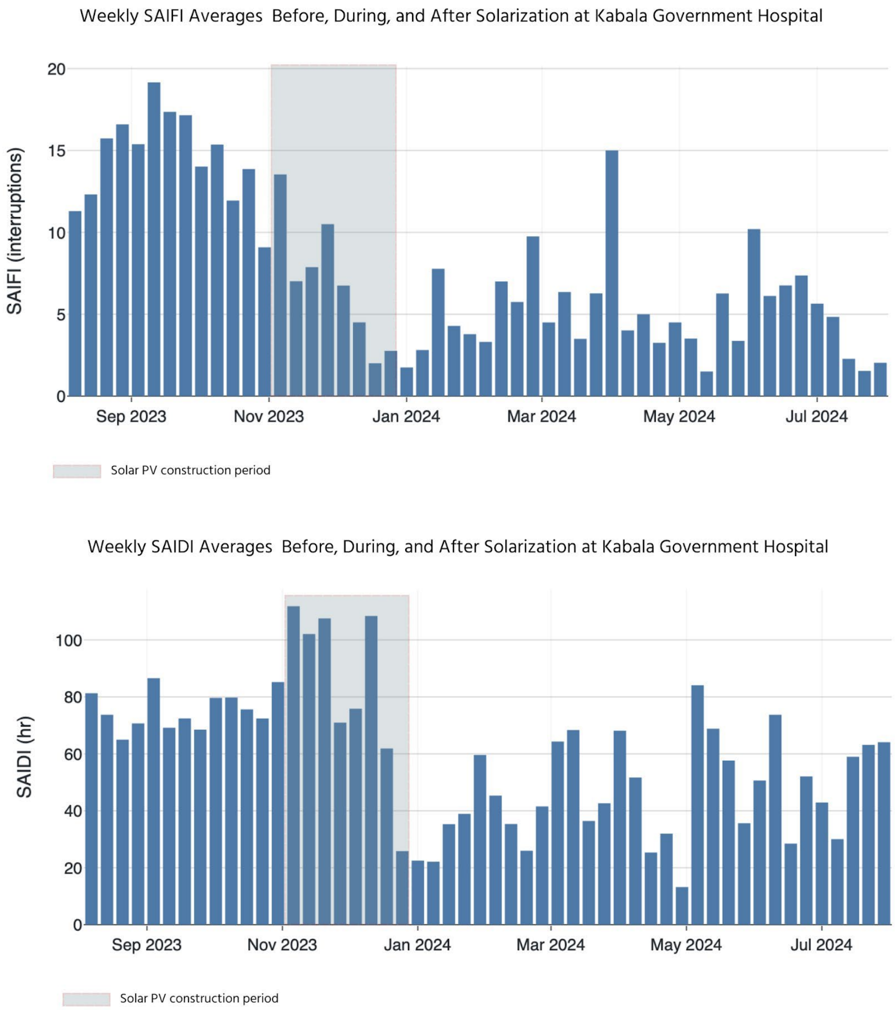
Kabala Government Hospital is an off-grid health facility that serves a catchment population of approximately 250,000 people (SEforALL, 2023b). Prior to the new solar PV system installation, the hospital relied on several generators and a small solar power system connected to the paediatric ward.

In 2023, SEforALL funded the installation of a 90.75 (kWp) solar PV generation and battery storage system. System installation began in November and testing and commissioning were completed by December 2023.

Beginning in January, there was a noticeable drop in the frequency and duration of weekly power outages at Kabala hospital. However, regular outages remained a constant occurrence every week.

Hospital staff reported issues with electrical wiring in the x-ray and paediatric rooms – two critical care rooms where sensors were installed – which potentially contributed to the long and frequent power outages experienced after the new system was installed. Further, sensors detected that nearly every day, power would shut off around 2 am and return around 9 am – possibly an artefact of batteries running out of charge at night. The daily off and on of power supply may also explain SAIDI and SAIFI.

FIGURE 7: Changes in facility-wide power reliability before and after renewable energy system installation at Kabala Government Hospital



Note: Beginning in December, when the new solar PV system went "live," there was a consistent decrease in the weekly frequency (top) and duration (bottom) of facility-wide power outages. However, Kabala still experienced regular facility-wide power outages each week.

Differences in facility-level and room-level power reliability

In the context of renewable energy interventions at health facilities, power reliability is often assessed at the facility level – i.e., has the intervention ensured consistent electricity supply across the health facility? While this question has been addressed by generating SAIDI and SAIFI at the facility level, this level of aggregation has limitations that, to an extent, explain why we were unable to record zero SAIDI and SAIFI at the six hospitals during the seven months of post-intervention monitoring.

Specifically, aggregating PQR metrics at the facility level:

- **fails to account for gaps and disconnects between original system design and practical implementation** (for example, despite procurement specifications requiring solar PV systems to be designed using a holistic, facility-wide approach, in some cases, we see only certain parts of the health facility are prioritised for consistent power supply)
- **overlooks behavioural patterns arising from insufficient power supply**, such as hospital management or technical staff resorting to manually shutting off power to non-critical rooms to extend battery availability
- **does not capture the lack of integration between newly installed and preexisting energy systems**
- **obscures the influence of already-existing supplementary power sources** (or their absence) in specific rooms, which can contribute to higher or lower SAIDI and SAIFI values post-intervention
- **masks variations in electricity quality and reliability experienced by individual rooms or specific areas within the healthcare facility**

At the start of monitoring and evaluation efforts, we anticipated and built some of the above limitations into our sensing strategy. In discussion with Crown Agents, we piloted room-level PQR measurements alongside traditional facility-level PQR measurements. At each hospital, sensors were placed in at least three critical rooms (i.e. a room where PQR issues have a high likelihood of causing very negative healthcare outcomes) such as the special care baby unit, maternity ward, intensive care unit/ high dependency unit, paediatric ward, and operating theatre/surgical ward. While it would have been more robust to have a minimum of two sensors per critical room, funding was only made available to instrument critical rooms with a single sensor. This leaves room for human behaviour to directly affect room-level PQR measurements if, for example, staff unplug the sensor or switch off the power supply to a wall outlet where the sensor is installed.

Finally, because we restricted the analysis to only allow for outages affecting at least two sensors to be considered as “true” outages, we may have missed out on single-sensor outages which might be impactful from a health perspective but do not represent system-wide operations. Thus, while aggregated metrics offer a high-level perspective on electricity system performance, disaggregated room-level data provide crucial context for evaluating the supply of electricity to different areas of a hospital.

Policy recommendations

Critical care health facilities need ongoing access to reliable electricity in order to ensure quality and timely health service delivery. This brief highlights policies that can bridge gaps in healthcare solarisation initiatives, contributing to more sustainable healthcare electrification investments. Below are four recommendations for ministries of health and energy, healthcare electrification donors and investors, project implementers, regulators, and researchers to improve the sustainability of healthcare electrification investments.

Conduct rigorous research to understand how power reliability impacts health facility operational effectiveness and healthcare service delivery

To develop electricity indicators and thresholds of “acceptable power reliability,” there must be a more rigorous understanding of how reliability affects the provision of medical services and a subsequent quantification of the human cost of such impacts. Furthermore, it is necessary to define what actually constitutes a “reliable” power supply for a health facility – which may vary based on facility type, size, and healthcare services provided. Pairing direct, continuous reliability measurements at health facilities with data on medical equipment usage and patient health outcomes can help standardise acceptable electricity parameters for healthcare electrification (WHO et al., 2023).

Move away from “install and forget” towards “install, monitor, and maintain”

Electrifying health facilities through decentralised renewable energy solutions can help build climate resilience and provide relatively rapid access to energy in rural contexts without waiting for grid connectivity (IEA, 2023). Global funders of healthcare electrification initiatives often showcase how completed projects provided a “reliable energy solution for health facilities,” resulted in “improved reliability of power supplied to health facilities,” or ensured “reliable access to electricity for essential medical services.” Yet, to our knowledge, data that is measuring the continued reliability of these installed systems is rarely collected, and reliability indicators and statistics are often not publicly shared. Instead, project indicators such as installed capacity and the number of people benefiting from health services are often forefronted. These metrics mask the true impact of the decentralised renewable energy solutions, especially their actual capacity to provide “round-the-clock” electricity supply to health facilities for weeks, months and years after initial system installation.

"Innovative technologies such as remote monitoring can generate valuable data that can help validate [energy system] performance and... ...[energy] services..." (SEforALL, 2021, p. 12)

It is imperative to verify system performance after an initial electricity connection is made and to establish "accountability mechanisms and long-term operations and maintenance" (IEA, 2023). Renewable energy projects must be measured, monitored, and evaluated to ensure these solutions provide adequate power to meet health facilities' operating needs. Similarly, power supply at grid-connected facilities should be monitored to inform if additional energy resiliency solutions are needed.

Fund efforts to evaluate the success and replicability of equipping health facilities with decentralised renewable energy solutions

In the last few years, key stakeholders in healthcare electrification in sub-Saharan Africa have increasingly recognised the critical importance of integrating remote monitoring systems into the deployment and uptake of decentralised renewable energy solutions at health facilities. There has been a gradually growing call for systematic monitoring of energy access, shifting away from the traditional "install and forget" approach toward a more sustainable "install and maintain" model for healthcare electrification.

Yet, funders of healthcare solarisation initiatives need to demonstrate their commitment to ongoing monitoring by providing financial resources for these efforts. Despite a public-facing emphasis on monitoring and widespread agreement on the importance of data collection to validate the performance of decentralised renewable energy systems, funding specifically allocated for the use of innovative remote monitoring technologies to support verification activities is either non-existent or scarce in public calls for concept notes or requests for proposals.

There is a pressing need for funding that is designated to measure the performance of renewable energy investments and to what extent they are providing continuous, reliable electricity supply to critical care facilities. Funding for remote monitoring and quality assurance can be baked in solicitations for the procurement and installation of solar PV systems or as separate solicitations focused exclusively on procuring digital remote monitoring technologies and services. By prioritising and adequately financing these efforts, stakeholders can ensure that decentralised renewable energy systems not only perform as expected but can be scaled and replicated in ways that deliver sustaining benefits to healthcare systems across sub-Saharan Africa.

Harmonise electricity data with existing public health facility national datasets to inform holistic health sector electricity interventions

The harmonisation of existing public health facility national datasets – such as Sierra Leone's openly accessible health facility dataset (MoHS and CIESIN, 2023), which contains attributes for over 1,500 facilities – with power quality and reliability datasets that track the state of electrification at facilities can provide a holistic and proactive approach to targeting energy interventions aimed at tackling unreliable power supply (Grid3, 2023). This merged dataset can serve as a national repository shared between ministries, public and private finance providers, and development implementing partners to prioritise healthcare electrification investments and better design, monitor, and evaluate these interventions.

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You can learn more about GridWatch at www.nline.io

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