WRI INDIA

REPORT

A spoonful of solar to help the medicine go down

Exploring synergies between health care and energy

Lanvin Concessao, Harsha Meenawat, Namrata Ginoya, Masfick Hazarika, Vandita Sahay, Dheeraj Kumar Gupta

AUTHORS

LANVIN CONCESSAO
is a Senior Program Associate for the Energy Program at WRI India

Contact: lanvin.concessao@wri.org

HARSHA MEENAWAT
is a Senior Program Manager for Energy and Development at WRI India

Contact: harsha.meenawat@wri.org

NAMRATA GINOYA
is a Senior Program Manager for Energy and Resilience at WRI India

Contact: namrata.ginoya@wri.org

VANDITA SAHAY
used to work at WRI India's Energy Program, as a Senior Research Specialist

Contact: vandita_sahay@rediffmail.com

MASFICK HAZARIKA
is Program Manager at WRI India

Contact: masfick.hazarika@wri.org

DHEERAJ GUPTA
is Senior Program Associate at WRI India

Contact: dheeraj.gupta@wri.org

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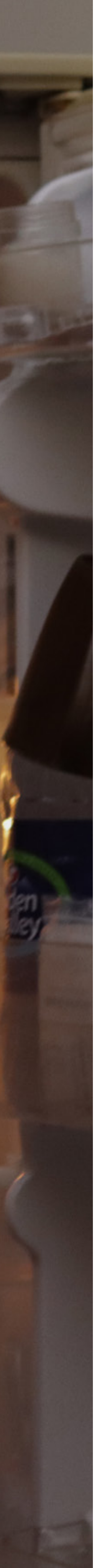

Foreword

In January 2023, the WHO, World Bank, IRENA, and SEforALL released a global report 'Energizing health: accelerating electricity access in health-care facilities,' which highlighted a stark reality: despite local, national and global efforts, at least one billion people worldwide still lack reliable access to electricity in their healthcare facilities.

The significance of reliable electricity in healthcare cannot be overstated. It powers diagnostic equipment, life-saving surgical procedures in operating theatres, enables sterilization, provides essential lighting, regulates temperature for comfort and health, ensures the safe storage of vaccines and medicines. Moreover, it creates a conducive environment for healthcare. And yet, millions of healthcare facilities globally grapple with the lack of reliable access to electricity. This is particularly true in sub-Saharan Africa and parts of South and Southeast Asia, where a sizeable proportion of the dependent population resides.

Since 2017, WRI India has been collaborating with health sector partners to understand the critical role of energy access in healthcare. We have partnered with government, private-charitable healthcare providers in India to demonstrate proof-of-concept for installing renewable energy solutions in remote, rural health facilities. These systems now provide critical power for medical equipment. These efforts have proven invaluable during the COVID-19 pandemic, powering ICUs, ventilators, and refrigerators to store vaccines. These partnerships aim to scale distributed renewable energy projects across various facilities, learning from initial proof-of-concept efforts.

Although there are many such interventions, systematic evidence of the impact of these solutions on health service delivery was limited and we began documenting the experiences of health facilities across India adopting renewable energy to meet their electricity needs. Some of these installations were successful, while others faced challenges. However, each experience offers invaluable insights that can improve the global rural healthcare landscape. We hope this report triggers the much needed conversation among stakeholders to come together and collaborate to resolve the challenges that our health systems face.

The title of this report draws inspiration from the 1964 adaptation of Mary Poppins, a character who could snap her fingers and magically solve her wards' problems. Technology is often seen as a panacea, but in reality, it merely aids "the medicine to go down." In this report, we underscore how distributed renewable energies like solar PV technology can undoubtedly enhance healthcare service delivery and positively impact patient well-being, staff and the health systems that are only just recovering from a global pandemic, but also contribute to our country's ambitious climate change mitigation and resilience efforts. This in turn presents multi-faceted opportunities for the betterment of People, Nature, and Climate.

MADHAV PAI
CEO
WRI India

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Executive summary

Access to reliable electricity is essential to a well-performing health system. However, the focus on electricity as a critical infrastructure need in health facilities has been lacking. Globally, nearly a billion people are served by health facilities that either lack an electricity connection or have unreliable electricity access (WHO et al. 2023). Decentralized solar energy solutions are being increasingly considered to bridge the energy access and reliability gap.

HIGHLIGHTS

- Many Indian rural and peri-urban health facilities function without electricity or with unreliable grid electricity, affecting their ability to provide quality health services. Decentralized solar energy has emerged as a solution for powering health facilities.
- We studied 22 decentralized solar interventions across six states to understand the role of decentralized solar energy solutions in rural health facilities under different financing, ownership, and operating modes.
- We found that solar energy in most cases was a complementary energy solution, rather than displacing the grid or diesel generators. Although positive impacts in terms of enhancement of electricity reliability and affordability were experienced, they were not quantitatively tracked in terms of energy consumption, energy savings, and emissions reduction.
- Developing decentralized energy solutions requires analyzing the present and future energy needs of health facilities. Energy-efficiency measures need to be incorporated in the project design phase to optimizing energy demand, rather than being an afterthought. Energy system procurement policies must look beyond the economics and prioritize technological compliance, modularity, and sustainability.
- Funding should be publicly allocated through convergence of state-specific budgets for health facility electrification to achieve universal health coverage, with support from corporate social responsibility (CSR) and philanthropic sources for public and not-for-profit health facilities.

WHY ELECTRICITY IS IMPORTANT FOR HEALTH SERVICE DELIVERY

A joint global report of the World Health Organization (WHO), the World Bank, the International Renewable Energy Agency (IRENA), and Sustainable Energy for All (SEforALL) (WHO et al. 2023) estimates that, globally, nearly 1 billion people access health facilities that are unelectrified or are devoid of reliable electricity. Primary health care services in rural India, provided through subcenters (SCs) and primary health centers (PHCs) are also plagued by the issue of electricity access. Data from the annual Rural Health Statistics mentions how there are still around 17,967 SCs (11.4 percent) and 934 PHCs (3.7 percent) that function without an electricity connection (Ministry of Health and Family Welfare 2023). In addition, several charitable or not-for-profit health facilities that provide affordable and accessible health care to unserved, underserved, and under-resourced populations face similar challenges of access to electricity. And with the focus of private for-profit hospitals largely concentrated in urban areas—with a greater density of hospital beds, number of medical staff, and hospitalization services—the accessibility to critical medical care is affected in rural areas (Sarwal et al. 2021).

Energy is interconnected to 125 of the 169 Sustainable Development Goal (SDG) targets (ESMAP 2017). An important barrier to achieving SDG 3, which aims *to ensure healthy lives and promote well-being for all at all ages*, is the lack of reliable and affordable electricity. Achieving SDG 7, which looks to *ensure access to affordable, reliable, sustainable and modern energy for all*, can therefore act as a driver toward SDG 3 attainment (ARE 2020; IRENA and SELCO Foundation 2022), while also supporting climate goals (SDG 13). This was reaffirmed at the Health Ministers Meeting of the G20 (2023a), held in India in August 2023, which committed to prioritize building sustainable, low-carbon, and climate-resilient health systems.

There has been significant progress in achieving universal household electrification in India, through targeted interventions like the Saubhagya electrification scheme[1] which has resulted in 100 percent household electrification (Ministry of Power 2023). In contrast, the same push has not been observed toward electrification of critical social infrastructure like health facilities. Given India's goal of achieving Universal Health Coverage, it is essential that universal health care electrification be viewed as an important prerequisite to achieving this goal.

Electricity acts as an enabler of health services and improved health outcomes. Reliable access to electricity is required for the majority of critical health services to be delivered to people. Electricity is essential to run medical equipment for sterilization, immunization, emergency medical procedures, childbirth, and water supply. It is also essential to provide lighting, ventilation and information, communication, and technology (ICT) access to create a conducive environment for staff and patients (WHO and World Bank 2015; United Nations Foundation and SEforALL 2019). The onset of COVID-19 in India and around the world further emphasized the need for a resilient electricity system, as health facilities needed reliable power especially for oxygen production, vaccination cold chains, oxygen concentrators, telemedicine services, and rapid two-way communication between health facilities and the state authorities.

Rural and remote parts of the country, where health facilities provide health care services to the most underserved population, suffer from the highest levels of energy poverty (WHO et al. 2023). In these locations, decentralized solar energy is being increasingly considered by health and energy departments and, public and not-for-profit health facilities as a solution to bridge the energy access gap, as well as enhance the climate resilience of health facilities and building its long-term adaptive capacity (WHO and World Bank 2015; Ginoya, Meenawat, et al. 2021). Last year, the Ministry of Health and Family Welfare (MoHFW) revised its Indian Public Health Standards (IPHS) guidelines to encourage adoption of decentralized solar energy and energy-efficiency measures for strengthening public health infrastructure, wherever feasible.

Despite the uptake of decentralized solar energy solutions in India and beyond, many systems have been underutilized by not accessing the capacity of the energy system[2] to meet the demand of the health facility or have failed prematurely due to various reasons. This can create doubts on the ability of decentralized energy solutions to create impact at scale (United Nations Foundation and SEforALL 2019). Moreover, there is a need for better evidence building on health outcomes to help unlock public, private, and philanthropic investments in resource-constrained regions for implementing decentralized solar energy solutions in health facilities (WHO et al. 2023).

ABOUT THIS REPORT

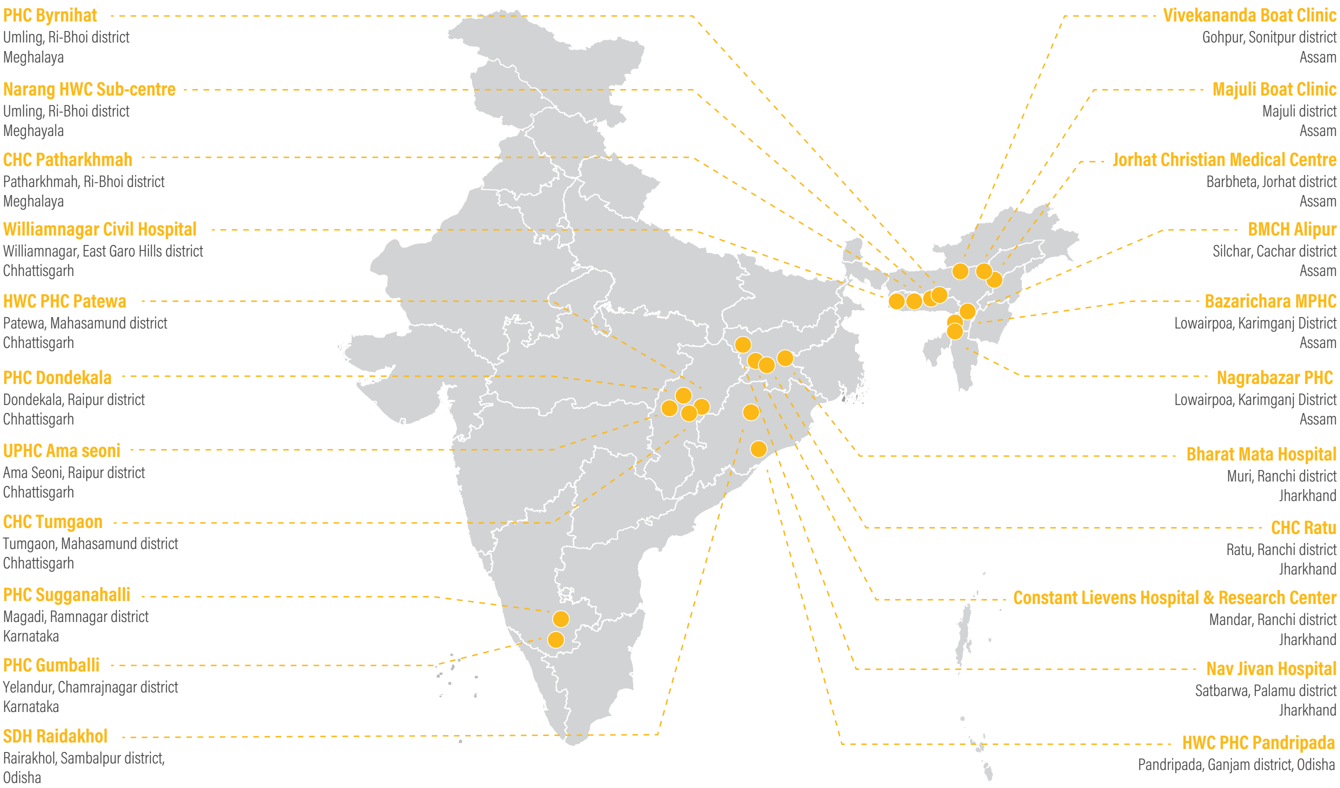
Given the wide adoption of decentralized solar energy systems in rural health facilities, this report explores the role of decentralized solar energy interventions in rural health facilities and its linkages to provisioning of health care services, especially for underserved populations. It reviews current decentralized energy interventions across multiple Indian states under different financing, ownership, and operating modes and attempts to understand the lacunae that certain implementation models face in terms of scalability and what conditions are essential to ensure the sustainability of decentralized renewable energy (DRE) systems in rural health facilities in the long run.

The report is a culmination of extensive literature review, in-person interviews, field visits to the health facilities, as well as our own experience in supporting development partners to implement decentralized solar energy solutions in India. We studied 22 health facilities that are being powered by decentralized solar energy systems in rural parts of six Indian states—i.e., Assam, Chhattisgarh, Jharkhand, Karnataka, Meghalaya, and Odisha. Based on background research, an initial list of government entities and development organizations, along with their respective decentralized solar energy interventions was created. These organizations supported solarization of over 3,000 interventions across the country. The health facilities were narrowed based on the geographic location of the health facility, patients served, affordability of health care services provided, tiers of health care, and electricity infrastructure enhancement through the decentralized solar energy intervention. Based on these parameters, 22 health facilities were shortlisted in rural or energy-deficient regions of six states, based on relevant permissions to access the health facility sites, and the willingness to share information. (Details of the selected interventions are highlighted in Appendix A.)

This sample of decentralized solar powered health facilities covers public health facilities (government led), not-for-profit health facilities (NGO led), as well as alternate forms of health care service delivery, such as boat clinics. Some facilities that blend characteristics of public and not-for-profit models through public-private partnership (PPP) modes are also covered. The case studies undertaken are shown in Figure ES-1.

This report is part of WRI India's Energy for Development Initiative, which looks at supporting governments and local institutions in development sectors to ensure reliable,

FIGURE ES-1 | Twenty-two case studies of decentralized solar energy interventions in health facilities



Source: WRI India authors.

affordable, and sustainable access to electricity for rural and underserved areas. Our work adopts a four-pronged approach that involves leveraging local data to identify unserved and underserved demand centers, right sizing, and selection of electricity solutions, designing sustainable financing instruments, and mainstreaming evidence to achieve policy outcomes.

HOW TO MAKE DECENTRALIZED SOLAR ENERGY SOLUTIONS IN HEALTH FACILITIES SUSTAINABLE AND SCALABLE?

In this report, we interviewed various stakeholders at the health-energy nexus who have been part of implementing decentralized solar energy solutions in health facilities in rural India. The study was designed to target rural and/or energy-deficient parts of Indian states where decentralized solar energy solutions were implemented to provide reliable access to electricity to specific areas of the health facility or to specific medical services that need uninterrupted power.

This study provides answers to questions on the electricity access situation prior to the decentralized solar energy implementation and what improvements in health service delivery were observed at the facilities after the intervention. The case studies allowed us to understand the processes adopted by various stakeholders on conducting needs assessment, site selection, solar energy system sizing, financing the solar energy system, selection of technology provider, and capacity building done at the intervention site.

Through this study, we are understanding the changes in health care service delivery, qualitatively. As the study was undertaken well after the completion of the implementation of decentralized solar systems, the analysis does not quantify impact due to the lack of baseline information and, rather, relies on interviewees' recall and the limited paperwork available with them.

The study ensured capturing a variety of health facilities in terms of number of beds and system size installed, as well as encompassing the different types of health facilities that provide service in rural and remote India. This included public health facilities, not-for-profit health facilities, and health facilities operating under PPP mode. In addition, we explored alternate forms of health facilities that serve remote populations, such as boat clinics. The field visits and stakeholder interviews were conducted from June 2022 to February 2023. During the field visits, tailored interview questionnaires were drafted for the various stakeholders such as the implementers, financiers, and recipients of the decentralized solar energy solution at the health facility, to obtain a holistic understanding of the intervention.

Building on the global report by WHO, World Bank, IRENA, and SEforALL, titled *Energizing health: accelerating electricity access in health-care facilities,* the interview responses, observations from the ground, and overall findings are structured under the four themes of technology, policy, capacity, and finance. These themes need to be addressed to create an enabling ecosystem for health facility electrification in resource-constrained settings (WHO et al. 2023). The technology section collates responses on need assessment for solar in health facilities, energy efficiency, and remote monitoring systems. Under policy, we discuss responses on procurement and insurance policies, and vendor selection. The capacity section covers responses on operation and maintenance (O&M) and staff living and working environment. Under finance, we discuss financing of capital costs, O&M expenses, and government subsidy models.

We expect the findings and suggestions of this report to guide state and national policymakers in the energy and health sector and implementing and funding agencies to scale the use of decentralized solar energy solutions in health facilities sustainably.

FINDINGS

The case studies presented in this report cover implementation of decentralized solar energy solutions on health facilities in the states of Assam, Chhattisgarh, Jharkhand, Karnataka, Meghalaya, and Odisha. The case studies dive deep into the roles and responsibilities of various stakeholders in health electrification projects and the impact of decentralized solar energy solutions on health care systems in different financing, operating and geographic contexts.

- Eighty percent of the health facilities surveyed already had an existing grid connection and reported varying hours of power outages, where a variety of decentralized solar energy configurations were connected. This included health facilities powered by 100 percent solar energy with battery backup—that is, no grid connection; grid-connected solar photovoltaic (PV)—that is, the Renewable Energy Service Company (RESCO) model; and off-grid solar energy with battery backup and grid charging. Most health facilities reported an energy demand assessment done by external agencies (technology providers, implementing agencies, etc.) to estimate what loads will be connected to the system. However, system sizes across multiple facilities of the same tier remained constant although the size of population served and types of services provided varied. So a fixed solar PV system capacity interconnected to specific medical and nonmedical appliances was the norm, rather than powering the entire health facility based on a demand assessment. Although remote monitoring systems have been installed at some sites for system performance monitoring, issues of added cost, network availability, hardware malfunction, and data transmission were observed.
- Technology provider selection for procurement of decentralized solar energy solutions is a key consideration to ensure sustainability of the system over its lifetime. In many cases, local technology providers tend to perform better as compared to out-of-state technology providers. The remoteness of health facilities led to challenges of serviceability, especially in places where technology providers had not set up service centers within the state or district of intervention. Organizations have gone beyond traditional procurement models that focus solely on installing decentralized solar energy solutions to bundle operations and maintenance requirements and energy efficient appliances within the tenders. This has allowed health facilities to reduce energy consumption and optimize solar energy system usage to integrate a greater number of appliances within the same system size.
- Insurance policy coverage was not observed for off-grid solar PV systems with battery backup solutions in health facilities. Therefore, health facilities rely on part warranties and long-term annual maintenance contracts (AMCs) for system sustainability. However, awareness and enforcing of regular maintenance as per AMCs has

been a challenge, as financial incentives are lacking for technology providers after installation since the capital costs for assets and operating costs toward maintenance are paid up front due to stipulations of fund utilization within a short time frame for certain projects. There was also a lack of clarity among health facility staff on who is responsible for financing parts replacement, especially batteries and inverters, during the lifetime of the project.

- The impact on staff living environments varied depending on the type of facility. Given that most facilities were powered by the grid and had existing inverter or diesel generator backup, staff did not observe much change in the working environment after solar intervention. Moreover, staff quarters were not prioritized for solarization in any of the public health facilities studied. In facilities that faced severe power cuts or were previously unelectrified, staff observed greater patient footfall and on-time patient care, with minimal delays in conducting procedures. The biggest positive impact was experienced in boat clinics, where staff had to live on the boats for up to a week during health camps. The presence of solar energy with batteries allowed them a safe working and living environment.
- Most of the cases studied in this report met either part of or all the capital costs for installation from a CSR grant or philanthropic funding. Decentralized solar energy installations are capital-intensive as compared to other interventions, which CSR agencies may prefer. There are also certain sources of public financing that remain largely untapped, and strategies need to be designed to access them to provide for not only capital costs but also the costs for operations, maintenance, and part replacement over the system's lifetime.

SCALING DECENTRALIZED SOLAR SOLUTIONS IN HEALTH FACILITIES

The sustainability of decentralized energy systems is vital to ensuring uninterrupted health care service delivery. Building on findings at the global level from a recent report *Energizing health: accelerating electricity access in health-care facilities* (WHO et al. 2023), we identify the following important considerations that are relevant to the rural Indian context on enabling health care electrification using decentralized solar energy systems:

Consider needs assessment of health facilities to understand present and future demand for medical services and appliances to adequately size the energy system to meet their needs. Beyond the health facility, this should also encompass the energy needs of staff quarters on the premises. Geospatial assessment can support implementation at scale through prioritizing health facilities as part of site selection process and, coupled with a needs assessment exercise, can standardize ranges of energy requirement for different tiers of health care.

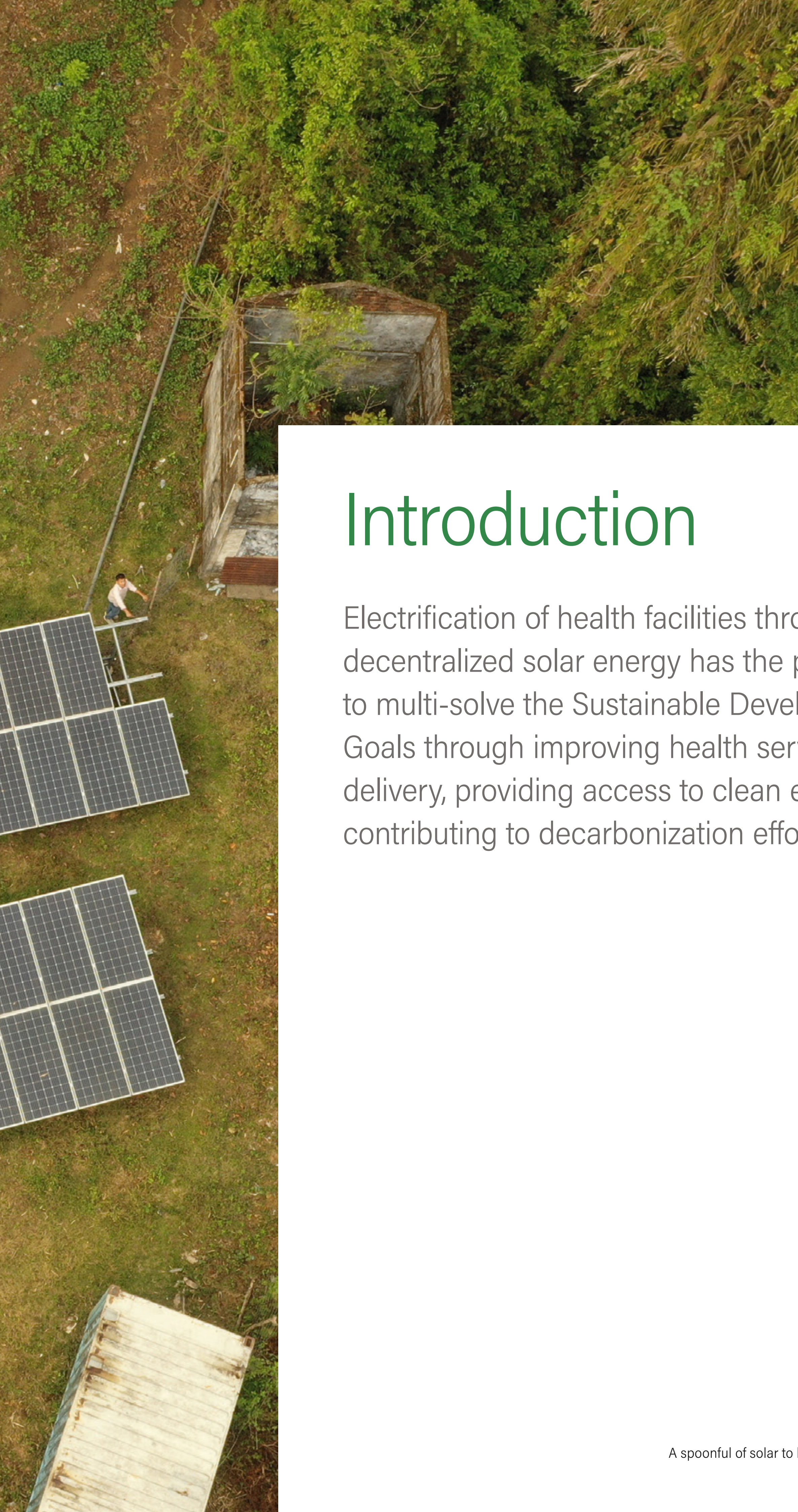
There is a need for further standardization of medical equipment with preference given to energy-efficient alternatives. The division of Healthcare Technology at the National Health Systems Resource Centre, for example, can develop technical specifications that ensures promotion of proven energy-efficient medical appliances for public procurement in the fields of medical cold chains and maternal and childcare, along with lighting and ventilation, as well as greater research and development in medical services where energy efficiency has not yet been considered.

Emphasis should be placed on selection of decentralized solar energy solutions that are both technologically compliant and economical, such as use of the quality and cost-based system (QCBS) procurement method. Identifying avenues for meeting operating and part replacement costs is central to the sustainability of the energy system in the long term. Financing and governing arrangements should be reexamined to ensure proper budgeting for equipment replacement and incentivizing technology providers for sustained upkeep of systems through long-term annual maintenance contracts. This should be complemented by capacity building to train health facility staff on routine maintenance needs. Customized insurance products for covering the entire energy system against climate-related events should be developed.

An integrated impact assessment framework can be helpful in broadening the evidence and bringing about financing for achieving multiple SDGs in tandem. For live data, efforts should be made to integrate remote monitoring systems with compatibility across different network service providers and flexibility to operate across wireless networks such as 2G for use in rural areas.

Public sources of funding need to be unlocked through exploring financing under the National Health Mission (NHM) as well as other central and state government schemes for installations at public facilities. This will need convergence in programmatic funding to ensure an integrated financing approach for health care electrification. Philanthropic and CSR funding also plays an important role in both these impacts by bridging any public financing gap. Public budgetary and grant allocations need to be spread out over the lifetime of the energy system; for example, through extended term funding to account for major operating expenses, rather than being limited to a single lump sum cost. Accountability for public financing should rest with a single administrative unit at the state level, preferably the state health department.

Funding agencies, policymakers, technology providers, and development organizations can build sustainable decentralized solar energy systems in health facilities at scale by incorporating these considerations at the various phases of the project. This will ensure that system design, procurement, and operations cater to the present and future energy needs of the health facility. Health facilities can extract maximum benefit from these energy systems to support health care service delivery provision, given that the system performance is maintained over the lifetime of the project.



Introduction

Electrification of health facilities through decentralized solar energy has the potential to multi-solve the Sustainable Development Goals through improving health service delivery, providing access to clean energy, and contributing to decarbonization efforts.

Decentralized solar energy solutions have been increasingly considered for health facility electrification, particularly in rural unserved or underserved areas that are electricity-deficient. While several case studies on decentralized solar energy interventions in health facilities have been documented through field reports and case studies, predominantly in Africa with some in India, the call for enhancing the pace of electrification requires further evidence on the role of decentralized electricity solutions in the health sector, and documenting the challenges faced in scaling these solutions sustainably across the country.

The study documents and assesses 22 health facility solarization initiatives to provide reliable electricity through DRE across six states of India. This publication seeks to answer the following research questions:

- How has the decentralized solar energy solution affected provision of rural health care delivery in India?
- Are the current decentralized solar energy interventions sustainable and scalable? If not, what are the lacunae in these projects that prevent sustainability and scalability?

While there is a lack of quantitative data on the impact of solar solutions in health care service delivery, primarily due to a lack of baseline information and attribution, we attempted to answer the research questions qualitatively through gathering evidence on the following subquestions:

- Has the decentralized energy technology improved affordability, reliability, or sustainability?
- Following enhanced access to electricity through decentralized solar, what changes are observed in health services at a facility level and accessibility of these services regionally?
- What are the existing procurement policies, installation, O&M, and capacity-building practices in health electrification that contribute to sustainability of the energy system?
- What are the existing financing arrangements for implementing, operating, and maintaining decentralized solar solutions in health facilities?
- What technology, policy, capacity, and financing factors should be considered to enhance the scalability of DRE solutions in health facilities?

The United Nations Foundation and SEforALL (2019) defined sustainability and scalability in order to evaluate different energy delivery models in public health and education facilities in resource-constrained settings. *Sustainability* refers to the reliable delivery of energy services over a period of 10 to 15 years—that is, the expected lifetime of stand-alone DRE systems—while *scalability* is the replicability of an energy service delivery model to multiple health facilities and beneficiaries served by health facility electrification projects over a period.

To answer the previous questions, this report studies 22 health facilities that cover a wide spectrum that includes public health facilities (government), not-for-profit health facilities, and alternate forms of health care service delivery like boat clinics. In public health facilities, the study looked at examples from multiple tiers of health care such as subcenters (SCs), primary health centers (PHCs), community health centers (CHCs), and district hospitals (explained in Figure 2, p. 22). This includes SCs and PHCs that were designated to be converted to Health and Wellness Centers (HWCs).

The health facilities analyzed were powered by stand-alone decentralized solar energy solutions installed at the location of the health facility in different solar electrification configurations, such as 100 percent solar electrification with battery backup, solar electrification in conjunction with the grid, solar electrification with battery backup in conjunction with the grid, and solar electrification with battery backup in conjunction with the grid and a diesel generator.

Mobile health clinics and health facilities electrified by solar powered mini-grids were beyond the scope of this study. As a single mini-grid serves several users ranging from households to different institutional loads, it would not be possible to attribute the electricity level benefits to a single health facility.

While the present section provides an overview of the study's objective and focus, the next section provides an extensive scoping literature review to gather information on current levels of access to electricity, shortcomings of the grid and rural electrification programs for health facilities, studies highlighting linkages between electricity access and health service delivery in India and globally, the structure of public and private health system in India, the rural-urban divide in accessing quality health care, health electrification work undertaken by various implementing agencies globally and India, and existing policies with energy and health linkages.

Following that, we describe the rationale for this report, which includes the research framework, and methodology for data collection and structuring the findings. We then present our findings across four important themes: technology (energy system and system performance monitoring), policy (procurement and insurance), capacity (operating and human capacity), and finance (capital and operation costs). Based on the findings from literature, surveys, and observations from the ground, we provide suggestions to be implemented for scaling decentralized solar energy solutions in rural health facilities in India. Finally, the study is summarized in the "Conclusions and way forward" section with overall recommendations.

BACKGROUND

Over the last decade, significant progress has been made on SDG 7, "*Ensure access to affordable, reliable, sustainable and modern energy for all.*" Almost 1.2 billion people in Asia have gained access to electricity between 2000 and 2020, and comparable progress was being made in sub-Saharan Africa with 41 million people gaining access to electricity each year between 2013 and 2019 (IEA n.d.). Tracking progress on electricity access for specific end uses is a gap coming into focus as various sectors articulate their own needs for electricity services. One such sector with intrinsic linkages to human development is health care.

Due to lack of universal electricity access and resource constraints, many health facilities in developing countries function either without access to, or without reliable access to, a supply of electricity. Moreover, the increasing frequency of climate-related events and reemergence of infectious diseases affects health systems' abilities to deliver essential and critical health services (G20 2023a). Based on available data from 27 countries, a WHO-led survey estimated that low-income and low- to middle-income countries in sub-Saharan Africa and South Asia reported that 15 percent and 12 percent of health facilities, respectively, lacked access to electricity. Translating this to global population estimates, the global South has nearly 433 million people accessing facilities without power, and 478 million people accessing facilities with unreliable electricity[3] (WHO et al. 2023).

Previous research by WRI shows that the linkages between electricity access and development are mutually reinforcing. If electricity access initiatives are linked to development outcomes in sectors of health, education, and livelihoods, then energy planners can leverage the expertise of community organizations, funding groups and development sector stakeholders to understand the energy needs, mobilize finance, and provide electricity solutions that match the community's development needs (Odarno et al. 2017). Wood (2020) proposed a "new nexus approach" to achieving the SDGs that involved a greater focus on demand-side perspectives to understand the energy needs of service-level organizations—government and nongovernment institutions that provide development services such as health care or education—and build their capacity to shape and expand electricity solutions to unserved, underserved, and under-resourced populations. In India, we previously analyzed the role of integrating electricity priorities within the health and education sectors (Ginoya, Narayan, et al. 2021), and designing resilient DRE solutions in climate vulnerable regions of India (Ginoya, Meenawat, et al. 2021), this study focuses on the role of decentralized solar energy solutions in rural health care service provisioning and describes the health systems level considerations needed to ensure that the decentralized solar energy solutions provide the intended development benefits in the health care sector.

HEALTH SYSTEM BUILDING BLOCKS

According to the World Health Organization (WHO), universal health coverage means that all people have access to the health services they need, when and where they need them, without financial hardship. This includes the full range of essential health services, from health promotion to prevention, treatment, rehabilitation, and palliative care (WHO and International Bank for Reconstruction and Development/The World Bank 2022).

As compared to the health sector, which is limited to actions of the government, aspects of the health system are described as being under the ministries of health and include provisions of health services by both state and nonstate actors. As defined by the WHO framework, strengthening of health systems relies on addressing any constraints across six components or key building blocks: *service delivery; health workforce; information; medical products, vaccines and technologies; financing; and leadership and governance* (WHO 2007).

These building blocks contribute to health system strengthening in multiple ways. Many of these blocks are cross-cutting components. While the health workforce and finance form key inputs to a health system, governance and health information systems form the base for all overarching policies and regulations for all the building blocks. Service delivery and medical products and technologies act as immediate outputs of the health system (WHO 2010).

The relationship among these building blocks is dynamic, wherein improvements in one area are not possible without the contribution of other areas. Managing the interactions among the six health system building blocks is essential to achieving equitable and sustainable improvements across health services and health outcomes (WHO 2007).

The majority of essential health services require electricity to be delivered to people. For certain services, continuous reliable electricity access is necessary, such as operating scanning and laboratory equipment; operating critical medical devices such as dialysis equipment, oxygen concentrators, ventilators, heart rate monitors etc.; and storing vaccines. Reliable electricity supply is also deemed important for other noncritical medical and nonmedical services, such as the treatment of certain diseases and injuries, providing medicines and nutrition, sterilization, access to clean water, and non-emergency maternal and childcare. Efforts have been made across the world to ensure continuous and reliable electricity access for several important needs in large health facilities dealing with complex health services or offering inpatient services. The same cannot be said for rural health facilities, in part due to the nature of services these provide and, in some part, due to where these are located.

In the sections below we look at the role of electricity solutions in strengthening health systems and their interlinkages with the various building blocks.

LINKAGES BETWEEN ELECTRICITY ACCESS AND HEALTH SYSTEMS STRENGTHENING

Modern energy sources in health care

Conventionally, health facilities, when established, are connected to the electricity grid network available at their location. In areas where the electricity grid is unreliable—prone to outages or experiences voltage fluctuations—health facilities rely on diesel generators as a backup source of electricity. Due to the nature of service provided, especially emergency services, even large hospitals in urban areas keep diesel generators as backup.

In case of off-grid scenarios, diesel generators have been the most common stand-alone solution (Franco et al. 2017), along with use of kerosene lamps, candles, or flashlights for lighting alone (WHO and World Bank 2015). In Liberia, for instance, the WHO sample surveys showed that two or three diesel generators are kept as a backup source of electricity for the majority of health facilities (WHO et al. 2023). The report further states that a survey conducted by the Liberia Electricity Sector Strengthening Access Project showed that 100 percent of the hospitals had at least two generators, and 40 percent of the lowest-level PHCs had at least one generator.

Over time, the cost of renewable energy technologies has fallen, making them affordable both as a primary source and as a backup source for electricity (WHO and World Bank 2015). In sub-Saharan Africa, there has been growing popularity for solar power, with a WHO-led review highlighting that in Uganda, 15 percent of hospitals use a combination of central grid-connected and solar sources (Adair-Rohani et al. 2013). Hybrid systems of diesel generators and solar PV have also been observed in remote off-grid areas where this combination has shown increased savings in fuel relative to using diesel generators alone, thereby making electricity affordable and suitable for medium and large health facilities where the daily load consumption is high (Alakori 2014), although the viability of such hybrid models (i.e., solar PV with diesel generators) will be relative and may differ from case to case.

Guided by economies of scale throughout the supply chain, the price of a solar PV module has decreased by over 80 percent in the last decade, making it a cost-competitive electricity generation technology (IEA 2022). Yet the high up-front investment of the energy system, replacement cost of batteries, lack of technical expertise to carry out equipment maintenance, and inadequate finance are the main barriers for its uptake. These costs also vary and depend on local economic conditions like taxes, transportation and installation costs, and the technology adopted (Alakori 2014).

The energy supply options at a health facility depend on various techno-economic factors, such as site-specific characteristics, electrical load requirement, local energy resource availability, environmental factors, affordability, and financial incentives (WHO et al. 2023). Broadly speaking, there are three major energy supply options:

Utility grid electricity: The electricity grids are the most common means of providing high-capacity power to the population at an affordable rate. These grid extension costs are borne by the government and electricity utilities and are charged as electricity tariffs to the end users. The Saubhagya scheme in India electrified 28.6 million households between October 2017 and March 2022, with grid electricity connection to households in unelectrified rural regions being the main mode of service (Ministry of Power 2023). In regions where grid electricity is not accessible or cost-effective, particularly rural and remote areas, DRE systems primarily through solar PV systems, have been adopted. These have been provided either through stand-alone modes or as mini-grids, as described below, using solar as the source of energy.

Stand-alone solar PV system: A stand-alone solar PV system is installed and dedicated to power appliances at a health facility. Being an intermittent source of energy, this may either be connected to the utility grid through an inverter to feed excess power back into the electricity grid or be off the grid, in which case all the power generated is consumed only at the facility or stored in a battery for later use; that is, evenings, nighttimes, or on cloudy days. The type of stand-alone solar configuration adopted depends on the reliability of an existing grid connection, costs, and the energy needs of the health facility, as described later in the report.

Mini-grid system: This form of decentralized energy system generates and distributes power to several households and institutional loads in a particular village or intervention area using energy sources such as renewable energy, diesel, battery storage, or a combination. Some of these institutional loads may include health facilities. In India, mini-grid systems have improved the reliability of electricity services in villages, particularly in rural and remote areas that either have been un-electrified under previous rural electrification schemes or face continuous reliability problems like power outages and voltage fluctuations (Concessao and Gupta 2023).

In addition to mini-grid systems, diesel-based generators have been a prominent source of power backup in many health facilities with unreliable grid electricity. Other DRE sources like small-hydro, wind, and biomass have been installed in specific geographies, although the existing uptake of these DRE solutions has been limited in comparison to solar, primarily due to the challenges in modularity and the geographic distribution of these energy resources (WHO et al. 2023).

Conventionally, access to electricity, has not been seen as a core function in health facilities. But with time, the adoption of modern, sustainable, and clean energy services has been gaining importance in delivering electricity to modern health care facilities, with new opportunities opening for innovative financing solutions (WHO and World Bank 2015). The recently concluded G20 "New Delhi Leaders' Declaration" (G20 2023b) reinforced its commitment to building more resilient, equitable, sustainable, and inclusive health systems to achieve universal health coverage.

However, the impacts on health outcomes, are difficult to quantify due to these outcomes depending on numerous factors like availability of specialized staff skills and knowledge, availability of medicines, proper infrastructure of the health facility, distance to a health facility in case of emergency or treatment, and time taken to observe measurable improvements. Hence, the paucity of literature to see the impacts of energy access on health facilities and then measuring positive health outcomes becomes challenging.

Linkages between electricity supply and health service delivery

The joint global report by WHO et al. (2023) estimates that globally around 1 billion people are attended to in health facilities where electricity is either unreliable or not present at all. The report underscores that health is a human right and a public good, and the lack of access to electricity or an unreliable electricity supply are major impediments to attaining universal health coverage.

SDG 3 aims to "*achieve universal health coverage, including … access to quality essential health-care services … for all*" by 2030 while the focus of SDG 7 is to "*ensure universal access to affordable, reliable and modern energy services.*" Both of these SDGs are interlinked as the accomplishment of SDG 3 is connected to achieving SDG 7, given its potential impacts on health care services, better disposal of medical waste, higher staff recruitment and retention, and prevention of disease (Shastry and Rai 2021). However, the evidence of a correlation between electricity access leading to better health outcomes is scarce. In fact, a WHO (2015) report clearly mentions that previous studies "*did not identify a single study in which linking energy access and health outcomes was the primary objective.*" The WHO et al. (2023) report indicates that the data on energy systems functionality as it relates to health outcomes are still lacking. There is a need to fill this void that examines the qualitative aspects associated with the health and energy nexus, including energy variables like energy system capacity, reliability, affordability, and sustainability.[4] Some localized studies have shown the challenges arising from the lack of reliable electricity access at health facilities, as well as the benefits.

In Asian contexts, the gains from electrification led to lower infant and maternal mortality in Indian districts, (Roychowdhury and Jones 2014), increased immunization and prenatal care in Pakistan (Majid 2013), and enhanced nutritional status in children in rural Bangladesh (Fujii et al. 2018). Unreliable electricity supply can hinder the smooth functioning of health facilities, thereby affecting both quality of care and the operation of lifesaving equipment. Power outages can disrupt the use of essential diagnostic devices like X-ray machines and MRIs, can pose a challenge to the refrigeration of vaccines and the availability of basic lighting, and hinder doctors in providing basic emergency and maternal delivery services (Koroglu et al. 2019). In sub-Saharan Africa, power failures have an impact on health services. For instance, in Ghana, power outages of more than two hours increased the risk of hospital mortality by 43 percent (Apenteng et al. 2018). Cronk and Bartram (2018) conducted a study to estimate the environmental conditions in health facilities of 78 low- and middle-income countries. They found that half of the health facilities lacked a piped water source on premises, 73 percent lacked sterilization equipment, and 59 percent lacked reliable electricity.

The health facility might have plans to tackle a shortage of medicines by keeping emergency stocks or diesel generators as backup in case of electricity disruption, but it becomes difficult to deal with water shortages. The medical facilities might have their own mechanical pumps, which are dependent on electricity, but with power cuts, challenges to pumping water are bound to take place. In these cases, facilities can consider installing solar-powered pumps and enhancing water tank storage to improve resilience (WHO and UNICEF 2022).

In a separate study, electrification increased the accessibility of 24-hour emergency services and access to communication devices within the health facility in Ghana (Javadi et al. 2020). In low- and middle-income countries, the role of electricity had impacts on health outcomes, Khogali et al. (2022) conducted a systemic review of 5,083 studies and found that with electricity access, the quality of antenatal care, vaccination, emergency services, and the supply of continuous oxygen improved. It was observed that in six of the studies they reviewed, the role of renewable energy played a pivotal role by providing solar-powered oxygen delivery, which reduced childhood mortality and the length of hospital stays in rural health facilities. In Sierra Leone, within six months of installing oxygen concentrators powered by a solar hybrid energy system, it was observed that the mean pediatric mortality significantly decreased from 3.7 to 1.8 percent (Morrissey et al. 2015).

Despite these benefits from renewable technology, various factors need to be evaluated like financing models, efficiency of RE systems, backup options, and ownership structure, among other factors since in rural and remote areas with unreliable electricity access, health facilities rely on diesel generators as a backup source of electricity. The availability of different financial mechanisms, along with the ownership of the technology (health facility, community, or technology developer) are important factors to consider. From the literature cited previously, it can be observed that electrification of health facilities results in efficient delivery of health services, administers to more patients, increases affordability by reducing out-of-pocket expenditure for patients travelling long distances and in search of private health facilities, helps in higher retention of medical staff, and encourages medical professionals to take up postings in rural areas. The electrification of health facilities does require coordination among different stakeholders, including central and state governments, the private sector, and local communities. Given the scarcity of broader literature on examining the quantitative impact of electrification on health outcomes, there is a need to thoroughly explore this relationship in the future while considering the adoption of DRE in electrification of health care facilities.

DRE adoption in the health care sector

Based on the literature discussed earlier, we have observed that all medical equipment—lighting facilities in operation theaters, refrigeration for immunization and blood banks, incubators in maternity wards, ventilators in intensive care units, and basic diagnostic services—needs a reliable, sustainable, cost-effective, and uninterrupted supply of electricity for a smooth delivery of health care services to people. In this context, DRE[5] can play a role, especially in developing countries with frequent power outages, by building a resilient health infrastructure. DRE solutions are one way to provide sustainable energy to health facilities in delivering uninterrupted service to the under-resourced populations and improve the socioeconomic health indicators as well (IRENA and SELCO Foundation 2022).

To reduce the financial, social, and environmental costs on communities, it is vital to make the primary health care infrastructure more reliable and resilient with a sustainable power supply in these facilities (IRENA and SELCO Foundation 2022). Health care facilities are the first stop for any medical attention needed in rural communities. More than 50,000 primary health centers are without access to electricity in the sub-Saharan Africa region (Moner-Girona et al. 2021). With recent survey data from the WHO et al. report (2023), 2 percent and 49 percent of the hospitals, respectively, had no access and unreliable access in sub-Saharan Africa. Thus, it becomes imperative to electrify these facilities with reliable and affordable energy systems. Low-income countries with poor national grid infrastructure can benefit from integrating decentralized energy solutions into the health care system, especially for the last-mile communities.

Climate change can exacerbate health emergencies through reemergence of pandemics, along with recurring climate disasters that can overwhelm health services (G20 2023a). Ginoya, Meenawat, et al. (2021) highlight the fact that DRE solutions have the potential to create more climate-resilient infrastructures that are economically, socially, and environmentally more sustainable, provided that they account for climate vulnerability in the planning, design, and implementation of the solutions. Moreover, DRE solutions offer economic benefits by generating employment opportunities to install, operate, and maintain off-grid systems locally, especially for women and youth (IRENA 2019).

Different types of ownership models exist for the overall management of DRE systems, such as facility-owned wherein the health facility staff is responsible for the working of the energy system or in a community ownership model where the ownership and accountability of the decentralized solar energy system can be by the whole community or the village. This also plays a vital role in discouraging theft (Welland 2017) as any damage to the DRE system will disrupt the working of the health facility and thereby affect its access by the entire village. The third type of ownership is under the developer, wherein the technology provider is the owner of the DRE system; and any theft or fault in the equipment will be the responsibility of the developer to oversee. Here, the developer is responsible for managing the energy system over its lifetime. The developer generates income on energy consumed by the facility or for a specific time period, after which management is handed over to either the facility or the community.

DRE solutions have played a role in strengthening health infrastructure globally. In Zambia, Chinunda Rural Health Center is the main health facility in Chitandika, which serves around 20 villages within a distance of 20 km. With the installation of a 28.35 kWp smart solar PV mini-grid, along with a battery storage facility at the health facility, the quality of health facilities within the area notably increased, particularly for pregnant women (ARE 2020). With reliable access to electricity, the retention of medical staff at the health facility increased as well, leading to better medical attention for the local communities. Vaya Energy and Schneider Electric installed a DRE solution that supplied round-the-clock electricity to a primary health center in Dakwa, Nigeria, and trained the staff in the O&M of the solar panels for long-term sustainability (ARE 2020). In Bangladesh, the Infrastructure Development Company Limited financed the installation of 26 solar mini-grid projects at the health facilities that were not connected to the national grid. Because these facilities had a higher load demand, stand-alone solar systems were not the ideal solution (ARE 2020). The benefits of these solar mini-grids were experienced across the community with the health center running at full capacity, including emergency services during nighttimes, with pregnant women and children being able to access medical services. The report also mentioned environmental benefits of the mini-grid with an estimated 1,523 tonnes per year of CO_2 emissions avoided.

A UNDP-led program installed solar PV-battery backup systems at 405 district hospitals, polyclinics, and primary clinics in Zimbabwe, and these systems became a reliable source of power supply to the health facilities (United Nations Foundation and SEforALL 2019). Timely and reliable access to health facilities in remote and rural areas was a boon for last-mile communities. Moreover, with DRE solutions, new and efficient medical appliances could be added, which resulted in providing additional services for maternal and childcare, COVID-19 vaccinations and immunizations.

The IRENA and SELCO Foundation (2022) report highlights that with the strengthening of health care centers closer to the patients' homes, out-of-pocket expenditures for end users have decreased with reduced time spent on transportation and use of private health care services. The

FIGURE 1 | Various energy needs in a health facility

Source: WRI India authors.

report also states that with electricity access, the working condition of these facilities resulted in medical staff taking better care of their patients. Electricity access also improved staff retention and readiness to travel and work in remote areas. It has been observed from the literature that integrating electricity access with health facilities has strengthened the health infrastructure, ensured quality delivery of health services, and provided safe working conditions for the medical team. But given these benefits, there are also challenges in the integration of electricity within the health sector, as elaborated in the next section.

Considerations of DRE-based electricity integration in the health sector

Despite the benefits of electrifying health facilities, there is still a lack of authentic data on the status of electricity access in developing countries within these health facilities. The challenges of electrifying health facilities persist, despite their successes. Some important factors are as follows:

Technical: The technical know-how of renewable energy equipment is an issue that needs to be considered in project plans. The lack of adequate O&M knowledge results in wastage and neglect of the equipment. In Guyana, despite the widespread use of solar PV systems for health facilities, the sustainability of these systems was not accounted for in the long run either by the funder or by the end users, and hence many systems had technical problems or were not working properly (Alakori 2014). Periodic upkeep of the equipment is important, including regular checkups of backup equipment (including diesel generators, inverters, and batteries), keeping an inventory of spare parts (either stocking up on site or with the technology provider's local office), and planning and budgeting for O&M of these routine procedures in advance (Walker 2018). Remote monitoring systems in these cases can help monitor the performance of the equipment and help reduce long-term maintenance costs.

Safety: Theft and vandalism of equipment parts pose a major barrier, especially in small towns and rural areas. The PV panels and batteries in the solar system are the most expensive part and pose a target for theft (Welland 2017). In Haiti, in order to prevent theft, tamper-free mounting systems were used in a few projects (Alakori 2014). Similarly, storing inverters and batteries in an indoor enclosed space can help reduce theft.

Reliability: The lack of reliable electricity access in running emergency and critical medical equipment, particularly in cases of emergency and childbirth scenarios, is a challenge. In case of electricity fluctuations, performance of emergency services like childbirth and post-natal care puts the lives of the mother and child in danger. An uninterrupted supply of electricity is needed to handle life-threating accidents and maternal emergencies. For this purpose suitable backup solutions need to be in place wherever the supply of electricity fluctuates or is unreliable. "Expensive thermal generators" had to be relied on to maintain the continuous flow of electricity in hospitals in Kamili, Uganda (Ezor 2009). In a study by Adair-Rohani et al (2013), it was found that primary health clinics in Liberia powered by solar systems had a higher level of electricity reliability than those reliant on fuel-based generators.

Costs: The installation of renewable energy needs higher investments by the health facilities and hence higher capital costs relative to conventional generators. Apart from capital costs, the operating and part replacement costs also need to be considered when the decision of financing for health facility electrification takes place. The decision on the sale of excess electricity back to the grid or using the energy-as-a-service model where facilities pay for electricity services, rather than taking ownership of the system, are novel ways of financing long-term O&M of the energy system (WHO et al. 2023; SEforALL and ESMAP 2021).

Capacity building: The need to build the training and capacity for the smooth functioning and maintenance of the energy system is crucial. Hiring of good trainers with the right expertise and knowledge is important, and the continuous running of such training programs is much needed. Raising awareness among the medical staff about the limitation of the energy system is important as well. In Haiti, the training of local staff became crucial to keep the power system sustainable and in running condition (Alakori 2014).

The ownership of the energy system creates a gap in the funding mechanisms when the capital is needed for the lifetime of the system. It has been seen that when the investment is donor driven, there is a specific timeline up to which they can fund such energy interventions, including procurement-based models, which often neglect O&M expenses and replacement of spare parts (SEforALL and ESMAP 2021). O&M expenses need to be clearly budgeted and accounted for, especially in equipment ownership models as responsibilities may be placed on public entities or on local staff, who may not possess the required technical knowledge. Integration of O&M costs right at the design stage can help overcome this challenge. This must be well captured in the procurement contract with the supplier of technology, and there should be strict adherence to ensure responses in real time.

To overcome this challenge, SEforAll (2021), outlines a long-term, performance-based service model under which private service providers selected by the government provide electricity services to public institutions over a longer time frame of 10 to 15 years. This kind of model is sustainable with the inclusion of the private sector, which has in-depth knowledge and expertise and can deliver long-run services along with the lifetime of the assets. Another aspect highlighted in WHO et al. (2023) is to consider the demand assessment needs for future energy demand scenarios in health facilities. This may include the adoption of new medical equipment in the facility or scaling up of medical operations and services that may require more lighting, cooling, and heating needs or increases in the number of operating hours, especially during night. Additionally, energy demand can go beyond the health facility to incorporate residential accommodations for medical staff on campus (WHO et al. 2023). This requires provision of basic amenities like electricity and water supply, proper ventilation, and backup electricity options in case of power cuts. This would help to retain skilled and professional health workers in remote and rural areas (WHO and World Bank 2015).

INDIAN CONTEXT

Health care system in India

The Indian health system is defined through diverse ownership structures (e.g., public, private, not-for-profit, railway, municipal hospitals, etc.), size of health facilities from clinics to super-speciality hospitals, and the types of medical services offered (NCDC 2023a).

The public health system in India, being the largest in size, adheres to a three-tier structure of primary, secondary, and tertiary health care services in both rural and urban areas (Ministry of Health and Family Welfare 2022a). Health services in rural areas have been an inherent feature of the public health sector in the country. In the year 2005, the National Rural Health Mission (now National Health Mission) was launched for "*attainment of universal access to equitable, affordable and quality health care services, accountable and responsive to people's needs, with effective inter-sectoral convergent action to address the wider social determinants of health*" (Ministry of Health and Family Welfare 2022a). Keeping this in view, in 2007, the Indian Public Health Standards (IPHS) for SCs, PHCs, CHCs, and sub-district and district hospitals were published. (Differences between the tiers are shown in Figure 2.) The rationale behind the IPHS was to standardize the quality of health care delivery in India, undertake regular improvements in quality, and serve as a yardstick to evaluate functioning of the health facilities. These IPHS provide guidance on health system components, such as infrastructure, medicine, human resources, equipment, and governance, to deliver quality health services at public health facilities. Since the last revisions of the IPHS in 2012, many new programs and interventions were implemented like the launch of National Urban Health Mission in 2013, introduction of quality enhancement initiatives like Kayakalp[6] and the

Labour Room Quality Improvement Initiative (LaQshya),[7] and Ayushman Bharat Health and Wellness Centers[8] in 2018. The aim of initiating Ayushman Bharat was to transform the existing SCs, PHC, and urban primary health centers (UPHCs) into HWCs to provide comprehensive primary health care (CPHC), which delivers "*preventive, promotive, curative, palliative, and rehabilitative services which are universal, free, and closer to the community*" (Ministry of Health and Family Welfare 2022a). There was a shift in the focus toward urban health centers in the IPHS 2022 guidelines with the introduction of HWCs in 2018. Therefore, to encompass all these developments, the IPHS guidelines were further revised in 2022 with a special focus on urban health facilities including (Ministry of Health and Family Welfare 2022a):

- Sub-district hospitals and district hospitals
- CHCs—non-first-referral unit CHCs (rural) and first-referral unit CHCs (rural and urban)
- HWC—primary health center– rural and urban, including multispecialty UPHC (polyclinics) in urban areas
- HWC-SC—rural and urban

While the IPHS cover public health facilities, private-sector health care does not come under the coverage of the same and only serves as guidelines. Private health care can be divided into for-profit and not-for-profit health care. Private-sector health care, especially for-profit, has accounted for 23.3 percent of all treated ailments in the National Sample Survey 75th round (Sarwal et al. 2021). Private health care also accounts for most of the health expenditure in the country because patients prefer using the private health sector, provided the option is available and they have the ability to pay for treatment (Kasthuri

FIGURE 2 | Three-tier health structure in India

PRIMARY

- Provide basic health facilties
- Present in villages and small towns
- Subcenter: Population coverage of 3,000 to 5,000
- Primary health center (PHC): Population coverage 20,000 to 30,000
- Presence of fewer medical staff

SECONDARY

- Provide basic health facility along with additional facilties of ICU, OT, labour/delivery, special newborn care unit, lab and imaging services etc.
- Present at district level
- Community health center (CHC): Population coverage 80,000 to 120,000
- District and sub-district hospitals (including government and private providers) bed strength varies based on population of district

TERTIARY

- Provide advanced medical facilities like surgeries, MRI, as well as medical education
- Present in cities
- Medical college hospitals and state-level institutions (including government and private providers)
- Advanced facilties including latest infrastructure and machines, specialized medical staff

Source: Adopted from Chokshi et al. (2016).

2018). The Rural Health Statistics of 2021–22 highlighted that 14.4 percent of the sanctioned female health worker or auxiliary nurse and midwife posts were vacant at SCs and PHCs. There was a vacancy of close to 17,500 specialists at CHCs, which comprise surgeons, obstetricians and gynecologists, physicians, and pediatricians (Ministry of Health and Family Welfare 2023). Due to the shortage of medical staff in public health facilities, private health-sector expertise has been harnessed to deliver national public health care schemes, wherein the private health care providers are reimbursed for these services by the government (Kasthuri 2018).

Private for-profit health facilities are mostly situated in urban or peri-urban regions and are out of reach of the economically weaker sections of society. Here, not-for-profit hospitals have played a huge role in bridging the gap of providing quality and affordable health care to low-income sections of society where quality health care is out of reach. These not-for-profit hospitals are owned by charitable organizations or nonprofit corporations, where the fees charged to patients are significantly lower than their for-profit counterparts. Revenues are reinvested back into the medical infrastructure for upkeep, improvement, and staff salary payment. These health facilities are located in remote and rural parts of the country with a significant presence in Northeast, West, and South India. In the regions of their work, non-profit hospitals have created a noticeable impact and goodwill among the local communities with their selfless health care with a social cause, along with several community engagement programs (Sarwal et al. 2021).

The role of reliable electricity in delivering an efficient health care system to society has been acknowledged in several policies although the level of attribution varies. As elaborated in Ginoya, Meenawat, et al. (2021), the review of national and subnational development policies provided insights into whether electrification needs have been integrated into policies. The paper looked at how some health initiatives mention electricity but fail to describe instruments to gauge whether reliable electricity is indeed supplied. Similarly, the Universal Immunisation Programme, which aims to provide universal coverage of lifesaving vaccines to infants, children, and pregnant women, needs cold chain infrastructure to store and transport vaccines at specified temperatures. But this program fails to make any reference to reliable electricity access. Similarly, Rajasthan's Health Department had created eight online monitoring systems to improve health care service delivery. These systems help to manage the supply chain of equipment, ambulances, medicines, diagnostic services, and human resources, but many health centers do not have access to computers, the Internet, or electricity (Ginoya, Narayan, et al. 2021). Hence, the need to integrate electricity requirements becomes relevant to achieve health sector policy outcomes.

The IPHS 2012 were considered as integrative as the standards discussed the relevance of electricity needs for critical services and mentioned the need for uninterrupted power supply in all tiers of health care, including the need for power backup via solar or generators (Ginoya, Narayan, et al. 2021).

In comparison to IPHS 2012, significant additions to electricity infrastructure can be observed in the IPHS 2022 guidelines. These guidelines promote the use of renewable energy solutions with battery backup to enhance climate resilience during floods, storms, and blackouts; measures to reduce voltage fluctuations; energy-efficiency measures such as efficient lighting and fans; and procurement of electrical appliances with a minimum 3-star rating from the Bureau of Energy Efficiency or equivalent organization. Heating, ventilation, and air-conditioning (HVAC) equipment should prioritize chlorofluorocarbon-free refrigerants with a low greenhouse warming potential. The 2022 IPHS guidelines also recommend Ministry of New and Renewable Energy (MNRE) standards and guidelines while selecting technologies for environmentally friendly and energy-efficient measures (Ministry of Health and Family Welfare 2022a). The IPHS 2022 guidelines recommend considering climate-related events while constructing new facility buildings, as well as measures to minimize heat gains in the buildings by using high solar reflective index materials to cover 75 percent of the exposed roof area or provide vegetation to cover at least 50 percent of the exposed roof area (Ministry of Health and Family Welfare 2022a). The revisions to the IPHS make it more up to date with the health infrastructure needs of the country but also recognize the integration of electricity priorities in health care. In comparison with other countries, the number of tiers of health care are far broader now to encompass three levels (tiers) of care and associated health facilities: *community level* (health post), *first level* (health center), and *referral level* (district hospital) (WHO 2016; WHO et al. 2023).

Strengthening Indian health systems through reliable electricity access

While the IPHS state the need for uninterrupted power supply in health facilities, according to the Rural Health Statistics 2021–22, 17,967 (11.4 percent) of SCs and 934 (3.7 percent) of PHCs were without electricity supply. Also, 9.5 percent of SCs and 5 percent of PHCs did not have a regular water supply. In terms of manpower, there was a shortfall of 6,249 female health workers and 776 doctors at PHCs, and 17,435 specialists at CHCs in rural areas (MoHFW 2023). While the Rural Health Statistics covers public health facilities, there is no data source on the electricity access levels in not-for-profit or private health facilities that serve populations in rural and remote parts of India. A survey conducted by the National Programme on Climate Change and Human Health (NPCCHH) across 18 Indian states analyzed the energy situation across a sample of 341 public and private health facilities. The survey noted how grid electricity was the primary source of power, accounting for 87 percent of the health facilities, with solar PV, diesel generators, and other power sources forming the other sources of power generation.

Exploring the accessibility of electricity at PHCs in India, Mani et al. (2019) found that with reliable electricity access, a greater number of PHCs were able to offer better health services relative to those centers without electricity access. Shastry and Rai (2021) used the data from India's District Level Household and Facility Survey and found that the lack of electricity access in PHCs relates to a lower number of deliveries and outpatients, by 64 percent and 38 percent, respectively, as compared to PHCs with electricity access. Health facilities with reliable electricity access also had a greater number of resident medical staff and critical medical equipment. The survey data revealed that the PHCs with low levels of electricity access resulted in a reduced number of childbirths in a month and a decline in the number of inpatients and outpatients as well. A gendered dimension was also seen by the authors, indicating that the availability of female medical staff is strongly related to access to electricity, especially in remote areas, as a majority of deliveries in PHCs are conducted by nurses (Shastry and Rai 2021). Chen et al. (2019) found that the probability of receiving the first dose of various vaccines increased following a village electrification program in Gujarat. Similarly, the probability of receiving checkups in the first trimester increased by 10 percent in India. (Chen et al. 2019).

Inadequate access to reliable and consistent electricity impedes the use of health equipment like heart rate monitors, X-ray machines, laboratory testing, dialysis equipment, and other critical medical devices and also affects the sanitization of medical equipment (Cahill 2021). Electricity is also needed for cooking, sterilization, water and space heating, and incineration of medical waste, which are important needs in large health facilities dealing with complex health services or offering inpatient services. (WHO et al. 2023)

Koroglu et al. (2019) conducted a study of women in the state of Maharashtra from 2015 to 2016 and found that frequent power cuts resulted in lower odds of delivery in a health facility for women coming from electrified households, and, additionally, longer and recurrent power cuts also reduced the odds of having a skilled professional to conduct deliveries or births in the health facility.

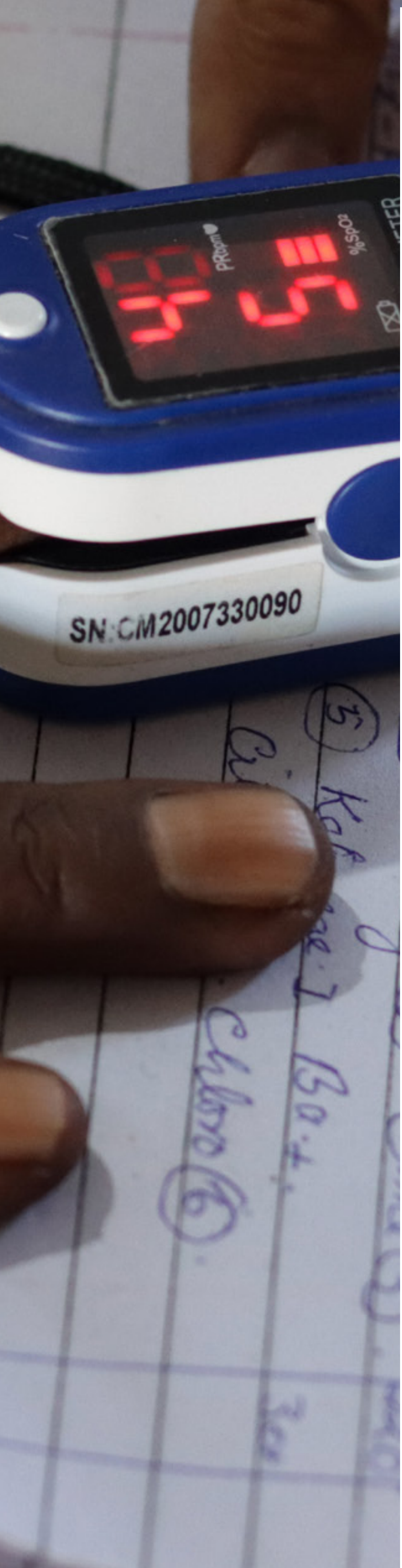
The distance from home to the health facility is another challenge since in a majority of the developing countries, rural communities have to travel long distances and incur high out-of-pocket expenses to reach the health facility (IRENA and SELCO Foundation 2022). Even in India, access to reliable electricity, especially in rural and remote areas, remains a challenge in health facilities. Electricity outages in health facilities lead to poor quality health services and less intake of patients for admissions, which could imply turning away pregnant women. These outages also limit the ability of women to travel long distances to a health facility, leading to women staying at home (Koroglu et al. 2019).

In rural India, many critical health services, such as antenatal medical checkups and diagnostics, were affected during the COVID-19 pandemic as nurse midwives could not travel to remote areas due to lockdowns. Since, these services relied on telemedicine, ICT infrastructure, and phones connected to the Internet, which needed access to electricity, the implementation of it became a challenge in rural and remote areas (Ginoya, Narayan, et al. 2021). Apart from lighting, cold storage, and water supply needs, a health facility also relies on thermal energy requirements needed for cooking, water heating, sterilization, and incineration of medical waste (Welland 2017). During the COVID-19 pandemic in India, the integration of electricity solutions through DRE contributed to powering of isolation wards, powering ventilators and ICUs, as well as creating new forms of infrastructure such as solarized COVID-19 sample collection and testing kiosks, quarantine centers, and dedicated therapeutic units (SELCO Foundation 2020; Concessao et al. 2020).

In the case of off-grid scenarios, diesel generators have been the most common stand-alone solution (Franco et al. 2017). In Chhattisgarh, which is a densely forested state in India, the extension of the national grid is difficult, and as a result diesel generators were used as a primary source of energy for the health facilities in some locations (United Nations Foundation and SEforALL 2019). In the past decade, however, the Chhattisgarh State Renewable Energy Development Agency (CREDA) has led the initiative to solarize public health facilities at all levels, having already covered 24 percent of public rural health facilities, including 100 percent solarization of all PHCs (CREDA 2023).

Similar DRE initiatives have been adopted by health facilities in other states, such as the Meghalaya Health Infrastructure Strengthening Project, where SELCO Foundation partnered with the state government to solarize over 300 SCs and 107 PHCs in the first phase (SELCO Foundation 2023). In Nagaland, the World Bank has been supporting the Nagaland Health Project in implementing hybrid DRE systems with refurbishment of electrical wiring in health facilities in over 170 public health facilities across district hospitals, CHCs, PHCs, and SCs (Directorate of Health and Family Welfare 2023).

Given these challenges in accessing reliable electricity at health facilities and the potential of integration of decentralized solar energy systems in health facilities through different operating and implementation models, our study looks at what role DRE can play in health facilities in rural and underserved parts of India and what factors can contribute toward scaling these solutions across the country. The study aims at analyzing solar solutions implemented in public and not-for-profit health facilities of varying sizes and energy demand across six states. The following section elaborates on the research objectives, scope, and methodology applied for selection of health facilities for the case study deep-dive assessment.



CHAPTER 1

Research framework and methodology

The health care system in India is heterogeneous in terms of size, ownership, socio-demographic profile of the population it caters to, and the disease prevalence in the region. Understanding the energy needs of the different types of health facilities is essential to designing sustainable decentralized solar energy systems.

As discussed in the previous section, decentralized solar energy solutions have been increasingly considered for health facility electrification globally, particularly in rural unserved or underserved areas that are electricity-deficient. While several case studies on decentralized solar energy interventions in health facilities have been documented through field reports and case studies, predominantly in Africa with some in India, the call for enhancing the pace of electrification requires further evidence on the role of decentralized electricity solutions in health systems and the challenges faced in scaling these solutions sustainably across the country.

This report explores the role of decentralized solar energy solutions in health care service delivery and how decentralized energy solutions can be made sustainable and scalable across rural health facilities in India. To answer this, the following section describes the rationale for building this evidence and the framework for presenting the findings from the ground.

Rationale and framework

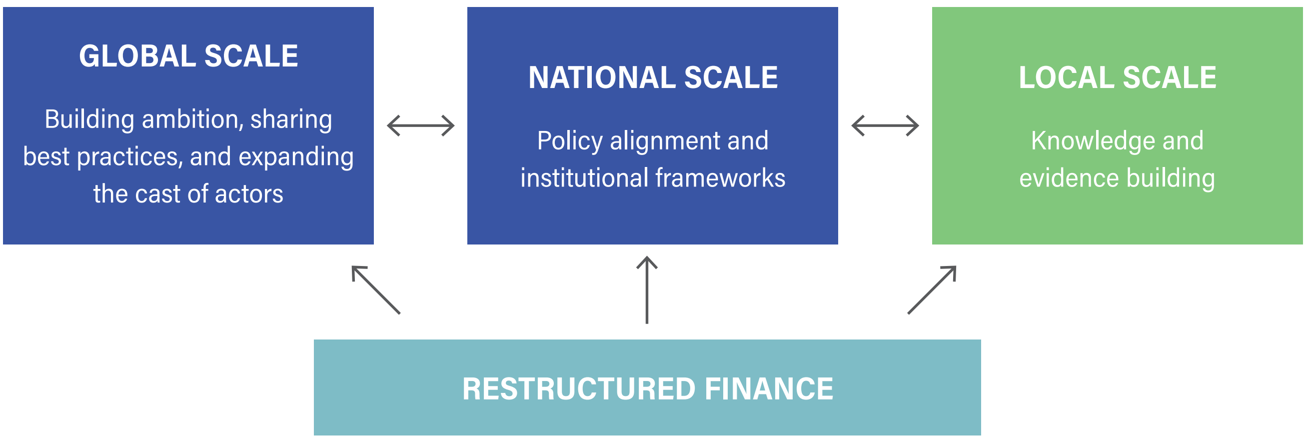
To link access to electricity and development outcomes, Odarno (2020) proposed a framework for adoption by governments, civil society, funding agencies, and the private sector that can help shape the energy and development agenda to achieve the SDGs. The ecosystem for this agenda necessitates global ambition and engagement, national-level policy and institutional alignment, local-level evidence building, and the restructuring of development finance.

For energy and health, the recent WHO global report highlighted the global urgency on addressing the challenges of reliable access to electricity in health facilities in resource-constrained settings (WHO et al. 2023). WRI India previously studied national and subnational health and multisectoral policies to highlight the gaps and provide suggestions on integrating the development-sector planning needs with electricity (Ginoya, Narayan, et al. 2021). This report aims to build on the existing studies to generate further local evidence that can inform the design of future rural health electrification projects (both nationally and globally), as well as shape the design of future procurement policies and financing needs for a cross-sectoral effort to addressing health service delivery challenges.

To build this evidence, we conducted field visits and in-person interviews at the 22 shortlisted health facilities, using dedicated questionnaires for different stakeholders, such as health facility staff, implementing organizations (government and nongovernment), financing agencies, and technology providers.

The stakeholder responses, findings from the ground, and our analysis builds on existing literature on creating enabling frameworks for electrification in resource-constrained settings from the global report *Energizing health: accelerating electricity access in health-care facilities*. The report states that addressing **technical, policy, capacity**, and **financing** barriers requires a supportive and enabling ecosystem (WHO et al. 2023).

FIGURE 3 | Elements for linking energy and development sector (e.g., health) ecosystem



Source: Adapted from Odarno (2020).

Accordingly, building evidence on the existing barriers across these four factors and how the barriers have been addressed, as well as highlighting the good practices already adopted, will allow energy and health-sector actors to scale the use of decentralized solar energy solutions in health facilities sustainably.

Methodology

We identified various decentralized solar energy installations in health facilities through secondary research on renewable energy interventions in the health sector carried out by various funding entities, implementing agencies, government departments, and local development organizations working in the health-energy nexus across India. The various stakeholders together have played a role in the electrification of over 3,000 health facilities through distributed renewable energy initiatives of a total solar PV capacity of over 6 MWp, across the country. The final list of potential case studies was further narrowed based on the following criteria:

Electricity intervention: The health facility has undergone an electricity infrastructure upgrade to solar with the purpose of improving electricity access conditions, either in terms of affordability, reliability, or sustainability (or a combination of the three).

Location: The health facility is located away from a metropolitan area, primarily in rural or remote part of the state or in a region that is electricity-deficient; that is, with unreliable electricity access.

Patients served: The patient footfall that the health facility caters to is primarily low-income and migrant populations.

Affordability: The health facility provides health care services free of cost (e.g., public health facilities), or at affordable or subsidized rates as compared to private health care (e.g., not-for-profit health facilities).

Tiers of health care: The health facilities represent all the tiers of rural health care from the sub-center level to the district hospital level. As not-for-profit hospitals are not defined in such tiers, the study also covered various sizes of not-for-profit hospitals based on bed strength and population served.

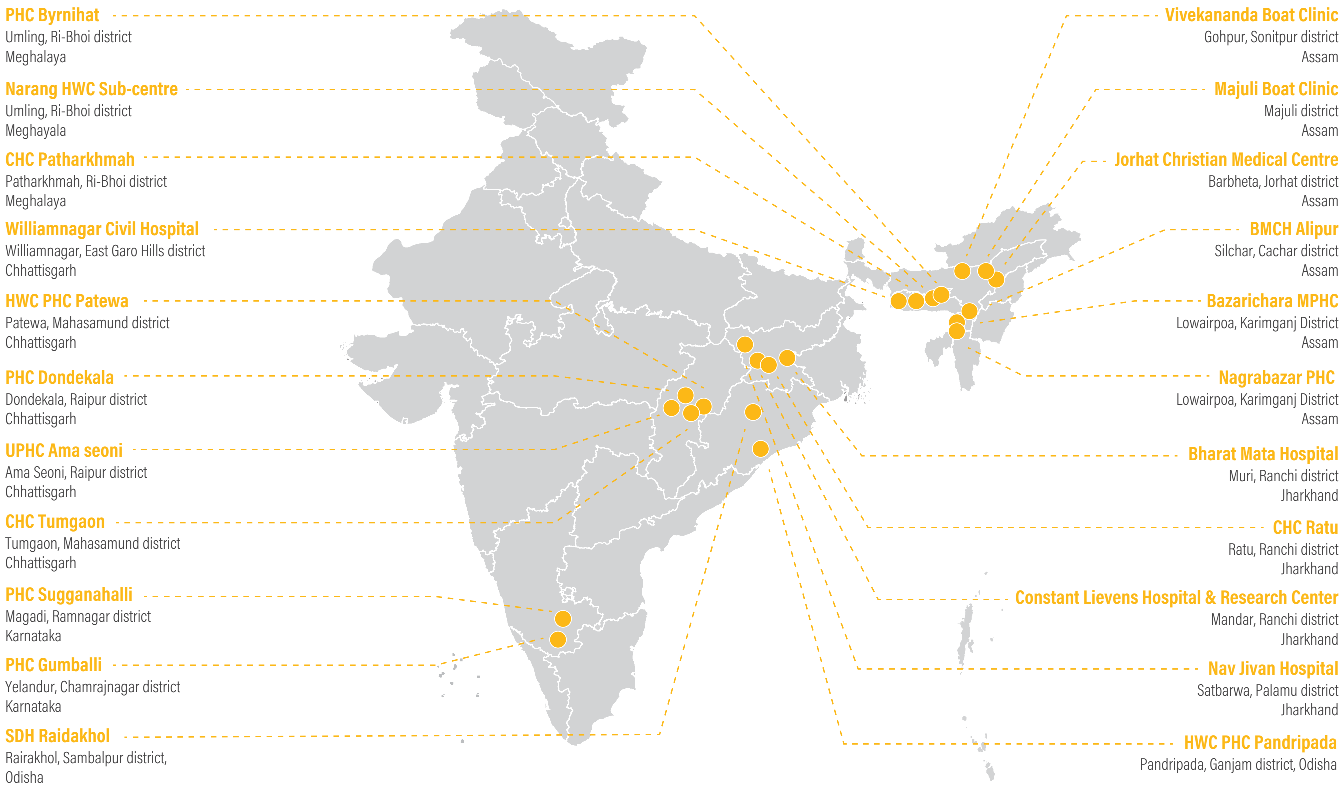
We used these criteria, along with the implementing organization or health facility's interest, availability, and responsiveness to participating in interviews, and based on an evaluation of travel conditions for field visits (such as available support in known remote locations).

We finally selected 22 health electrification interventions across six states for the interviews. Details of the interventions can be found in Appendix A. While most of the findings speak to the 22 case studies across six states, our interviews with the implementing organizations attempted to cover experiences from their broader solarization initiatives in the health sector, beyond these 22 case studies.

The health facilities examined in this report primarily rely on solar energy, either as a primary source or for backup power for electrification. When referring to DRE solutions, this report primarily focuses on decentralized solar energy interventions that provide electricity to health facilities in various operating modes, such as off-grid or on-grid installations.

It is important to note that the final selection of health facilities for the case study interviews relied on partnerships with health and energy-sector organizations and the interest of the facilities in being interviewed, which may not fully represent nonfunctional facilities or those with negative experiences related to solarization. All interviews were conducted after the installation of solar energy systems, so data collected on the pre-intervention situation relied on the information provided by the respondents and their recall. Lastly, our study was limited to multiple health facilities of different types within a single district when identifying a state, thereby restricting comparisons between similar health facilities across multiple districts.

FIGURE 4 | Twenty-two case studies of decentralized solar energy interventions in health facilities



Source: WRI India authors.

Most of the selected case studies were part of larger multi-project initiatives from funding or implementing agencies, making the findings in this report applicable to larger ongoing and future initiatives nationwide.

Primary data for case studies was collected through field visits and in-person interviews with different stakeholders: funders, government stakeholders, health facility staff in each facility, implementing agencies, and technology providers. For this study, end users are considered to be health facility staff at medical and administrative levels and not the patients. The information collected on the field from health care and administrative staff of the health facilities was supplemented by interviews with key stakeholders involved in the conceptualization and implementation of the project; that is, financing agencies, renewable energy enterprises, and implementing agencies. This approach allowed us to address any missing or unavailable information at the time of the field visit.

In total, we conducted 40 stakeholder interviews belonging to 30 organizations over a period of eight months. We gathered qualitative data on current infrastructure on site, the procurement and vendor engagement process, the process of selecting and sizing technology solutions based on the needs of the respective health facilities, challenges in implementation, handover of systems, O&M and monitoring and evaluation (M&E) of these solutions on health care service delivery, and, finally, thoughts on current and potential scaling models. Interview guides for the various stakeholders are provided in Appendix C.

Although the findings are not representative of India's overall health electrification efforts, they offer a snapshot of implementation challenges and opportunities at different scales and locations. The findings from the specific health facilities on various technical, policy, capacity building, and financial aspects are presented based on the states, health facility typology, and modes of financing:

- **States**: The study reviewed different types of DRE-powered health facilities across the six states mentioned: Assam, Chhattisgarh, Jharkhand, Karnataka, Meghalaya, and Odisha. Factors for choosing these states were WRI India's long-term engagement with Assam and Jharkhand and the presence of partners and solar for health interventions in Chhattisgarh, Karnataka, Meghalaya and Odisha (WRI India 2023; United Nations Foundation and SEforALL 2019; SELCO Foundation 2023).

- **Health facility typology and mode of operation**: The study reviewed health facilities run publicly (government), in a not-for-profit mode, as well as alternate forms of health care service delivery like boat clinics. In public health facilities, the study looked at examples from multiple tiers of health care such as SCs, PHCs, CHCs, and district hospitals. This includes SCs and PHCs that were designated to be converted to HWCs, to ensure delivery of CPHC. Under boat clinics, two modes of operations were studied: one where the solar intervention was grant-funded, and the boat run and financed entirely by a not-for-profit organization, and another where the boats operate in a PPP mode and are managed and operated by non-governmental organizations (NGOs), with operating finance split between the NHM and the NGO.
- **Mode of financing**: This can be segregated to purely grant-based financing, financed through single or multiple government programs or budgets, financed through RESCO where the health facility only pays the electricity tariff that is set by the project developer or a mixed mode of financing where a portion of the capital cost toward implementation of the system is shared between different financing entities or is a mixture of financing modes (grant, equity, debt, etc.), including the health facility itself financially investing in the installation.

In order to answer our research questions, we present the facility-level case study findings across the thematic areas that underpin the enabling frameworks for health facility electrification in the report "*Energizing health: accelerating electricity access in health-care facilities*" (WHO et al. 2023). The findings of our interviews are presented under the four important themes (and subthemes): technology (energy system and system performance monitoring), policy (procurement and insurance), capacity (operating and human capacity), and finance (capital and operation costs).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CHAPTER 2

Case study findings

The report analyzes decentralized solar energy interventions implemented in health facilities across six states: Assam, Chhattisgarh, Jharkhand, Karnataka, Meghalaya, and Odisha. It covers a mix of health facility tiers, energy system configurations, ownership, and operating models.

The installations covered under these case studies have multiple stakeholders involved in delivering decentralized energy solutions in the facilities. In this report, we cover inputs provided via surveys from four types of stakeholders: implementing agencies responsible for designing and, at times, financing the health electrification projects; funding agencies that cover the capital and operating costs of the energy system; administration and staff of health facilities (classified as beneficiaries) responsible for coordination and upkeep of the system on their premises; and technology providers such as system integrators or enterprises that are responsible for procurement, installation, commissioning, and O&M.

TYPES OF HEALTH FACILITIES SURVEYED

The case studies were broad-based to cover multiple governing modes in these health electrification projects. These include a mix of public rural health facilities at all tiers of health care; not-for-profit health institutions working predominantly in regions unserved and underserved by the public sector; public health facilities run in PPP mode with state-level health departments; and alternative means of accessing health care like boat clinics, which have been evaluated for both functioning in a pure not-for-profit mode and in PPP mode with the NHM.

The models of interaction among health facilities and development partners vary. Karuna Trust has been a pioneer in PPP models, starting in 1996, with the handing over of management of PHC in Gumballi, Chamarajnagar district, Karnataka to Karuna Trust by the MoHFW. The management entailed managing human resources, procuring generic drugs and vaccines, quality control, and introduction of eye care, mental health, and traditional medicines among many other health system-strengthening initiatives (Karuna Trust 2011). As of 2022, Karuna Trust managed 71 PHCs, including mobile medical units covering a population of 1.5 million across seven states: Andhra Pradesh, Arunachal Pradesh, Karnataka, Maharashtra, Manipur, Meghalaya, and Orissa (Karuna Trust n.d.). Similarly, the NHM under the Government of Assam, collaborated with the Centre for North East Studies and Policy Research (C-NES) under a PPP mode to provide health services to communities residing in *char* areas; that is, remote and rural islands of the Brahmaputra River. The 15 boat clinics under this partnership cover 13 districts in Assam (C-NES 2020).

On the other hand, World Vision India works across multiple geographic areas through its area development program (ADP) to improve the well-being of children through multisector projects in the fields of health; nutrition; water, sanitation, and hygiene (WASH); and education. The focus of each of the ADPs can vary in size and context, covers a population of at least 100,000, and is selected based on evaluating various health, social, education, and demographic indicators. In the study area of Assam, the ADPs support public health facilities through infrastructural support of renovation of physical health infrastructure, skill training for frontline health workers, and joint monitoring and awareness creation on maternal and child care. In these public-private partnerships, the level of operational risk allocation between the public and private agency varies, based on cost and sharing responsibility among the entities financing the O&M, cost of the energy system, operating costs for procuring fuel, medicine, for paying staff salaries, and other costs.

While facilities operating in partnerships have been described earlier, the study also looked at the more traditional health institutions, such as public health facilities and not-for-profit health facilities. The roles and responsibilities of health facility staff and implementing organizations vary, based on the type of health facility where the decentralized energy solution is installed, in terms of how it is financed, who operates the energy system, and how it is maintained.

The findings of the study are presented under the themes of technology (energy system and system performance monitoring), policy (procurement and insurance), capacity (operating and human capacity), and finance (capital and operation costs) to help provide answers to our research questions. A lot of subthemes under these topics have cross-cutting elements and will feature in the other broader themes as well.

TECHNOLOGY

Assessing the energy needs of the facilities

Deciding the size of the solar installation and, if applicable, the battery backup size are key factors that determine the cost of an installation. In addition, feasibility of a system design hinges on the roof or ground space available, its accessibility, shade from the natural or built environment, expected weather events, and the appropriate space to store system components and spares. A preinstallation site survey assesses these design considerations. Most of the health facilities confirmed that such an assessment was done at their facilities; however, a few staff who were interviewed at the health facilities mentioned that they were not involved in the final decision-making on placement of solar panels or housing of inverters and batteries inside the health facility. The actual operation of the system may be affected by the electrical loads to which the system will be connected, existing electricity supply options, and adverse weather events.

This demand assessment needs to be done in coordination with the beneficiaries so that it is clear to them what the objective of the DRE system implementation is. Health facility staff were at times unclear about the objective of installing DRE systems: whether it was to provide a primary source of electricity supply or to act as a form of backup to existing electricity supply sources (grid). There was lack of understanding on whether the energy system caters to a particular medical service or to a particular block of the building and whether integration of future medical loads and services was considered.

Some interventions had clearly defined objectives. For example, CREDA implementation had the objective of strengthening the cold chain infrastructure in the state. Therefore, all the public health facilities being solarized by CREDA at the minimum covered lights, fans, and medical cold chain equipment. CREDA has also procured solar direct drive vaccine refrigerators and deep freezers that are powered with dedicated solar PV modules and are operational without battery backup. The public health facility interventions in Meghalaya had access to a printed document that stated the load assessment details and what equipment was connected to solar.

Most of these load prioritization approaches were led by the technology provider. In these projects, a standard size of energy system was provided to all health facilities of a particular tier. This was particularly common for projects being developed at scale where multiple health facilities had to be solarized. It has been seen that while facilities of a particular tier of health care are mandated through the IPHS guidelines to have a set number of essential medical devices and population to be served, this varies significantly on multiple factors such as population demographics, disease prevalence, availability of specialized medical services and respective medical staff, access to electricity, and other matters. Thus, energy needs of the facilities vary across locations. Moreover, with the IPHS 2022 guidelines in place, the types of health facilities and their associated services have been further segregated. Further measures will need to be taken to ensure that the right solar PV system size is aligned to the appropriate type of health facility, rather than opting for a uniform size across the different segregated tiers.

The existing electricity supply solution also plays an important role in understanding what type of system configuration to adopt. While a majority of the interventions had some sort of grid electricity supply, coupled with uninterruptible power supply (UPS) battery backup or diesel generator sets, one health facility was completely off the grid. Because electricity is needed to run the most basic medical services, lack of access to electricity means that the facility remained nonfunctional with minimal patient footfall until the solar intervention.

RESCO project developers indicated that in many cases there was a lack of understanding of the role of on-grid solar PV systems while adopting those through government-led schemes. A lack of communication between the electricity departments and the health facilities results in poor awareness on the intended benefits of the on-grid systems. The primary function of on-grid solar systems is to reduce grid electricity bills. It does not have the capacity to be an alternate or backup source of power when the grid connection goes off. In the on-grid health facility surveyed, the primary backup source was a diesel generator. Therefore, the RESCO mode of solar PV installations has been prevalent in urban areas, especially higher tier hospitals such as district hospitals and medical college hospitals where the challenge being addressed is reduction of electricity bills in regions where power supply is reliable, with minimal outages. These installations are not feasible for rural and remote regions, where power supply quality and reliability are low; therefore, off-grid DRE systems with properly sized battery backup were the most common mode of electrification that was observed, with limited examples of on-grid solarization in rural areas.

Among the loads to be connected to the energy system, technology providers generally prioritize lighting, fans, and computers as first to be solarized while high power-consuming loads such as geysers and autoclaves are generally always kept off the DRE system, especially for off-grid DRE systems of limited size. In these cases, these loads remain connected to the grid (if available) and are provided power backup through diesel generators. This is due to the appliances' need for high starting current, which can deplete the batteries at a faster rate and impact the longevity of the energy system. Therefore, while solar energy can allow health facilities to go permanently off the grid (i.e., be independent of grid electricity), the option is not always chosen as it is far costlier from a capital and operational investment perspective, especially when a three-phase power supply is needed to meet the energy needs of high power-consuming appliances. And so several loads continue to rely on the grid even after decentralized energy installation.

Nevertheless, medical devices are frequently connected to solar PV, with many health facilities running on single-phase solar power systems. The commonly connected medical loads include cold chain equipment (deep freezers, ice-lined refrigerators, etc.), maternal and child care (suction cups and baby warmers), laboratory equipment, lighting for critical procedures like operating theater lights and spotlights, dental equipment, and other procedures.

WASH facilities, especially electric water pumps, tend to get included or excluded on a case-by-case basis, depending on the system size and the relative size of the pumps. If pumps are a relatively high proportion of the total energy demand, then other loads have been prioritized, given the various equipment that can be powered. Moreover, if the grid is fairly reliable with a short duration of power cuts, then the health facilities choose to run their pumps at times when power is available.

Some sites in Chhattisgarh had a dual pump installed on site. This dual pump was installed by a separate scheme to the health care electrification scheme by CREDA at the site. Dual pumps can be operated via a solar PV system, whenever power is available, whereby water is pumped and stored in an overhead tank. When energy is not available, water can still be accessed through a hand pump. This installation benefits not only the health facility but also the nearby village population.

Apart from the one un-electrified health facility, the boat clinics in Assam have no grid connectivity and were reliant on fuel-based generators previously. Two of the health facilities reported elimination of a diesel generator once the solar PV system came, after which their diesel fuel consumption was reduced to zero. However, in other places, primarily larger health facilities, the role of diesel generators was still seen as critical in the overall electricity infrastructure of hospitals, to provide for power backup to critical medical devices that were not connected to the DRE solar system, either due to their high-power consumption or not being prioritized for DRE connection by the system integrator. One health facility had even reported procurement of a new diesel generator, while two other facilities did not report any reduction in diesel fuel consumption after the implementation of DRE. This was because the solar PV system allowed some loads to shift toward cleaner sources of power, thus allowing facilities to integrate newer medical services or enhancement existing medical services.

An NCDC survey (2023a) across 18 states also provided similar observations wherein health facilities are not deploying solar PV system as a source for power backup to critical services and continue to rely on diesel generation during power outages. Therefore, while solar played a critical role in enhancing reliable access to electricity, its role was seen as complementary to the existing source of power supply rather than as displacing one.

Focus on energy efficiency

Due to design feasibility constraints, DRE electrification initiatives have usually focused on the supply side in terms of designing the energy system, rather than on the demand side in terms of what medical equipment the energy system will power. While a larger focus has gone into implementing solar PV systems, measures to incorporate energy-efficiency measures in health facilities have lagged. Initiatives in most health facilities on greening have been limited to replacement of lights and fans. There is a lack of appropriately designed medical equipment. Medical equipment manufactured, often in developed countries, is unfit for target markets, as it is not compatible with an unreliable grid, harsher operating environments, and voltage fluctuations that lead to equipment damage and failure (CLASP 2021). Mapping of health facility equipment in India across 29 states revealed that at any point in time, 13 to 24 percent of the medical equipment was found to be dysfunctional in public health facilities, resulting in wastage of expensive, imported medical equipment that was discarded after a period of time (MoHFW 2019).

A low hanging fruit for energy-efficiency gains is the replacement of lighting fixtures in health facilities with light-emitting diode (LED) lights, along with replacement of inefficient fans with brushless direct current (BLDC) fans. The LED lights consume just a third of the energy in comparison to fluorescent lights and over seven times less than incandescent bulbs (NCDC 2023b). The vaccination cold chain has also gained prominence during the COVID-19 pandemic, as several countries suffered from lack of adequate cold chain infrastructure to store vaccines. In these cases, energy-efficient cold chain infrastructure is important to address the last-mile challenges of vaccine delivery, especially in regions where grid electricity is unreliable or unavailable. Research by CLASP and the Clinton Health Access Initiative found that a highly energy-efficient vaccine refrigerator consumes 90 percent less power than an inefficient one, and a switch to super-efficient refrigeration could help power multiple other medical devices, such as 10 LED lights and four pedestal fans, a fetal heart monitor, a sterilizer, phone charging and other devices (Abagi 2019). As a single-purpose solarization, adoption of solar direct-drive refrigerators in rural health facilities has also been considered in India. In these refrigeration systems, solar energy is used to freeze water or similar phase-change material, which is used as the cooling medium for storing vaccines. These solar-driven refrigerators function without the need for batteries or inverters (Singh 2022).

A comparative study of existing medical equipment and its energy-efficient alternatives showed how energy savings of 55 percent can be realized by switching to efficient 5-star refrigerators and blood banks. Similarly, energy-efficiency gains of 40 to 93 percent were visible in other selective medical appliances in the health facilities (SELCO Foundation 2021). Although laboratory, maternal and child care, cooling, and lighting appliances have seen significant improvements in efficiency gains, further research is needed to ensure that other critical medical services can also incorporate energy efficiency in their medical devices. These include radiology, sterilization, dentistry, and space-heating appliances.

Technology advancements in many medical appliances has ensured that the medical equipment manufactured is also able to run on single-phase electricity. This becomes particularly important in rural and remote parts of the country where single-phase electricity grid connection is most common. Continued research and innovation in medical appliances is crucial as we observed that most of the high power-consuming equipment has not been connected to the solar PV system, especially in off-grid DRE systems with battery storage. Connecting such equipment would need much larger investment in DRE system capacity, thus making the system less cost effective in providing reliable backup to high-power critical services. Therefore, health facilities continue to rely on diesel generators for power backup to large medical equipment such as sterilizers, X-rays, geysers, and autoclaves.

Most of the health facilities had incorporated DRE systems without actively changing medical equipment prior to implementation. Therefore, systems are designed to cater to the present load, rather than first making the health facilities more energy efficient, and then implementing a system. Part of this challenge comes down to financing commitments as well, where donors' or projects' end goals focus on installing a DRE system of certain kW capacity, and that is considered as project output. Moreover, public health facilities can only put in requests to procure medical equipment, but the availability and selection of energy-efficient versions is not in their hands.

As any change in equipment adds further to the costs of not-for-profit hospitals, the approach has been more measured. While installing energy systems, one of the health facilities in Jharkhand was able to replace all its indoor lights and streetlights with LEDs as well as procure five BLDC fans through its own budget. Although staff are pleased with their efficiency gains, they suggested how fans could be made more user friendly as they felt more comfortable in using the regulator-style fans rather than using remotes for regulating fan speed. While they expressed interest and inquired about switching to a baby warmer that was 60 percent more efficient than their existing equipment, they found the cost difference to be too high. So achieving cost parity with inefficient alternatives remains important to replicating energy-efficient medical equipment across health facilities, especially those that are under-resourced.

The SELCO Foundation has been integrating energy efficiency within its projects especially in the program design phase, where the overall technology procurement considers supply, installation, commissioning, and maintenance of the off-grid energy system, as well as energy-efficient medical equipment and fans LED tube lights, and bulbs. Initially, the foundation partnered with the Health Department, Meghalaya, to power 100 subcenters in the state. A program was launched to look at upgrading the health facilities with energy-efficient equipment and solar energy for basic loads, immunization, labor rooms, and staff residential quarters. While medical services at subcenters are generally limited to immunization and delivery services, the State Health Mission decided to further decentralize medical services, keeping in mind the terrain and distances of facilities in Meghalaya. The state government also provided 60 percent of financing toward the program. Along with powering the health facilities through solar PV, many of the health facilities were also provided with energy-efficient equipment like baby warmers, spotlights, suction apparatus, and vaccine refrigerators.

In addition, the SELCO Foundation also partnered with public health stakeholders in Meghalaya, Manipur, and Nagaland to design DRE for health programs that included procurement of energy-efficient medical equipment among other holistic support, such as ensuring asset registry, training, system utilization, and O&M. The energy-efficient medical equipment procurement encompassed services such as labor room, immunization, laboratory, and outpatient departments, and included medical equipment like radiant warmers; suction apparatus; examination lights; ECG machines; nebulizers; autoclaves; automated external defibrillators; blood cell counter machines; portable ultrasounds and vaccine carriers; and laboratory equipment such as centrifuges, microscopes, hematology analyzers, biochemistry analyzers, and multipara monitors (SELCO Foundation 2022).

When it comes to energy efficiency, the SELCO Foundation has also looked beyond medical equipment to also incorporate built environment principles into how health facilities are newly built or renovated. This includes reducing energy consumption while also improving thermal comfort in health facilities through a number of measures, such as efficient spatial design, appropriate materials and insulation, and design of fenestrations. As part of the Meghalaya government's health systems strengthening program, the SELCO Foundation is partnering with them toward incorporating climate-resilient infrastructure and sustainable building design, apart from integrating solar energy and energy-efficient appliances.

With these efforts, about 40 percent of public health facilities in the State of Meghalaya have been sustainably upgraded by incorporating energy efficient equipment, solar energy, and in some cases passive built environment methodologies for energy efficiency. As already mentioned, the SELCO Foundation is also working at the state and national level to complete similar upgrades for 25,000 health facilities by 2026. By aiming at 10 percent of the total health facilities incorporating these measures, the foundation aims to prove at scale how sustainable energy and energy efficiency can be used to improve, operate, and maintain health facilities.

Medical staff shared how greening of health facilities is mainly practiced through replacement of lights as well as refrigerators and air conditioners with a star rating. The rating system introduced by the Bureau of Energy Efficiency has helped facilities understand which equipment is more efficient. One staff member suggested that there is a need to replicate a similar star rating system to medical devices across various services. This will also help them to choose the most efficient equipment that they can procure, as presently there is no metric to evaluate the same. Presently, only guidelines for energy-efficient medical cold chain equipment exist, through the WHO Performance, Quality and Safety (PQS) specifications of all immunization-related products that have been prequalified for procurement across multiple countries, including India (WHO Department of Immunization, Vaccines and Biologicals 2021).

At one health facility in Odisha, a set of three solar air conditioners were piloted in a patient ward. These air conditioners ran on the facility's independent off-the-grid solar PV system with battery backup and were not part of the larger DRE system installed. There was no form of grid power input to supplement the solar PV or batteries to power these air conditioners. The system was not cooling the rooms as expected, and patients reported discomfort due to poor levels of cooling, despite the air conditioners running round the clock. One reason for the lower levels of cooling could be the lower level of insulation in the room, but in comparison to the size of the air conditioners, the room was warmer than it could be. Staff felt the solar air-conditioning innovation was untested in real world circumstances and therefore has the potential to affect the quality of service in the health facility.

Remote monitoring system

Monitoring of DRE systems can be conducted in multiple ways. These can be through physical regular monitoring of system performance or remote monitoring to allow multiple stakeholders to monitor performance remotely, as well as detect failures and initiate timely corrective maintenance of the system. The remote monitoring system (RMS) is an added cost to the decentralized solar energy system, and the decision to incorporate the RMS primarily lies with the implementing organization, funding agency, or technology provider. Live data from the RMS provide visibility to implementing organizations, technology providers, and health facility management on the energy system performance, as well as helping track utilization of the system. Many RMS devices also provide additional features, such as live alerts to the end user on detecting any faults in the energy system function and customized reports and insights based on historical energy generation and consumption patterns.

Of the sites visited, only 5 out of 22 facilities had RMS systems installed, while another 4 more facilities had analog energy meters installed on site. Out of the five RMS systems installed in two states, three RMS systems continued to function (two off-grid solar systems and one grid-connected system), while two of them were out of service, as they were not reporting any data. On seeking clarifications from the technology providers, it was found that the systems did not work for multiple reasons: The RMS system was 4G connectivity-based in regions that were remote and did not have that level of network connectivity; the RMS hardware in some instances was only compatible with a single Internet network provider, which made it tough to standardize the RMS reporting across multiple health facilities spread across the state. RMS systems do not have the same level of standardization in off-grid systems as is seen in on-grid systems or in solar water pumps. In pumps, the RMS integrates more seamlessly with the pump controllers, than in solar off-grid inverters. Studies done in other regions showed similar results. Monitoring of 20 health facilities in Benin under a Solar4Clinics project revealed that, while data transmission was reliable in all grid-connected facilities, only 50 percent of the off-grid energy systems were able to do so, primarily due to poor network availability for data transmission (Herzog et al. 2023).

It is also a challenge to track energy consumption through the inverter back end as currently data recorded by the inverters is mainly on energy generation and what is fed to the batteries. What percentage of power makes it to the end-user loads, and thereby the electricity and fuel bill savings it provides, and associated reduced or avoided carbon emissions reductions, cannot be accurately tracked without a reliable RMS system.

With the challenges associated with the RMS hardware and network connectivity, CREDA-powered health facilities in Chhattisgarh have instead utilized two analog or electronic energy meters as part of their alternating current distribution boxes (ACDBs). These meters record power output from the power conditioning unit (PCU) inverter (the energy consumption or energy fed to the loads), mains output from the grid to batteries (energy consumed to charge the batteries from grid whenever battery is not adequately charged via solar due to inadequate solar energy generation). These meters are in addition to an energy meter on the direct current distribution box (DCDB) front to record the energy generated by solar PV system that is fed to the inverter. Although tracking of these meters is manually done by staff or CREDA technicians, the accuracy of data collection there and the trends noted can show whether the system is performing adequately or not. This model of performance monitoring has not been replicated in any of the other states both for public as well as not-for-profit health facilities as designated implementing agencies do not have the manpower to physically monitor the systems, thereby leaving this activity to be executed by the health facility. Regular manual logging of energy data is also a cumbersome task for health facilities to undertake, given their other responsibilities.

In the RESCO model, renewable energy enterprises (integrators) are mandated to have an RMS at all sites. Every plant is monitored, and data are collected on a daily basis. Although realizing the challenges of network connectivity at multiple places, many RMS manufacturers now design their products to provide 2G and 3G network coverage and also compatibility with multiple telecom network providers.

Tracking the RMS of some of the sites, we have also seen that the level of utilization of the DRE solar energy system has been very low at some sites. This could be due to the number and type of equipment (loads) connected to the energy system. Such an indication does help health facilities to plan for other loads to be integrated into the DRE energy system, thereby enhancing system utilization in the long run.

With most installations, the RMS does not seem to be a priority yet. Beneficiaries in facilities that do not have an RMS system have stated that they were unaware of such a tool that can provide information on system performance. Currently, they have no means of measuring and tracking the DRE system's performance on reducing their energy consumption from other sources. More critically, the only way to know that there is an issue with the system is to see if the inverter display is still flashing readings and that the devices are being powered through battery storage when grid electricity is not available. A challenge to foresee or detect minor faults can eventually lead to larger system failures and breakdowns.

This has implications with health facilities not being able to track the performance of their energy generation and battery-storage related parameters. Being able to track energy consumption and peak load can also support incorporating more appliances and medical devices into the energy system while ensuring that the system does not end up being over-utilized or breaks down.

POLICY

Existing electricity supply situation

As mentioned previously in the literature, the IPHS 2012 guidelines had already integrated electricity priorities within the guidelines to ensure uninterrupted power supply across public health facility tiers (Ginoya, Narayan, et al. 2021). The updated IPHS guidelines in 2022 went a step further to warrant how public health facilities should have access to adequate, affordable, continuous, and reliable electricity supply with alternate options such as solar to be considered in places where reliable grid electricity is not feasible (Ministry of Health and Family Welfare 2022b).

Two of the public health facilities surveyed in Northeast India, one PHC and one HWC subcenter, respectively, were un-electrified prior to the solar intervention. The PHC faced a challenge of adding new medical equipment due to the lack of electricity. In both cases, solar PV intervention came about through a combination of public and not-for-profit financing support toward the capital cost. In fact, the role of development sector and state government partnerships has been prevalent in realizing the electrification-related mandates under the IPHS guidelines.

Reviewing the electricity bills of many health facilities also provided some insights. While health is considered a public good, most of the health facilities have electricity connections where tariffs are to be paid at commercial rates. Two of the not-for-profit health facilities interviewed in Jharkhand and Assam, respectively, had a high-tension commercial power supply. This means that the fixed charges to be paid, as well as the tariffs charged, are equivalent to charges for an industrial or commercial category of electricity consumer. Respondents from the health facilities in these two states believed that these charges should be lowered, and a separate category for social institutions (including schools, community buildings, panchayats, etc.) needs to be provided. Moreover, while reviewing electricity bills, there was usually a mismatch between contracted demand and the actual demand of a health facility. In one hospital in Assam, the average daily actual demand was less than 25 percent of the contracted demand on site in kVA. This meant that health facilities were paying very high fixed charges for power that they were not consuming, leading to a heavy cost burden on electricity bills.

Procurement of electrification solutions and vendor selection

Ensuring timely completion of DRE projects depends on how tenders are structured and on renewable energy enterprise selection. Health facilities may not be aware of what is the right system configuration (on-grid or off-grid), system requirement and design, whether battery storage is needed or not, or who is the right renewable energy enterprise. Many installations in the not-for-profit hospitals are usually donor-driven, where funds are allocated toward a health electrification and are either executed by the health facilities or with the support of development partners.

Similar to many procurement tenders for DRE intervention (even beyond the health sector), technology providers stated that it is usually the least-cost bidder (L1) who is awarded the contract. Claims of system integrators with poor experience are common. There are bidders who provide bids even lower than the benchmark cost just to become L1 and win a contract. In this case, good quality renewable energy enterprises end up being left out of the system, and a lot of work is being given to developers who deliver substandard work in many electrification projects. Most of these developers struggle to follow the ambitious timelines that they state in their offers, and there have been cases where projects have been delayed for over a year. Even though there are penalty clauses present in the tenders, these don't get enforced. Projects also tend to suffer in places where the majority of the capital cost is paid up front to the vendor, and then the procuring entity is left with no leverage to enforce timeline or quality.

Good practices have been observed in tender creation that provide for a structured payment mechanism. A review of tenders that the SELCO Foundation supported for drafting procurement of energy systems in public health facilities in multiple states showed that, to ensure timeliness of delivery and implementation, payments to successful bidders were divided into three or more tranches: the first installment paid in advance along with the work order, the second installment against delivery of materials to 50 percent of the health facilities, and the third installment after commissioning of systems at all facilities with handover letters and certification of satisfactory working conditions issued by the health facility and designated representatives.

The Catholic Health Association of India had adopted similar practices in its health facility electrification projects with multiple tranches and a condition that the final tranche of payment be made two to three months after commissioning and handover of the systems, after taking feedback from all health institutions on satisfactory working of the DRE system. If any defects were realized in this time period, vendors had to rectify those prior to receiving final payment.

CREDA has a more rigorous, yet effective, practice of payment terms, which are difficult to establish if projects are not of significant scale. The terms of payment provide 95 percent of the fund only after commissioning of the DRE systems and submission of a joint commission certificate where the payment disbursement process will begin upon verification by CREDA staff (service units). This payment can be received in batches as and when the bidder completes a certain batch of installations. However, no payment is provided in advance. The remaining 5 percent payment is reserved for five years and provided at the end of the annual maintenance contracts (AMC) period. CREDA also mandates that a bidder should create or have an existing local service center with trained manpower and adequate spare parts availability within the district of implementation.

While it is a challenge for CSR or donor-driven projects to preserve funds for O&M, state agency-led public health electrification projects have requests for bank guarantees or security deposits to be furnished by the bidders (technology providers)—amounting to 5–10 percent of the overall project cost—which are reserved for servicing and maintenance of the DRE system throughout the AMC period of five years.

For procurement of DRE systems, implementing organizations generally have used the MNRE benchmark costs for off-grid and decentralized solar PV systems as reference. These benchmarks are updated annually based on prevailing conditions and are inclusive of system costs, installation and commissioning, transportation, warranties, and maintenance for five years (MNRE 2021). While the intended purpose of the benchmark costs is mainly for the purpose of estimating the proportion of central financial assistance for intended government schemes, using the benchmark costs as a marker for small-scale DRE projects has not been found to be practical. Technology providers have highlighted how it is only possible to match the benchmark costs when projects are executed at a significant scale in an aggregated procurement model. And even then, overall costs vary significantly based on the location of installation, which affects the costs of procurement, transportation, and maintenance of these DRE systems. Moreover, if the technology providers are out of state, that further adds to their costs of setting up local service teams in the region.

In addition to costing and technology selection, there is a need for minimum standards to be in place for bidders (technology providers) to meet. Some of the relevant standards observed include minimum experience criteria in the field of DRE implementation, experience working with health facility electrification projects, presence of local service centers (in the state or district), audited financial statements, mandating preinstallation site survey reports, and preventing the handover of installation and commissioning work to subcontractors or unskilled laborers, who may not be formally trained on maintaining quality and standards desired by the DRE-based health electrification project. This eligibility criteria provide a starting point to eliminate any technology service providers who may not be able to fulfill the project's long-term needs.

Insurance

Currently insurance in DRE systems for health facilities is limited until the equipment is supplied to the health facility and until material is handed over to the facility. However, no sites surveyed reported having any insurance coverage solely for their DRE system. Many of the health facilities interviewed faced reported climate-related impacts in their region such as high wind, thunderstorms, cyclones, heavy monsoons, and floods. With floods and thunderstorms being a recurring challenge for many health facilities in Northeast India, one of the health facilities faced nearly two days of blackouts during thunderstorms when the transformer got damaged. This prompted the health facility to install a dedicated 10 kW solar PV system for the blood bank last year. Being the only health facility in a 70 km radius providing blood transfusion services (with the nearest blood collection center also being 3 km away), the health facility saw significant footfall for the service. The hospital has not reported any blackouts following implementation of the solar PV system, with minor issues resolved within 12 hours. In areas prone to climate impacts, customized module mounting structures are needed that can withstand high wind of 200 to 250 km per hour.

The energy system protection is limited to individual equipment warranties and AMCs agreed upon with the renewable energy enterprises. Insurance is critical for DRE installations, especially in locations where the systems are exposed to the risks of lightning, fire, and other allied perils, as well as burglary. However, the scope of insurance (beyond installation and commission of solar PV systems) is limited to mainly the solar PV panels or for stand-alone solar pumps. For health electrification projects, technology providers arrange insurance limited to transportation of the components until they are delivered at the facility. Theft of the DRE system was not observed at any of the sites studied; however, staff mentioned that they prefer to have their systems installed at the rooftop as opposed to ground-mounted systems, due to the apparent risk of theft and vandalism. The health facility staff at two locations mentioned that the solar streetlights installed around the premises were now not in operation as the batteries had been stolen. To secure the system, commonly observed practices included the use of anti-theft nuts and bolts to safely secure the PV panels on the module mounting structure. Additionally, the inverters and batteries at most sites were placed in rooms that were locked, secured, and inaccessible to outsiders.

CAPACITY

Operations and maintenance

While selecting the right renewable energy enterprise is essential to delivering a good installation, a similar focus should be given to a renewable energy enterprise's ability to maintain the system over the lifetime of the project. System sustainability is essential to building a health facility's confidence in the reliability of service that a decentralized solar energy system is meant to provide.

This is usually done through maintenance contracts in the form of AMCs or comprehensive maintenance contracts that are agreed upon with renewable energy enterprises at the start of the project when the contract is signed between the user (or donor) and the renewable energy enterprise.

The O&M of the plant can be comprehensive to include wear and tear, overhauling, system breakdown, and replacement of defective modules, inverters, PCUs, batteries, consumables, and other parts for a defined time period. Depending on the scope of the contract and its cost implications, the duration of the maintenance contract usually varies anywhere between one and five years. These contracts also include carrying out routine and preventive maintenance and, if necessary, replacement of any system components at a defined interval (quarterly or biannually or annually) to ensure hassle-free operation of the DRE system. The MNRE issued benchmark costs for off-grid and decentralized solar PV systems and also lists out the total cost of the system to be inclusive of warranties, insurance, monitoring, and maintenance for five years (MNRE 2021).

While surveying health facilities that have DRE systems installed for over one year, we have observed that renewable energy enterprises primarily visit the sites when called upon, rather than undertaking a scheduled visit at agreed-upon time intervals. Many times, these visits have been delayed and have not occurred when needed. In cases where the procurement of energy systems is done at the headquarter, regional, or state level, it was found that health facility staff were unaware of the fact that these routine visits were even part of the procurement contracts. They assumed that the scope of the renewable energy enterprise's work was limited to providing corrective maintenance when called upon by the health facility. Some users were also not aware of what the contract's scope was and who was responsible for covering costs of replacement of any system parts if damaged. An NCDC survey (2023a) of 341 public and private health facilities also indicated how nonrenewal of AMCs is common in public health facilities, in part due to ineffective maintenance of solar PV systems.

Simple awareness-building initiatives observed in solarized health facilities across Meghalaya included descriptive posters in the inverter and battery room. These contain information on best practices to maintain inverters, batteries, and solar panels, as well as contact information of technology providers and implementing agencies for troubleshooting. In addition, solar energy system-complaint registration was included as part of a customer relationship management system that is managed by the NHM. This allowed for complaints outside of routine maintenance to be registered with the technology provider through this platform.

A main challenge in the enforcement of routine visits is the way payment structures are designed. Given that most of the off-grid energy systems in health facilities are donor or CSR-funded, the challenges of grant-funded projects are becoming more evident in the long-term sustainability of the DRE system. The up-front financing of the entire project cost, which includes the costs for maintenance contracts, is paid in advance to renewable energy enterprises with the entire cost paid to the renewable energy enterprise in the first three months of the installation. This is with the assumption that the renewable energy enterprises will honor their contracts of providing routine, preventive, and corrective maintenance for the stated time frame and at defined regular intervals. However, by doing so, there is barely any incentive for the renewable energy enterprise to focus on the existing projects for which they have already been paid.

Another challenge is the time taken for troubleshooting. Most projects at the tendering phase ask the renewable energy enterprises to provide a response time in case of any breakdown or maintenance. The response for this has generally ranged from 24 to 72 hours. However, the response time has been difficult to maintain. We have noted response times for troubleshooting to be far higher than the duration stated. Multiple factors influence this: If the health facility is remote, time taken to travel to the site is generally higher if the renewable energy enterprise does not already have an office in the state or district of intervention. Other factors include nonresponsiveness or delays in initial response from the vendor's side, the health facility staff's lack of knowledge of the focal point of contact for troubleshooting, delays due to multiple layers of contact to reach the renewable energy enterprise, lack of availability of spare parts, and procurement delays. In many cases of troubleshooting for investers and batteries, the energy enterprise deputes the problem rectification's responsibility to the original equipment manufacturer, which was never required to troubleshoot within the stipulated time in the contract. Here once again, it is difficult to penalize renewable energy enterprises for any delays in troubleshooting as the entire budget for the system installation, commissioning, and maintenance has been paid up front. Therefore, a lack of enforcing mechanism creates a hurdle in ensuring long-term sustainability in an equipment-ownership model.

This equipment-ownership model inevitably prioritizes disbursement of financing where funder priorities are aligned to financing capital for the next DRE project (once a particular intervention is complete), rather than ensuring long-term sustainability of the existing project. As such, none of the projects surveyed has seen a refinancing of the existing system for replacement of older and defunct equipment such as batteries, inverters, and other components. In cases where O&M costs have been provided annually as well, these costs form a small percentage of the overall project cost, whereby renewable energy enterprises would be willing to forgo that cost, depending on the site's accessibility and transportation costs.

To overcome the equipment-ownership structure, SEforALL and ESMAP recommended an innovative service-based model where the technology provider works as a RESCO and raises its own up-front capital to install a system, and the government (in our case, the state health department) pays the technology provider for its energy service on a regular basis (SEforALL and ESMAP 2021). However, our observations from the interviews indicate that, although this could work effectively for grid-connected systems, there are still shortcomings that need to be addressed to promote this for off-grid solar energy systems in rural India. The shortcomings are primarily on three fronts: the maturity of remote monitoring systems in off-grid projects to provide results-based financing; the ability of technology providers to raise grant-based financing, as philanthropy and CSR would prefer financing NGOs than private enterprises; and the ability to obtain buy-in from the health department for regular budgetary allocations toward this service model.

BOX 1 | Innovative O&M model: government department-led service units

CREDA has been at the forefront of department-led public health facility solarization in the country. The state has solarized over 1,400 health facilities as of March 2023 (CREDA 2023). With around 570 PHCs solarized between 2012 and 2016 (Ramji et al. 2017), a majority of these installations are over five years old, which is the general AMC period for most DRE projects, and are still in operation. This is because the responsibility for the continued operation and sustainability of these DRE systems rests with CREDA. To execute this task, CREDA has established 18 service units all across the state, which have generated over 250 employment opportunities. Each unit has service technicians on the payrolls of the district who are responsible for managing the O&M of a cluster of solar projects. These clusters not only include solarized health facilities of all sizes (from 300 Wp anganwadis11 to 15 kWp CHCs), but also solar-powered drinking water units, irrigation pumps, cold storage facilities, and others.

The cluster service technician is mandated to visit every site under his individual cluster at least once a month to check the functioning of solar panels, batteries, and inverters and report back in a specified plant maintenance format to the block project officer. This format also includes collecting data on individual solar array voltage and current, battery voltages, and AC distribution box indicators; checking for any loose connections; and reporting any system downtime during the month. The technician also has to obtain a signature from the hospital administrator on the maintenance report to confirm his presence and the work done on site every month.

The roster or schedule of visits for the service units is prepared by the block officer with flexibility to attend to major breakdowns, if any. For some installations which are larger in size, the technician may visit the health facility twice a month.

In addition to M&E data reporting, the technician also takes up responsibility for routine cleaning of solar panels; topping up of lead acid batteries, if required, with distilled water; checking individual battery terminals for corrosive deposits; and applying lubrication if needed. The service unit is also responsible for verifying completion of new DRE projects that are happening in various domains within its cluster.

Establishment of service units has not only helped create new employment opportunities and capacity for renewable energy within the state but has also ensured that the burden of O&M and troubleshooting does not fall on the health facility staff. The service units act as a bridge between the health facility and the renewable energy enterprises. If any system component breakdown takes place within the warranty period, service units coordinate with the renewable energy enterprises to get the parts replaced free of cost. These service units have helped ensure that DRE systems can function well throughout the lifetime of the system.

Source: WRI India authors.

As battery maintenance and upkeep has been the challenge, off-grid systems have faced a greater challenge than on-grid systems that have fewer parts needing replacement or maintenance. Therefore, in regions where grid connectivity is reliable, health facilities that have experience with an off-grid solar energy system are inquiring about grid-connected alternatives for a section of their loads.

Staff availability and living environment

The IPHS guidelines set out a uniform standard of benchmarks for the quality of infrastructure, manpower, and services to be provided by public health facilities at all tiers of health care. While the not-for-profit health care sector has its own way of defining levels of health care, these are closely associated with the IPHS guidelines in terms of level of care provided for populations at various locations.

It was observed that most public health facilities showed deviations in terms of provision of medical services and availability of medical equipment and medical staff, as compared to the norms established under the IPHS guidelines. While certain services were missing at most facilities, the biggest issue faced in multiple states was shortage of staff. The lack of medical specialists for dental care, newborn delivery, and radiology meant that medical equipment and services associated with these specialties were either not procured or, if present, lay unused. An absence of an anesthetist in health facilities meant that any surgeries to be done under anesthesia could not proceed, and therefore patients had to be referred to a nearby health facility.

Some health facilities in Chhattisgarh highlighted the lack of housekeeping staff for cleaning, sweeping, and other tasks, which made it challenging to maintain hospital cleanliness.

There are multiple reasons for lack of staff availability. While the willingness and interest of staff to work in rural and/or remote regions with poor facilities in the vicinity for education and entertainment for staff and their families is a common refrain, not-for-profit institutions highlighted difficulty in hiring doctors due to high salary expectations that could not be fulfilled.

Electricity was highlighted as important for creating a conducive environment for medical staff, especially to run into night hours. However, in what form electricity is provided was not relevant to them as long as the power source is reliable.

In terms of staff living environment, both government and non-for-profit health facilities have staff quarters of some capacity present on site. While a majority of the staff live outside the quarters, either because they are local staff or live in rented houses, some staff stay in these quarters. However, when it comes to evaluating the impact of reliable DRE on health facilities, a conducive environment for staff is limited to their working conditions and does not particularly extend to their living conditions on site. Staff quarters have been usually separated from the health facility buildings and have not been considered for solar integration in any of the installations reviewed.

Although medical staff wholeheartedly agree that there is a need for DRE integration in staff quarters, the nature of the establishment prevents health facilities from including this integration in their needs assessments in the first place. Maintaining the electricity infrastructure of staff quarters is considered to be the sole responsibility of the respective staff residing there. They are meant to pay their own electricity bills and any other utility bills, as well as arrange for any sort of power backup (mostly in the form of home UPS and batteries) at their own cost in the absence of reliable access to electricity. At a few sites, some senior medical staff also had their own mini diesel generator sets. Because of these factors, staff generally never requested that vendors include these quarters in their energy demand assessment. In one health and wellness center, the infrastructure was so poor that staff refused to stay at the quarters, and therefore the facility had disconnected the electricity. In another public health facility, staff quarters are not sufficient to support staff strength, leading to even senior medical staff having to live outside the facility.

A significant impact of DRE integration has been on solar boat clinics, where DRE has helped create a conducive environment for medical and nonmedical staff who live on boats during weeklong visits to island villages. During the regular medical camps, staff have to stay for about five to seven days at each island village where the staff live on the boats.

The Majuli boat clinic stated that prior to installation of solar energy on the boat in May 2017, the boat was reliant on a kerosene generator. Kerosene of 5–6 liters per day was needed to provide power for medical services, as well as to power lights and fans. Prior to the solar integration, when the facility had to rely on the kerosene generator, it could only operate the lights and fans for around four hours in the nighttime, 5:30–9:30 p.m., during which time they had to cook, charge their phones, and attend to any other needs. This was a huge challenge during the summertime when the staff had to sleep on the boats without any fans.

There is a separate diesel engine for running the boat, which consumes nearly 400 liters per month. The boat staff also used two gas cylinders per month for cooking.

Once the solar PV system was installed, the kerosene generator was decommissioned. Now a petrol generator is present as backup on the boat in case the solar PV with battery system is inoperative on certain days, especially during bad weather or monsoons. This petrol generator is connected only to the dental chair, lights, and fans. The staff keep a stock of 10 liters per month of petrol.

With the integration of the DRE solution, lighting and ventilation are now available 24/7. The biggest improvement from access to renewable electricity came in the improvement of staff living conditions. This mainly helped in mobile charging and being connected with the mainland through the Internet and social media channels like WhatsApp. Female staff on the boat particularly felt a sense of security in the night, as this allowed for safe movement around the vicinity of the docked boat.

Although the operating hours of service have remained the same (as the camp happens outdoors), it is now possible to handle emergency services better. While camp times are from 9 a.m. to 5 p.m., the boat also provides for emergency cases, such as hypertension or vomiting, at night. There have been times when the staff have also conducted normal deliveries on an urgent basis. During flood season, staff on boat clinics conducted six deliveries.

Getting the right medical staff for the boats is a challenge, given that it is not just a village environment setup and that they also must live on the boats from time to time. It has also been a challenge to get specialized medical staff, such as dentists and ophthalmologists, at the salaries provided. DRE interventions do help in enhancing staff retention. It is essential that they also be translated to traditional health facilities where staff quarters have an urgent need to be connected with electricity from decentralized solar energy.

FINANCE

Apart from CREDA interventions and the RESCO installation, most of the interventions reviewed were implemented primarily using grants to finance the capital expenditure. Grants were provided in various forms: CSR funds by corporations and international development finance provided either directly to the not-for-profit hospitals or to various NGOs to implement these solutions.

SELCO Foundation's work with public health facilities in states was a mixed mode of financing with different proportions of philanthropic financing and state government health department-led financing. The share of financing from state governments ranged from 0 to 80 percent coverage of capital expenditures for the DRE system. In Meghalaya, while the pilot installations were primarily grant-funded, the success of the installations led to scaling up the program through government-led financing where 70 percent of the capital costs was funded through state or local-level health funds for the upcoming solarization of public health facilities, while the implementing organization (SELCO Foundation) provided 30 percent of the capital cost that was supported through philanthropic funding (WHO et al. 2023). This 30 percent of financing requirement from implementing organizations was mainly to ensure ownership and accountability in executing the project in a timely manner. In addition, the government also provided resources to set up systems for training, staff allocation, and customer relationship management to ensure sustainable integration of DRE into their health systems.

DRE interventions in Chhattisgarh have been implemented in a partnership between CREDA and the State Health Department. Financing for the public health centers has been obtained from a number of sources: the Ministry of Health, the District Mineral Development Fund, the Transformation of Aspirational Districts Programme, and CSR funding (Ginoya, Narayan, et al. 2021). While the CREDA model includes AMCs signed with the vendors, this is further supplemented by the energy development agency's own service units. It will be important to monitor how the responsibilities taken up by the service units evolve in the long run as the scale of the renewable energy installations goes forward across multiple sectors such as health, livelihoods, education, and so on.

Financing Operation and Maintenance (O&M) costs

For public health facilities, as diesel fuel and electricity bills of these facilities are paid by the health department, the motivation to switch to solar is not as high as for not-for-profit health facilities looking to reduce their operating costs.

While cost savings from switching to small decentralized solar energy systems have been reported, it is in most cases insufficient to cover replacement costs of the solar energy system components. The contribution of savings to the overall replacement cost will be limited to a small proportion based on the size of the system, its utilization, and the prevailing electricity and diesel generator usage (United Nations Foundation and SEforALL 2019).

While institutions like Jan Arogya Samiti (JAS)/Rogi Kalyan Samiti (RKS) and Untied budget allocation funds can support identifying and addressing physical infrastructure gaps, the presence of such a limited budget to be utilized on an annual basis means that it is difficult for them to carry forward or collect funds to be expended on a particular year when the battery replacement is due. To overcome these funding constraints, installations led by CREDA have been able to gather recurring O&M funding from various sources such as state health departments and energy departments as well as district-specific funding entities like District Mineral Foundation.

Though with most other energy systems being 100 percent grant financed, the procurement contracts to technology providers include costs for Annual Maintenance Contracts usually varying from one to five years. However, the cost of ownership of the PV system, maintenance, and part replacement falls on the health facility, the relevant department or not-for-profit entity, or the implementing organization. Within health facility staff, there was a lack of clarity on who is ultimately responsible to pay if some major troubleshooting is required. For financing of DRE systems through philanthropy and CSR grants, there is a need to look beyond funding limited to the capital expenditure of installing plants.

Financing Capital Costs

It is evident that for health facilities in rural and remote areas where grid-connected power provision is limited, electrification using solar PV systems with battery storage is the most practical way forward. However, this means a significant upfront capital investment need to solarize at scale.

The NHM, which receives an annual budget allocation from the MoHFW, also provides for annual funds to states to implement electrification schemes and conduct activities under its programs. States can request funds for public health facility electrification with renewable energy sources through the program implementation plans submitted annually, although this will require states to conduct an assessment of public health facilities to prioritize and submit an estimated budget. Financing from multilateral banks or bilateral official development assistance (ODA) funding would also have similar requirements.

Implementing organizations state that there are several avenues of public funds that remain virtually untapped for health electrification projects—some of which organizations, like CREDA and SELCO Foundation, have been able to unlock. There needs to be a detailed program design while approaching government departments to unlock financing, as opposed to treating these projects as a single intervention. These pertain to identifying the energy needs of the health facilities, procurement processes, defining accountability among different actors throughout the system's lifetime, and showcasing the systemic impact of these electrification programs on health care service delivery.

While public financing and grants both play a role in financing solar-based electrification in public health facilities, not-for-profit health facilities are entirely reliant on grants through charitable donations, philanthropy, and CSR. Our interviews with funding agencies, especially those pertaining to allocating CSR funds toward the health-energy linkages, indicated that the majority of CSR financing was allocated to the health sector between 2020 and 2023, owing to COVID-19. This included vaccination, oxygen supply and related equipment, health infrastructure upgradation, and any COVID-19-related medical devices. Specifically, the government sanctioned nearly 1563 Pressure Swing Adsorption (PSA) oxygen plants. As these plants needed to be run continuously, hospitals were also provided with diesel generators to power these plants. However, some hospitals found it challenging to keep up with the costs associated due to diesel fuel procurement for continuous plant operation.

Two CSR interventions studied for this report received financing for solarizing six health facilities. In fact, one of the health facilities, received two tranches of CSR funding to install and then expand the size of their solar PV system, from 16.65 kWp in the first year, to a total of 36 kWp of system size. So, for smaller tranches of money, a modular approach to energy system implementation can also be followed.

Our findings indicate some challenges in accessing CSR funding. First, there is a lack of awareness among CSR entities on the benefits of implementing DRE systems in health care settings, partly due to the lack of availability of a proper framework for monitoring and measuring the impacts of a DRE system on health service delivery. The social return on investment is difficult to show due to these being capital expenditure (CAPEX)-heavy projects. Funders prefer easy to quantify projects in terms of direct beneficiaries served by their intervention. Therefore, only those corporations with interest and a mandate toward 'greening' or 'decarbonization' have shown willingness to contribute to such projects.

Secondly, while this source of funding for capital costs is quite prevalent in the health sector, the geographic distribution of their disbursement is uneven. Since most CSR funds are deployed in regions where the company operations are located, larger amounts of funds have been observed to be skewed toward industrialized states where larger companies operate—except for banks and IT sector funds that are prevalent across the country. States that require focused CSR grants toward health facility solarization—for instance states in the Northeast—do not have a larger proportion of CSR funds being directed toward them. In these regions, philanthropic financing for solarizing health facilities have been more prominent than CSR.

Moreover, the CSR fund availability is also heavily skewed, with five companies[9] in India accounting for 25 percent of the total CSR spending (CSRBOX and NGOBOX 2022). The annual CSR budgets for most Indian companies are not large enough to meet the funding requirements for DRE interventions at multiple sites. And organizations prefer to provide funding to the same set of recipients, as follow-on financing, which makes it more convenient for organizations to disburse funds and track. There is a lack of platforms that direct NGOs toward the right CSR organizations for such a project of this type, and vice versa.

RESCO model

Under the Renewable Energy Service Company ("RESCO") model, the health facility studied was solarized under Ministry of New and Renewable Energy (MNRE) sanctioned scheme of 14 MW Grid Connected Solar Rooftop Programme, which commenced in the year 2017-18 with Assam Energy Development Agency (AEDA) as the project implementing agency in the state of Assam. This included a 70 percent subsidy for residential, institutional (e.g., health facilities, schools, etc.) and social sector buildings (Assam Energy Development Agency n.d.). Under the scheme, only 80 percent of the contract demand can be interconnected with the grid. There are two modes under the scheme. One is the CAPEX mode, where the institution pays the balance of capital cost post-subsidy and thereby get electricity bill reduction by generating solar energy, or in RESCO mode, where the facility need not pay anything upfront and will instead be paying a fixed tariff (lower than the cost of power purchased from the grid) to the system developer (integrator) for solar power generated by the system for 25 years; that is, the life of the energy system. Under the RESCO mode, the tariff at the time was 3.43 INR/unit (1 unit = 1 kWh), which the health facility had to pay the project developer. The biggest benefit of the RESCO mode application is the lifetime O&M services that a facility gets from the technology provider (or system developer), as the tariffs earned by the latter are solely dependent on the system's performance.

With falling costs of solar PV panels, increasing developer experience, aggregation of demand and thereby economies of scale, Madhya Pradesh was able to find tariffs as low as INR 1.63/unit for state government medical colleges under the RESCO model in 2018. This tariff was supported by state and central subsidy; that is, 18 percent from the Madhya Pradesh government and 25 percent from MNRE. The unsubsidized tariff rate was INR 2.59/unit. Both tariffs come with a 3 percent annual escalation, but are far lower than the grid electricity tariffs in the region (*The Economic Times* 2018; Takyar 2021). It is important to note that the size of the installations at these sites was in the range of 200 kW to 1.4 MW, along with being primarily urban medical colleges. The same level of tariffs would be tougher to realize in rural areas with smaller health facilities and at the same time tougher to execute if the grid electricity quality and reliability were poor.


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CHAPTER 3

Achieving scale:
Considerations to implement decentralized solar energy solutions in health facilities

The sustainability of the decentralized solar energy system is essential to build confidence in its ability to be a resilient energy solution. This requires selection of the right technology service provider and proper accountability established to operate and maintain the energy system over its lifetime.

The decentralized solar energy solutions are meant to provide sustainable energy solution for the health facility in the long run. However, challenges in the sector persist in terms of technology, financing arrangements, ownership and responsibilities, operations, maintenance, etc., that need to be effectively managed to build energy solutions that are scalable. Based on the facility-level findings described in the last section, this section describes the key health-system level considerations to implement decentralized solar energy solutions in rural health facilities in India. We have distilled recommendations into the four themes of technology, policy, capacity, and finance, as used in the previous section. Many of the recommendations, though, are cross cutting and feature across multiple themes.

TECHNOLOGY

Energy demand assessment

The IPHS have now been revised to cover both urban and rural health facilities and widen the scope of comprehensive primary and secondary health care service delivery. Due to the wide variety of health facility configurations within a particular tier of health care and the essential and desirable standards for medical equipment, identifying distinct energy needs is crucial to appropriately sizing energy systems. The energy needs of a system will vary based on the type of facility, number of beds, medical services provided, population levels accessing the facility, patient footfall, disease prevalence etc.

All this combined with the existing electricity supply situation, reliability and quality of power, and available backups help define the DRE system size and the required hours of battery backup. The overall demand assessment should also consider aspirational loads; that is, addition of equipment considered desirable for a facility, essential equipment not available on site, and staff quarters if present within the health facility building. This will allow the health facility to appropriately size the system to account for future expansion of services in the facility. However, while taking into consideration the future energy needs of the facility, it will be important to consider the additional costs implications and the timeframe for the projected energy demand growth to provide sound advice to facility management. Investing upfront on a bigger energy system for an expansion planned in the longer term, will be costlier and will lead to an underutilized solar PV system. Given the modularity of decentralized solar energy solutions, designing a modular system that can be expanded with the growth of energy needs would be prudent depending on the timeframe for energy demand expansion.

A sample demand assessment for a PHC is shown in appendix B. It is relevant to create similar demand assessments for different tiers and configurations of health facilities, so that the system sizes can be adapted to a particular tier and state. Moreover, within each tier of health care, there is a need to provide health departments with energy system options based on the energy needs of the facility and the existing backup options. For example, a 'comprehensive' energy system that covers all the critical and emergency health services, lighting, and ventilation through the building as well as the staff quarters. A second option could be a 'critical' energy system, covering only emergency services (or rooms within the health facility), and select equipment such as vaccine cold chain, baby warmers, medical equipment within the operation theater, intensive care unit, and high dependency unit, along with lab services. While a third could be 'basic' or 'essential' services being covered, which have been the most common services connected to DRE systems such as lighting, fans, cold-chain etc. The number of options in each tier of health facility is left to the health department or network hospitals' administration to decide, but it can naturally increase with the size of the hospital and the respective number of services offered, patient footfall, and medical equipment.

Deciding energy system configuration

It is important to decide what configuration of DRE is the ideal power source for a specific health facility. System configuration and sizing can help optimize costs for operation and maintenance of the energy system in the long run. While regions of reliable power (with little to no outages) and low voltage fluctuations can primarily opt for on-grid systems, the same is not possible in regions with hours of power cut.

There is a misperception that a decentralized solar energy system that is on-grid will continue to power the loads during power outages. However, due to the way grid-connected systems are designed, without any batteries, any excess power that is produced is fed to the grid, through different metering arrangements (such as net metering or gross metering). When there are extreme voltage fluctuations or power cuts, the inverters shut off to prevent any feeding of power to the grid, and the solar energy produced is going nowhere. Therefore, the primary function of on-grid systems is for savings on electricity bills, and not as a form of backup power to be used during power cuts. In many of the cases where backup is required only for certain critical loads during outages, the best form of backup is a battery storage, where batteries are recharged through the electricity grid.

For regions facing power reliability issues, off-grid systems with battery storage are recommended, as these DRE systems can store excess power generated by the energy system in batteries to be used during night hours as well as during power cuts. The size of the battery can be altered based on the hours of autonomy that a health facility needs.

In regions with multiple energy supply options, decentralized solar energy is not meant to displace existing power sources, but instead to complement them to provide reliable energy supply for health service delivery. The health facility and implementing agency should be clear on the objectives of installing the energy system. This will ensure a proper needs assessment done, with the health facility staff being guided through the decision-making on system size and loads connected to the solar energy system, based on the outcomes of the energy needs assessment.

Incorporating resilience within health infrastructure

For new infrastructure, it is essential that planning for climate-related events is incorporated into the project design phase—both for the building envelope as well as the DRE system. This includes considering passive building design interventions related to lighting, ventilation, and thermal comfort through selection of right building material and insulation, window glazing, design of structural openings, proper orientation, and optimized spatial design (IRENA and SELCO Foundation 2022; NCDC 2023b). Similarly, while the DRE system builds resilience to climate events that cause disruptions to diesel fuel supply and the electricity grid, they are also not immune to climate change uncertainties and hazards. It is imperative that site-specific design considerations are incorporated to deal with various risks that can impact the DRE energy system, such as floods, droughts, and lightning (Ginoya, Meenawat, et al. 2021).

To ensure sustainability of DRE systems in the long run, it is important to focus on providing system components for which spare parts that are readily available and accessible. This prevents delays in troubleshooting and reduces system downtime in health facilities that run critical services 24/7.

Integrating Remote Monitoring Systems

Future solar energy projects in health facilities should mandate installation of remote monitoring systems (RMS). The integrated RMS should be able to share data via the cloud to a centralized database that plays the dual role of system performance monitoring and equipment troubleshooting. Since the need for DRE systems will be greater in regions that are rural and remote, challenges of connectivity need to be overcome, through RMS operability in 2G and 3G mode, along with ability to locally store performance data for a minimum period of one month, in case data transmission via the cloud is deemed unfeasible.

POLICY

Mandating guidelines and building equipment standards

The IPHS Guidelines form a strong set of standards to provide quality care to patients, with detailed guidance on various health system components, including promoting and incorporating the use of decentralized energy solutions in health facilities. While the IPHS guidelines provide the minimum essential services that are expected in a health facility of a particular size, there is a need for monitoring and addressing of the gaps in the availability of these services, primarily on medical staff, medical equipment, and the required electrification needs to run these equipment.

In 2022, the Ministry of New and Renewable Energy (MNRE) launched a framework to promote decentralized renewable energy livelihood applications, under which economical and energy-efficient applications for end-uses in the health sector are also considered as applicable. There is a need for standardization of medical equipment, where energy efficient medical devices are prioritized. On the other hand, medical equipment providers need to widen their base of service centers to be more accessible to the needs of remote and rural health facilities, with the minimum response time. Medical equipment manufacturers can also train local technicians in these regions to troubleshoot medical devices, if needed, and enhance coordination with the main headquarters.

Cooperation between the MNRE and the MoHFW could support in development of energy efficient medical devices, especially in services where significant improvements are yet to take place, such as radiology, dentistry, sterilization, heating, and ventilation. The updated IPHS guidelines emphasize that new electrical appliances should ideally have a minimum 3-star equivalent rating from the Bureau of Energy Efficiency or similar organization. However, such rating standards are limited to lights, fans, and HVAC equipment. Further standardization, like WHO's PQS process for prequalified immunization-related medical devices will significantly help health facility administration choose the right equipment. Similar energy rating programs need to extend beyond refrigeration and air conditioners, to encompass different heating and cooling loads that can create more awareness in procuring the right equipment.

Imparting scale in procurement of energy efficient medical equipment can bring down the costs. Here the role of the Healthcare Technology (HCT) division at National Health Systems Resource Centre under the MoHFW is critical, as the division has been recognized as a "WHO Collaborating Centre for Priority Medical Devices and Health Technology Policy." The HCT division can ensure that the technical specification of medical devices for public health facilities integrate energy efficient criteria in standardization of medical devices. This will assist health department public procurement committees in procuring energy efficient medical devices for public health facilities. Such standardization will not only help reduce the electricity costs that health departments have to cover for the health facilities but will also help develop more optimized DRE energy solutions for the health facilities, with more critical medical equipment connected. Furthermore, in switching over to energy efficient alternatives, the repurposing of the older generation of medical equipment need to be thoroughly planned as well.

Accountability to improve service delivery by ensuring reliable electrification of a health facility should rest with the health department rather than the health facility (Ginoya, Narayan, et al. 2021). To ensure uninterrupted power services, institutionalizing frameworks for interdepartmental coordination and cooperation, especially between the power and health department at the state level, are required to address reliability and affordability issues.

In addition to creating provision of decentralized solar energy solutions, state health departments should take up responsibility of establishing communication mechanisms with the electricity distribution companies to rectify issues of reliable access to electricity, given that IPHS guidelines have provisions for uninterrupted electricity supply to these facilities. In terms of budgeting for electricity consumption at health facilities, an understanding of electricity bills is essential for health facilities to know how much they are being charged for power consumed from the electricity grid. As some health facilities reported a very high electricity bill owing to a disproportionately high unused contracted demand (sanctioned load) at the facility, it is important to monitor the peak fluctuations and maximum demand of the facility over a certain period and review the contracted demand with respect to these factors. This evaluation will accurately determine and update the contracted demand with the respective distribution companies. By reviewing and adjusting the contracted demand in line with the facility's peak power consumption throughout the year, the health facility can effectively reduce its electricity bill expenditure. This activity should be carried out in coordination with the distribution companies, ensuring that a reasonable buffer of contracted demand is maintained to account for peak loads as well as future aspirational loads. Additionally, the incorporation of energy-efficient medical equipment could further contribute to reducing the actual demand on site, leading to greater energy savings.

Improving procurement processes

For selection of technology providers to execute this work, there is a need for procurement departments of both government and not-for-profit entities to select the right technology provider based on a QCBS, instead of the prevailing least cost (L1) bidder system. The Economic Survey 2020–21 states how the L1 procurement system is of use for procurement of routine works but not for high-impact and technologically complex procurements (Ministry of Finance 2021).

QCBS ensures that the work gets contracted to the most technologically compliant and economical solution, rather than the selection being based purely on cost. Given the technocentric nature of such DRE-based electrification projects, using technology-related parameters to finalize technology providers ensures that the system remains sustainable in the long run. Such a vendor selection process will ensure that the procurement committees consider the quality of equipment being provided, seamless integration with the existing electricity system, sustainability of individual components and the overall system, and the vendor's previous experience to execute projects at such a scale without the need to subcontract any portion of the work to inexperienced suppliers and system providers. Quality assurance frameworks to incorporate technical bidding specifications as part of procurement contracts have been developed globally for public facilities, such as the World Bank's Lighting Africa program (Harper et al. 2021). Similar frameworks need to be adopted in the Indian context to cater to the needs of the different ownership structures of health facilities, such as public or not-for-profit health facilities.

Request for proposals need to clearly define the responsibilities of the technology providers, what equipment and services are to be provided, and what is excluded. The tenders also need to be disseminated through relevant channels in order to reach a wider range of technology providers. This leaves no room for confusion as to what is required to be executed by the technology provider and what would be the facility's responsibility. When signing letters of acceptance of tenders, the technology providers need to adhere to all the provisions contained in the contract. Also, that same contract should be shared with health facility staff at the department level and with the implementing agencies. This will ensure that health facility staff are clearly aware of the scope of O&M work that the vendor has to undertake during routine visits, and what costs have to be borne by the different parties if a breakdown of any particular component happens.

It is essential for the insurance industry to expand its scope to build customized products that cover the entire decentralized energy system from solar panels to inverters and batteries. Policy coverage for the entire system should consider insuring against damages that occur due to climate-related risks such as cyclones, lightning, storms, floods, inundation, fires, and burglary.

Using data to scale

Although several studies state that globally there is a lack of data on access to electricity in health facilities (United Nations Foundation and SEforALL 2019; SEforALL and ESMAP 2021; WHO et al. 2023), there is a robust M&E digital system in India, the Health Management Information System (HMIS), wherein granular data were uploaded monthly by over 220,000 health facilities in the country in 2020–21 (MOHFW 2021). The data collection system includes data entry on physical infrastructure of the health facility, which encompasses the provision of the presence of electricity across the building, standby generator backup availability, the presence of an electrician, and the condition of the electric power supply; that is, whether the power supply is uninterrupted or there is no power supply and whether the power cuts are occasional, regular, or in summers only.

To cater to the effective planning, management and decision-making of infrastructure facilities in public health facilities, Rural Health Statistics is an annual report that provides state-level information, including the number of rural SCs and PHCs that are without electricity supply in each state. However, the publicly available information on electricity supply is limited to only two tiers of health care, SCs and PHCs, and does not provide information on those facilities that suffer from reliability issues or poor quality of power supply in these tiers or in other tiers, such as the CHCs or HWCs.

The facility-wide data on electricity challenges, as well as data on availability of medical equipment designated as essential or desirable under IPHS guidelines, provided with geolocation data can provide great support in geospatially mapping health facilities, prioritizing energy-deficient facilities for solarization, and identifying the energy gaps as well as the investment needed to improve electricity infrastructure in the states. Geospatial planning tools, such as WRI India's Energy Access Explorer (EAE) tool have been piloted with geospatial data from the health sector in the states of Jharkhand and Assam, as well as going granular to the district level in the case of Dhubri district in Assam. Globally as well, the tool has supported the estimation of energy needs of health facilities in countries like Uganda. WRI, in collaboration with the Ministry of Health of Uganda and the Energy Sector GIS Working Group, applied a geographic information systems (GIS)-based assessment methodology to estimate ranges of electricity requirements at a facility level (Lecaros et al. 2023), based on different health facility tiers, and accordingly provided medical services and facility sizes within each tier (as discussed in Box 2). Similar methodologies can be replicated in Indian states to support prioritization of health facilities for renewable energy implementation, as well as support in estimating energy demand and defining system size and investment needs.

BOX 2 | GIS-based demand assessment for health facilities

Facility-level data in the health care sector are at times scattered, outdated or nonexistent, especially for the existing electrification status of health facilities (WHO et al. 2023). Furthermore, executing electrification interventions at scale requires facility-level data on power availability and quality, which is often lacking. In these cases, geospatial data can help bridge the data gap by combining facility-level information from existing data portals with geospatial data on demographics, location, climate trends, and existing electricity infrastructure to help inform policy and design pathways for electrification at scale (Energy Sector Management Assistance Program 2022).

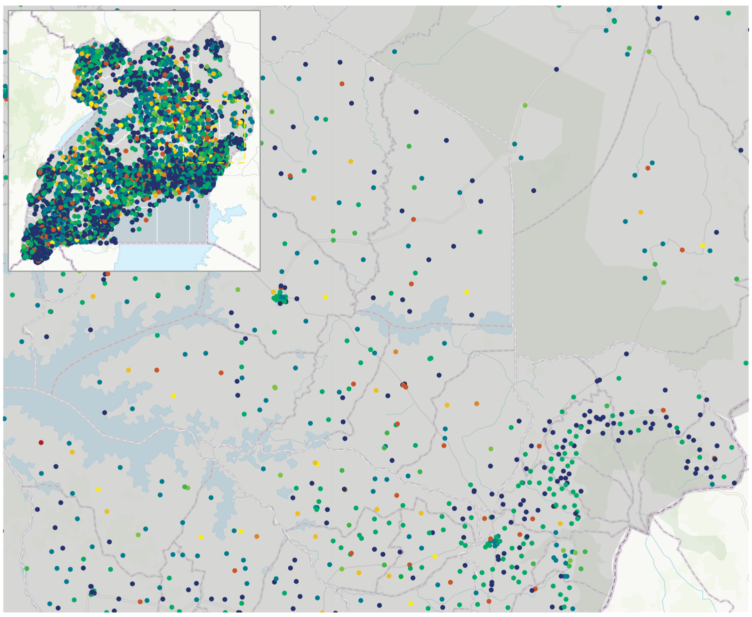
WRI put forth a GIS-based demand assessment methodology with a case study in Uganda to estimate ranges of electricity requirements for unserved and underserved health facilities, in collaboration with the Ugandan Ministry of Health's Health Infrastructure Department, the International Institute for Applied Systems Analysis, Politecnico di Milano, and the Energy Sector GIS working group in Uganda (Lecaros et al. 2023). The case study combined a bottom-up approach to assessing the electricity requirements at the facility level with an analysis based on GIS to assess the catchment population of each facility. Outputs of the analysis were integrated into WRI's Energy Access Explorer (https://www.energyaccessexplorer.org/), an interactive online geospatial platform that analyzes multiple spatial datasets across the electricity and development sectors.

The existing health facilities, within Uganda's health center tiers (Health centers II, III, and IV), are disaggregated into 14 archetypes to analyze the differences within each of these health center levels and build load profiles. The archetypes are based on the number of beds and catchment population, along with the types of services, number of pieces of equipment, and usage hours. The load profiles of each health facility archetype are used to compute the annual load curves and estimate plausible ranges of annual and daily electricity demand (kWh) as well as peak power requirements (kW) for each health center.

The georeferenced facility-level data is integrated into the EAE tool to include the attributes related to ranges of estimated electricity demand and power requirements that would provide the required health facility electrification information for data-driven planning on investments needed for electrifying facilities using solar PV, based on the facility's energy needs. The EAE tool will allow the health facility datasets to be overlaid with current and potential supply and demographic, environmental, and financial data and can be made available for a dynamic, multi-criteria prioritization analysis and the development of customized tenders for health facility electrification.

Source: WRI India authors.

FIGURE B2 | Estimated peak capacity (kW) of Ugandan health centers at the facility level



CAPACITY

Capacity building

While renewable energy enterprises have been capable of arranging temporary and permanent workers for construction and commissioning of the system, the major gap comes in servicing and maintenance of the DRE systems. To reduce troubleshooting times, there is a need to provide detailed training of health facility staff on basic troubleshooting and maintenance and to clearly lay out communication protocols. This ensures that any major breakdown-related complaints are registered appropriately and the follow-up processes are minimized on the health facility's end. With a high rate of staff turnover in the health sector, especially due to staff postings, it is important that multiple staff can be trained on site so that the handover process of training materials can happen smoothly. This is needed especially in the public sector where transfer of medical staff takes place on a regular basis. Here, the selection of the right trainees is important from the health facility's side to minimize needs for rebuilding awareness on maintenance needs. If existing health facility staff, medical or nonmedical, take up this new responsibility, additional and nominal payments can be considered so that the designated staff are incentivized to maintain the energy system, although hiring and training of designated staff at either the state level or facility level with the chief responsibility of maintaining these energy system(s) would be ideal. The mechanism to identify such staff should be taken up at the system design phase so that the staff can also be involved during the energy-system installation and commissioning period.

Awareness-building measures like posters on top of the inverter-battery system can be a useful communication medium to establish contact with the technology provider in case of breakdowns. This includes instructions, preferably in vernacular language, on basic do's and don't's for system maintenance, periodicity of maintenance of different components, and protocols for contacting technology providers and implementing agencies in the case of troubleshooting.

On the technology side, the renewable energy job ecosystem has been growing at a healthy pace over the past few years, particularly in the solar PV sector. The International Labour Organization estimates 217,000 jobs created in the solar energy sector, with 137,000 in the on-grid segment and 80,600 jobs in the DRE segment (IRENA and ILO 2022). The renewable energy workforce still struggles with gender parity with women constituting just 3 percent of the workforce in construction and commissioning, and barely 1 percent in O&M (IEA and CEEW 2019).

As the DRE sector's growing importance in remote and rural areas comes to the forefront, adequate local capacity in these regions is essential for minimizing troubleshooting time. Renewable energy enterprises, especially those operating from out of the states of intervention should set up local service centers, preferably at the district level, to manage projects of all sizes. In addition to ensuring technology providers' presence closer to the client, it is also important to look for collaborations with local energy entrepreneurs who could partner with technology providers for real-time provision of O&M services. Renewable energy enterprises usually connect with local enterprises present in the districts to subcontract installation work, but at the same time they should be accountable for maintaining the quality of work that meets industry standards. More localized training programs that focus on vernacular language, as well as introducing training programs for community members with primary education to qualify for skilled worker programs, can create green job ecosystems in rural regions. These programs can also support the inclusion of women and communities experiencing marginalization into the workforce (Jairaj et al. 2017).

Strengthening health facility staff capacity and retention will depend on creating a conducive work and living environment for staff. Decentralized solar energy interventions need to ensure that staff quarters on the health facility premises are considered to be essential for coverage under future decentralized solar energy interventions. This will ensure that staff enjoy similar levels of access and reliability in electricity as is observed in the health facilities that are covered under these interventions. As the inclusion of staff

quarters comes at additional costs, public and grant-based budgets need to account for a packaged solution right from the very beginning.

FINANCE

Looking beyond capital costs

Since decentralized solar energy systems can help reduce electricity bills and diesel fuel usage, the equivalent savings need to be measured, and the budget savings should be allocated toward O&M, especially after AMC periods have lapsed. This is important for both public budgetary allocations as well as philanthropic and CSR funding, which are limited to annual cycles. Arrangements need to be in place to ensure that savings in certain years can be capitalized in future time periods toward maintenance and parts replacement. Untied budgets and district- or state-specific development funds need to be flexible enough to allow a portion to be carried forward and accumulated toward larger expenditures for any major corrective maintenance.

Moreover, sufficient budgetary allocations beyond savings are needed to cover replacement of batteries, inverters, and other components over the system's lifetime. In cases where budgetary allocations exist, they are spread over multiple departments and at different levels of administration at the national, state, and district level (SEforALL and ESMAP 2021). An integrated approach through governance and financing mechanisms should be taken up to ensure renewal of AMCs after their five-year period (NCDC 2023a).

Therefore, accountability of financing lifetime operational expenses needs to be established at the start of the project and should lie with a single administrative unit. Given that public health is a state subject in India, the accountability of budgeting for energy systems O&M in public health facilities should lie with the state governments and respective state health departments to ensure sustainability in the long term. State governments may consider making five-year action plans to prioritize all relevant health facilities for solarization in a phased manner. As seen in some states already, convergence of funds from various sources can support financing both the capital and operating costs of the DRE system in public health facilities. There is a need for inclusion of DRE systems as part of electricity infrastructure costs within a state's program implementation plans. Locally available annual funds in the form of untied budgets, Rogi Kalyan Samiti grants, annual maintenance grants, and district development funds should include DRE system repair and replacement. Local area development schemes, such as the Members of Legislative Assembly Local Area Development (and the Members of Parliament Local Area Development schemes also need to be tapped.

Implementing agencies need to provide a financial breakdown of the replacement costs that will be needed over a 20- to 25-year solar energy system lifetime, which will help health departments plan in advance to undertake large-scale part replacement across the timeline. An integrated approach needs to be laid out to support health facilities in securing such funding, like procurement of medical equipment or other infrastructure upgrades in health facilities, where different departments and ministries can break the siloed approach to planning and budgeting for unlocking finance for interventions of equal importance to multiple sectors like health and power.

While private-sector financing has found traction among the private, for-profit health facilities in urban areas, the not-for-profit health facilities, especially those operating in rural areas, rely entirely on grants to finance their decentralized solar interventions. This is different from other contexts where the role of private financing may be much more important to integrate DRE into health facilities. Therefore, the sustainability of such solutions in private and not-for-profit rural health facilities depend on their ability to raise capital for repairs and maintenance beyond the first five years of the project. Many such facilities operate as part of a network of health facilities that are geographically dispersed. Such networks offer leverage in raising new grants for project sustainability to help negate the factors of small ticket sizes and high transaction costs for the financier.

As has been mentioned earlier, none of the interventions studied for this report featured private financing. However, there may be a role to play for private-sector financing especially via multilateral development banks (MDBs) for public health facility solarization, in partnership with state governments or sovereign guarantees provided by the central government. As is true of all development projects, the requirement of partial financing from beneficiaries—in this case, health facilities or health departments—can help attract private-sector financing. We have already seen examples of states making a 70 percent contribution to capital expenditure catalyzed by successful grant-funded pilot installations. Similar models could be developed for greater private-sector participation in decarbonizing the health sector and improving health service delivery. Another opportunity for private-sector and MDBs to participate could be in the development of the new health facilities that states are planning to build to increase the overall network of facilities. A statewide or nationwide program focusing on building new facilities or improving current health facilities could be developed for this in partnership with MDBs.[10]

Multiyear demonstration projects for philanthropic donors also need to look at O&M costs to refinance their existing installations completed in the past so as to ensure that the metric of focus is not limited to the number of health facilities solarized but can be expanded to the number of health facility electrification projects sustained. An extended-term funding approach for grants can help shift the focus from up-front capital investment to sustainability. Such a phased approach—where lessons learned from previous phases inform the design and implementation of subsequent phases—can be an important instrument to increase efficiency of grants over a longer-term horizon. The World Bank has been implementing multiphase programmatic approach projects for energy access, focusing on phased loans and/or grants, to partners across a time span of four to six years (Operations Policy and Country Services 2017). Similar approaches can support more efficient use of philanthropic grants for projects in health facility electrification.

Development organizations and funders need to review existing installations that have been funded, identify stranded assets and assets that are past their shelf life, and look for adequate funding mechanisms to revive existing decentralized solar energy installations. Technology provider selection should prioritize those who have the capacity and commitment to extend AMC contracts beyond the traditional 5-year period and cover preventive maintenance for 10- to 15-year periods.

DRE interventions are capital-intensive as compared to multiple other options to deploy CSR funds. However, the larger CSR entities struggle to find a common interest between their stated agenda for CSR and DRE installations. As these energy solutions scale up in the health sector, the critical nature of medical services makes it essential to build an M&E framework for the health sector that looks at the electrification component as an essential metric for improved service delivery. Presence of better data and analysis will allow organizations to make scalable electrification plans as well as attract more financing into health facility electrification programs. The evidence of linkages across SDGs could also pave the way for financing instruments that allow for projects that are funded under one SDG but create impacts across other SDGs. This requires development of an integrated impact assessment framework based on the evidence available.

Monitoring and evaluation

Most decentralized solar energy projects talk about impact in terms of number of installations or number of kW installed, but rarely do programs have data on how many systems are still functioning or have broken down and on how this source of electrification contributes toward changes in health indicators (WHO et al. 2023).

The potential scale of DRE implementation in the health sector is significant. This includes a multilateral energy compact for health facility electrification that aims to power 25,000 health facilities between 2020 and 2025 with renewable energy. Just in India, IKEA Foundation and SELCO Foundation announced the solarization of 25,000 health facilities in 12 India states by 2026, coupled with energy-efficient medical equipment and climate-resilient buildings. With the scale being planned, the interdependencies between health care service delivery and DRE need to be further brought out. To create a body of evidence, there is a need for innovative frameworks of impact assessment to assess modern energy interventions and their linkages to health outcomes. This includes measuring improvement in patient health outcomes; improvement in the range, quantity, and quality of health services that facilities can offer; and an evaluation of whether the benefits of energy cost savings are passed on to the patient through lowering the cost of medical care.

While this report brings out several qualitative aspects of DRE impacts on health care service delivery, there is a lack of baseline data available on the ground on the quantitative indicators to support this information. This calls for a standardized impact assessment approach with more indicators related to electricity and the socioeconomic development of health care staff and community to be included in existing health infrastructure surveys like the HMIS. The adoption of such an approach by health departments, implementing agencies, and philanthropies can help gather data needed to establish relationships between reliable electricity access and health care service delivery while also creating the enabling environment for further funding mobilization and policy support.

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SIEMENS
DANGER
440 VOLTS
SIEMENS
EXIDE
SOLATUBULAR
DESIGNED FOR SOLAR APPLICATION
LOW MAINTENANCE
EXTENDED LIFE
6LMS150L
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EXIDE
SOLATUBULAR
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LOW MAINTENANCE
EXTENDED LIFE
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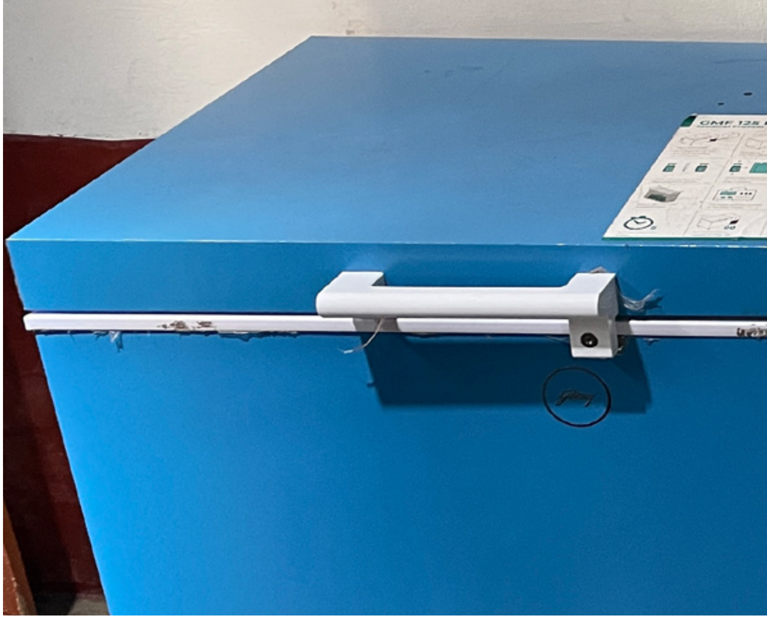
LUMINOUS

Conclusions and way forward

Scaling of decentralized solar energy solutions in health facilities needs to be accompanied by monitoring and evaluation frameworks to regularly assess the impact of electricity access and reliability on health outcomes.

As the findings and recommendations have indicated, decentralized solar energy interventions have a role in addressing constraints across the six health system building blocks that WHO identifies as critical to strengthening health systems: service delivery; health workforce; information; medical products, vaccines, and technologies; financing; and leadership and governance (WHO 2007). The frequency and better provision of *service delivery* was observed in many locations through greater autonomy during power cuts with the installation of battery storage systems along with solar PV systems and with more regular ventilation and lighting for patients in wards for a comfortable stay. The integration of DRE in health facilities has created a conducive work environment for the health workforce through better ventilation and lighting on boat clinics and has the potential to create more impact through inclusion of decentralized solar energy in staff quarters. Health *information systems* can be further enhanced with data from energy systems through remote monitoring systems that show how energy is utilized through the facility, how operational savings can be made in electricity and diesel fuel bills across various seasons, and how to proactively solve O&M issues. While the role of electricity in vaccine storage is evident through solarizing cold chain equipment being considered a priority, improvement in energy efficiency of medical appliances and optimization of energy options can support integrating new *technologies* for building cost-effective and sustainable energy systems. *Financing* for these solutions is the need of the hour and can be achieved through better and long-term design of funding programs; convergence of funding from various public programs at the central, state, and district level; and philanthropy and CSR support in bridging the financing gap for development. Lastly, *governance* needs to be established both at a health system level, with state governments taking *leadership* of financing decarbonizing health care initiatives, as well as at the facility level, with clear accountability established for various phases of the decentralized solar energy intervention in terms of routine maintenance, operations, procurement, installation, and ownership of the energy system.

India has the opportunity to achieve its goal of universal health coverage while also achieving its renewable energy targets and reducing climate impacts. Universal health care electrification through decentralized solar energy solutions, particularly in rural and energy-deficient parts of the country, has enormous potential. Meeting this potential will require the development of electricity solutions that are planned, designed, implemented, operated, and maintained in a way that meets the present and future



energy demand of health facilities and is sustainable in the long run. This report presented 22 case studies on decentralized solar energy interventions in health facilities. The interviews conducted under this study helped us understand the challenges faced by various stakeholders, as well as what the broader learning is for the health and energy sector. The following actions can help ensure that health facility electrification programs powered by decentralized solar energy are designed and implemented in an inclusive, efficient, and sustainable manner. Each of these action items necessitates the involvement of multiple actors in the ecosystem such as the central and state government, technology providers, corporate entities and NGOs, health and energy development-sector partners, financing institutions, and, most importantly, health facilities.

- Consider needs assessment to understand present and future energy demand of medical services, appliances, and staff quarters at various tiers of health care to create energy-system configurations that can meet the differing energy needs of health facilities. Geospatial assessment can support implementation at scale through estimating ranges of energy requirement for different tiers of health care. Existing HMIS data should be supplemented by an energy needs assessment of health facilities that includes geo-tagging of public health facilities, as well as exploring how not-for-profit health facility data can be collected.
- Integration of energy-efficient medical equipment should be considered prior to designing a decentralized energy system. This will allow optimization of the energy system to power more equipment with the same energy-system capacity. Standardization of robust, energy-efficient medical equipment as well as its inclusion in public procurement can spur increased adoption. Greater uptake will see prices come down

and obtain parity with inefficient alternatives and will support widening the base of service centers for efficient medical equipment.

- Ensure that procurement follows a quality cost-based system where the most technologically compliant and economical solutions are chosen. This would need tender evaluation teams consisting of staff from multiple departments or the inclusion of external technical stakeholders to support in evaluation. More weight should be given to technology providers offering long-term O&M service through localized service centers or partnerships with local energy service providers, along with proper capacity-building tools to train local health facility staff on routine maintenance.
- To address the gap of the evidence-based effect of energy interventions in health facilities, a robust impact assessment framework needs to be established and administered to collect relevant data from the start of the intervention to monitor the effects of the intervention. Such a quantitative and qualitative impact assessment of the health outcomes and socioeconomic development of the community will help inform policymaking for incorporating DRE solutions for rural and remote health facilities. Electricity-side data collection can be supported through integrating remote monitoring systems that are compatible for low-network conditions in rural and remote parts of the country.
- For public health facilities, state governments need to take the lead in ensuring convergence of funds from various sources so as to unlock greater budgetary allocation from state and district development funds. This will need creation of a broader evidence base that will allow health departments to build elaborate electrification plans and also take the lead in sustaining projects in the long run by allocating budgets to public health facilities for energy-system costs beyond the up-front capital. Not-for-profit facilities need to leverage existing CSR and philanthropic funding by aligning electrification as a critical component of health care service delivery. This will ensure that organizations can target grant funding from the perspective of decarbonizing the health care sector and improving health outcomes simultaneously, thereby making the projects more appealing.
- Financing institutions should prioritize extended term financing to support health sector stakeholders for decentralized solar energy interventions where impacts on health outcomes are realized over a longer time span, as opposed to single-year impact targets. The financing should integrate local capacity enhancement in sustaining these decentralized energy systems in the long run through skill building and longer-term system cost considerations, along with financing opportunities for replacement of defective energy system parts and repurposing of nonfunctional energy systems.

Appendices

APPENDIX A. CASE STUDY INFORMATION

Serial number	Name of health facility	Location (village/block/tehsil and district)	State	Size of health facility (no. of beds)	Solar PV capacity (in kW)	System configuration
1	**Majuli Boat Clinic (C-NES)**	Majuli, Majuli district	Assam	1 bed	3 kW	off-grid, boat rooftop, system with lead-acid battery backup (with grid charging)
2	**Vivekananda Boat Clinic (Karuna Trust)**	Gohpur, Sonitpur district	Assam	2 beds	5 kW	off-grid, boat rooftop, system with lead-acid battery backup (with grid charging)
3	**Nav Jivan Hospital**	Satbarwa block, Palamu district	Jharkhand	100 beds	15 kW (2 systems)	10 kW system: off-grid, rooftop, with lead-acid battery backup (with grid charging) 5 kW system: 500 W off-grid DC system packs with dedicated inverters and li-ion batteries
4	**Constant Lievens Hospital & Research Center**	Mandar, Ranchi district	Jharkhand	100 beds	30 kW (2 systems)	off-grid, rooftop, with lead-acid battery backup (with grid charging)
5	**Bharat Mata Hospital**	Muri, Ranchi district	Jharkhand	24 beds	10 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
6	**CHC Ratu**	Ratu, Ranchi district	Jharkhand	30 beds	30 kW (3 systems)	off-grid, rooftop, with lead-acid battery backup (with grid charging)
7	**Williamnagar Civil Hospital**	Williamnagar, East Garo Hills district	Meghalaya	100 beds	38.7 kW (3 systems)	off-grid, rooftop, with lead-acid battery backup (with grid charging)
8	**CHC Patharkhmah**	Patharkhmah, Ri-Bhoi district	Meghalaya	30 beds	26.4 kW (2 systems)	off-grid, rooftop, with lead-acid battery backup (with grid charging)
9	**Narang HWC Subcenter**	Umling, Ri-Bhoi district	Meghalaya	2 beds	1.98 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
10	**PHC Byrnihat**	Umling, Ri-Bhoi district	Meghalaya	10 beds	4.95 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
11	**PHC Gumballi**	Yelandur, Chamarajanagar district	Karnataka	6 beds	3.4 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)

12	**PHC Sugganahalli**	Magadi, Ramnagar district	Karnataka	6 beds	6.03 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
13	**SDH Raidakhol**	Rairakhol, Sambalpur district	Odisha	70 beds	29.04 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging) solar-powered DC air conditioners
14	**HWC PHC Pandripada**	Pandripada, Ganjam district	Odisha	6 beds	3.3 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
15	**CHC Tumgaon**	Tumgaon, Mahasamund district	Chhattisgarh	30 beds	15 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
16	**HWC PHC Patewa**	Patewa, Mahasamund district	Chhattisgarh	10 day care beds	2 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
17	**UPHC Ama seoni**	Ama Seoni, Raipur district	Chhattisgarh	8 beds	2 kW	off-grid, rooftop, with valve-regulated lead-acid (VRLA) battery backup (with grid charging)
18	**PHC Dondekala**	Dondekala, Raipur district	Chhattisgarh	6 beds	2 kW	off-grid, rooftop, with lead-acid battery backup (with grid charging)
19	**Jorhat Christian Medical Center**	Barbheta, Jorhat district	Assam	100 beds	300kW	on-grid, rooftop, system in RESCO mode, with EXIM metering no battery backup system integrated with solar PV system
20	**BMCH Alipur**	Silchar, Cachar district	Assam	70 beds	35.55 kW (2 systems)	system 1: off-grid, ground-mounted, with valve-regulated lead-acid (VRLA) battery backup (with grid charging) system 2: off-grid, rooftop container-based, with valve-regulated lead-acid (VRLA) battery backup (with grid charging)
21	**Bazarichara MPHC**	Lowairpoa, Karimganj District	Assam	6 beds	5.94 kW	off-grid with lead-acid battery backup (with grid charging) with remote monitoring system
22	**Nagrabazar PHC**	Patharkandi, Karimganj district	Assam	6 beds	3.96 kW	off-grid with lead-acid battery backup (with grid charging) with remote monitoring system

Source: WRI India authors.

APPENDIX B. ENERGY DEMAND ASSESSMENT

The following table shows a sample energy demand assessment carried out at a PHC in Assam. The energy demand assessment allows the health facility to understand the usage of all medical equipment, lighting, and fans within the facility, as well as to prioritize what loads need to be connected to solar for uninterrupted use. As this is for a single health facility, the configuration of rooms, and the type of loads in each room, can change depending on the type of health facility, the population served, and the medical and nonmedical appliances that it has in place.

Such an energy demand assessment also provides technology vendors with clarity on how the energy system should be sized and what is the size of the battery backup requirement, based on the loads to be served in non-solar hours. Such assessments should also consider the future or aspirational loads that a facility expects to add in the coming years (or to meet minimum IPHS standards), so that the energy system is sized not only for present demand but also for future needs.

Although hours of usage and appliance type and number can be collected from observation, information on power consumption per appliance (in watts) is sometimes a challenge. This information can usually be found in the nameplates of various appliances. For ease of use, a list of medical devices along with the range of indicative power ratings has been provided in the report *Energizing health: accelerating electricity access in health-care facilities* (WHO et al. 2023). Any lack of data can be supplemented using that list. In the Indian context, the National Centre for Disease Control's guidelines on green and climate resilient public health facilities provide an estimation of energy-efficient lighting requirement, in terms of number of fixtures and required wattage (NCDC 2023b). For powering essential medical services in a public health facility across various tiers, such as lights, fans, immunization, blood bank, labs, operation theaters, labor room, etc., the NCDC has also provided indicative guidelines for loads that can be considered to be powered by solar PV systems (NCDC 2023c). Using this guidance, health administrators can conduct their own energy demand assessments to understand what critical loads or services they would prefer to be connected to a solar PV system and battery storage to enhance the reliability of health services.

Along with that, while the energy consumption from most appliances like lighting is a product of power rating (W) and number of hours of usage (hrs.), motor-based appliances like fans and refrigerators have various speeds and duty cycles, respectively. This means that a fan is not always running at full speed. Similarly, refrigerators, which are plugged in and consume power 24 hours a day, operate in an on/off duty cycle where the refrigerator compressor turns on and off based on the cooling requirement. The HOMER Powering Health Tool provides average power usage for various equipment based on the equipment's duty cycles, which we use for calculating energy consumption (kWh) in a day (USAID et al. 2020).

TABLE B-1 | Energy demand assessment of a sample PHC

Services or buildings	Name of appliances	No. of units	Power rating [Watt (W)]	Total connected power (Load - in kW)	Appliance usage per day [5AM to 5PM]	Appliance usage per day [5PM to 5AM]	Daily energy consumption [kilowatt-hour (kWh)]	No. of days of consumption in a month (max 31 days)	Monthly consumption [kWh/ month]	Connected to Solar (Y/N)	Critical loads (kWh/ day)	Critical loads (kWh/ month)
Entrance and waiting area	Tubelight (LED)	6	20	0.12	0	12	1.44	31	44.64	Y	1.44	44.64
	Ceiling fans (AC)	1	75	0.075	8	3	0.825	31	25.575	Y	0.825	25.575
	Water purifier	1	40	0.04	1	0	0.04	31	1.24	Y	0.04	1.24
Labor room	Tubelight (LED)	4	20	0.08	3	0	0.24	31	7.44	Y	0.24	7.44
	Ceiling fans (AC)	3	75	0.18	3	0	0.54	31	16.74	Y	0.54	16.74
	Exhaust fan	1	50	0.05	3	0	0.15	31	4.65	Y	0.15	4.65
	Refrigerator - mini	1	80	0.0336	12	12	0.8064	31	24.9984	Y	0.8064	24.9984
	OT Spotlight	1	80	0.08	1	0	0.08	31	2.48	Y	0.08	2.48
	Oxygen concentrator	1	350	0.35	1	0	0.35	31	10.85	Y	0.35	10.85
	Suction machine	1	180	0.18	1	0	0.18	31	5.58	Y	0.18	5.58
	Radiant warmer	1	700	0.42	0	0.5	0.21	31	6.51	Y	0.21	6.51
	Autoclave	1	2000	1.5	0	1	1.5	31	46.5	N	0	0
	Water geyser 5L	1	3000	3	1	0.5	4.5	31	139.5	N	0	0
Public toilet	Light bulb (LED)	1	9	0.009	0	2	0.018	31	0.558	Y	0.018	0.558
Maternity room	Tubelight (LED)	1	20	0.02	0	6	0.12	31	3.72	Y	0.12	3.72
	Ceiling fans (AC)	1	75	0.075	1	5	0.45	31	13.95	Y	0.45	13.95
	Light bulb (LED)	3	7	0.021	0	3	0.063	31	1.953	Y	0.063	1.953
Female and male ward	Tubelight (LED)	2	20	0.04	2	5	0.28	31	8.68	Y	0.28	8.68
	Light bulb (LED)	3	9	0.027	0	5	0.135	31	4.185	Y	0.135	4.185
	Ceiling fans (AC)	2	75	0.12	2	6	0.96	31	29.76	Y	0.96	29.76

OPD [9 AM - 2 PM]	Tubelight (LED)	2	20	0.04	2.5	0	0.1	31	3.1	Y	0.1	3.1
	Ceiling fans (AC)	3	75	0.18	5	0	0.9	31	27.9	Y	0.9	27.9
Office room and com-puter room	Tubelight (LED)	4	20	0.08	5	0	0.4	26	10.4	Y	0.4	10.4
	Ceiling fans (AC)	4	75	0.24	5	0	1.2	26	31.2	Y	1.2	31.2
	Computer desktop	2	60	0.12	5	0	0.6	26	15.6	Y	0.6	15.6
	Printers, laser	1	259	0.259	2	0	0.518	26	13.468	Y	0.518	13.468
Immunization cold chain	Tubelight (LED)	4	20	0.08	5	0	0.4	31	12.4	Y	0.4	12.4
	Ceiling fans (AC)	2	75	0.12	5	0	0.6	31	18.6	Y	0.6	18.6
	Ice lined refrigerator	1	230	0.0759	12	12	1.8216	31	56.4696	Y	1.8216	56.4696
	Deep freezer	1	185	0.111	12	12	2.664	31	82.584	Y	2.664	82.584
Laboratory	Needle cutter	1	20	0.02	5	0	0.1	31	3.1	Y	0.1	3.1
	Tubelight (LED)	2	20	0.04	5	0	0.2	26	5.2	Y	0.2	5.2
	Light bulb (LED)	1	9	0.009	5	0	0.045	26	1.17	Y	0.045	1.17
	Ceiling fans (AC)	2	75	0.12	5	0	0.6	26	15.6	Y	0.6	15.6
	Centrifuge	1	200	0.2	1	0	0.2	26	5.2	Y	0.2	5.2
Pharmacy	Light bulb (LED)	5	9	0.045	5	0	0.225	31	6.975	Y	0.225	6.975
	Tubelight (LED)	2	20	0.04	5	0	0.2	31	6.2	Y	0.2	6.2
	Ceiling fans (AC)	2	75	0.12	5	0	0.6	31	18.6	Y	0.6	18.6
	Refrigerator - large	1	200	0.084	12	12	2.016	31	62.496	Y	2.016	62.496
Water pump	1 HP water pump	1	745	0.745	2	0	1.49	31	46.19	N	0	0
Staff quarters (12 no.s)	6 LED bulbs	72	9	0.648	2	4	3.888	31	120.528	N	0	0
	3 ceiling fans	36	75	2.16	2	8	21.6	31	669.6	N	0	0
	0.5 HP water pump	12	372.5	4.47	1	1	8.94	31	277.14	N	0	0
	TV set	12	30	0.36	2	2	1.44	31	44.64	N	0	0
Total				16.7875			63.635		1953.87		**20.3**	**609.772**

Source: WRI India authors.

APPENDIX C. INTERVIEW GUIDES

This section provides the questionnaires that were administered to the different stakeholders interviewed for this report: beneficiaries, implementing organizations, technology providers, and funding organizations. Beneficiaries in this case are primarily health facility administration and staff. Implementing organizations manage and coordinate the tendering, contracting, procurement, and installation of energy systems and in many cases are responsible for M&E of the project. Technology providers are energy enterprises that design, install, commission, and maintain the energy system. Funding agencies can be donors (philanthropy, CSR) or government departments that fund the capital cost of the energy system.

INTERVIEW GUIDE FOR BENEFICIARY

Informed consent script:

I am _________________ from the Energy Program at WRI India. We are conducting a study on how energy-access solutions address energy needs and contribute to health outcomes in rural and remote health facilities. We would like to ask you a few questions regarding the energy solution in this health facility. This interview will take around one hour. The information we capture will be used for research purposes only. The information will be treated as confidential, and any individual identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project name:
2. Interviewed by:
3. Date:
4. Name of the interviewee(s), organization(s) and role(s):

Contact details

5. Village and block:
6. District:
7. State

About the facility

8. Number of beds in this facility
9. What is the facility size equivalent (SC, PHC, CHC, DH etc.)?
10. What services are provided by the facility?
11. What is the average patient footfall?
12. What is your role in the facility?
13. To your knowledge, what are the demographics of the population who avail themselves of services from this facility?
14. What are the charges that patients pay to access various health services?
15. If charges are subsidized, who helps provide funding to cover cost of subsidized services (grants, government etc.)?
16. Are there any aspirational services that you would like to serve in the future? What are those, and why can't you provide those health services currently?

Electricity situation

17. Is your facility connected to the grid?
    a. If yes, since when?
    b. Is it single or three phase connection?
    c. When is the electricity consumption highest in the day?
    d. Which services are responsible for this high electricity consumption?
18. Did you face power cuts before the intervention: (If yes, please give some idea about the duration.)
19. Did you witness fluctuation in voltage?
20. Did you have backup power for your institution before the installation? If so, what backup did you use, and what is the capacity? Are you still depending on that backup system?

Impact of solar installation on health services

21. System size installed (solar and battery backup).
22. What services is the solar installation connected to? Entire hospital or some critical health services?
23. Any critical health services omitted from connection that you wish you could connect? Why have they been left out?

24. Have you noticed any changes in the services offered by the facility after the coming of the energy solution?
    a. Is there any change in operating hours?
    b. Is there any change in the number of personnel living here or available when needed?
    c. Is there any change in facilities like lights, fans, drinking water?
    d. Is there any change in medical services or diagnostics services provided: hospital services or new medical equipment, lab support, etc.?
    e. Any other changes?
25. Do you think the RE solution in this facility is the best solution? Why/why not?
26. Have you or any organization been able to conduct an assessment on the impact of solar energy solution on health services?
27. What were your broad experiences with the following issues when you think about the procurement and the process for installation?
    a. space for installation:
    b. approvals/permissions from the government:
    c. funding:
    d. civil work:
    e. energy vendors, including O&M support:
    f. logistics like transportation of system components:
    g. natural calamities or conditions:
    h. other:
28. To raise funds for either solar installation or for O&M, has the cost of service to patients been increased? Or are you providing service at the same cost?
29. Has patient satisfaction increased due to solar energy installation? If yes, how did you gather this perception of satisfaction?

Staff living environment

30. Does the health facility have in-house staff housing? Do you live in staff quarters or far away?
31. What is the condition of access to electricity and water to the staff quarters? Is it similar to access to health facility?
32. What amenities do you have access to in the staff quarters (TV, running water, heating, cooking, entertainment etc.)?
33. Was the solar installation also connected to the staff quarters? If not, then why not (limited access to funding, limited space availability, limited system size)?
34. Would access to reliable electricity help motivate staff?
35. Have there been staff who have left due to poor electricity access conditions?

Financing for electricity in the health facility

36. Do you get electricity bills regularly every month? Are you able to pay the bills regularly?
37. Who pays the bill, and is there financing in place for the same?
38. If you have a diesel generator, how much fuel on average do you consume, and what is the monthly cost of procuring fuel?
39. How do you manage procurement of diesel fuel?
40. How is the bill payment financed?
41. For financing of energy costs, how do you cope with the situation?
42. Do you know who funded the solar energy installation?
43. Was the hospital management directly involved in raising funds? Or did you receive them from partner organizations?

Maintenance of the system

44. Have the systems been performing as expected?
45. How prompt are the maintenance services?
46. Has there been a situation where you had to halt operations as the system was not working? Elaborate on the experience.
47. How do you track the efficiency of the system—performing as vendor had promised?
48. Are you aware of the maintenance and replacement (battery) requirements over the lifetime of the system? (Explain the requirements.)
49. Is there an AMC contract in place for regular O&M of the system? What is the average duration of the AMC?
50. Are you in direct contact with the vendor? How do you connect with them when there is need for maintenance?
51. Is there a plan in place to collect funds for the O&M of the system beyond the initial AMC?
52. Is there any money collection from the community for O&M?

53. Has anyone in the facility been assigned responsibility of taking care of O&M?
54. Do you have access to in-house technicians here to rectify or repair solar systems?
55. Did you receive any local capacity building training for day-to-day troubleshooting?
56. Is there remote monitoring of the system and its performance or disruptions caused by climate vulnerabilities or natural calamities?
57. Do you have access to the RMS, and do you regularly monitor it?
58. Did you or do you do local capacity building for day-to-day troubleshooting?

Sustainability in the climatic context

59. Does this facility function during natural calamities like extreme heat days, extreme rains, floods, droughts?
60. Have you seen the system breaking down during natural calamities? How frequently does this happen?
61. Have you had challenges procuring fuel for diesel generators in this time period?
62. During calamities, have the solar energy systems been running? Are they sufficient to meet your energy demand?

Operational sustainability of the system

63. Were you or anyone from the community involved or consulted in any way during the implementation process?
64. Are you happy with the services provided by the facility? What else is needed?
65. Which stakeholders came together to design the project (organization/individual/community/government)?
66. What role (if any) did you play during the installation process?

INTERVIEW GUIDE FOR IMPLEMENTING ORGANIZATION

Informed consent script:

I am from the Energy Program at WRI India. We are conducting a study on how energy-access solutions address energy needs and contribute to health outcomes in rural and remote health facilities. We would like to ask you a few questions regarding the energy solution that your institution has implemented in health facilities. This interview will take around one hour. The information we capture will be used for research purposes only. The information will be treated as confidential, and any individual identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project name:
2. Interviewed by:
3. Date:

Details of organization

4. Name of the interviewee(s), organization(s), and role(s):
5. Contact details (mail/phone):
6. Address:
7. State:
8. Tell us about your organization and the work that it does.
9. What are your geographic areas of interest and why (related to health)?
10. Do you own a health facility? If not, who owns it (government/private/communities, etc.)?
11. What is the (equivalent) category of the health facility? (HSC, PHCs, CHCs, district hospital)
12. What health services are provided there to patients?
13. To your knowledge, what is the demographic of population who avail themselves of services from this facility?
14. What level of fee is charged to patients here (free of cost, nominal fees, or normal)?
15. If not a public health facility, do these facilities provide any government health schemes?

Electricity situation

16. Are your facilities connected to grid? When were they connected? Do you have a single or three phase connection? What is the sanctioned load (in kW)?
17. Average power outages per day (hours).
18. Do you experience voltage fluctuations?
19. How does unreliable electricity or no electricity affect service delivery in the target health facilities?
20. Who is responsible for payment of electricity and diesel bills? Do you have to raise finances for the same, or are the bills covered through what is charged to patients?
21. How do the health facilities manage diesel procurement?
22. Do you keep track of diesel and electricity expenses of individual facilities?
23. Expense on diesel/electricity (prior to installation).
24. Expenses/savings on diesel/electricity (post-installation).
25. Is there a backup power system for your institution before the solar installation? If so, what backup did you use? Are you still depending on that backup system?
26. What challenges did you face that prompted you to think of installing solar solutions or a backup system?

Energy needs/assessment

27. Who conceptualized the idea of installing the electricity/renewable energy solutions, and what were the reasons for doing so?
    - Access to reliable electricity
    - Strengthen health services or powering critical equipment
    - Stabilization of voltage
    - Reduction in electricity cost
    - Others
28. Where is the solution installed? Who owns the space where it is installed?
29. Have you or anyone done system sizing or demand assessment for energy needs? If yes, can you please let me know the estimated demand? If not, then why?
30. How did you go about assessing energy demand?
31. If yes, to what extent (%) is your current solar system meeting the demand?
32. If financing and space or feasibility were not an issue, what size of system would you have chosen for installation?
33. Is your system off-grid or on-grid or hybrid?
34. On an average, what are the system specifications for the energy solutions you have implemented in your facilities?

Total installed capacity in kW (range, average)	
Year of installation	
Vendors/company name of installation	
Space occupied	
Module cost (if available)	
Is there a battery? battery type	
Battery capacity in Ah	
Battery cost (if available)	
Inverter specs	
Inverter cost (if available)	
Does system have warranty/guarantee? If yes, no. of years covered?	
Does system have AMC included? If yes, for how many years?	
Total system cost	

35. Have you tried out alternate financing or implementation models (RESCO, equity, debt financing)?
36. Is there any planning to add more capacity to systems? If yes, then how?
37. If yes, will you go with the same vendor or want to change the vendor or any system specifications?

Financing the energy system

38. Do you know who funded the installation or who helped to install the system financially? (Ask about grant, loan, government support/subsidy, self-funded, and break down by source.)
39. What convinced you or funders to invest in this energy solution? Have you developed or submitted any proposal?

40. Was the organization or hospital management involved in raising the funding?
41. Have you or funders done any scoping or need study for intervention?
42. Do you have any separate funds for O&M of the system? Who is financing the O&M for the system's lifetime?
43. Who will fund or support post completion of the AMC tenure?

Operation and maintenance of the system

44. Who takes care of the day-to-day O&M (human resources)?

Please answer the following questions regarding your experiences with maintenance of the systems:

45. Have the solar systems been performing or working well?
46. Is there any breakdown or complete blackout of the system? If yes, then how much time does it take for the maintenance services?
47. How do you contact the service provider or vendor for repair and maintenance?
48. Do you track the efficiency of the system—i.e., if it is performing as the vendor suggested or promised? If yes, then how?
49. Is there any remote monitoring for the system? Tell us about performance and disruptions caused by climate vulnerabilities or natural calamities.
50. Is there any local capacity building done by you or the vendor for day-to-day troubleshooting? Has anyone been trained from your facilities to do so?
51. What is the limitation of the solar systems or challenges that you face?
52. If similar projects come up in such locations, would you be willing to take them on? If not, why?

Impact of the energy intervention in the context of better service delivery

53. In your opinion, has access to electricity enabled better access to health care service delivery?
54. How has the electricity access situation improved health services after installation across your facilities (changes to operating hours, reliability, less equipment breakdowns)?
55. How has the improved electricity access situation affected service delivery or helped communities nearby (more added services, more footfall, etc.)?
56. Did these implementations bring about the changes you expected to see when you began this project? Please explain how.
57. Have you conducted an impact assessment of the energy solution installation? If so, can you share the findings or report? Were there any changes to the electricity cost?
58. Do you or other stakeholders have plans to scale up this model?

Sustainability in the climate context

59. What natural calamities or conditions are faced by the state or districts in general and your facility in particular?
60. How do your facilities get affected and how do they cope? Is access to the facility affected during adverse weather? What is the impact on footfalls during and after such events?
61. What additional precautions have you taken to ensure that your energy solutions are not affected by natural calamities or conditions?
62. Do the solar energy systems run well during climate events, or have they also been temporarily or permanently affected by them? Please elaborate.
63. Have you enlisted or ensured that some equipment like lighting arrestors, elevated structure, or quality structures will help to overcome a natural event?
64. Have you seen any impact of climate vulnerabilities or natural calamities on O&M of the system?
65. How do you deal with the same and ensure that the system performs as planned?

Learning from the implementation

66. If you have already scaled up, please share more about how you scaled this up and who are the partners.
67. Are there any broad lessons learned for you and your organization from this implementation?
68. What is your expectation from government agencies in providing support for electrifying or solarizing health facilities?

INTERVIEW GUIDE FOR TECHNOLOGY PROVIDER

Informed consent script:

I am from the Energy Program at WRI India. We are conducting a study on how energy-access solutions address energy needs and contribute to health outcomes in various states of the country. We would like to ask you a few questions regarding the energy solution you have installed in health facilities across the region. This interview will take around one hour. The information we capture will be used for research purposes only. The information will be treated as confidential, and any individual identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project Name:
2. Interviewed by:
3. Date:
4. Name of the interviewee(s), organization(s) and role(s):
5. Contact details:

About the company

1. Where is your company located and its presence?
2. What are the services provided by your company, in terms of RE solutions?
3. How long have you been in this business?
4. Are you empaneled by MNRE or any state nodal agencies?
5. Can you give a brief description of the manpower in your company? The total number, how they operate, and technical qualifications.
6. Are you also in the business of manufacturing or assembling any solar equipment?
7. Have you installed RE solutions (mainly for health) only in your state or in other states as well?
8. Have you installed RE solutions in models beyond CAPEX, such as RESCO, leasing models etc.?
9. In your perspective, what is the demand scenario of RE in your state? How is or will the health sector be benefited?

About the location

10. Please provide the name of the district, block, or village where you have completed the intervention(s). You can name two to three major health interventions, but your focus can be on one of those that we have visited.
11. In the context of these energy issues, what challenges was the client facing in delivering services?

Issue	Intensity	Comment
Not connected to the grid		
Connected but no power	(hours of outage)	
Connected but no power and depending on DG set	(hours of outage) (hours of DG set operation)	
Voltage fluctuations	(frequency and range)	

About the solution

12. What is the energy solution? (off-grid or on-grid or hybrid)
13. When was it installed?
14. Why was it installed? To solve what problem (according to vendor)?
15. What was the motivation for you to take this project?
16. Where is it installed (what type of health care institution, i.e., public or private)? Who owns the space where it is installed?
17. Technical specs of the energy solution—please fill in the table below:

Component	Capacity/ make	Any modifications made to the structure or technology to accommodate hospital requirements
Solar panel		
Mounting structure (rooftop or ground mounted) - provide details		
Battery		
Inverter		
Balance of system (electrical wires/panels)		
Power backups if any		
Any other specification		

18. Did you need to make any structural changes to conform to any climate vulnerability issues at the site (flood-prone, lightning, rains, heavy winds, droughts etc.)?
19. Generally, how many days or months (average) do you take to execute any project in health facilities? (We acknowledge that it will depend on several factors, including location, transportation, procurement, etc.)
20. What challenges do you face in meeting the original project implementation schedule?
21. Has COVID-19 affected your ability to execute projects on time? Has it increased your costs for providing service?
22. For the RESCO mode, what are the tariffs charged to the consumer? Who decides the tariff?
23. What type of metering arrangement is provided to customers?
24. Who bears the capital cost for procurement, components, installation, and O&M?
25. What is the role of state government departments in facilitating RESCO models?

Understanding energy demand and system sizing

26. Did you conduct an energy demand assessment to ascertain system size? If not, then who conducted it?
27. What energy demand did you take into consideration while designing the system?
28. Who established the system size for the system, the health facility or implementing agency? If a multi-site project, was the system size established across all health facilities?
29. Is the entire facility covered by an RE solution or selective loads? If selective, then what health services (or loads) were covered by RE? Were any critical loads included?
30. How did you decide on which loads to omit? Who made a decision on this? Did the health facility provide guidance, or could you plan based on the system size?
31. If there is an increase in energy demand in the future, how will your system respond or change?
32. Up to what level of increase (in %) in daily demand is the system designed to deliver?
33. Do you support health facilities in medical equipment procurement, or is your work limited to RE system installation?
34. For these particular facilities, was any intervention required and undertaken on changing medical equipment to energy-efficient alternatives prior to installing system?

Meeting O&M needs of customers

35. Do you establish long-term AMCs with customers? Describe the structure:
    a. Payment structure (one-time up-front or regular payments)
    b. Length of the contracts
    c. How often you are mandated to visit the site for inspection
36. Are the O&M contracts always included in the contract? If not always, how do you respond to health facility servicing needs otherwise? What is the payment structure in these cases?
37. As a vendor, do you insist on having O&M contracts in place or conducting O&M as and when needed by health facility?
38. Do you also offer independent O&M services for systems that you have not installed, but have been asked to maintain? How do you charge customers in this respect?
39. What is the response time that you strive for to troubleshoot? Are you always able to meet that response time? What are the challenges?
40. For health facilities located beyond the location where your team is situated, how do you provide quality troubleshooting in time?
41. Have there been cases where you have been requested to extend O&M contracts beyond the five-year period?
    a. Do you accept the request?
    b. What does this extended O&M contract include?
    c. Is parts replacement, especially batteries and inverters beyond five years, covered in the contract or paid for separately?
42. Who will fund post completion of the AMC tenure?
43. Do you provide remote monitoring system?
44. Do you have a specific vendor for the RMS? Or does it change depending on the project?
45. What metrics can the RMS track? And how are the data made available to users?
46. On what network is data transmitted and stored? 2G/3G/4G/SMS?

47. How often have remote monitoring system interventions been successful, especially in remote areas where network connectivity is poor?
48. Do health facility staff or implementation agencies keep track of data on the RMS? What do they use it for? Is it limited to alerts or warnings or continuous tracking?
49. Do you receive alerts from the RMS when system troubleshooting is needed?

Capacity building of the user

50. Do you provide any training to the health facility staff? If yes, can you describe what kind of training programs you offered?
51. Who provides this training?
52. Who identifies the right candidate for the training? The facility or vendor?
53. Do you also provide any training manuals on O&M to the client?
54. Does the client have contact details for your team so that the client can reach out for any system troubleshooting?

Financing the energy system

55. What was the total cost of the installation, and how was it funded? (Ask about grant, loan, self-funded, and their breakdowns by source.)
56. Who funds the O&M of the system?
57. Have you taken up project government tenders for health facility solarization?
58. If yes, describe the project in brief, including the system size, the number of facilities, and whether off-grid or on-grid.
59. Do you take a different approach to O&M or AMCs, depending on whether it is a government or nongovernment project?
60. How different is the approach to a government project, in terms of project delivery, as compared to private tenders?
61. In case of government tenders, have you been able to deliver the project at benchmark cost rates?
62. Are the current benchmark costs feasible for vendors to deliver a high-quality solution profitably?
63. If not, how does a vendor compromise? On quality, on profitability, or other parameters?
64. In your opinion how do benchmark costs need to change for quality vendors to deliver on energy solutions?

INTERVIEW GUIDE FOR FUNDING AGENCIES

Informed consent script:

I am__________________from the Energy Program at WRI India. We are conducting a study on how energy-access solutions address energy needs and contribute to health outcomes in rural and remote health facilities. We would like to ask you a few questions regarding the energy solution in this locality. This interview will take around one hour. The information we capture will be used for research purposes only. The information will be treated as confidential, and any individual identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project/program/site name
2. Project/program/site details (number of sites, locations, duration of this project/program)
3. Interviewed by
4. Date
5. Name(s) of the interviewee(s), organization(s) and role(s)
6. Contact details

About the location

7. What energy issues are faced by the areas covered by this project or program?
8. Name of the organization you are funding
9. Project that is being financed
10. Are these facilities private or public health facilities?
11. Was the health facility previously electrified? If so, what was the source of power?

Motivation or context for implementation

12. Tell us about your organization and its work in the energy-development space.
13. How do you perceive your role in the implementation—as a funder of energy access, as a funder for improved health care (or socioeconomic development), M&E role, ecosystem support, etc.?

14. Why did you decide to invest in this health facility electrification?
    a. Geography
    b. Implementation model
    c. Implementation organization
    d. Energy solution
15. How and when did you decide on funding this project/program/site?
16. Have you or a partner organization done any scoping or feasibility study or identification of issues?
17. Is your long-term funding strategy area region-specific or sector-specific (i.e., health)?
18. When are these decisions taken (specific times in a year, frequency)?

Financial sustainability of the health facility

19. Are you contributing to the one-time up-front investment or CAPEX plus ongoing O&M or to O&M only?
20. If you are contributing to one-time up-front investment,
    a. What was the one-time CAPEX for this project/program/site (as applicable)?
    b. What are the various items that have been financed? Does the investment go beyond financing the RE component (e.g., medical equipment, health infrastructure, staff costs, M&E etc.)?
    c. For the one-time up-front cost, what was the mode of funding: CSR/foreign grant/concessional debt/loan/equity investment/or innovative financing measure like a revolving fund?
21. If the financing is an on-going engagement, beyond CAPEX, are there any regulatory hurdles to having multiyear financing? How is the financing structured for multiple years?
22. If you are not the sole financial contributor to the electrification project, who else has contributed to the funding of this project/program/site?
23. Was this the funding model for other partners, or was it the same or different from your model?
24. Is this the best-suited model for this implementation?

Sustainability of the system

25. Who owns the energy system on the facility? Is there any assets-transfer process?
26. Who is taking care of financing the O&M of the energy system? Are you aware of whether responsibility has been assigned to certain individuals or organizations?
27. If financing accountability for O&M has not been fixed, how do you ensure the long-term sustainability of the project?
28. Do you have any exit plan as a funder from the health sector, or will you continue to invest in the sector?
29. Is there any other financing model being adopted to fund this project (e.g., energy service companies, on-bill financing)? Who is responsible for paying the monthly charges?
30. What is the gestation period of this project/program/site?
31. How is the revenue generated for this project? What kind of revenue model has been adopted?
32. What financial and nonfinancial (social) returns do you expect out of this investment?
33. What is the time frame for returns you are looking at when making these kinds of investments?
34. Is this project being viewed from the perspective of payback of financial returns? If yes, how long will it take to break even in this project (months or years)?
35. What is the operational size/scale/capacity of the current project?

Impact in the context of climate vulnerabilities and natural calamities

36. Do you know if the vendor or implementation agency has taken any precautions to ensure the project/program/site is resilient to natural calamities or conditions?
37. What are the climate vulnerabilities or natural calamities faced by the communities and institutions living here?
38. Did you see any negative impact from climate vulnerabilities or natural calamities on project/program/site post during or after installation?
39. Did that have any impact on the financial returns from the project/program/site?
40. What is the impact of this project/program that you expect to see on the facilities or communities?

Monitoring project effects and lessons learned

41. Have you been able to monitor the developments of this project, post installation?
42. How do you assess the impact of this project/program? Are you happy with it? If not, why?
43. Do you see any changes in impacts during chronic climate events or conditions or climate-related disruptions? (Please explain.)
44. Based on your experience, have other organizations like yours expressed an interest in learning about this intervention and contributing to this or other similar interventions?
45. Do you currently have plans to scale this up or invest further with similar
    a. geographic areas
    b. implementation models
    c. implementation organizations
    d. energy solutions
46. What are the overall lessons learned for you from this investment?
47. Have you taken or do you plan to take any measures to reduce the risks of climate events or conditions in your projects or investments?
48. Are you interested in investing in similar projects in these areas or other areas?
49. In your opinion, is it better to have multiple funding partners or a single entity to finance, based on the operational size/scale/capacity of the projects?
50. Are there any barriers or challenges you faced in financing this project/program/site?
51. How did you overcome those barriers or challenges?
52. What in your experience has been the best and most successful financing mechanism for the majority of your projects?

ABBREVIATIONS

AMC	Annual maintenance contract
CHC	Community health center
C-NES	Centre for North East Studies and Policy Research
COVID-19	Coronavirus disease of 2019
CREDA	Chhattisgarh Renewable Energy Development Agency
DRE	Decentralized renewable energy
HVAC	Heating, ventilation, and air-conditioning
HWC	Health and wellness center
INR	Indian rupee
IPHS	Indian Public Health Standards
kW	kilowatt
MNRE	Ministry of New and Renewable Energy
MoHFW	Ministry of Health and Family Welfare
MWp	megawatt peak (of solar)
NHM	National Health Mission
PHC	Primary health center
SC	Subcenter
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
PPP	Public-private partnership
RHS	Rural Health Statistics
UPHC	Urban primary health center
WASH	Water, sanitation, and hygiene
WHO	World Health Organization

ENDNOTES

1. Pradhan Mantri Sahaj Bijli Har Ghar Yojana or the Saubhagya scheme was announced in 2017 to achieve universal household electrification covering every village and every district in India.

2. Energy system capacity, often measured in kilowatts (kW) or megawatts (MW), is the maximum amount of power generated through a solar energy system. This is different from human capacity or capacity building, which is related to providing supplemental support to build capacity among health facility staff through information sharing, training, and skill building.

3. Unreliable access is defined as access to some form of electricity, experiencing frequent outages lasting two hours at a stretch in the previous week (WHO et al. 2023).

4. The aspects of affordability, equitable access to energy, and sustainability and resilience of energy services are factors that define the range of energy poverty. Equitable access refers to low-income communities facing lower power quality, more interrupted power, and/or spending a larger percentage of their income on energy needs (SEforALL 2021).

5. A decentralized energy system is characterized by locating of energy production facilities closer to the site of energy consumption. A decentralized energy system allows for optimal use of renewable energy, as well as combined heat and power, and reduces fossil fuel use and increases eco-efficiency (UNESCAP n.d.).

6. The "Kayakalp" initiative was launched by the MoHFW in 2015, to complement the Swachh Bharat Abhiyan, and promote cleanliness, hygiene, and infection control practices in public healthcare facilities (Ministry of Health and Family Welfare, n.d.).

7. The Ministry of Health and Family Welfare has launched a program called LaQshya, a quality improvement initiative in labor room and maternity operation theaters, aimed at improving quality of care for mothers and newborns during intrapartum and the immediate post-partum period (NHM 2017).

8. To ensure universal access to an expanded range of CPHC services, existing SCs and PHCs are being transformed to HWCs (NHM 2021).

9. The top five companies based on actual CSR spent in India in FY 21–22 are Reliance Industries, HDFC Bank, Tata Consultancy Services, Oil and Natural Gas Corporation, and Tata Steel (CSRBOX and NGOBOX 2022).

10. The Nagaland Health Project, for example, aims to improve health services and increase their utilization by communities in targeted locations in Nagaland. Part of this project includes an investment in off-grid electricity supply solutions in health facilities. The recipient of this finance is the Ministry of Finance, whereas the implementing agency for this project is the Department of Health and Family Welfare in Nagaland (World Bank 2017).

11. Anganwadis were started as part of Integrated Child Development Services program, which provides early education, supplementary nutrition, health awareness, immunization, health checkups, and referral services in Indian villages.

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LGF, AADI, 2 Balbir Saxena
Marg, Hauz Khas,
New Delhi 110016, India
WRI-INDIA.ORG