

Energizing health: accelerating electricity access in health-care facilities



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FOREWORD

Access to electricity is fundamental to the provision of health services – from lights to illuminate a midwife’s work guiding childbirth, to enabling nurses and clinicians to correctly diagnose and respond to emergency conditions.

Yet this critical aspect of essential health care has remained almost invisible in the decades-long push to improve health service delivery and health outcomes. Among the dozens of global and national indicators used to track and monitor the performance of health services, access to electricity has been most glaringly absent from the list, at least until very recently.

This landmark report aims to change that, and give access to energy – particularly electricity – its rightful place in health services and systems planning, implementation and evaluation. Co-led by the World Health Organization, the World Bank, the International Renewable Energy Agency, and Sustainable Energy for All, this report represents the first official interagency mapping of electricity access in low- and middle-income countries worldwide – with reference to the sparse available data.

Those data reflect huge gaps in electricity access in the world’s poorest countries. In South Asia and Sub-Saharan African countries reporting on electricity, 12%-15% of facilities respectively lack any access whatsoever. Only a little more than half of hospitals in sub-Saharan countries with data report that they have reliable electricity access.

Altogether, at least one billion people globally are served by health facilities that lack reliable access to electricity. It is simply unacceptable that tens of thousands of clinics in rural areas of Asia, Africa and Latin America are equipped with little more than kerosene lanterns and rapid diagnostic tests.

This report provides a much-needed baseline for electricity access and provides insights and recommendations on how to accelerate health facility electrification while supporting the transition to clean, sustainable energy systems that improve health and climate outcomes. To that end, this report provides guidance and tools to assess energy needs and options, including renewables; financing alternatives; policy requirements; overcoming barriers; and case studies.

But we need to do much more to put this issue on the map, first by monitoring energy access in health facilities more systematically; second, by dramatically increasing investments in electrifying health care facilities; third, by providing the necessary resources to design and implement clean energy plans, tailored to the needs of the health sector; and fourth, by developing policy and finance schemes to unlock the potential of sustainable energy solutions, and to address the health sector needs.

From national health ministries to field practitioners, providing reliable, affordable and clean electricity access to all health-care facilities must be considered a development priority.

In remote field locations, the image of health care providers bent over a patient's bedside, hand-holding his or her pulse under a fading kerosene lamp – needs to be relegated once and for all to the annals of history.



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ACKNOWLEDGEMENTS

This report is the result of a joint collaboration between the World Health Organization (WHO), the World Bank, the International Renewable Energy Agency (IRENA) and Sustainable Energy for All (SEforALL).

It was developed under the overall guidance of experts from the four organizations, including Salvatore Vinci (WHO), Heather Adair-Rohani (WHO), Raluca Georgiana Golumbeanu (World Bank), Rahul Srinivasan (World Bank), Jem Porcaro (SEforALL), Luc Severi (SEforALL), Ali Yasir (IRENA), and Kamran Siddiqui (IRENA).

Technical support was provided by Duke University, World Resources Institute, University of North Carolina at Chapel Hill, and Selco Foundation.

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Valuable technical contributions to the report were also provided by staff of the following institutions: GAVI (Karan Sagar); Duke University - James E. Rogers Energy Access Project (Colin Lee, Aria Cai and Alex Baad); KTH Royal Institute of Technology (Francesco Fuso-Nerini, Babak Khavari); University of British Columbia (Erin Litzow); University of North Carolina at Chapel Hill (Emery Hoos); University of Tunis El Manar (Majdi Bahrouni); WHO (Alina Cherkas, Richard Paul Johnston, Francesco Mitis and Paul Safar); World Bank (Chris Purcell); World Resources Institute (Davida Wood, Benson Ireri, Pamli Deka, Uttara Narayan, Lily Odarno and Adugna Nemeru).

Peer reviewers

Jonathan Archimi (United Nations Institute for Training and Research), Gregor Broemling (GIZ), Ranjan Choudhury (Ministry of Health & Family Welfare, India), Ranjit Dhiman (UNICEF), Raihan Elahi (World Bank), Michael Emch (University of North Carolina at Chapel Hill), Elaine Ruth Fletcher (Health Policy Watch), Laxman Prasad Ghimire (AEPC), Gurbuz Gonul (IRENA), Harish Hande (SELCO Foundation), Terry Hart (UNICEF), Huda Jaffer (SELCO Foundation), Marc Jeuland (James E. Rogers Energy Access Project at Duke University, Sanford School of Public Policy, Duke University, Global Health Institute), Jana Koperniech (United Nations Development Programme), Magda Moner-Girona (European Commission), Margaret Montgomery (WHO), Sitra Mulepo (Ministry of Health, Uganda), Jalia Nanfuka (GAVI), Chitra Narayanswamy (IRENA), Jonathan Parr (University of North Carolina at Chapel Hill), Elisa Portale (World Bank), Megha Rathi (WHO), David Riposo (United States Agency for International Development/Power Africa), Henryk Rytter Jensen (World Bank), Michelle Seidel (UNICEF), Katie Sindelar (Clinton Health Access Initiative), Jaivardhan Singh (UNICEF), Carlo Starace (IRENA), Jeff Stottlemeyer (CLASP), Rakshya Rajyashwori Thapa (UNICEF), Gianluca Tonolo (International Energy Agency), Douglas Webb (United Nations Development Programme), Saira Zaidi (Clinton Health Access Initiative).

High-level guidance on the report production was provided by Maria Neira (WHO).

Financial support

The report development was possible thanks to the generous financial contribution from the Norway Agency for Development Cooperation, the Swedish International Development Cooperation Agency, and IRENA.

ABBREVIATIONS

AC	alternating current
AEPC	Alternative Energy Promotion Centre
Ah	ampere-hour
ARS	Arogya Raksha Samithi
CCEOP	Cold Chain Equipment Optimization Platform
CEAT	Clean Energy Access Tool
CFL	compact fluorescent lamp
CHC	community health centre
CREDA	Chhattisgarh Renewable Energy Development Agency
DC	direct current
DHIS2	District Health Information System 2
EAE	Energy Access Explorer
EHFDB	Electricity Access Health Facility Database in Africa
EmONC	Emergency Obstetric and Newborn Care
ERT	Energy for Rural Transformation
ESCO	energy service company
ESMAP	Energy Sector Management Assistance Program
GEP	Global Electrification Platform
GHO	Global Health Observatory
GIS	geographic information system
HDB	harmonized database
HeRAMS	Health Resources and Services Availability Monitoring System
HFEAR	health-care facility electricity access rate
HHFA	Harmonized Health Facility Assessment
HOMER	Hybrid Optimization Model for Multiple Energy Resources
IDCOL	Infrastructure Development Company
IRENA	International Renewable Energy Agency
kVA	kilovolt-ampere
kW	Kilowatt
kWh	kilowatt-hour
kWp	kilowatt-peak
LCHF	share of grid versus off-grid connected health-care facilities
LED	light-emitting diode

LI	low-income
Li-ion	lithium-ion
lm	Lumen
LMI	lower-middle-income
M-LED	Multi-sectoral Latent Electricity Demand Assessment
MTF	Multi-Tier Framework for Energy Access
NGO	nongovernmental organization
NPC	net present cost
O&M	operation and maintenance
PHC	primary health centre
PMA	Performance Monitoring for Action
PPP	public–private partnership
PV	photovoltaic
RISE	Regulatory Indicators for Sustainable Energy
RKS	Rogi Kalyan Samiti
RMS	remote monitoring system
S4H	Solar for Health
SARA	Service Availability and Readiness Assessment
SDD	solar direct-drive
SDG	Sustainable Development Goal
SDI	Service Delivery Indicators
SIDS	small island developing states
SM2015	Salud Mesoamérica 2015
SPA	Service Provision Assessment
SEforALL	Sustainable Energy for All
THF	total number of health-care facilities
UHC	universal health coverage
UMI	upper-middle-income
UNDP	United Nations Development Programme
UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development
WASH	water, sanitation and hygiene
WHO	World Health Organization

EXECUTIVE SUMMARY

KEY MESSAGES

Reliable electricity in health-care facilities is essential to save lives.

Electricity is critical to effective health-care provision, from managing childbirth and emergencies to immunization – without reliable electricity in all health-care facilities, universal health coverage cannot be reached.

Yet this aspect of health infrastructure is still neglected, and urgently needs more attention by all, from governments to donors and development partners, from philanthropic institutions to international organizations.

This collaborative report, based on thorough analysis, is intended to catalyse action to accelerate electricity access in health-care facilities, and highlight some key priority actions and figures, including the following.

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It is estimated that close to 1 billion people in low- and lower-middle-income countries are served by health-care facilities without reliable electricity access or with no electricity access at all.

- The assessment is based on representative findings from 27 low-income and lower-middle-income countries that have national survey data on electrification status of health-care facilities, for any year between 2015 and 2022.
- There is a sharp urban–rural divide: urban health-care facilities often report more access to any electricity and more reliable electricity access than rural facilities in the same country.

In low- and lower-middle-income countries of South Asia and sub-Saharan Africa, approximately 12% and 15% of health-care facilities, respectively, have no access to electricity whatsoever.

- At least 25 000 health-care facilities in sub-Saharan Africa have no electricity access, and 68 350 health-care facilities only have access to unreliable electricity.
- Only half of hospitals in sub-Saharan Africa have access to reliable electricity.

Reliable energy provision – particularly electricity – is a major enabler of universal health coverage. Conversely, lack of electricity and an unreliable supply of electricity are major barriers to attainment of universal health coverage.

- Electricity is needed to power the most basic services – from lighting and communications to clean water supply. Reliable power is also crucial for the medical equipment necessary to safely manage childbirth or to ensure immunization as well as for undertaking most of the routine and emergency procedures.
- Access to reliable electricity can make the difference between life and death.

Electrification of health-care facilities must be considered a development priority. Support, financing and investments must be scaled up accordingly.

Health is a human right and a public good. Increased support, financing and investments from governments, development partners, philanthropic institutions, and financing and development organizations are necessary to accelerate health-care facility electrification.

- The included World Bank analysis shows that almost two thirds (64%) of health-care facilities in 63 low- and middle-income countries require some form of urgent intervention, in the form of either a new connection or a backup power system to improve faulty energy infrastructures that impede effective health-care delivery.
- The analysis estimates approximately US\$ 4.9 billion is urgently needed to bring health-care facilities in the assessed 63 low- and middle-income countries up to a minimal or intermediate level of electrification to ensure that all the essential health services are covered.
- This required amount is much lower than the social cost of inaction.

Delaying electrification means denying access to life saving health services. There is no time - and no need - to “wait for the grid”.

- Today, a myriad of energy solutions exists to electrify health-care facilities that were not available, or were more expensive, a few years ago. For example, decentralized sustainable energy solutions based on solar photovoltaics (PV) are not only cost-effective and clean but rapidly deployable on site, without the need to wait for the arrival of the central grid.
- We have no excuse for delaying. Solutions are available and rapidly deployable. The impact on saving lives and improving health of vulnerable populations would be huge.

Powering health-care facilities through decentralized renewable energy is a concrete action to build climate resilience.

- Health-care systems and facilities are increasingly affected by the accelerating impacts of climate change. Building climate-resilient health-care systems means building facilities and services that can meet the challenges of a changing climate, such as extreme weather events, while improving environmental sustainability.
- This includes leveraging the opportunities provided by decentralized renewable energy generation – which make health-care facilities independent from the diesel supply needed for generators – and by energy efficiency, from infrastructure to medical devices.

The “install and forget” approach to electrification needs to be transformed into “install and maintain”.

- Long-term operation and maintenance of energy systems must be ensured, along with replacement of batteries and spare parts.
- The necessary funding for long-term operation and maintenance of a facility’s energy systems, including costs of battery replacement and waste management, should be an integral part of budget planning for health-care facility electrification, and dedicated funds should be allocated accordingly.
- Funding procedures and disbursement time frames of governments and development partners should be adapted to cover these long-term maintenance costs.
- Functionality of installed energy systems in the medium and long term should be monitored (including through remote monitoring), and accountability mechanisms should be put in place.

Building the capacity of local stakeholders is key to the long-term functionality of energy systems.

- Programmes should be designed to support the development of local skills and markets.
- Strengthening the technical knowledge and capacities of health sector staff at different levels increases the ability of the health sector to identify energy needs, select the best electrification options, design and implement programmes, and properly use the energy systems most appropriate for the local context and needs.
- Strengthening the capacity of local energy technicians (including in rural areas) is critical to ensuring sustainability, and providing timely operation and maintenance to guarantee continued service delivery. It also creates flow-on benefits for local communities and economies.

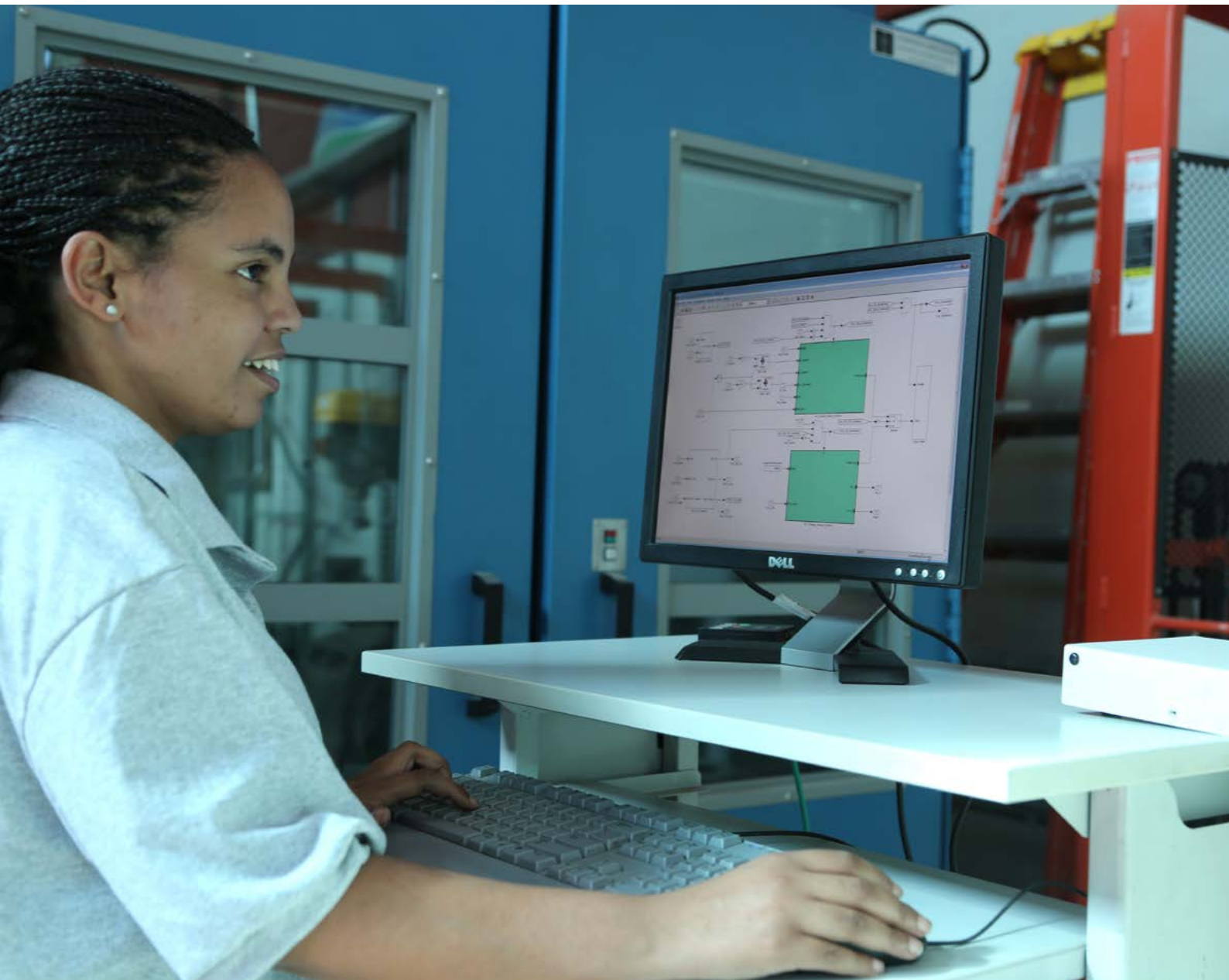
Precise and holistic health–energy needs assessments are critical for effective electrification plans.

- Comprehensive health–energy needs assessments provide a robust evaluation of the energy requirements needed to deliver quality health services. These assessments aim to provide understanding of energy needs in relation to the health services provided, the availability of trained staff and the medical equipment used at a facility type (with the identification of critical and non-critical loads).
- Online tools and geospatial data can be helpful in a pre-screening phase, but a detailed on-site health–energy audit developed in partnership with local health stakeholders is still essential for the correct design and implementation of any health-care facility electrification programme.

Electricity access initiatives need to be complemented by investments in medical devices and equipment.

- Electricity supply is only one part of the equation and can only have an impact if coordinated with other key elements, such as the provision of medical devices and training of staff.
- Health-care facility electrification programmes should coordinate with efforts focused on the provision of medical devices and appliances. This is necessary to avoid situations in which a health-care facility becomes electrified but does not have devices and appliances to use the electricity. The converse situation must also be avoided: where an unelectrified or barely electrified facility is provided with energy-intensive medical devices whose operation would be incompatible with, or would exhaust, all the available energy supply.
- In addition to the support tailored to electrification programmes, facilities may need further support to acquire new equipment and appliances. Relevant stakeholders and development partners should coordinate accordingly.
- Energy efficiency should be encouraged from infrastructure design to equipment selection. Energy efficient medical devices and appliances significantly reduce the energy demand, and therefore the size (and cost) of the decentralized energy systems to be installed.
- Medical devices and appliances need to be suitable to the specific contexts in which they will be installed. In harsh conditions, devices need to be not only energy-efficient but also resilient to factors such as high temperatures and dusty environments.

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Improved coordination is needed between relevant stakeholders at the global and local levels.

- Addressing the energy needs of health-care facilities requires better cooperation between the energy and health sectors. This should involve ministries of health and energy and other relevant stakeholders, and should happen at all levels, from strategy and planning to policies, budgeting, procurement and implementation.
- Strong collaboration between public, private and nongovernmental institutions needs to be facilitated, to leverage synergies and unlock resources.
- Donors and development partners need to increase dialogue and collaboration at country level, to maximize impact and avoid duplication of efforts.

Data collection, analysis, accessibility and sharing need to be improved.

- Data on simple, but critical, energy access indicators should be collected routinely at the national level, building on national health information systems already in place. This would dramatically help with tracking of progress and gaps.
- Countries, and bilateral and multilateral institutions should ensure that energy access questions are incorporated in health-care facility surveys, systematically and in a harmonized way.
- Development partners and other actors that collect such data need to make the data more readily and transparently available to researchers, policy-makers and other development partners, as well as the public, to avoid inefficiencies and duplication of efforts.

Political commitment, awareness and advocacy are critical to generating local action.

- Increasing awareness and advocacy for the political prioritization of health-care facility electrification will help to ensure that it is a priority in both national and subnational plans – establishing a clear mandate across a country or a region.
- Dialogue and engagement with all relevant stakeholders, from the energy and health sectors and beyond, is crucial from the national to the local level.

1

Background and context – sustainable energy at the nexus of universal health coverage

Access to affordable, reliable, sustainable and modern energy, particularly electricity, is a critical but under-recognized enabler of health services. Without access to reliable electricity in all health-care facilities, the aspiration for universal health coverage under the United Nations Sustainable Development Goal 3 simply cannot be achieved.

This report provides a comprehensive update on the status of electricity access, and proposes a way forward and guidance for:

- assessment of the energy requirements of health-care facilities;
- technical and economic considerations for electrification approaches tailored to health-care facilities;
- assessment of investments required to provide reliable electricity access to all health-care facilities;
- enabling frameworks to accelerate electrification; and
- priority actions, taking into account lessons learned and analysis of country-level case studies.

The report concludes by identifying suggested way forward and key actions for governments, development partners and other stakeholders, articulated in terms of data, system planning and programme implementation.

Electricity access as an enabler of health services and better health outcomes

Electricity is required for operation and use of a wide variety of vital medical equipment and appliances. Electricity plays a crucial role in availability and reliability of essential health services, as well as better health outcomes, including safe childbirth and newborn care, prenatal and antenatal care, childhood vaccinations, diagnostic capacity, and emergency response.

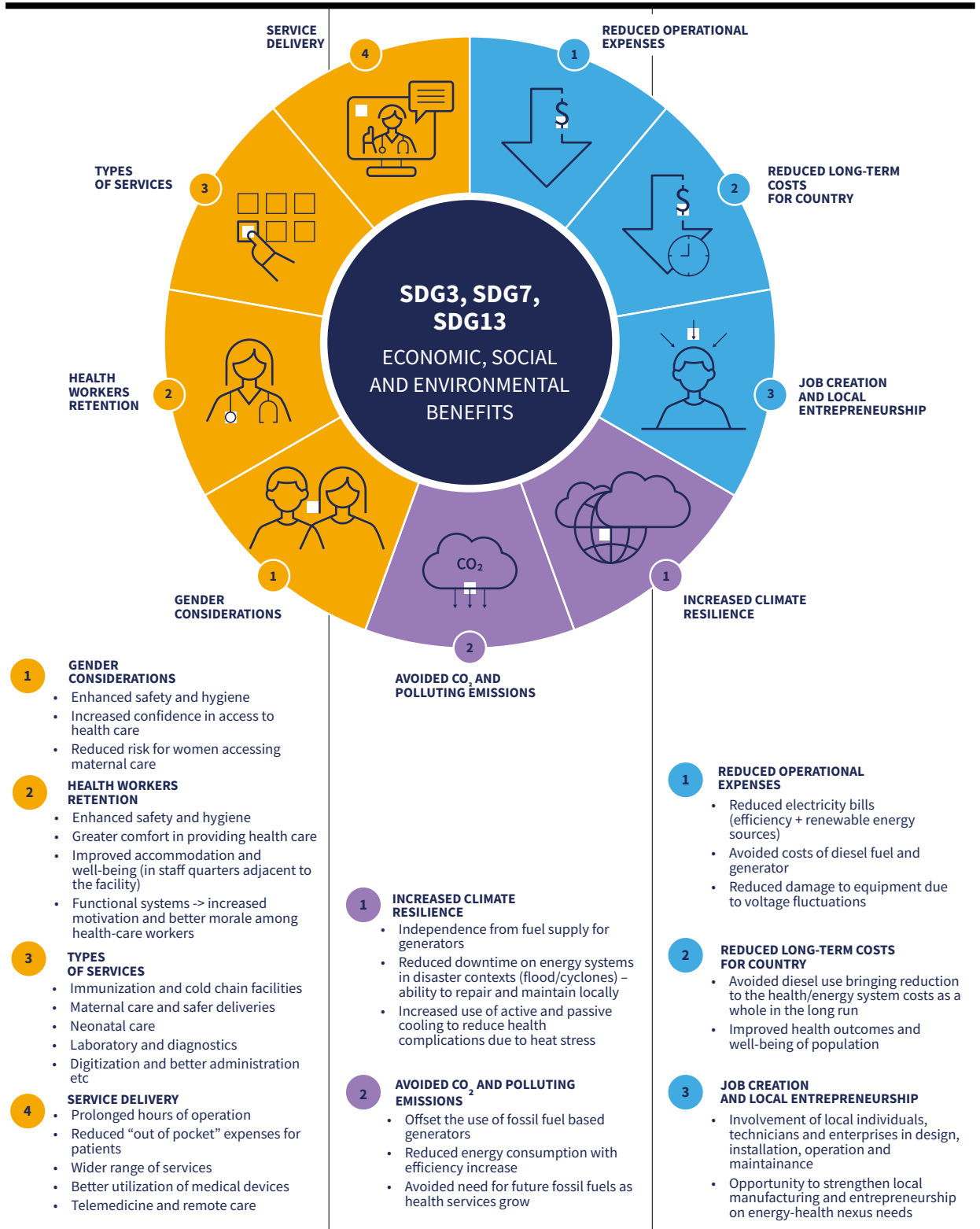
When health-care facilities have sufficient and reliable electricity, women can more safely give birth at night and during emergencies, medical equipment can be powered and better sterilized, and clinics can safely store life-saving vaccines and medicines for newborns, children and adults. Electricity is also important for supply of clean and hot water, communication, lighting and other basic amenities. Access to reliable electricity in health-care facilities can make the difference between life and death.

Role of sustainable energy in the health–energy nexus

Health-care facilities that serve the poorest and most underserved populations have the highest levels of energy poverty. Providing reliable, affordable and sustainable energy to these facilities is essential to protect the most vulnerable populations.

As well as ensuring that people are provided with health services, access to sustainable energy by all health-care facilities, including those in rural and remote areas, contributes to achieving multiple social, economic and environmental benefits, such as increased sense of security of staff and patients, and easier health worker recruitment and retention. Decentralized sustainable energy systems save costs of fuel for generators, as well as of often expensive grid-supplied electricity. They reduce the harmful pollution from on-site diesel generation in health-care facilities, leading to wider community health benefits. Reliable electricity also reduces the damage to medical devices caused by low-quality electricity supply.

Fig. 1. Sustainable energy and health nexus



Decentralized electrification to expand access and increase climate resilience

In many rural and remote areas of the world, grid extensions are both costly and technically difficult. Today, with falling costs of renewable energy technologies, myriad solutions exist that were not available, or were more expensive, a decade ago. For example, decentralized renewable energy systems based on solar PV panels and batteries are often the most cost-effective and readily deployable solution for electrification of health-care facilities not reached by the central grid.

Decentralized renewable energy systems can also play a key role in providing backup or supplementary electricity in grid-connected health-care facilities where the electricity supply is unreliable or too expensive.

Energy systems based on decentralized and sustainable energy sources, being independent from the diesel supply chain, increase the climate resilience of health-care facilities, and make them less vulnerable to the impacts of climate change, including extreme weather events. Furthermore, they reduce air pollution and deliver climate mitigation benefits, creating a pathway to a low-carbon future. Sustainability and climate change impacts should therefore be central to efforts to close the energy gaps in health-care facilities across the world.

Convergence between health and energy sectors

Health and energy actors have often worked in silos. Increased collaboration is needed to leverage synergies and maximize impact. A more integrated approach, and a comprehensive process to assess, design, implement and manage energy solutions for health care is necessary. This requires both health and energy stakeholders to contribute to a more nuanced understanding of the needs, working more closely together to bridge knowledge and skill gaps, and to identify and implement joint solutions. Increased cooperation is needed at all governance levels, from national ministries to local stakeholders, and in all phases, from strategy and planning to policies, budgeting, procurement and implementation.

2

Status of electricity access in health-care facilities

Overview

This report undertakes a systematic stocktake of available national survey data on electricity access in health-care facilities to produce comparable cross-country and cross-regional estimates of electricity access and reliability at health-care facilities in underserved areas around the world.

The data were extracted from available national health-care facility surveys, including by the World Health Organization (WHO) (Service Availability and Readiness Assessment – SARA), the World Bank (Service Delivery Indicators – SDI) and the United States Agency for International Development (Service Provision Assessment – SPA). Available data were collected for low-income and lower-middle-income countries worldwide (based on the World Bank income group classification in 2022).

As a key outcome of this report, WHO established a database on electricity access in health-care facilities on its Global Health Observatory. The data and methods described here can inform and guide countries in similar assessments, as a first step towards understanding and addressing electricity gaps.

Indicators

The indicators used were access to any form electricity; reliable access to electricity; and primary source, operationality and uses of electricity. Data were mapped and analysed with reference to a standard set of indicators for electricity access in health-care facilities disaggregated by health-care facility type (hospitals versus non-hospital facilities) and geographic location (urban versus rural), when available.

In the case of the first two indicators, national survey data on access to any form of electricity and reliability were used to benchmark electricity access at national and regional levels, based on 27 countries with available data. For other indicators, there were insufficient data to draw regional conclusions. A closer look based on selected country examples is provided for indicative insights.

Key figures

The proportion of health-care facilities lacking any access or reliable access to electricity was determined as follows.

- **Access to any electricity:** 12% of health-care facilities in the low- and lower-middle-income countries of South Asia, and 15% of facilities in the low- and lower-middle-income countries of sub-Saharan Africa lacked any access to electricity whatsoever. Health-care facilities in the Latin American and the Caribbean region fared somewhat better, reporting 8% of facilities with no electricity access.
- **Access to reliable electricity supply:** In the low- and lower-middle-income countries of the sub-Saharan Africa region, only 40% of facilities had reliable electricity, and in the Latin America and the Caribbean region, an average of 72% of facilities had reliable electricity. In other regions, data were insufficient to make average estimations.

Fig. 2. Percentage of health-care facilities reporting no access to any electricity in national surveys, 2015–2022

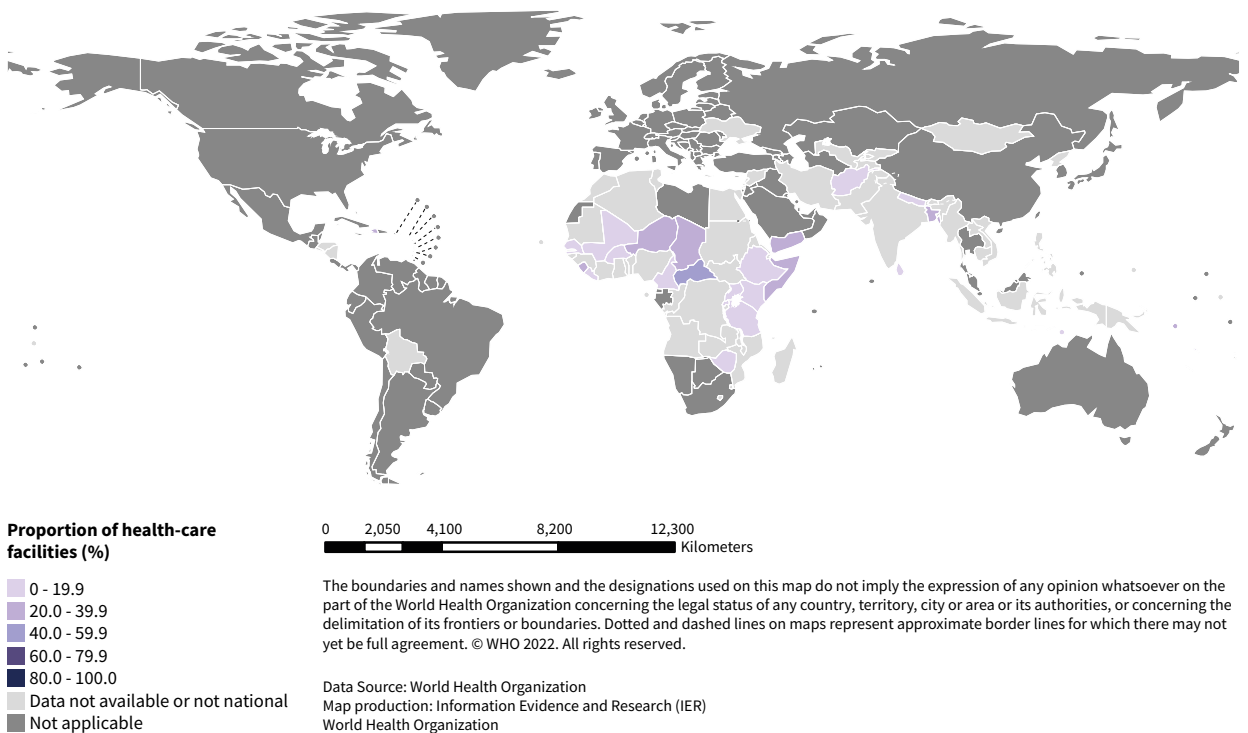
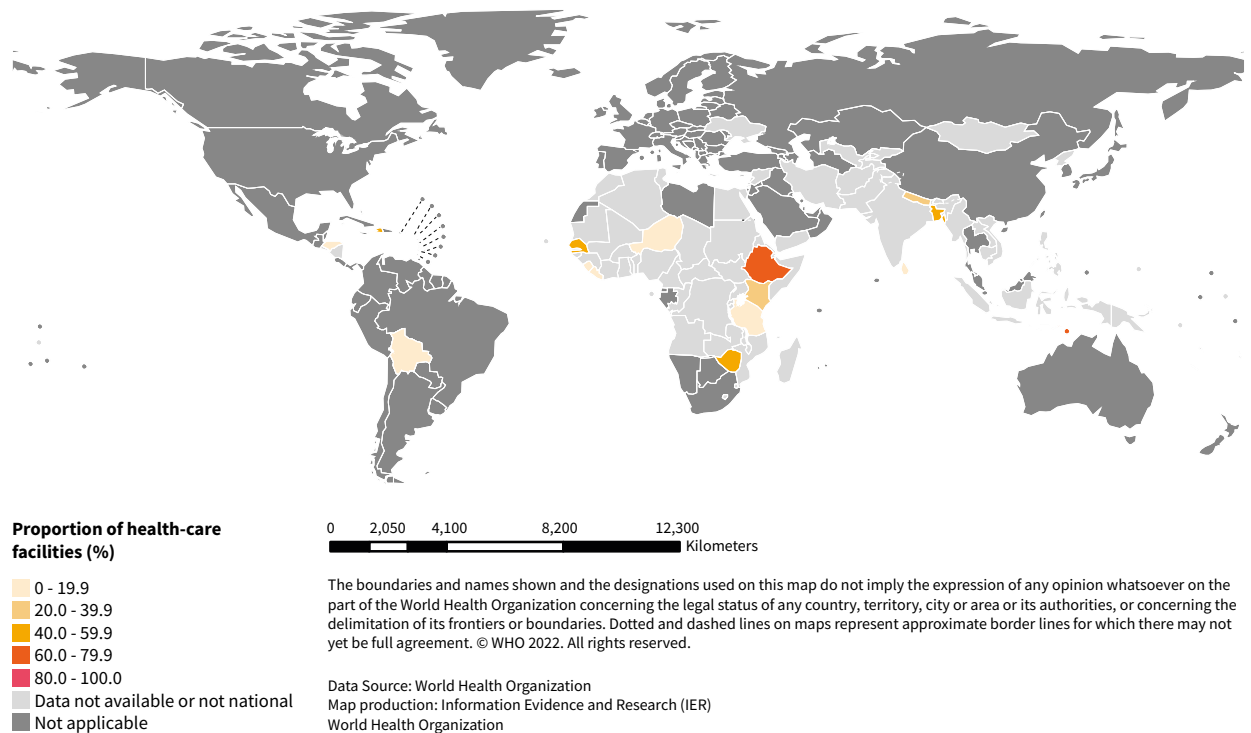


Fig. 3. Percentage of health-care facilities reporting unreliable electricity in national surveys, 2015–2022



Among the estimated 166 720 health-care facilities situated across the 41 low- and lower-middle-income countries of sub-Saharan Africa, this report estimates that at least 25 000 health-care facilities lack any electricity access, and at least 68 350 health-care facilities lack reliable electricity, illustrating the high level of energy insecurity in health-care facilities of this region.

Similar inequities are evident when looking at access by countries' income levels, facility type and geography. Rates of reliable electricity access are lower in health-care facilities of low-income countries than in lower-middle-income countries. Non-hospital health-care facilities, such as primary health centres, tend to fare worse than hospitals in access to any electricity supply or reliable electricity supply. Additionally, there is an urban–rural divide. Urban health-care facilities often report greater access to any electricity and reliable electricity than rural facilities in the same country.

A more global snapshot of the population served by health-care facilities lacking electricity access

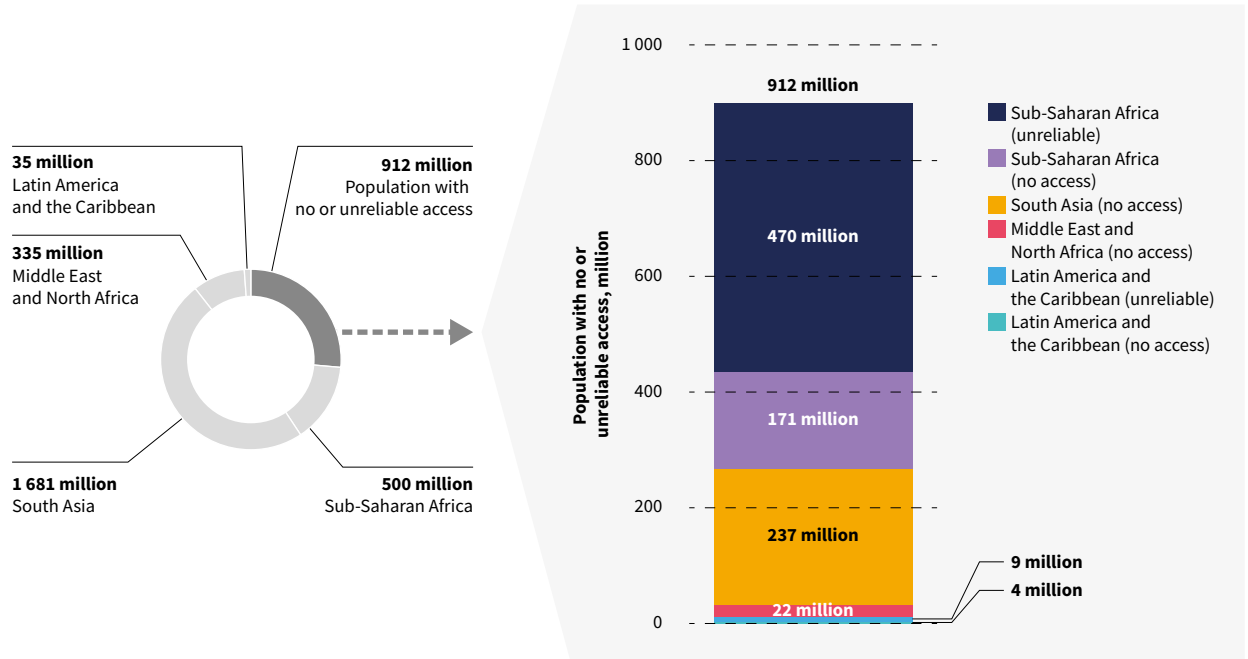
Weighted by 2022 population figures, across the Latin America and the Caribbean, Middle East and North Africa, South Asia, and sub-Saharan Africa regions where data on energy access in health-care facilities are available and sufficient, the population in these regions served by hospitals and clinics lacking adequate energy services was estimated as follows.

- 433 million people rely on facilities without any electricity.
- 478 million people are served by facilities lacking a reliable supply of electricity.

At least 912 million people across these four regions are served by facilities with no electricity access or with unreliable supply of electricity (Fig. 4).

This is approximately the size of the entire populations of the United States of America, Indonesia, Pakistan and Germany combined. Globally, the lack of any electricity and of reliable electricity in health-care facilities is likely to be even greater, considering that the estimates presented here focus on countries representing only three quarters of the population living in low- and lower-middle-income countries.

Fig. 4. Estimated population served by health-care facilities with no electricity access or with unreliable electricity, disaggregated by region



A closer look at energy access

Data on the availability of any access and reliable access to electricity provide a basic snapshot of the energy access situation in a country’s health-care settings. However, this fails to give policy-makers much insight into the primary source of electricity, the operability of the systems, the uses of the electricity supply, and other key indicators useful for policy and programmatic decision-making.

In subsets of countries, more detailed information on such indicators was available (e.g. primary source of electricity, adequacy of supply). A closer look at these indicators provides more nuanced insights into what works and what does not in terms of health-care facility electrification for quality health service delivery. For example, the data show that generators are often not operational, and that facilities are often underserved, with energy supply being insufficient to cover all the needs of the facility.

Improving data collection, processing and accessibility is a key challenge to overcoming gaps.

Although a basic set of health service indicators are routinely reported on at national and global levels, energy (and electricity) access is a notable exception. Data on access are not routinely collected at a national level. Even the widely used questionnaires such as the SPA, SARA and SDI surveys differ in how (and whether) they collect certain electrification data.

There is an urgent need to standardize data collection using harmonized indicators and methodologies that reflect current trends and needs, and provide georeferenced data where feasible. It is also essential to increase resources and support for collecting and analysing data to properly assess the situation and track progress.

Public access to data and metadata on health-care facility electrification should be ensured.

There are critical challenges in accessing health-care facility data sources, including a lack of clear mechanisms for making data requests and an often complex bureaucracy associated with soliciting microdata – and even summary reports – from responsible agencies.

Future efforts to gather data to facilitate planning and prioritization would benefit from the establishment of publicly accessible online platforms, including by multilateral institutions collecting electrification data, allowing survey data to be obtained by researchers upon request.

The entities that hold health-care facility data may not always have the resources to compile an entire programme website to make data publicly accessible. Solutions such as the WHO Global Health Observatory or the World Bank Microdata Catalog can help by providing a centralized infrastructure for housing and providing public access to data.

A more holistic approach to health-care facility infrastructure services is needed.

The paucity of energy and WASH (water, sanitation and hygiene) services in health-care facilities of low- and lower-middle-income countries highlights the need to prioritize basic infrastructure on the pathway to universal health coverage. Furthermore, programmatic synergies and efficiencies will occur with a more holistic approach to building a coordinated tracking framework and monitoring progress in health-care facility infrastructure for water, sanitation and energy together.

A coordinated effort is needed to advance a framework to measure uniformly and fully the diverse dimensions of energy access in health-care facilities.

Key institutions managing facility surveys, as well as ministries of health, ministries of energy and related actors, need to work together to identify and harmonize the most suitable electricity access indicators, survey questions and methodologies relevant to delivery of health services and health outcomes. Such a framework could contribute to the development of more comprehensive, routine, global energy assessments of health-care facilities by national ministries, as well as by multilateral organizations and other development partners in the health and energy sectors, to support joint monitoring and reporting of energy access in health-care facilities.

3

Assessing energy needs of health-care facilities – technical guidance and tools

Chapter 3 provides insights on how facility administrators, planners and other stakeholders can estimate the electricity and overall energy requirements of health-care facilities. The chapter also examines energy load considerations, and provides guidance for conducting a health–energy needs assessments as well as references to key technical standards and tools.

Determinants of energy requirements

Energy needs span a wide range, including medical equipment, lighting, information technology and communications, refrigerators for vaccines and medicines preservation, supply of clean and hot water, ventilation, cooking, sterilization and, depending on the setting, space heating and cooling. For maternal and newborn care, for example, a suite of life-saving, essential devices require electricity, including fetal heart monitors and ultrasounds, baby warmers, oxygen concentrators, suction units and phototherapy. From emergencies to internal medicine, almost every area of care has unique energy requirements. Other factors include the following.

- ***Facility type and population served.*** Needs vary widely by the type or tier of health facility (e.g. health post, clinic, hospital); demands are much higher for higher-tier facilities. Within the same tier, the energy requirements of a facility can be influenced by multiple factors, such as the sociodemographic profile (in terms of the population it caters for) and the diseases prevailing in the served community.

- **Load variability and operational hours.** In many clinics, the electricity load may vary widely depending on the time of day and the season, and the combination of demands that might be imposed at any one time (e.g. during a childbirth emergency). Other important aspects include the load characterization (critical/priority devices and non-critical ones), the time of use of high-power demand appliances (with opportunities for load shifting/shaving), and assessment of potential future load growth.

Conducting a health–energy needs assessment

Health-care facilities, even within the same tier of a public health system, vary in the type and amount of daily health services they deliver. This variation could be a function of the demand in the region, accessibility, affordability, and availability of doctors and other staff, among other factors. As a result, a “one size fits all” approach to determining the energy requirements of a health-care facility and installing a standardized energy system would fail to note nuances in equipment efficiency, equipment use or special needs reflecting the health conditions in different regions.

Energy assessment for health-care facilities should integrate health and energy needs simultaneously for better design, local sense of ownership and use. This includes aspects from the health side (i.e. health services and facility profile), the nexus between health and energy (i.e. infrastructure, equipment, accessibility and environment) and the energy side (i.e. energy scenario, related impacts and systems). Benefits of an integrated health-energy assessment will accrue to patients, who will gain both increased access to health services and improved quality of services, and to facility managers and staff, who will experience improved well-being and productivity, as well as reduced equipment damage and financial savings.

Since energy is only one part of the equation, a combined health–energy needs assessment can also help identify other critical and related needs, such as the need for additional staff or for appropriate equipment. A basic energy assessment focusing only on the existing energy situation would not provide these insights, which are critical in improving health-care delivery on the ground.

A variety of tools and methodologies exist to help planners characterize the health–energy needs of a facility through bottom-up assessments. Chapter 3 describes basic features to consider, while Chapter 4 includes more details about available online tools.

Toolkits for health–energy needs assessments may include checklists for interviews with staff at the health-care facility; collection of data on health-care appliances, and their power consumption and usage patterns using energy meters, data loggers and registers; observations about built environment structures; and assessments to enable design of energy systems.

Seasonal variations that affect basic services such as lighting and space heating or cooling need to be considered, as well as seasonally variable disease burdens such as a high growth in malaria cases at the onset of the rainy season in some countries. Reliability of the energy supply can also vary daily, seasonally and from year to year – for instance, due to changes in grid power reliability, generation capacity of hydropower due to climate change, and the variability of solar or wind power.

Geospatial data can help planners by combining facility-level information with satellite imagery showing demographic data and existing power infrastructure, to build representative demand estimates at both facility and community levels. Geospatial tools allow data to be scaled up from current facility-level surveys to estimate ranges of requirements for unserved and underserved health-care facilities of similar type, size, location and catchment population. The estimated electricity requirements can then be inputs to least-cost electrification modelling tools to ensure

that health-care facility needs are fully considered in estimates of optimal supply configurations and investment needs for the community as a whole. Although geospatial data and related models can provide important support, the energy needs evaluation must always include an on-the-ground health–energy assessment at the facility level.

Assessing the power requirements of medical devices

The steps involved in assessing power demand include listing all medical equipment required in the facility, the estimated hours of operation (including which hours or periods of the day the equipment would be powered, which is necessary for estimating peak load), and the critical nature of certain equipment that always needs to be powered.

Power requirements should also be assessed to identify critical and non-critical loads; critical loads require greater reliability and availability of the service. For example, fans, mobile charging points, laptops and printers are considered as non-critical and consumptive loads, whereas baby warmers, oxygen concentrators and refrigerators are considered as critical loads. Usage patterns of one should not disrupt the functioning of the other. For example, overuse of lights and fans (non-critical loads) should not drain the power required for refrigerators and baby warmers (critical loads) when required. These aspects should be considered in the electricity system design of the facility.

Key role of energy efficiency

Energy efficiency in medical devices and appliances needs to be encouraged at a wider scale and a more rapid time frame, to truly take advantage of the opportunities that different power solutions can bring to health service delivery. Studies focusing on several types of commonly used medical equipment in health-care facilities and their energy-efficient alternatives found that energy savings of nearly 55% in blood bank refrigerators, 53% in baby warmers and 75% in oxygen concentrators could be made by switching to available energy-efficient medical appliances. These energy savings directly translate to reduced energy bills from lower energy consumption, as well as a considerable reduction in the size of the decentralized energy system (e.g. solar panels, batteries, inverters) needed to power health-care facilities.

Suitability of medical devices for harsh conditions

A major challenge for health-care facilities in resource-constrained settings is a lack of appropriately sized and designed medical equipment for health service delivery. Manufacturers of medical equipment typically focus on safety and reliability, and take for granted that a consistent, reliable electricity supply is guaranteed. Very few medical devices are suitable for performance in settings with harsh conditions (e.g. hot and/or humid climate, dusty environment) or intermittent power supply. In 2010, WHO highlighted that over 50% of the medical equipment in low-income countries was not functioning, not used correctly or not maintained, with some being entirely unnecessary or inappropriate to fulfil its intended purpose. Nearly a third of failures of medical devices globally was estimated to be caused by unreliable electricity supply. Furthermore, in sub-Saharan Africa, almost 70% of equipment was found to lie idle due to mismanagement of the acquisition process, absence of user training and lack of effective technical support.

Procurement guidelines should encourage the purchase of medical equipment suitable for the specific conditions where it will be used. At the same time, innovation in medical devices is needed to support the development of devices that are suitable for use in harsh conditions and rural settings.

4

Techno-economic considerations for electrification of health-care facilities

Chapter 4 documents key technical and economic aspects of the electrification options for health-care facilities, including grid extension, mini-grid and stand-alone on-site solutions.

The chapter builds on the insights from Chapter 3 on analysis of energy requirements, and highlights how these insights play a key role on the choice of the electrification solutions for different contexts and needs.

Key energy supply options

After evaluating the overall electricity demand – and the demand for uninterruptible and reliable power supplies for critical services – planners should weigh alternative least-cost technology solutions that could be used to provide power for delivering quality health services.

The right energy system configuration for a given health-care facility depends on a combination of **techno-economic factors**, including:

- site characteristics;
- size and characteristics of the electrical load;
- local availability of energy resources;
- environmental and climate factors;
- affordability and financial resources;
- public policies and incentives; and
- financing sources.

Centralized grid extension has served as the main electrification approach for decades. If grid electricity is available, a grid connection is typically the most logical primary source of power. However, in several low-income countries, grid extension is often slow. This is particularly the case for rural and remote regions due to the distance between the user and the existing grid, challenging local terrain for infrastructure expansion, and a low population density and size of the load to be served, including other nearby loads. Furthermore, grid power interruptions and irregularities in voltage and frequency have a dramatic impact on the health services available and can damage sensitive medical equipment, especially if the equipment is not engineered to operate in harsh environments.

Decentralized sustainable energy solutions are often the most technically and economically viable solution to provide reliable energy to health-care facilities that are in remote locations not connected to the central grid, or that are supplied by unreliable and expensive energy sources. In facilities that are not connected to the central grid, off-grid solutions (stand-alone systems or mini-grids) based on sustainable energy can be deployed in a timely manner. Decentralized sustainable energy solutions can also be installed in grid-connected facilities as backup options, to ensure reliability, adequacy and affordability of electricity supply.

Mini-grids are a form of decentralized generation and distribution that provides power to several users and buildings in one or more local communities. They use electricity produced from on-site generators using fossil fuels, renewable energy or a combination of the two. Mini-grids require significant high upfront infrastructure investment (unlike stand-alone solar systems), which is usually recovered through high rates of use and regular tariff collection over several years. Policies and regulatory frameworks (e.g. legal and licensing provisions, cost recovery, tariff regulation) play a critical role in influencing (or delaying) mini-grid implementation.

A **stand-alone solar PV based system** is a decentralized solution based on solar panels not connected to the central grid or a mini-grid. The energy generated is used to power the appliances of a facility and to charge a battery bank used for energy storage. The average price of solar PV modules declined by as much as 93% between 2010 and 2020. In the long run, stand-alone solar-based systems are more competitive than fuel-based generators, and are more resilient because they are independent from the fuel supply chain (e.g. diesel). A stand-alone solar PV system is a versatile, modular system that can be customized to meet specific electricity demand.

Although solar PV-based systems have been the most common form of decentralized renewable energy generation in rural areas, other forms of renewable energy sources have played – and will continue to play – a key role in some locations, such as small (run-of-river) hydro, wind and biomass-based systems.

Fuel-based generators, using diesel or other fuels, remain a widespread backup solution for many hospitals and health-care facilities across the world. They are available in a wide range of sizes, from portable to large stationary systems. Along with their reliance on fossil fuels, generators emit considerable pollution, which can be damaging to health, as well as noise. Despite a lower upfront cost, portable generators are typically more expensive in the long run than solar systems, as a result of continued fuel and maintenance costs – for which a stable supply chain of fuel and spare parts is necessary. **“Hybrid” solutions** – generators paired with other solutions – are often used to provide a more reliable backup burst of power.

Batteries form an integral part of decentralized (both stand-alone and mini-grids) energy systems, which provide continuous and reliable electricity to health-care facilities in off-grid settings. Batteries are often also used in grid-connected facilities with frequent power outages, to store electricity for use when the grid is down.

The most common battery storage technologies are lead-acid and lithium-ion batteries. Batteries require regular operation and maintenance, including cleaning and topping up with distilled water (in the case of certain types of lead-acid batteries). Disposal of batteries is a growing environmental concern; discarded lead-acid batteries pose a particular risk to the environment and health if their disposal is not properly managed. Funding needs to be secured for battery maintenance, replacement, recycling and disposal. Accordingly, local capacity must be built to operate and maintain batteries to achieve long-term operational sustainability.

Building climate-resilient health-care infrastructure

Climate change and the need to strengthen the health system against its impacts mean that planners should incorporate principles of resilience into health system planning. The increased frequency and intensity of extreme events (e.g. floods) associated with climate change can disrupt the existing electricity supply, leading to the need for alternative or backup electricity sources. Health-care facilities are not necessarily designed to withstand physical climate risks, which can include droughts, floods, lightning, extreme temperatures and wildfires. In addition, unpredictability of water supply and water scarcity can affect the availability of water for drinking, washing, sanitation and hygiene.

Designing solutions that are climate-resilient and sufficiently flexible to adapt to evolving risks is important for all facilities. In this context, decentralized renewable energy solutions represent a key opportunity to guarantee the energy supply. Decentralized renewable energy solutions, unlike diesel-based generators, also allow health-care facilities to avoid the risk of disruption to the fuel supply and of fuel price variability. Reliability of electricity supply is key, particularly for the operation of sensitive medical equipment in areas that are remote and vulnerable to extreme weather events or other climate-related physical risks. This also implies the need for appropriately designed medical equipment that is energy-efficient, requires low maintenance and is robust to the harsh conditions

(e.g. dust, heat) found in many areas. Adoption of technical standards, government incentives and regulatory policies are needed to support the increase of climate resilience in the health sector.

Design and costs of solar systems for decentralized health-care facility electrification

A wide range of issues need to be considered in the design of a decentralized solar system for a health-care facility, including:

- sunshine hours/peak sun hours, which will vary between locations and climatic conditions;
- days of autonomy (the number of days the load can operate from the energy stored in the batteries without any charging from the sun);
- battery charge and discharge capacity;
- equipment load requirements and load profile throughout the facility's operating hours, including load peaks that could be shifted with manual or automatic demand-side management; and
- equipment efficiency, which can significantly change the sizing of PV panels and battery capacity of a decentralized solar energy system.

The costs of procuring, installing and maintaining decentralized solar systems vary from country to country, depending on several factors. Examples of costs associated with solar energy systems in health-care facilities are shown in Table 1.

Table 1. Examples of costs associated with solar energy systems

Capital costs	Operating costs	Soft costs
Supply of solar equipment	Operation and maintenance	Health-energy assessments
Installation costs	Battery replacement costs	Stakeholder engagement and meetings
Transport of materials to site	Remote monitoring	

A wide range of other factors also shape the investment and running costs of the system. They include decisions made about ownership of the system (e.g. health-care facility, energy provider), and the manner in which operation and maintenance costs are integrated into the long-term plan. Long-term operation and maintenance, as well as replacement of batteries, play a key role in the sustainability of electrification programmes, and adequate funding must be considered from the design phase. Advantages and challenges of different technology, ownership and financing models are described in detail in the chapter.

Tools for planning and system design

Geospatial data and technology can narrow the existing data gap in electricity access in health-care facilities – for example, by allowing estimation of ranges of electricity requirements for unserved and underserved facilities. Demand estimates can be made by combining available facility-level information (e.g. facility type, health services provided, ownership of equipment, population served, number of beds) with satellite imagery and geospatial data on demographics (e.g. population density, catchment population), facility location, disease rates, weather and climate patterns, and power infrastructure (grid and off-grid). Geospatial data and tools can be useful for initial valuation, screening and planning, however, they can provide only a partial view of the situation, and need to be complemented and verified through proper on-site assessments before moving forward with design and implementation. Geospatial tools and methodologies that relate to health electrification and are open source include the Global Electrification Platform (GEP), the Energy Access Explorer (EAE), the Multi-sectoral Latent Electricity Demand Assessment (M-LED) and the Clean Energy Access Tool (CEAT).

Online tools can also be useful for an initial estimate of costs and system sizing. An example is the HOMER Powering Health Tool. This tool combines energy demand data related to specific equipment with combinations of power supply, and helps calculate the lowest cost per unit of electricity generated over a project lifetime.



Solar system design for different facility types and tiers

Each country has a different way of organizing its public health system, depending on its needs, resources and historical context. From village-level clinics to specialty hospitals, the tiers of the public health infrastructure typically include first points of care, primary care facilities, first referral units, secondary care facilities and higher-level tertiary care hospitals. The health services delivered at each of these tiers, combined with the operational hours and the size of the populations that use their services, determine the facility's energy requirements.

Indicative loads and design for stand-alone solar PV systems for different tiers of health-care facilities are included in the chapter. For each tier, an indicative system design is mentioned for low-sunshine (3 hours per day) and high-sunshine (5 hours per day) scenarios, along with a comparison of powering traditional equipment (based on an estimated demand) versus powering efficient equipment (based on an estimated demand). These comparisons show that using efficient equipment significantly reduces the required capacity of solar panels, batteries and inverters, and therefore dramatically reduces the cost of the overall energy system.

As an example, Table 2 illustrates loads and solar PV system design for a possible primary health-care facility, which is usually the cornerstone of rural health services – a first port of call to a qualified doctor of the public sector in rural areas for the sick, and those who directly report or are referred from first points of care for curative, preventive and promotive health care.

Table 2. Examples of loads for a possible primary health-care facility

Type of room	Examples of loads
OFFICE	Lights, fans, laptop, printer
REGISTRATION	Lights, fans, laptop, printer
LABOUR ROOM	Lights, fans, phototherapy, radiant warmer, suction machine, spotlight, phototherapy
MEN'S AND WOMEN'S WARDS	Lights, fans
NURSES ROOM	Lights, fans
LABORATORY	Lights, fans, microscope, centrifuge
MINOR OPERATING THEATRE	Lights, fans, nebulizer, needle cutter
OUTPATIENT DEPARTMENT	Lights, fans
COLD CHAIN ROOM AND PHARMACY	Lights, fans
IMMUNIZATION ROOM	Lights, fans
DRESSING ROOM	Lights, fans
COLD CHAIN EQUIPMENT IN COLD CHAIN ROOM, PHARMACY, IMMUNIZATION ROOMS	Cold chain room and pharmacy – ice-lined refrigerator, deep freezer Immunization – refrigerator
EMERGENCY ROOM	Lights, fans, mobile light, oxygen concentrator, ECG machine
STOREROOM	Lights
WAITING AREA	Lights, fans
WASHROOM/BATHROOM/TOILET	Lights
ENTRANCE	Lights
CORRIDOR	Lights, fans

Table 3. Example of solar PV-based system design for a possible primary health-care facility

Parameters	Powering traditional equipment		Powering efficient equipment	
	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Maximum load that can be connected	7 870 W		4 620 W	
Maximum units that can be used per day	18.4 kWh		10 kWh	
Peak sun hours per day	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Solar system capacity required	10.11 kW	6.6 kW	6 kW	3.6 kW
Battery capacity	6 100 Ah 12V	6 100 Ah 12 V	3 300 Ah 12V	3 300 Ah 12V
Inverter capacity equivalent to	20 kVA	12.5 kVA	7.5 kVA	7.5 kVA

Chapter 5 presents World Bank estimates of the investment required to improve the electrification status of health-care facilities in 63 low- and middle-income countries. The countries included in this analysis were selected based on data availability, and compatibility between the stocktaking exercise presented in Chapter 2 and an analysis undertaken by the World Bank as part of the Global Electrification Platform (GEP) initiative.

While Chapter 2 assessed the current national electricity access situation of health-care facilities based on recent (2015–2022) national survey data from 27 low- and lower-middle-income countries, Chapter 5 estimates the total monetary cost required to improve the electrification status via new connections and/or backup systems for 63 low- and middle-income countries.

This investment analysis is not exhaustive, but rather provides high-level estimates based on a series of assumptions that may differ between countries and between health-care facilities.

Summary of methods

To assess the level of investment required to improve the electrification status of health-care facilities in each country, data were gathered for both hospital and non-hospital facilities from an array of resources, mainly the World Bank GEP database,¹ on four key parameters: total number of health-care facilities, health-care facility electricity access rate, proportion of facilities experiencing frequent interruption, and proportion of grid versus off-grid electrified facilities.

The GEP database contains information related to the least-cost electrification option for millions of unserved settlements in the developing world. Based on these parameters, the required level of intervention per country was estimated. Two levels of intervention were defined:

- new connection – installation of a new electricity connection for health-care facilities that do not have any access to electricity; and
- backup system – installation of a backup system in health-care facilities with access to grid electricity with low reliability of supply (frequent outages or interruptions).

After identifying the level of intervention required for each country, this information was paired with additional data to derive the total number of new connections for grid and off-grid powered systems in each country and the total number of health-care facilities that require an additional off-grid backup system.

Proxy technology costs for each country were calculated, with reference to the assessed needs at different tiers of health-care facility. These proxy costs are based on:

- the average cost per kW of grid connection; and
- the average net present cost per kW of off-grid PV–battery–diesel connection (hybrid array).

The estimated daily electricity requirements were assumed as 500 kWh/day for hospitals and 15 kWh/day for non-hospitals.

1 For five of the 63 countries considered – for which GEP results were not available – these proxies were estimated based on regional averages from the GEP database. These countries were Afghanistan, Nepal, Sri Lanka and India (South Asia region), and Viet Nam (East Asia and Pacific region).

The load factor was set at 21% for referral-level facilities, 15% for primary-level facilities and 16% for community-level facilities. However, different types of health-care facilities might be subject to different load factors depending on their equipment, services and operation status.

The backup to peak load ratio was set at 50%.

Results – quantifying investments for electrification of health-care facilities

The total net present cost of electrifying health-care facilities in 63 low- and middle-income countries is estimated as about US\$ 4.9 billion. Regionally, the costs break down as shown in Table 4.

Table 4. Investment requirements for electrification of the 459 206 health-care facilities in 63 countries, by region, type and intervention level required

Region	Type	New connections CAPEX – grid (million US\$)	New connections CAPEX – off-grid (million US\$)	New connections OPEX – off-grid (million US\$)	Backup system CAPEX – off-grid (million US\$)	Backup system OPEX – off-grid (million US\$)	Total NPC (million US\$)	
							BY TYPE	TOTAL
LAC	Hospital	2.7	–	–	13.8	8.0	24.6	33.3
	Non-hospital	1.5	1.2	0.1	3.9	2.0	8.7	
SAR	Hospital	46.9	–	–	89.5	60.0	196.5	1 961.3
	Non-hospital	277.9	32.6	17.4	928.0	508.9	1 764.8	
EAP	Hospital	47.2	16.5	7.7	113.6	55.4	240.4	374.8
	Non-hospital	28.7	20.7	2.6	56.7	25.8	134.4	
SSA	Hospital	327.5	44.3	2.5	530.6	40.6	945.4	2 537.4
	Non-hospital	812.2	360.7	29.2	349.4	40.5	1 592.0	
Total	–	1 544.7	475.9	59.5	2 085.5	741.2	4 906.8	

Note: Estimates are in US\$ for 2022.

CAPEX: capital expenditure; EAP: East Asia and Pacific region; LAC: Latin America and the Caribbean region; NPC: net present costs; OPEX: operating expenditure; SAR: South Asia region; SSA: Sub-Saharan Africa region.

In terms of infrastructure outlays, the cost breakdown estimate is:

- US\$ 2.8 billion for supporting the deployment of backup off-grid generation in already connected health-care facilities; and
- US\$ 2.1 billion for new connections, comprising about \$1.5 billion for new grid-based connections and about \$476 million for off-grid-based new connections.

About 64% of the health-care facilities in 63 low- and middle-income countries require an intervention – in the form of either a new connection or a backup power system. In absolute terms, this amounts to 100 926 facilities requiring a new connection and 223 506 health-care facilities requiring a backup energy system.

The highest rates of intervention needed were found in the South Asia and sub-Saharan Africa regions, followed by the East Asia and Pacific region; the rate is significantly lower in countries in the Latin America and the Caribbean region.

Limitations – granularity of data and electricity requirement assumptions

The current analysis only estimates the costs of the most basic interventions required to power currently unserved facilities, and provide backup generation to unreliably connected facilities, bringing them up to a basic or intermediate level of electrification. This means that daily electricity requirements were assumed at 15 kWh for the category “non-hospitals” and at 500 kWh for the category “hospitals”. In reality, the daily requirements vary, depending on equipment and

services available, and operation status. Clearly, changing the demand assumptions can have a considerable impact on the estimated investment requirements.

For example, increasing non-hospitals' electricity access to 32 kWh/day could increase the total net present cost of electrification to US\$ 8.9 billion (Table 5). This comprises \$5 billion for backup off-grid generation in already connected health-care facilities and about \$3.8 billion for new connections.

Table 5. Estimated investment costs in relation to daily electricity load requirement assumptions

Type of facility	Daily electricity requirements (kWh/day)			
Hospital	500	500	1 000	1 000
Non-hospital	15	32	15	32
Type of costs	Estimated investment (US\$ million)			
New connections CAPEX – grid	1 544.7	2 814.5	1 969.1	3 238.8
New connections CAPEX – off-grid	475.9	946.4	536.6	1 007.1
New connections OPEX – off-grid	59.5	115.3	69.6	125.5
Backup system CAPEX – off-grid	2 085.5	3 601.8	2 833.1	4 349.4
Backup system OPEX – off-grid	741.2	1 395.4	905.3	1 559.4
Total NPC	4 906.8	8 873.4	6 313.7	10 280.3

Note: Estimates are in US\$ for 2022.
CAPEX: capital expenditure; NPC: net present costs; OPEX: operating expenditure.

Although the targeted electricity requirement aims to capture latent demand by being at the higher end of the range of typical values (e.g. greater population, higher catchment area, additional equipment), the analysis does not include new facilities that might be built in coming years.

The sizing of the power system for each health facility was based on assumed load factors and a selected backup system deployment strategy. A change in those assumptions will have an impact on the estimated investment. Similarly, selecting a different electrification scenario from the GEP database may lead to different least-cost mix (grid vs. off-grid) for health facilities, and thus to different investment requirements.

Finally, the costs reflect only the intervention required for power generation, distribution, and operation and maintenance associated with new connections and backup generation; the costs of acquiring the medical equipment in the facilities were not included.

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Chapter 6 provides an overview of policies, regulations, financing approaches and institutional frameworks to accelerate electrification of health-care facilities, as well as lessons learned, across different scales of governance.

Barriers to electrification

A range of technical, capacity, policy and financing barriers can slow the pace of electrification.

- **Technical** issues include the unreliability of electricity supply, lack of supply of appropriately designed medical equipment, poor coordination between planning of electrification and procurement of medical equipment, poor access to solar vendors and spare parts in remote and rural areas, and poorly maintained systems that affect reliability of electricity supply, especially in off-grid systems. Lack of finance for appropriate maintenance of energy equipment and for battery replacement is a critical gap.
- **Policy and governance** barriers include a lack of understanding of the linkages between electricity access and health-care delivery; a disconnect between agencies/departments responsible for health-care services and energy services; siloed policy-making; a lack of supportive policies and regulations; a lack of clear standards and procedures for the design, procurement, installation and servicing of energy systems; and a scarcity of data on electricity gaps, as well as a lack of harmonized data.
- **Institutional capacity** barriers mean that mechanisms are lacking to build local institutional capacity to design and manage electrification programmes tailored to health-care facilities. At the same time, local knowledge to properly operate and maintain energy systems is essential to avoid failure of health electrification programmes.
- **Financial** challenges include a lack of adequate funding to support electrification of health-care facilities. This includes not only capital costs but also funds for operation and maintenance, and for replacement batteries throughout the lifetime of the system. Supporting policies, such as subsidies and fiscal incentives for renewable energy products to be installed in health-care facilities, and appropriate monitoring and accountability mechanisms to measure the impacts of investment are often lacking.

Building the enabling environment for acceleration of electrification

Taking into consideration the key role of electricity in health-care facilities to ensure quality health services, this should be considered a development priority. Creating an enabling environment that overcomes barriers and facilitates improvements in access involves developing fair and transparent policy and planning frameworks; solid data infrastructure; and increased and dedicated financing, including for ongoing maintenance. Institutionally, coordination between the energy and health sectors is critical. Equally important is the fostering of champions who can articulate and advocate for electrification in the health sector context. Key priority actions covered in the chapter include the following.

- **Integrate electrification of health-care facilities into energy sector planning.** Energy demand of health-care facilities need to be integrated into broader national and community electrification plans. Integrating energy planning with health policy planning supports win-win outcomes.
- **Improve financing models to cover long-term operation and maintenance.** There is a need to scale up investments and to move from a short-term approach to capital investments to a time frame of at least 10–15 years, with operation and maintenance costs and replacement of parts adequately covered. This change in approach also requires an adaptation of the traditional model of funds disbursement by governments and development partners. For

instance, whereas funds for diesel fuel are often an established line item in ministry budgets, operation and maintenance of solar PV systems is unfamiliar and requires focused advocacy for inclusion. Blending diverse sources of finance and enhancing public–private partnerships, when possible, can help unlock new resources.

- **Develop supporting policies and accountability mechanisms.** A broad range of support measures, from import tax exemptions for sustainable energy equipment to be installed in health-care facilities to renewable energy subsidies tailored to the health sector, can be used to support sustainable electrification of health-care facilities. The most suitable policy instrument needs to be identified, taking into consideration the specific country context.
- **Build capacity at local level.** Capacity-building should be encouraged among all actors involved in health-care facility electrification programmes, from health sector staff to local energy enterprises. Institutional capacity must be strengthened to enable the public sector to design and manage health-care facility electrification programmes. Health sector stakeholders play a key role in supporting the accurate assessment of the electricity demands of a facility, as well as the necessary operation and maintenance of the electricity system (especially for decentralized electricity systems) and medical devices. Local sustainable energy providers can promptly and efficiently support operation and maintenance of energy systems in a sustainable way. Health-care facility electrification programmes can play a crucial role in creating a skilled workforce; they can also support local electrification more broadly in homes, farms and businesses. This, in turn, lowers the transaction costs of doing business, and channels profits to local communities rather than to actors outside the community or even overseas.
- **Ensure that development is needs driven, not supply driven.** One-size-fits-all energy systems may be underdesigned or overdesigned for the current and future needs of the health-care facility. And heavy reliance on external actors, along with insufficient leadership by local stakeholders, tends to create an ownership vacuum, jeopardizing the long-term sustainability of the electrification programme. A demand-driven approach, with the active involvement of local stakeholders, including frontline health-care workers, is critical from the local to the national level.

7

Country case studies and lessons learned

Chapter 7 analyses case studies of health-care facility electrification – in India, Uganda, and Nepal – that may provide valuable insights on programme design and implementation. The chapter closes with a synthesis of lessons learned that can be important for other countries.

INDIA – building local ownership

SELCO Foundation, an India-based not-for-profit organization, uses an innovative approach to scale up the electrification of health-care facilities in rural communities of India. To better ensure the long-term sustainability and use of a health-care facility electricity system, SELCO Foundation found that working directly within the local community, specifically with the health facility staff who rely on the system, to complete the energy needs assessment was an important way to ensure that the facility’s most important electrical needs were accounted for in the system design and rollout. SELCO Foundation also trained local health-care facility staff in the maintenance and operation of the electricity system to ensure its long-term sustainability.

In the SELCO Foundation model, public health-care facilities own the solar system, with 60–80% of capital expenditure paid by state government health infrastructure funding and the remainder

supplied by SELCO Foundation through the philanthropic capital provided by its funders. The decentralized approach used by SELCO Foundation also applies to operation and maintenance of the energy systems, which are the responsibility of the health-care facilities.

UGANDA – learning from the past to inform the future

Much work has taken place to electrify the health-care facilities of Uganda, providing important experiences on the role of government and development partners, and the need for greater coordination and staff retention to maximize long-term impacts of electrification efforts.

Over the past decade, the World Bank’s Energy for Rural Transformation (ERT) programme has played a key role in health-care facility electrification in Uganda. As this programme has evolved, it has provided some important lessons on financing, government ownership and data sharing.

The initial ERT programme used a 1+4 operation and maintenance contract approach, in which the World Bank financed the capital expenditure and the first year of maintenance, while the Ministry of Health was responsible for the following 4 years of maintenance contracts. After 5 years, the responsibility for renewing the maintenance contract was transferred to the district local governments. However, in many cases, the districts preferred to fund repairs on an ad hoc basis, rather than to tender full operation and maintenance contracts. In some cases, the lack of regular maintenance has led to systems falling into disrepair.

To help mitigate such a risk in future work of the ERT programme, the subsequent phases, ERT-2 and ERT-3, aimed to better ensure system longevity. A commitment was made by the Ministry of Health to increase the budget to ensure regular maintenance and repair, as well as battery replacement and disposal.

Another key actor working on health-care facility electrification in Uganda has been the UN Foundation. Keeping in mind the importance of staff retention and morale, the UN Foundation’s Powering Healthcare initiative expanded the scope of electrification to include staff quarters. This project, launched in 2016, aimed to electrify 36 health-care facilities with solar PV systems to account for future growth. The 2–6 kilowatt-peak (kWp) capacity included power for staff quarters, to improve staff satisfaction and retention by allowing the use of televisions and radios in addition to standard lighting and phone charging.

Although electrification of Uganda’s health-care facilities remains a challenge, there has been an increase in the number of health-care facility electrification programmes supported by donors. The proliferation of initiatives increasingly demands more efficient coordination mechanisms to maximize impact, ensure efficiency and avoid duplication of efforts. Stakeholders describe concerns that solar technologies may be installed in facilities that have already been electrified under another programme, instead of repairing the systems previously installed in the facilities, some of which are no longer functional.

NEPAL – key role of policy and governance

Under Nepal’s Renewable Energy Subsidy Policy of 2016, public health-care facilities in rural areas are eligible for a subsidy of up to 65% (up to US\$ 6500) for solar PV. The subsidies are managed by Nepal’s Alternative Energy Promotion Centre (AEPC) under the Ministry of Energy, Water Resources and Irrigation. In the design phase of the programme, the AEPC undertook a review of health-care facility needs, and identified two standard systems sized at 1 kWp and 2 kWp. The 1 kWp system is for community health subposts, village-level health posts and birthing centres. The 2 kWp system was designed for community or government (district-level) health posts, snakebite centres, primary health centres or hospitals.

To support those facilities in need, the AEPC puts out an annual public call through daily newspapers asking institutions in need of support for electrification to apply for the subsidy. At this stage, if there is insufficient budget to cover all the needs of the requesting facilities, a selection process takes place using criteria based on the facility's current level of electricity access, the size of the facility's catchment population and whether there is already electricity-reliant equipment present in the facility. Facilities with equipment and medical devices already in place, or that have a commitment letter from donors or other institutions to support them with equipment supply in the short term, are then prioritized for government support.

After installation of the solar system by a local supplier, the AEPC pays the energy system supplier the first 90% of the total subsidy. The remaining 10% is held back to ensure after-sales service for 2 years. After the 2-year warranty with after-sales service expires, it is understood that all operation and maintenance is the responsibility of the health-care facility.

This subsidy model has been effective in providing rural health-care facilities with solar systems. However, integration of long-term maintenance costs into health-care facility budgets remains a challenge for some facilities.

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LESSONS LEARNED

Lesson 1: The cases in this chapter highlighted that **financial support**, through either national budget and government subsidies, development partners, philanthropic institutions or bilateral and multilateral organizations, **is necessary for any electrification programmes targeting public health-care facilities**. The private sector can play a role as an energy service provider, or to unlock some financing sources. However, as health is a public good, the public sector is responsible for leading and making adequate financial resources available for health-care facility electrification as an essential element for the delivery of quality health services for all, particularly the most vulnerable.

Lesson 2: Correct system sizing plays a key role in the success of any health-care facility electrification programme. System sizing is a trade-off between standardization and customization, and diverse approaches can be used to build standardization into an electrification programme. Great attention needs to be given to the energy needs assessment in the initial design stage. Engagement with health staff at facility level in this phase is crucial to properly identify current and future energy–health needs.

Lesson 3: Operation and maintenance of energy systems can be institutionalized at the government or at the health clinic level – but it does **need to be institutionalized**. Most programmes fail to include operation and maintenance budgets for more than 5 years, when warranties typically expire and batteries need replacement. In some cases, the operation and maintenance situation is even more dire, covering only 2 years. It is critical that maintenance funds, including for troubleshooting and replacement of batteries and other system components, are earmarked in budgets to ensure long-term sustainability (e.g. 10–15 years). Monitoring and accountability mechanisms should also be put in place.

Lesson 4: Programmes should be designed to **support local market development and capacities**, to improve the ability of local actors to supply equipment, replace parts and provide maintenance services. This will contribute to the longevity and functionality of energy systems in health-care facilities, and will have cascading economic benefits for local communities. In the case of international contracts, programmes should encourage international companies to partner with local companies (e.g. to ensure that a local service provider is available).

Lesson 5: Data on the success of existing electrification programmes are severely lacking, which hinders decision-making. Most programmes **evaluate** success on the basis of number of installations, not **long-term functionality**. Remote monitoring can facilitate and automate collection of these data. Remote monitoring data could also be connected to other facility-specific information to help prioritize resources. It is also important to monitor health outcomes as part of these programmes.

Lesson 6: Coordination of actors and development partners working on different health-care facility electrification programmes **at country level is needed**. This is essential to maximize impact, ensure efficiency and avoid duplication of efforts. In this context, the potential to repair systems already installed in facilities that are no longer functional should be considered before installing new systems to facilities that have already been electrified under another programme.

Lesson 7: It is essential that programmes focusing on electrification of health-care facilities **coordinate with programmes** focusing on **providing medical devices and appliances**. Electricity is only one side of the equation; to really generate impact, it must be provided along with all other components, including suitable medical devices and staff training. Government actors and development partners need to increase coordination efforts in this direction.



Some dominant themes of this report are the need for closer cooperation between the health and energy sectors, and the need for improved collection of data to enable monitoring, evaluation and building the evidence base to identify what works best for sustainable health-care facility electrification.

Climate change and the need to make health systems more resilient against its impacts, including extreme weather events, make the case for accelerating electrification all the more urgent. The COVID-19 pandemic further highlighted the need for reliable electricity to enable essential services, such as oxygen production, vaccine cold chain, and rapid two-way communication between outlying clinics and central authorities.

Designing solutions that are resilient and sufficiently flexible to adapt to evolving risks is important for all facilities. In this context, decentralized renewable energy solutions represent a key opportunity to guarantee the energy supply.

Decentralized renewable energy solutions also allow health-care facilities to be energy independent, thus avoiding the risk of fuel shortages and price variability which can affect facilities relying on fuel-based generators. Reliability of electricity supply is key to the functionality of sensitive, lifesaving medical equipment, as well as provision of clean water, in areas that are remote and vulnerable to water stress, extreme weather events or other climate-related risks.

Hand in hand with these requirements is the need for design and procurement of more robust, energy-efficient, low-maintenance medical equipment. National-level guidance and standards across the tiers of health care are crucial to identify priority and suitable medical equipment. Such guidance, along with data and knowledge of the quality of electricity supply, helps build essential knowledge flow between health-care decision-makers and equipment providers.

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Health sector actors are essential to co-lead the electrification process, by identifying priority needs. Encouraging multisector coordination groups at different levels, involving both energy and health stakeholders, is key to advocating for health and electricity interests in the decision-making process. Mechanisms that encourage integration and interaction between the health and electricity sectors, involving both public and private stakeholders, are important building blocks for translating policy intent into action.

Training and capacity-building for the technical and financial requirements of electrification in health-care facilities are critical, and must involve both health sector and energy actors. Strengthening institutional capacity is key for the public sector to design and manage health-care facility electrification programmes. Similarly, capacity should be built at the central and local level to ensure the integration of electricity into national and local development plans, and sustainability of initiatives.

Increasing awareness of, and advocacy for, the political prioritization of health-care facility electrification will help to ensure that it is a priority in both national and subnational plans – establishing a clear mandate across a country or a region. Identifying and engaging with champions of health-care facility electrification, from national officials and inspirational cultural figures to frontline health-care workers, is critical to creating momentum that will push this lifesaving aspect of health care higher on political agendas.

The conclusions chapter of this report summarizes some of the actions that governments, development partners, academic institutions and other stakeholders could take to accelerate electrification of health-care facilities, and the provision of reliable electricity in the short and long terms. The proposed actions are based on the review of data on, investment in, and case studies of, electrification programmes, including successes and shortcomings, and are articulated in terms of I) data, II) system planning and III) programme implementation. This final chapter proposes a way forward to change pace and consider electrification of health-care facilities as a development priority, calling all relevant actors to action.



Chapter 1

Background and context – sustainable energy at the nexus of universal health coverage



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1.1 Context - energy as an enabler of health care

Access to affordable, reliable, sustainable and modern energy, particularly electricity, in health facilities is critical to meeting Sustainable Development Goal (SDG) 3 of the United Nations 2030 Agenda for Sustainable Development: “Ensuring healthy lives and promote well-being for all at all ages” - and underlying targets from reduced mortality from a range of diseases and conditions to access to universal health coverage (UHC).

Access to reliable electricity is required for operating a wide variety of essential medical equipment as well as basic information and communication technologies. Reliable access greatly improves the quality, reliability and availability of many basic infrastructure services in health-care facilities, from refrigeration and lighting, to clean and safe water, proper sanitation, ventilation and cooling. Access to affordable and clean energy is itself an SDG (SDG 7). Reliable power is thus critical for health service delivery.

Yet, until recently, the role electricity access plays as an enabler of effective health services and UHC has been unrecognized. As Chapter 2 of this report documents, it is estimated that close to 1 billion people globally are still served by health-care facilities lacking access to any electricity and reliable electricity.

Growing body of literature demonstrate impacts of electrification on service provision

A growing body of studies have demonstrated, more directly, the impacts of health-care facility electrification, or lack thereof, on the provision, use and quality of essential health services, as well as health indicators and outcomes (Welland, 2017; Dholakia, 2018; Irwin, Hoxha & Grépin, 2020; Khogali et al., 2022). Many of these studies have also highlighted how insufficient access to electricity at health-care facilities disproportionately affects women and children, and how improved access and reliability improve outcomes for these vulnerable populations. For instance:

- Lack of available or reliable electricity has been associated with lower availability of medical equipment that is needed for a basic health service – for example, autoclaves, lighting, ultrasounds, vaccine refrigerators, deep freezers, light microscopes, water pumps and centrifuges (Mubyazi et al., 2012; Chen, Chindarkar & Xiao, 2019; Shastry & Morse, 2021; Shastry & Rai, 2021).
- Inadequate energy access in facilities may adversely affect the safety of health-care workers and patients by affecting the regularity of water supply, sufficiency of lighting, sterilization of medical equipment (Reuland et al., 2020) and safety during surgical procedures (Forrester et al., 2017).
- Facilities with central electricity supplies were more likely to provide optimal quality of antenatal care in Kenya, Malawi, Namibia, Rwanda, the United Republic of Tanzania and Uganda (Owili et al., 2019).
- Numerous other studies have found that increasing electricity access for health-care facilities improves service availability and readiness, including inpatient, outpatient, child vaccination, delivery and laboratory services, as well as health-care worker availability, motivation, recruitment and retention (Mubyazi et al., 2012; Javadi et al., 2020; Mani, Patnaik & Lahariya, 2021; Shastry & Rai, 2021; Chang et al., 2022).

Reliable electricity access also increases community satisfaction with, and use of health services by local populations. As just two examples, in Mozambique, the World Bank’s Energy Development and Access Project that increased access to electricity by health centres was associated with an increase in the number of patients, the quality of services and the number of services provided.

Electricity allowed clinics to test for malaria and HIV infection (World Bank, 2017; Elahi, Srinivasan & Mukurazhizha, 2020). In Ghana, health service electrification improved community satisfaction with health-care facilities, from 10% approval to 95% in Ghana, and in Uganda, from 34% to 96% (Javadi et al., 2020).

Linkages with individual and population health outcomes

There is also considerable evidence that electrification of health-care facilities improves individual and population health indicators and outcomes, including reduction in mortality, improved prenatal care and child vaccinations.

Mortality reduction

For instance, in Ghana, a positive association was found between the frequency of power outages at health-care facilities and mortality in the facilities; the risk of death increased by 43% for each day the power was out for more than 2 hours (Apenteng et al., 2018). Duke et al. (2021) evaluated a programme for improving reliable oxygen therapy using oxygen concentrators, pulse oximeters and facility-wide solar power in 38 remote health-care facilities in nine provinces in Papua New Guinea, and found that provision of reliable power and devices reduced paediatric mortality by 40%. Facilities with electricity in Uganda (along with the presence of midwives, water availability and laboratory equipment) had lower rates of maternal death (Mbonye et al., 2007).

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In settings where grid power is available but unreliable, solar-powered backup or secondary systems can augment service provision and improve health outcomes (Dholakia, 2018). Thus, for instance, solar-powered oxygen delivery systems reduced paediatric mortality from pneumonia in Sierra Leone (Morrissey, Conroy & Estelle, 2015), the Democratic Republic of the Congo (Conradi et al., 2021), and Somalia (WHO EMRO, 2021), and the length of hospital stays in Uganda (Hawkes et al. 2018). Similarly, solar-powered oxygenation systems led to increased oxygen saturation in critically ill patients by an average of 12%, with significant improvements in their clinical profiles (Turnbull et al., 2016).

Prenatal care and child vaccinations

A number of other studies have demonstrated how improved access to reliable electricity increases prenatal care and childhood vaccinations, both key indicators for population health. For instance, in Gujarat, India, the Jyotigram Yojana rural electrification programme increased the probability of children receiving vaccinations and pregnant women receiving antenatal care (Chen, Chindarkar & Xiao, 2019). In Maharashtra, India, frequency of power outages was associated with significantly lower odds of delivering in a formal health-care facility (Koroglu, Irwin & Grépin, 2019). Also in India, primary health centres (PHCs) with regular electricity provided delivery and vaccination services to 50% more patients than PHCs without reliable electricity or any electricity (Mani, Patnaik & Lahariya, 2021). Among PHCs without a reliable power supply, those with back-up generators conducted twice as many maternal deliveries as PHCs without a generator (Shastry & Rai, 2021). Kumar, Dansereau & Carlo (2014) also found that access to electricity was significantly associated with a higher volume of deliveries. Finally, facility-level access to electricity improved community use of maternal and child health services in Zambia, including child vaccinations (Maboshe & Kabinga, 2018).

Data and knowledge gaps

Health services are fundamental to human capital development, and therefore to economic development and quality of life. Yet there is a striking dearth of even the most fundamental data on energy access and energy requirements for health-care facilities in many countries, as well as consistent benchmarks for these requirements. The lack of such data, and the need to identify good

practices and key actions to accelerate electrification of health-care facilities, were highlighted at the International Conference on Renewable Energy Solutions for Healthcare Facilities, held in Singapore in 2018, and at the Clean Energy for Health Care Conference, held in Nairobi, Kenya, in 2019. This was highlighted as an opportunity for joint action by key stakeholders active at the nexus of energy and health care.

This report – *Energizing health: accelerating electricity access in health-care facilities* – is one step towards responding to this need. The report was developed by the World Health Organization (WHO), World Bank, International Renewable Energy Agency (IRENA) and Sustainable Energy for All (SEforALL), with technical support from Duke University, the University of North Carolina and the World Resources Institute, and technical contributions from SELCO Foundation. Its purposes are to:

- take stock of the status of health-care facility electrification in multiple regions;
- document obstacles, as well as successful and scalable models, for sustained electrification, including through case studies;
- highlight key techno-economic considerations for powering health-care facilities, particularly technologies that are environmentally sustainable; and
- assess the investment needs to achieve global access to reliable electricity for all health-care facilities.

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A key part of development of this report has been systematic data stocktaking and construction of a harmonized database (HDB) that covers data between 2015-2022 for low-income (LI) and lower-middle-income (LMI) countries in East Asia and Pacific, Latin America and the Caribbean, Middle East and North Africa, South Asia, and sub-Saharan Africa regions. The stocktake builds on prior studies that have analysed data on health-care facility electrification using a multicountry or global scope (e.g. Adair-Rohani et al., 2013; Chawla et al., 2018; Cronk & Bartram, 2018; Moner-Girona et al., 2021). Collectively, these studies highlight how electricity access by health-care facilities is far from universal in many low- and middle-income countries, and accessing reliable power is a challenge even for hospitals. These studies point out the general dearth of data on indicators for electricity access by health-care facilities, and emphasize the lack of specificity and standardization across the limited data that do exist.

The lack of data and data standardization – indeed as Chapter 2 reports only 27 countries had national data on electrification of all health-care facilities between the years 2015 and 2022 - hinders the ability of ministries of health, planners and donors to measure and comprehend the extent of the problem; describe common challenges across countries and regions; observe progress over time; and identify the institutional, policy, technical and financial elements of successful solutions. The lack of data also exacerbates the challenge of siloed decision-making between ministries of health and energy: clinic electrification and health sector energy needs are often afterthoughts in national and regional electrification plans. Although health is a public good that ultimately must be ensured by the public sector, better data would also help to unlock investment in both products and systems that are better designed for resource-poor areas. Companies need to become more innovative about products that can be used in resource-poor areas in the most economical manner; inefficient appliances, along with poor building design, are an unnecessary strain on energy requirements. The provision of consistent and comparable data would also build up the evidence base for how reliable electricity access improves health service delivery, and health outcomes for individuals and communities.

This document builds upon prior efforts, and attempts to address their limitations, by undertaking a systematic, rigorous and carefully documented process of stocktaking and harmonization of existing survey data sources to produce consistent cross-country indicators and estimates of electricity access and reliability for health-care facilities. The level of detail goes beyond that of previous studies, providing estimates by health-care facility type (i.e. hospitals and non-hospitals) and facility location (urban/rural). This approach provides updated estimates on how and where disparities in electricity access have changed over the past decade, and where disparities remain.

1.2 Delivering basic health care in the climate change era

Climate change has been identified as the biggest global health threat of the 21st century (WHO, 2021a). WHO has recognized that rapid demographic, environmental, social and technological changes are likely to accelerate the spread of several infectious diseases. Combined with the health impacts of extremes in temperature, and in climatic and weather events, these changes have the potential to cause a severe strain on the health-care system, particularly in growing economies (WHO, 2021b). Underserved communities that have the least capacity to adapt are likely to be the most affected by the impacts of climate change (Dhara, Schramm & Luber, 2013).

Climate change affects human health in two main ways (USGCRP, 2016). First, it changes the severity or frequency of health problems that are already affected by climate or weather factors. Second, it creates unprecedented or unanticipated health problems or health threats in places where they have not previously occurred. Climate change directly and indirectly impacts the health of vulnerable populations through a broad range of mechanisms, and may have far-reaching social, economic and health consequences, as shown by the following examples (Roos et al., 2021).

- Heavy precipitation may lead to floods and other natural disasters, resulting in damage to infrastructure and critical services, crop loss, population displacements, and disrupted access to maternal and child health services.
- Shortage of safe water and sanitation may lead to an increase in diarrhoeal disease, gastrointestinal parasite infections and cholera outbreaks.
- Drought may lead to failed crops and livestock deaths, and consequently malnutrition and household poverty, further increasing nutritional deficits in low- and middle-income countries in those at greatest risk: women of reproductive age and neonates.
- Climate change and climate-related disasters are associated with new internal displacement patterns.
- Competition over depleted natural resources can spark conflict between communities.
- Indirect consequences of climate change include altered disease patterns, and an increase in vector-borne diseases such as malaria, dengue and schistosomiasis, which are important complicating infections during pregnancy.
- Heat stress affects maternal and child care by increasing the risk of preterm birth, premature rupture of membranes, low birth weight and stillbirth.

As global health systems face increasing burdens from climate change, they are also a growing source of emissions that contribute to climate change.

The health sector must build facility-level and systems-level resilience while also reducing its carbon emissions. Sustainability and climate impact mitigation must therefore be central to all efforts to close the energy gaps in health-care facilities across the world.

1.3 Role of energy in catalysing universal health coverage

The SDG on good health and well-being (SDG 3) aims to ensure healthy lives and promote well-being for all age groups through UHC. The health of the population is key to the attainment of many other SDGs, including those on reduction of poverty, better education, attainment of gender equality, provision of clean water and sanitation, creation of employment opportunities, and economic growth. Stronger primary health-care systems are essential to achieving SDG 3.

Primary health-care systems in many countries, especially in the developing world, lack the resources and facilities necessary to provide adequate, accessible and quality health care. Whether it is a pregnant woman seeking basic maternal care in the conflict-prone deserts of Somalia, a child seeking vaccination in a high Himalayan village, or those seeking routine chronic care in the migrant settlements of our sprawling cities, access to quality and reliable health care is far from a guaranteed basic human right.

The lack of access to basic health care is disproportionately borne by vulnerable populations across the world. For example, sub-Saharan Africa and South-East Asia combined accounted for 86% of global maternal deaths in 2017 (WHO, 2019). The under-5 mortality and maternal mortality in these regions are much higher than the global average. The COVID-19 pandemic and its successive waves have posed further challenges to already overburdened health-care systems.

Regions with underdeveloped health infrastructure are also those most affected by energy poverty. Problems in global public health infrastructure relate to access to medicines, human resources, infrastructure, and so on, and one of the key underlying drivers of these challenges is the absence of reliable energy services at every public health centre. As shown in Chapter 2, 15% of facilities in sub-Saharan Africa have no access to electricity, and only 40% have reliable electricity access. It is estimated that approximately 1 billion people globally are served by health-care facilities with unreliable electricity, or no electricity at all. Most of these facilities are in remote areas – they range from very small “health posts” providing basic medical care to “health centres” that include maternity care, treatment of diseases and laboratory facilities, to “district hospitals” that provide the full range of medical services but depend on diesel generators for electricity (with economic and environmental implications).

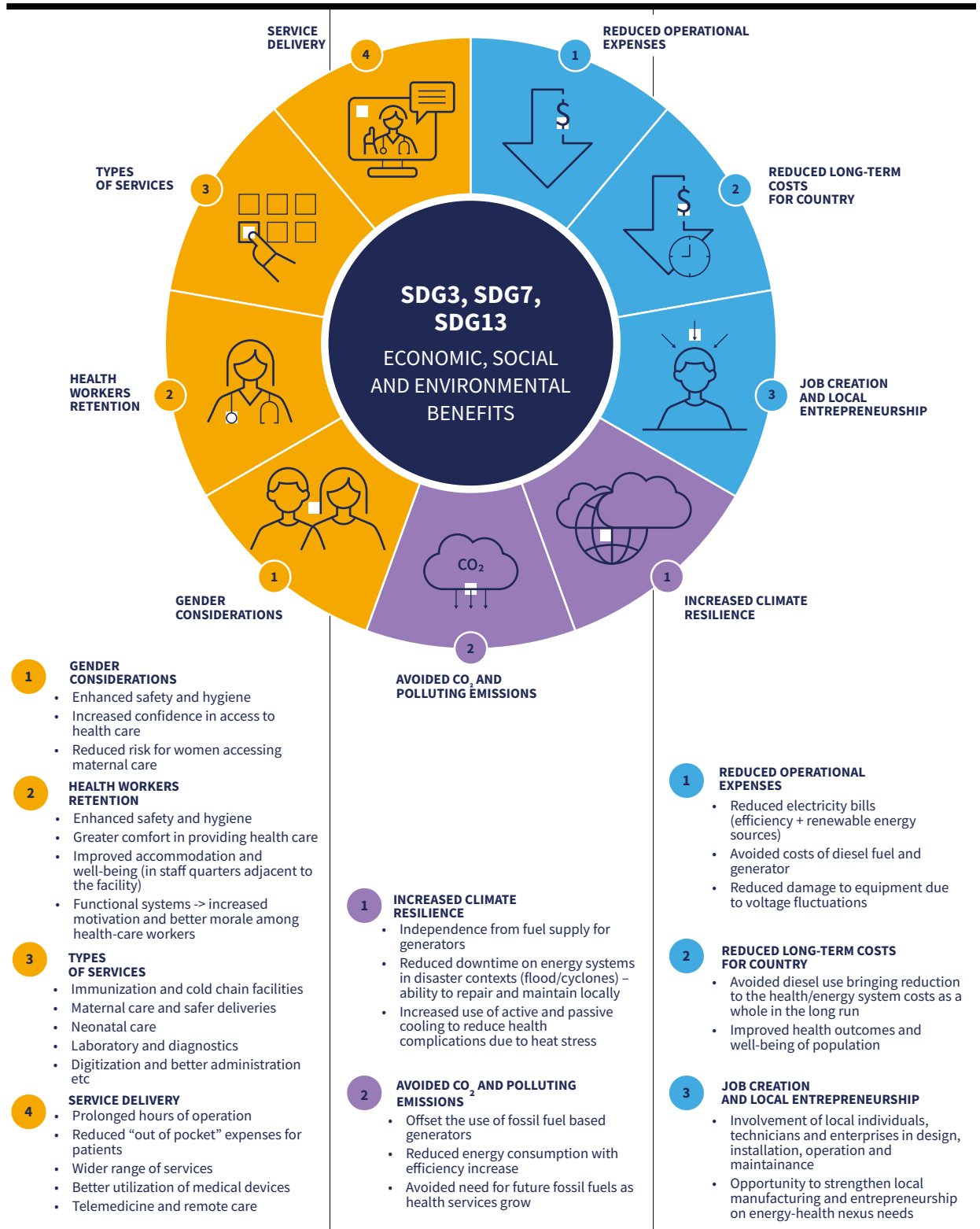
Recent studies have highlighted that community-level health-care facilities that are most accessible to the poorest and most underserved populations (“last-mile populations”) have the highest levels of energy poverty (Shastry & Morse, 2021). In some of the least developed countries, at least 40% of medical devices were found to be dysfunctional, often due to unreliable or low-quality electricity (Perry & Malkin, 2011). Research has also shown that health-care facilities without reliable electricity access delivered more than 40% fewer basic health services than facilities with reliable electricity, underscoring the critical interdependence between health-care delivery and electricity access (Shastry & Rai, 2021).

Most parts of a reliable health-care infrastructure are electricity-dependent: from administration, communications and staff satisfaction to storage of medicines, delivery of health services and patient satisfaction. Some of the key services in primary health care that are dependent on reliable energy access are:

- maternal and child care – diagnostic equipment used to identify high-risk pregnancies, and during and after deliveries, including suction machines, radiant baby warmers, operation spotlights and phototherapy;
- immunization – deep freezers and ice-lined refrigerators for storing medicines, drugs and vaccines, to maintain cold chains;
- basic diagnostics, laboratory services and medical care – lighting for operations; and energy for microscopes and centrifuges, instrument sterilizers and noncommunicable disease kits;
- basic administrative services – lighting, fans, laptops, computers, printing services, and mobile phone charging for staff and patients; and
- COVID-19 preventive and therapeutic care – space heating and cooling, testing and quarantine facilities, and cold chains for vaccine storage and delivery.

Access to reliable energy therefore catalyses the delivery of health services. The combination of improved energy access and appropriate medical and electrical appliances can improve the quantity and quality of health services delivered by facilities. **Fig. 1**, based on IRENA & SELCO Foundation (2022), shows the expected impacts of a health–energy nexus programme that links SDG 7 (“Ensure access to affordable, reliable, sustainable and modern energy for all”) and SDG 3 to provide modern energy access for improved health and well-being, to benefit the last-mile communities in low-resource contexts.

Fig. 1. Health and energy nexus



Source: Adapted from IRENA & SELCO Foundation (2022).



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1.4 Role of decentralized sustainable energy in electrification of health-care facilities

At least some 433 million people worldwide are served by health-care facilities with no access to electricity whatsoever, often because conventional grid connections simply don't exist. In several other cases, health-care facilities are connected to the central grid, but the power supply is unreliable. Health-care facilities in remote locations, low resource settings and areas vulnerable to extreme climate events are especially prone to long run term breakdowns in centralized electricity infrastructure (when this exists) or to fuel supply interruptions for their diesel generators, which affect the delivery of basic health services. Therefore, it is important to improve the resilience of health-care infrastructure, ensuring a more independent, reliable and sustainable power supply in facilities that can better serve last-mile communities while also reducing financial, social and environmental costs.

The economics of which source may be appropriate to electrify a facility are site-specific, depending on project characteristics and local conditions. As described in Chapter 4, multiple techno-economic considerations need to be taken into consideration to identify the most suitable electrification option. In this context, decentralized renewable energy solutions have become increasingly cost-effective as technology costs decrease, deployment grows and supply channels are established.

In off-grid settings and last-mile communities, decentralized renewable energy based solutions, such as solar photovoltaic (PV)-based systems, are increasingly used to provide cost-effective, reliable, affordable power to health-care facilities. Even in grid-connected areas with poor quality power supply, decentralized renewable energy solutions can provide back-up or complementary power, and can represent a rapidly deployable solution to increase climate resilience as well as social, economic and environmental sustainability.

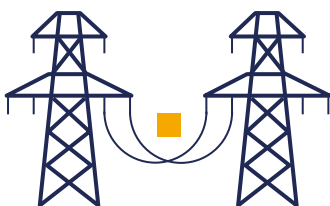
Recognizing the importance of rapidly electrifying health-care facilities in underserved regions, as well as the techno-economic and environmental benefits related to the use of decentralized renewable energy solutions, the past few years have seen an acceleration of their deployment, as described in detail in the following chapters.

1.5 Convergence between health and energy sectors

Globally, health care is a sector with significant government involvement – often extending from creation of guidelines and frameworks to actual implementation, operation and management of health-care facilities at different levels. Health departments at national and subnational levels are actively involved in determining how facilities function.

However, the powering of health infrastructures has traditionally been the purview of energy departments or private energy enterprises. Even with private and non-government actors, traditionally, there has been little engagement between those in the energy sector and those working on health-care issues. When actors in the energy sector lack contextual understanding of local health needs and health system characteristics, they are less likely to create customized design solutions that effectively and efficiently address the health sector needs.

These challenges clearly outline the need for a more integrated approach, and a comprehensive process to assess, design, implement and manage energy solutions for health care. This requires both health and sustainable energy stakeholders to cooperate at all levels, from policy and planning, to budgeting, procurement and implementation. This will contribute to reaching a more nuanced understanding of the sectors and to bridging knowledge and skill gaps.





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Chapter 2

Status of electricity access in health-care facilities



Quantifying the energy access situation of health-care facilities in LI and LMI countries is critical to understanding the extent to which a lack of electricity is a barrier to the delivery of quality health-care services, a key component of UHC and the agenda under the SDGs. Knowing what fraction of health-care facilities lack access to electricity can help prioritize countries and settings (e.g. clinics in rural areas) that require urgent attention. It can also inform estimates of the health and financial costs of inaction; identify suitable technologies for different settings to ensure reliable and adequate power supply (e.g. grid versus off-grid); secure the allocation of limited resources; and track progress in scaling up electricity access and its impact on service delivery, health, climate and other outcomes.

To support countries, development partners and other stakeholders better understand and track the situation in their country, WHO established a database on electricity access in health-care facilities on its Global Health Observatory (GHO) (GHO, 2022). Analysis in this chapter summarizes the information in this online database. The chapter provides summary statistics from health-care facility assessments, surveys and reports on the percentage of facilities reporting no access to any electricity, unreliable access and reliable access to electricity. The data are disaggregated by health-care facility attributes, when available, including facility type (hospital versus non-hospital) and geographic location (urban versus rural). Data on the primary source of electricity (e.g. grid, solar system, generator), the operability of the source, and the uses of the electrical supply are available for some countries. However, constraints in data collection methods (e.g. geographic coverage) meant that it was not possible to derive global or regional estimates; therefore, only country examples are presented to provide additional insights on energy access barriers and their magnitude in health-care facilities.

Section 2.1 provides a brief overview of methods used to build this HDB; further details of methodology can be found in **Web Annex A**. **Section 2.2** defines the indicators generated, and **section 2.3** documents key findings; further details of results can be found in **Web Annex B**. **Section 2.4** offers some high-level conclusions and steps for improved practice in the future.

2.1 Methods

2.1.1 Data sources

National data on electricity access of health-care facilities in LI and LMI countries are not widely available. Health facility assessments periodically collect information on the availability of health-care facility services and the capacity of facilities to provide health-care services. Such routine data collection allows decision-makers and implementing partners to establish a baseline and to track progress on a set of key indicators used to illustrate a facility's readiness to provide care. Data on availability and reliability of electricity supply, and other attributes (e.g. primary source of electricity) are sometimes included in such routine health-care facility assessments. In other cases, electricity data are gathered and reported in country reports or peer-reviewed journal articles.

To identify as many sources of national data as possible, a comprehensive search strategy was used to populate the database on health-care facility electrification, beginning with a review of standard health-care facility assessments (**Web Annex A**). Key national surveys with at least one question on electricity access identified and used for this analysis included the Service Provision Assessment (SPA), Service Availability and Readiness Assessment (SARA), Emergency Obstetric and Newborn Care (EmONC), Service Delivery Indicators (SDI), and Health Resources and Services Availability Monitoring System (HeRAMS) (**Box 2.1**). In addition to providing information on electricity access, a few of these

assessment tools include a more detailed set of questions on energy access, such as service outages, uses of energy in the facilities and, in some cases, even the primary source of electricity (e.g. grid, solar panels, generator). Other surveys identified with relevant data include the Energy Sector Management Assistance Program (ESMAP)’s Multi-Tier Framework for Energy Access (MTF) (**Box 2.4**) and Performance Monitoring for Action (PMA), developed by the Johns Hopkins Bloomberg School of Public Health (**Box 2.5**). Although these two surveys were not used in the main analysis because they are incompatible with the analysis, they each make a unique contribution to the evidence base: the MTF provides a comprehensive review of electricity access attributes for health-care facilities, and the PMA provides trends on any electricity access on the day of survey.

BOX 2.1.

MAIN NATIONAL SURVEYS IDENTIFIED AND USED FOR THIS ANALYSIS

Service Provision Assessment (SPA)

The SPA is a health-care facility survey developed and administered by the Demographic and Health Survey programme of the United States Agency for International Development (USAID). It employs a robust sampling methodology and a harmonized questionnaire that is designed to provide indicators at a national level for different types of facilities and managing authorities. It collects information on service availability (physical and human resources) and quality of care (provision and experience of care), with a focus on maternal and child health, in a representative sample of facilities. SPA survey data are available for 18 countries dating back to the late 1990s.

Service Availability and Readiness Assessment (SARA)

SARA is a health-care facility survey instrument developed jointly by WHO and USAID. It is designed to assess and monitor service availability and readiness of the health sector, and to generate national evidence to support the planning and managing of a health system. SARA is a systematic survey using trace indicators for service delivery (e.g. availability of human and infrastructure resources). The SARA survey has been used by governments and others to assess health-care facilities but has recently been replaced by the Harmonized Health Facility Assessment (HHFA) (**Box 2.7**).

Emergency Obstetric and Newborn Care (EmONC)

EmONC is a survey designed to assess the availability of emergency obstetric and newborn care in countries with high maternal mortality. The survey, developed by Columbia University’s School of Public Health, is

intended to be used by ministries of health or United Nations partners to evaluate how well the health system is providing emergency obstetric care, as well as other reproductive health services such as family planning and prenatal care. The EmONC survey has supported more than two dozen governments in developing national programmes to improve obstetric care.

Service Delivery Indicators (SDI)

SDI surveys are an initiative of the World Bank that aim to measure experiences of health and education service delivery in countries. These data aim to identify gaps, track progress, and serve as evidence for planning policies and interventions. Initially focused on the African region, the SDI is now global, providing data for 17 countries since 2013. Using standardized data collection and sampling methods, typically measuring 200–2000 facilities, SDI results are representative at the national and subnational levels.

Health Resources and Services Availability Monitoring System (HeRAMS)

HeRAMS is an initiative of the WHO Health Emergencies Programme to support countries with routine and standardized data collection on the availability of essential health services and resources at point of service delivery. It also aims to strengthen health information systems by building authoritative master lists of health-care facilities. It is easily deployable to support emergency response and fragile states, and can be used for real-time monitoring as individual facilities are responsible for uploading information into the HeRAMS platform. HeRAMS is currently used in 19 countries.

Additional surveys were identified through web searches in different languages (English, French, Portuguese and Arabic), using a standard set of search terms; review of published analysis on this topic (Chawla et al., 2018; Cronk & Bartram, 2018); review of individual ministry of health and national bureau of statistics websites; professional contacts; and other data search efforts – for example, some of the data used were compiled and shared by the WHO/United Nations Children’s Fund (UNICEF) Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (WASH) for this analysis.

2.1.2 Data inclusion and harmonization

During the past decade or so, some progress has been made on accelerating access to electricity in health-care facilities. In some countries, significant efforts are underway to electrify facilities. To best capture the current situation on the ground, data for this analysis were limited to health-care facility assessments conducted from 2015 and onwards in LI and LMI countries.¹ Furthermore, as electricity access can vary significantly within a single country and across different types of facilities, only surveys or reports with national coverage, and datasets that employed a robust sampling strategy to ensure representation of the different facilities at the national level were used to derive summary statistics. In some cases, these values may differ from other assessments conducted at a subnational level or using other sampling methods or questionnaires.

Methods applied to assess electricity access are not uniform across assessments. Variations in survey questions, sampling and other factors limit the comparability of results across countries, surveys, and years, and, in some cases, exclude their use in global and regional averages. An effort was made to harmonize indicators and variables across settings, survey types and years through a careful review of survey questionnaires and metadata from each survey, and systematic mapping of relevant survey questions to identify common concepts. The resulting indicators are described in **section 2.2**.

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1 The income grouping refers to the World Bank analytical income of economies as of 1 July 2022, based on the 2021 gross national income per capita estimates (<https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>).



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Studies and datasets that have nationally representative samples or were deemed to have sufficient national coverage of health-care facilities were prioritized for inclusion. In cases where missing data were reported for 25% or more of sampled health-care facilities, these data were considered insufficient and excluded from the analysis. Where data were only available for a subset of facilities (e.g. only hospitals, non-hospitals, urban or rural facilities), these data were only included in related analyses if it was clear that the data were meant to capture the national situation of that facility type. However, where only non-public² facilities were surveyed (e.g. the USAID Strengthening Health Outcomes through the Private Sector survey), data sources were excluded from this report’s analysis.

In essence, for inclusion, a dataset or source had to meet all the following criteria:

- data from 2015 or from more recent years;
- public health-care facilities included in survey sample or census;
- relevant and clear information on electricity access included, aligning with harmonized definitions employed for this analysis; and
- representative sample of all health-care facility types, with no more than 25% of facilities reporting missing data.

See **Web Annex A** for more details.

² Public health-care facilities are any health-care facilities that are government managed. Non-public health-care facilities are any health-care facilities that are not (or not solely) government managed (i.e. government owned) – for example, facilities that are private, semi-public, or managed (owned) by nongovernmental organizations (NGOs) or faith-based organizations.

2.1.3 Analysis

For each data source analysed, if raw data were available, appropriate survey weights were applied and data extracted according to the indicator definitions in **section 2.2**. A data source was considered to have included all health-care facility types when it sampled both hospital and non-hospital facilities. In cases where additional “stratification” variables (i.e. hospital versus non-hospital, urban versus rural) were provided, these data were extracted and compiled in the database. Because of inconsistencies in facility categorization and sampling methods employed across surveys, disaggregation was only possible for hospital versus non-hospital and urban versus rural. The “hospital” category only includes data specifically reported for hospitals. “Non-hospital” refers to all other health-care facilities within the survey sample. **Web Annex A** provides additional information about how these stratification variables are defined. In cases where no raw data were available, the results of the survey were taken from associated reports insofar as definitions of reported indicators aligned with those in this analysis.

Where multiple surveys were available for a country, the most recent survey was used to define the electricity access situation of health-care facilities in that country and to derive regional averages, unless communication from national authorities and subject matter experts suggested otherwise.

Considering the limited geographic coverage of the available national data, and the inherent variability between countries within a particular region, regional³ population-weighted averages for each of the major indicators (i.e. no access, unreliable access, reliable access) were calculated only in cases where country data were deemed sufficient to derive these averages.⁴ When facility survey data were missing for a country, regional averages were used to derive estimates of the population impacted. See **Fig. 2.1** and **Table 2.2** for geographic coverage of surveys searched and identified for this analysis.

2.2 Indicators

With no access to electricity, facilities lack basic lighting, and cannot maintain vaccine refrigeration or operate critical medical devices. Without an adequate and reliable source of power, some medical devices and services such as fetal heart monitors, incubators and ventilators cannot operate. Fluctuations in power can damage valuable and costly equipment.

The fraction of facilities that have any electricity access at all and the fraction that suffer from unreliable power are basic proxies available that can be used to understand the impact that electricity access has on the delivery of health-care services. More importantly, this information can help target limited resources to settings where electricity can have the greatest impact on improving public health.

For the purposes of this report and based on the limited data collected on health-care facility electricity access, two indicators were used to benchmark and track progress on electricity access.

- 1. Access to any form of electricity:** a single binary (yes/no) indicator that represents whether the health-care facility has access at least some of the time to any source of electricity.⁵

3 World Bank regional classifications were used: East Asia and Pacific, Latin America and the Caribbean, Middle East and North Africa, South Asia, sub-Saharan Africa, and Europe and Central Asia.

4 Data were deemed sufficient to derive regional averages when survey data were available from sufficient countries to represent 25% of the regional population.

5 A few surveys provide data on stand-alone medical devices and appliances (e.g. solar or gas-powered refrigerators, solar lanterns) present in health-care facilities. In cases where only stand-alone medical devices or appliances are reported as their only source of electricity, this facility is coded as not having any access to electricity. In the few cases where surveys gather data on the functionality and/or the availability of fuel or battery of off-grid electricity sources, a facility with only off-grid sources is considered as having access to any electricity when the sources are reported as functional with fuel or battery available.

This is the most common electricity-related variable reported in surveys of health-care facilities.

2. **Access to reliable electricity supply:** whether electricity was available at the facility during service hours at the time of, or preceding, the survey. For this analysis, power is considered reliable if the facility answers “no” to the question “At any time in the previous one (or two) weeks, have you experienced an outage lasting more than two hours at a time?”⁶ (see **Web Annex A** for details).

Data on these two indicators are most widely available, spanning the most countries and years. Although they do not fully capture the capacity of the reliable electricity supply thus limiting their interpretation to some extent, in combination the two indicators can still provide some insight into the degree to which the lack of an adequate electricity service can impact the delivery of quality health-care services in a country (**Table 2.1**).

Table 2.1. Electricity access levels in health-care facilities

Electricity access level	Definition
No access	Lack of access to any form of electricity, excluding stand-alone medical devices and appliances
Unreliable access	Access to some form of electricity, but the supply suffers from frequent outages (e.g. an outage lasting more than two hours at a time in the previous one (or two) weeks)
Reliable access	Access to some form of electricity, with limited or no service outages in electricity supply

Note: All statistics relating to access to any electricity or reliability of electricity presented in this chapter apply to the full set of facilities, unless indicated otherwise. That is, percentages are based on all health-care facilities surveyed, not only those with access to any electricity. This is important to consider when comparing indicators between countries.

2.2.1 Beyond the basic indicators

In addition to the more universal indicators on any access to electricity and reliability of supply, a few facility assessments have started to include more detailed questions on other electrification parameters like sources of electricity, as well as the operationality of the power supply. Such additional information provides decision-makers and other stakeholders with valuable insights into the operationality and uses of power solutions used by different facility types. Currently the data are too limited in geographic coverage for these other indicators to derive global or regional estimates; however, country estimates are presented when available to provide more context for the electricity situation on the ground. See **section 2.3**.



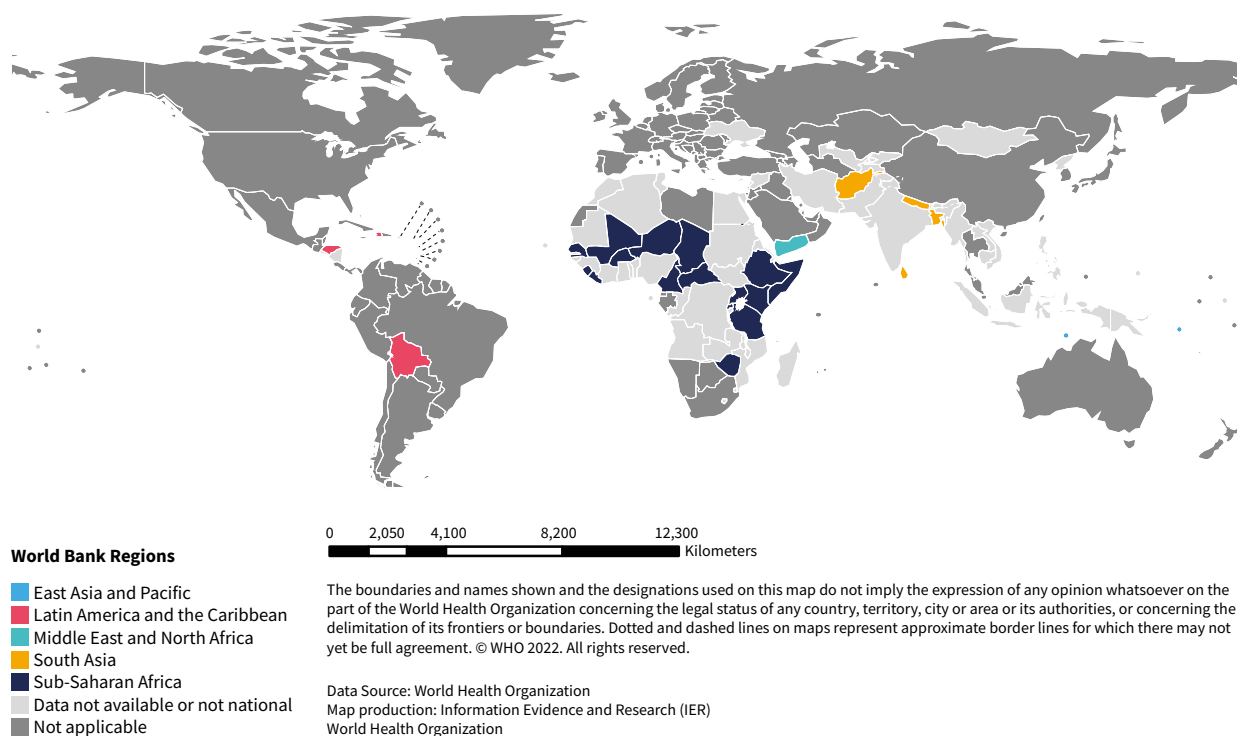
⁶ Some surveys, notably the PMA which was not included in the analysis, ask if there were interruptions lasting two or more hours in the previous day. In a few other surveys, the length of interruption is not specified (e.g. the indicator is “Health-care facility had continuous power supply during the past 7 days” but “continuous” is not defined in available survey documents).

2.3 Results

2.3.1 Data availability

The data search strategy was global in scope, designed to gather data on electricity access for all LI and LMI countries. Electricity data on all health-care facilities were identified for 27 countries. As indicated in **Fig. 2.1** and **Table 2.2**, data representing the regional populations of LI and LMI countries were most available for the Latin America and the Caribbean region (72%) followed by the sub-Saharan Africa region (43%). Only Yemen from the Middle East and North Africa region had national survey data, amount to only 9% of the LI and LMI population in this region. Data for the East Asia and Pacific region were limited to three small island developing countries and therefore could not be considered representative of the regional population; however, these data offer some insights into the electricity access situation among health-care facilities in small island developing states (SIDS) in that region (**Box 2.2**).

Fig. 2.1. Availability of national data on electrification status of all health-care facilities in 81 LI and LMI countries



Source: See **Web Annex B** for details.





NOTICE
If you have cough
AND
Fever
AND
History of travel abroad in past
28 days
OR
Contact with someone COVID-19 patient
Please inform HOSPITAL STAFF
who will SHOW you where to go
**DO NOT WAIT AROUND WITH
OTHERS**

SIGATOKA HOSPITAL


Table 2.2. Countries with national data on any key indicators of electrification status of all health-care facility types, by region and income group

Region	Income group	Country	With health-care facility survey data		
			No access	Unreliable access	Reliable access
EAST ASIA AND PACIFIC	LMI	Solomon Islands	√		
		Timor-Leste	√	√	√
		Vanuatu	√		
LATIN AMERICA AND THE CARIBBEAN	LMI	Bolivia (Plurinational State of)		√	√
		Haiti	√	√	√
		Honduras		√	√
MIDDLE EAST AND NORTH AFRICA	LI	Yemen	√		
SOUTH ASIA	LI	Afghanistan	√		
	LMI	Bangladesh	√	√	√
		Nepal	√	√	√
		Sri Lanka	√	√	√
SUB-SAHARAN AFRICA	LI	Burkina Faso	√		
		Central African Republic	√		
		Chad	√		
		Ethiopia	√	√	√
		Liberia	√	√	√
		Mali	√		
		Niger	√	√	√
		Rwanda	√		
		Sierra Leone	√	√	√
	LMI	Somalia	√		
		Uganda	√		
		Cameroon	√		
		Kenya	√	√	√
		Senegal	√	√	√
		United Republic of Tanzania	√	√	√
Zimbabwe	√	√	√		

Source: See **Web Annex B** for details.

BOX 2.2.

ACCELERATING ACCESS TO RENEWABLE ENERGY FOR ENERGY SECURITY AND CLIMATE RESILIENCE OF HEALTH-CARE FACILITIES IN SIDS

Access to electricity in health-care facilities is variable across SIDS. The few surveys from SIDS including Haiti (de Walque et al., 2016), Solomon Islands (WHO/UNICEF Joint Monitoring Programme, unpublished data, 21 July 2022), Timor-Leste (Ministry of Health, 2015) and Vanuatu (Tupaia, 2022) suggest that access rates across SIDS range between 73% and 99% (**Web Annex B**).

Health-care facilities in SIDS face unique challenges for energy transition. In SIDS, energy supply typically relies on imported fossil fuels, particularly diesel, which is very expensive and may be unaffordable, especially in rural areas (Dornan, 2015). Health-care facilities in SIDS tend to be located close to low-lying coastal areas, meaning that power supply and therefore delivery of essential health services are highly vulnerable to

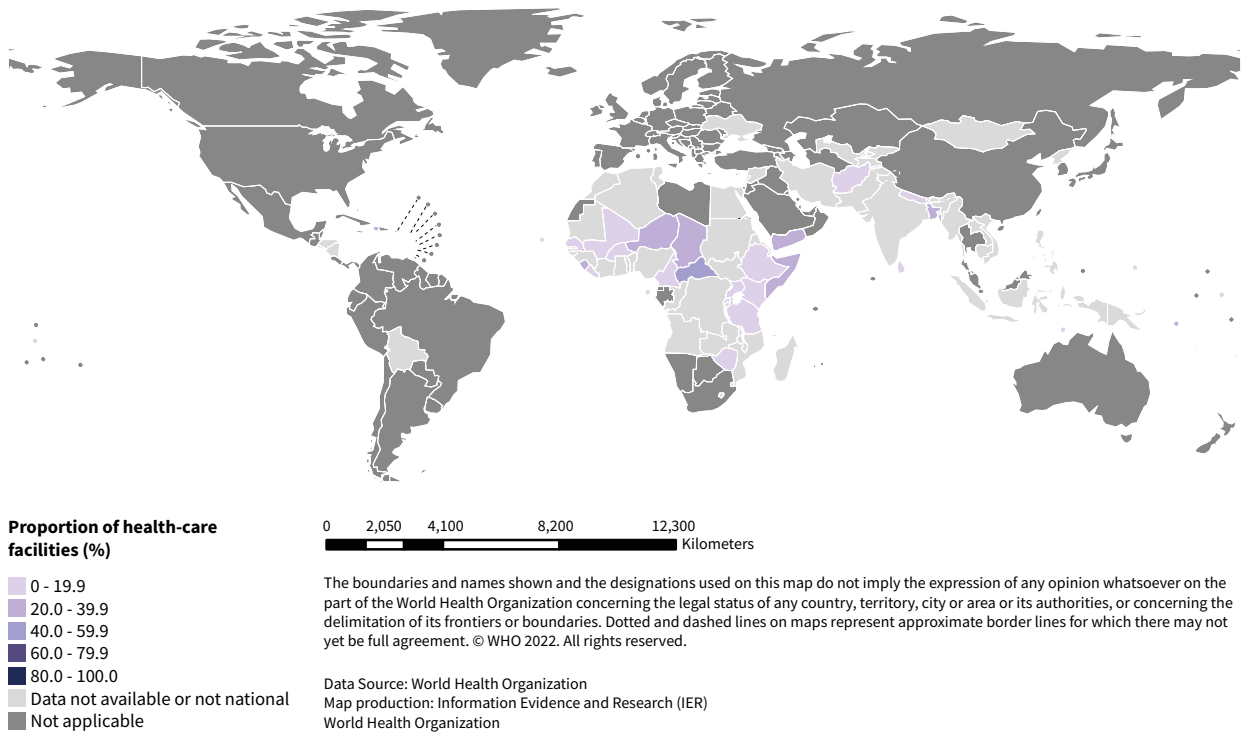
cyclones, floods, storm surges, sea level rise and other climate-related disturbances (WHO, 2018). Furthermore, some SIDS have weak health systems, a growing noncommunicable and mental health disease burden, and constrained financial and human resources, limiting options for transitioning to climate-resilient and sustainable health systems.

Renewable energy solutions, for example, can provide health-care facilities in SIDS with reliable and cost-effective electricity. Off-grid solar systems, for example, do not require connection to a central grid, and can be particularly suitable for facilities being scattered across a vast area. Furthermore, these solutions can be rapidly deployed and adapted to a facility's needs, and help overcome space limitations (Shumais & Mohamed, 2019).

2.3.2 Access to any electricity

National data on any electricity access were available for 25 countries, spanning four regions. Substantial variation exists in access rates across different regions and countries (**Fig. 2.2**). On average, the LI and LMI countries in the South Asia and sub-Saharan Africa regions reported similar estimates of 12% and 15%, respectively, of facilities lacking access. Somewhat higher rate of facilities with access to any electricity is seen in the Latin America and the Caribbean region.

Fig. 2.2. Percentage of health-care facilities reporting no access to any electricity in national surveys, 2015–2022

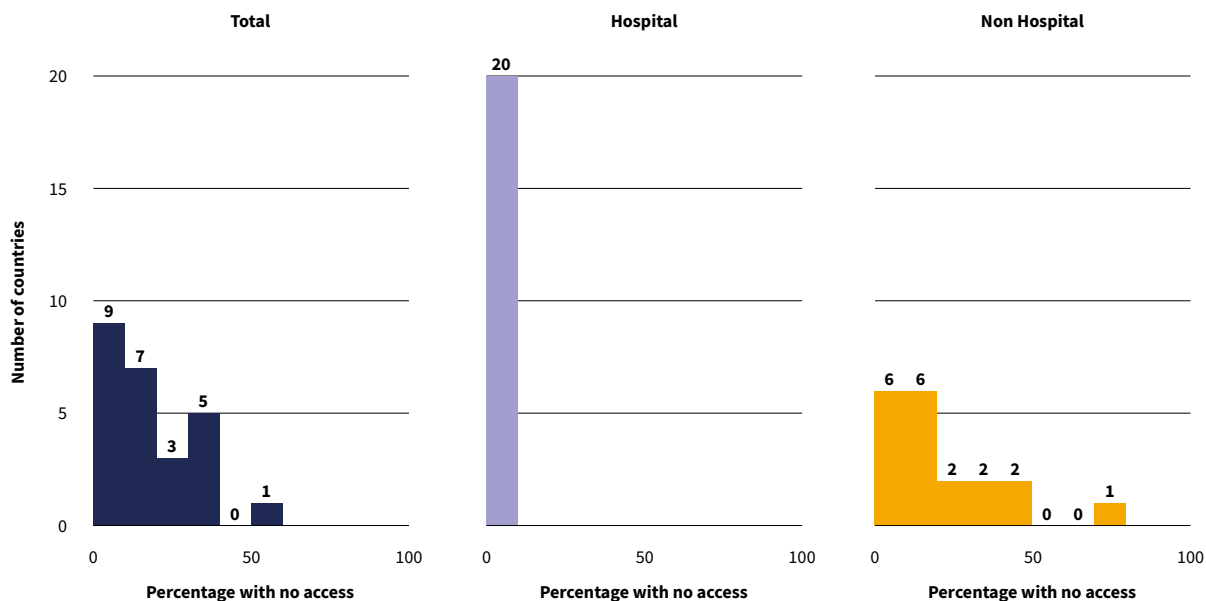


Source: See **Web Annex B** for details.

The range of access to any electricity across countries is vast. In some countries, such as Burkina Faso (HeRAMS, 2022a) and Rwanda (Ministry of Health, 2020), nearly 100% of all facilities report any electricity available. Six countries including Bangladesh (NIPORT, Ministry of Health and Family Welfare, and ICF, 2020), Central African Republic (HeRAMS, 2022b), Chad (HeRAMS, 2019), Niger (Ministère de la Santé Publique de la Population et des Affaires Sociales, 2020), Sierra Leone (Statistics Sierra Leone, 2018) and Yemen (HeRAMS, 2022c) across the sub-Saharan Africa, Middle East and North Africa, and South Asia regions reported 30–50% of all facilities lacking any access to electricity.

Looking at access to any electricity by facility type (hospital versus non-hospital), there are stark differences (**Fig. 2.3**). For the 20 countries with data on any electricity access for hospitals, 11 (more than half) reported 100% access, and most others reported 95% or more of hospitals with electricity access. For non-hospital facilities, the situation is more variable and, in many cases, more dire. The percentage of non-hospital facilities lacking any electricity access ranges between 1% and 74% (median of 13%), with a population-weighted average of 8% for the Latin America and the Caribbean region, and 19% for the sub-Saharan Africa region.

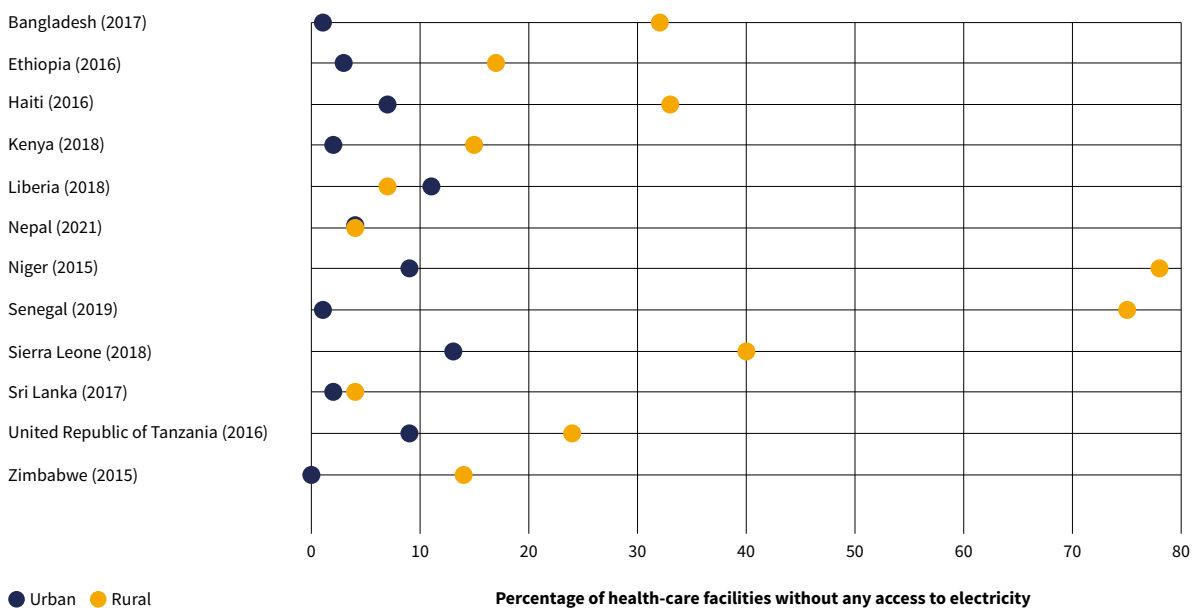
Fig. 2.3. Distribution of percentage of health-care facilities reporting no access to any electricity in national surveys, by facility type



Source: See **Web Annex B** for details.

Among the 12 LI and LMI countries, mainly in the sub-Saharan Africa and South Asia regions, for which there are disaggregated data by urban and rural areas, similar discrepancies are seen in the level of any access to electricity (**Fig. 2.4**). In health-care facilities located in urban areas,⁷ nearly all countries in both regions have access to electricity; between 0% and 13% (median of 6%) of urban facilities in the sub-Saharan Africa region and between 1% and 4% (median of 2%) of urban facilities in the South Asia region reported no access to electricity. The situation is more dire for rural facilities: the percentage of facilities lacking any access to electricity ranges from 4% to 78% (median of 21%).

Fig. 2.4. Percentage of health-care facilities reporting no access to any electricity in national surveys, disaggregated by urban and rural areas



Source: See **Web Annex B** for details.

⁷ Urban areas are all areas not reported as “rural” in facility assessments.

2.3.3 Access to reliable electricity

A continuous supply of power is critical to ensuring quality health-care services. Frequent cuts and irregular interruptions in the electricity supply can have devastating consequences for health-care service delivery. Some health-care facility assessments inquire about electricity supply outages in the recent past. Although this measure of reliability does not fully capture the extent which health services are impacted by such power cuts and interruptions, and in some cases, understates the energy challenges on the ground, it currently serves as the most universal proxy indicator widely available for measuring the reliability of supply in surveys and across countries.

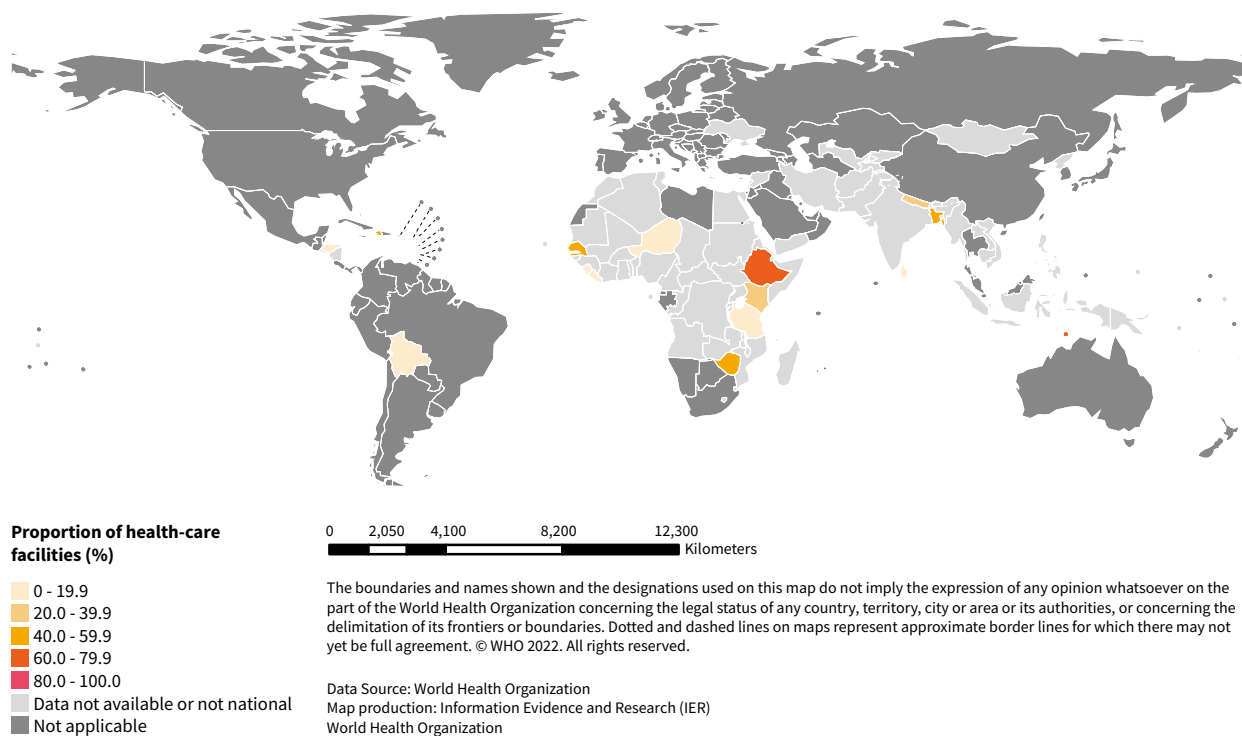
Fifteen countries reported data on the reliability of the electricity supply in all health-care facilities, three from the Latin America and the Caribbean region, three from the South Asia region, one from the East Asia and Pacific region, and the remaining eight from the sub-Saharan Africa region (**Fig. 2.5**). Sufficient data were available to derive averages for the Latin America and the Caribbean, and sub-Saharan Africa regions (i.e. survey data were available for 25% or more of the regional population). Overall, the three LMI Latin American countries had the highest percentage of all health-care facilities with reliable access, with an average of 72%. sub-Saharan Africa – the other region for which sufficient data were available – showed 40% of facilities with access to a reliable source of electricity.

Country estimates of access to reliable electricity varied substantially. In the Latin America and the Caribbean region, two of the three countries – Honduras and the Plurinational State of Bolivia (OPS & OMS, 2022) – reported 89% and 95%, respectively, of all facilities having access to reliable electricity. This contrasts with Haiti (de Walque et al., 2016), which reported only around one third of all facilities with access to reliable electricity. Similar variation is seen among the South Asia and sub-Saharan Africa regions, where some of the reporting countries with the least reliable coverage showed 19% and 20% access to a reliable supply (Rockmore, 2015; NIPORT, Ministry of Health and Family Welfare, and ICF, 2020), and countries with the most reliable coverage showed 81% and 91% access (Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia, 2018; Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics, 2018).

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Fig. 2.5. Percentage of health-care facilities reporting unreliable electricity access in national surveys, 2015–2022



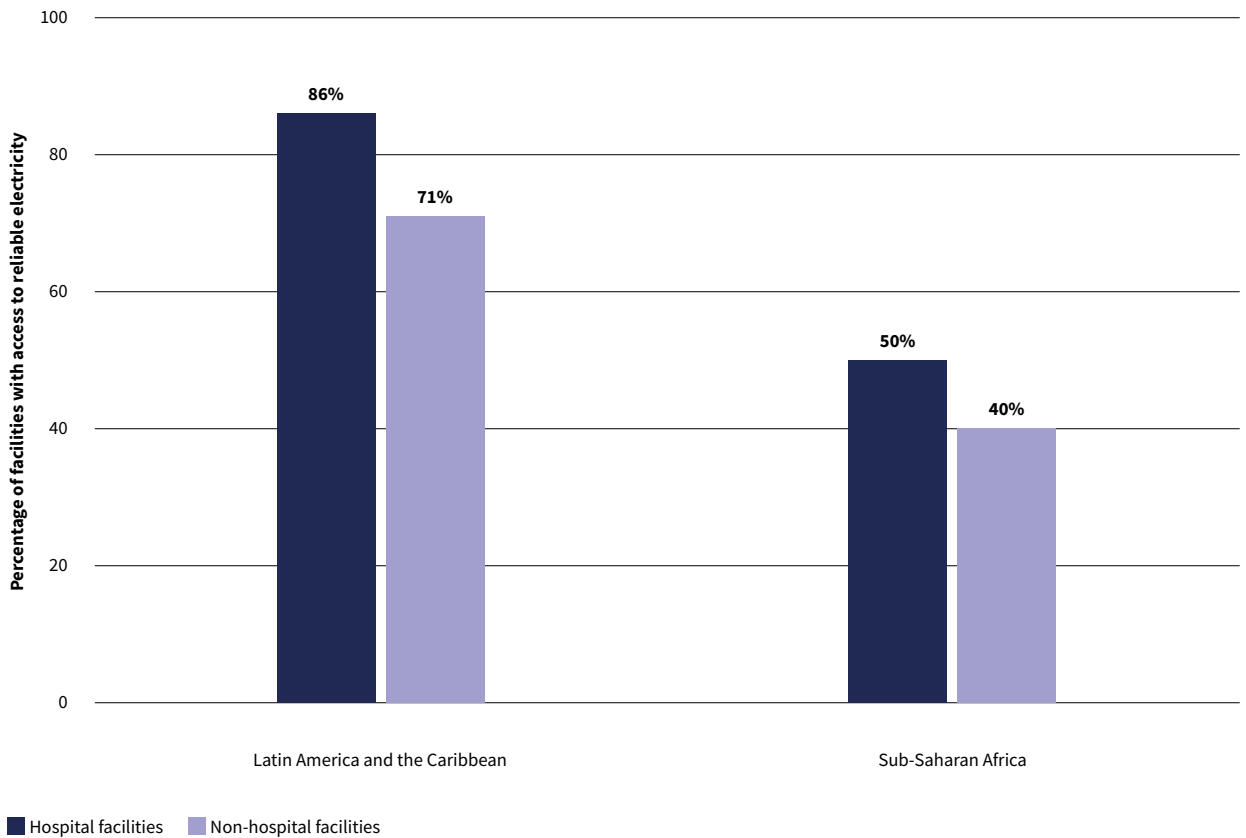
Source: See **Web Annex B** for details.

Access to a reliable supply of electricity is a common challenge for health-care delivery shared by hospitals and non-hospitals (**Fig. 2.6**). There are differences of 15% and 10% between the regional averages of hospitals and non-hospitals in both the Latin America and the Caribbean region and the sub-Saharan Africa region, respectively.



Sub-Saharan Africa showed 40% of facilities with access to a reliable source of electricity.

Fig. 2.6. Percentages of health-care facilities with reliable electricity access in Latin America and the Caribbean region and sub-Saharan Africa region, disaggregated by hospitals and non-hospitals

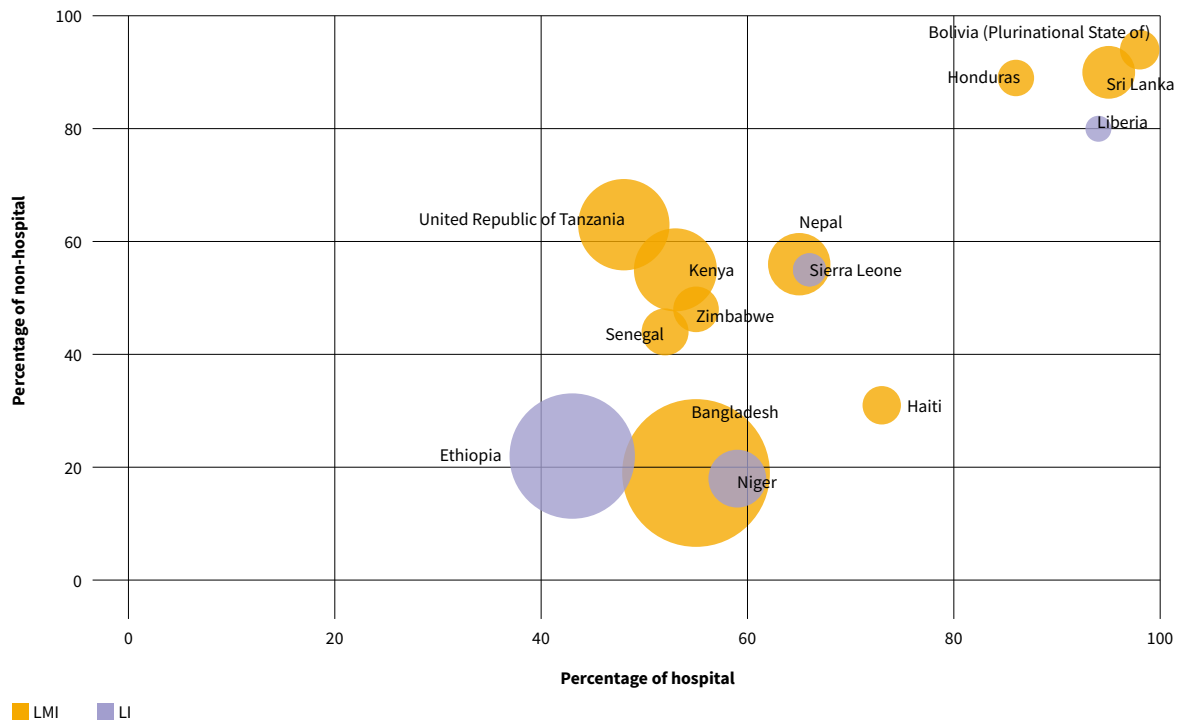


Source: See **Web Annex B** for details.

Taking a closer look at specific country values by facility type, surveys from Honduras (OPS & OMS, 2022), Sri Lanka (Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics, 2018), the Plurinational State of Bolivia (OPS & OMS, 2022) and Liberia (Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia, 2018) all showed more than 80% of hospitals and non-hospitals with access to reliable electricity (**Fig. 2.7**).



Fig. 2.7. Percentage of health-care facilities reporting reliable access to electricity in national surveys, disaggregated by facility type and income group



Note: The size of the bubbles is proportional to the total country population.

Source: See **Web Annex B** for details.

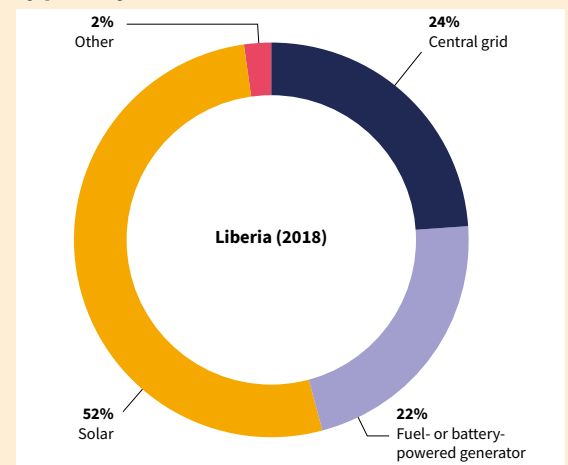
Liberia is the only country in the sub-Saharan Africa region with more than 80% of both hospitals and non-hospitals reporting access to reliable electricity. Such a figure is notable, especially considering in 2020 only 28% of Liberian households had electricity and less than 5% of health facilities had access to the grid (World Bank, 2021). However, taking a closer look on the ground in Liberia, sample surveys show a majority of facilities, both PHC facilities and hospitals, are equipped mainly with diesel generators, often paired with solar systems in both urban and rural areas (**Box 2.3**).

BOX 2.3.

LIBERIA CASE STUDY: DEEP DIVE ON ENERGY ACCESS SITUATION IN HEALTH-CARE FACILITIES

This analysis has found at face-value, the energy access situation in health-care facilities of Liberia to be exceptional. Liberia reports a great mix of electricity sources - about one quarter of electrified facilities in Liberia rely mainly on the grid, a one-fifth on generators, and over half rely on solar electricity as their primary source of electricity (Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia, 2018) (**Fig. 2.8**). Liberia’s reliability figures are notable with more than 80% of both hospitals and non-hospitals reporting access to reliable electricity, and a greater percentage (85%) of rural facilities reporting reliable electricity supply compared to urban facilities (76%). However, in spite of these relatively positives figures, looking more closely at how this translates in health-care service delivery, the story is more sombre.

Fig. 2.8. Percentage of electrified health-care facilities by primary source in Liberia



Some 42% of facilities in Liberia do not have enough electricity to meet all their energy needs. In some cases, the situation is so dire that facilities report not even having enough electricity to meet the basic lighting requirements. Even with strong penetration of solar PV systems in Liberian facilities, there is still a gap in the actual energy services provided by such a ‘reliable’ supply.

To better illustrate how such inconsistencies in top-level indicators can mask the situation on the ground, below is a summary of key results from sample surveys (2022 April) conducted as part of phase I of the Liberia Electricity Sector Strengthening Access Project (World Bank, 2021) (Table 2.3). This survey was conducted in 24 rural lower-level PHC facilities in preparation for scaling up the electricity grid in Liberia and provides a more diagnostic evaluation of the energy access situation facing Liberian facilities despite the overall positive-looking statistics for reliable electricity access.

- **Diesel generators, typically thought of as a back-up supply, represent a substantial primary source of electricity for health facilities.** In Liberia all hospitals and most health centres report having 2 to 3 diesel generators on site; however, this is not the case for more remote lower tier facilities. On average, the Liberia Electricity Sector Strengthening Access Project survey

showed that only about 40% of the lowest-level PHC facilities surveyed reported having at least one generator.

- **Solar PV serves as important complement to a health facility’s power supply, these systems often provide low institutional coverage of buildings.** Ninety-five percent of the 24 primary-health sites analysed in the Liberia Electricity Sector Strengthening Access Project showed solar PV providing less than 25% of each site’s total energy needs (kilowatt hour per day - kWh/day), with most facilities reporting an inadequate supply, often not even meeting half of facilities lighting needs. The reliability of supply increases through the diversity of the supply options.
- **Diesel fuel, a requisite for most generators, is often too costly for the limited budgets of facilities,** particularly in more remote areas. Donations often finance diesel fuel costs, but typically such funds are insufficient to keep the generator operation 24/7, thus impacting the availability of health-care services.
- **Proportionality of energy needs met by reliable energy sources:** Of all 24 sites surveyed, most facilities remain significantly underserved by solar PV, and overly dependent on diesel fuel for the balance of energy demand.

Table 2.3. Energy supply findings from World Bank Liberia Electricity Sector Strengthening Access Project survey 2022

Diesel generators installed	Solar PV (installed 2013-2022)
<p>Installed diesel generator capacity:</p> <ul style="list-style-type: none"> • 100% of hospitals with ≥ 2 generators (48 kilovolt-ampere - kVA) • 63% of health centres with generators (24 kVA) • 50% of PHC1 with generators (6.5 kVA) • 18% of PHC2 with generators (6.5 kVA) • Average of sample (19 kVA, 42%) <p>Functionality of generators:</p> <ul style="list-style-type: none"> • 74% of generators were functional (13 of 17 quantities) • 56% of capacity was available (112 kVA of 198 kVA) <p>Fuel availability is insufficient (although principally donor-financed).</p>	<p>Installed solar PV-based systems capacity:</p> <ul style="list-style-type: none"> • Hospitals: 7 PV systems, 180 watt peak-3.2 kilowatt peak (kWp) (total average installed capacity of 4.1 kWp per site) • Health centres: 4 PV systems 10 watt peak-4.6 kWp (average 1.7 kWp) • PHC1: 4 PV systems 10-200 watt peak (average 530 watt peak) • PHC2: 5 PV systems 10 watt peak-3 kWp (average 890 watt peak) <p>Functionality of solar PV systems:</p> <ul style="list-style-type: none"> • 80% of systems were functional (79 of 99 quantities) • 59% of capacity was functional (17.5 kWp of 29.6 kWp)

Source: World Bank (2021).

Looking at these data, it is clear that “reliability” may not imply that power and energy for full services are available at all times, but rather, perhaps, that the most critical medical services currently offered by that facility can be reliably provided, due to diversity of energy supply sources. However, there remains insufficient energy to provide for the fuller suite of services intended under Liberia Health Infrastructure Standards. Therefore, all of these facilities are also underserved by (reliable) energy.

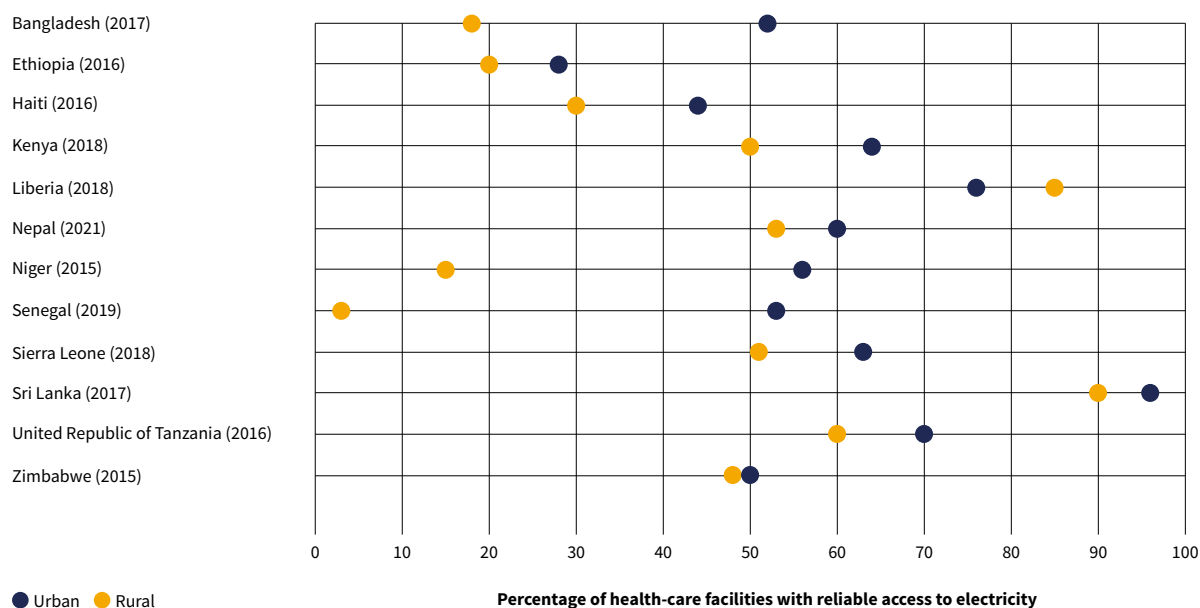
Taking a closer look at the energy mix of Liberia and pairing that with more detailed parameters on the electrification status and how it impacts the delivery of care, and the need for more robust and harmonized definition and methodology of ‘reliability’ power for health-care facilities is clear.

In most cases, greater access to a reliable source of electricity is seen among hospitals than among non-hospitals, with a mean difference of 13 percentage points across the 14 countries with data. In three instances – Honduras (OPS & OMS, 2022), Kenya (Wane & Chuma, 2018) and the United Republic of Tanzania (Wane, 2016) – non-hospitals reported a greater level of access to reliable electricity than hospitals, at 3%, 2% and 15%, respectively.

Access to reliable electricity is a greater challenge for health-care facilities in more remote rural areas (Fig. 2.9). National data on reliable electricity access disaggregated by urban and rural areas were available from 12 countries: three in the South Asia region, eight in the sub-Saharan Africa region,

and one in the Latin America and the Caribbean region. In all but one country, urban areas reported a greater percentage of facilities with access to a reliable source of electricity. The largest difference in urban compared with rural rates are in Niger (Rockmore, 2015) and Senegal (ANSD & ICF, 2020), where rural facilities reported 15% and 3% access, respectively, and urban facilities reported 56% and 53% access, respectively. Both countries showed greater reliability access among urban facilities with a difference of 41 percentage points for Niger and 50 percentage points for Senegal. Liberia (Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia, 2018) is the one exception, where 85% of facilities in rural areas reported reliable electricity access compared with only 76% of facilities in urban areas, a difference of nearly 10 percentage points.

Fig. 2.9. Percentage of health-care facilities reporting reliable access to electricity in national surveys, disaggregated by urban and rural areas



Source: See **Web Annex B** for details.

2.3.4 Absolute impact: population and number of health-care facilities impacted

Presenting statistics on the percentage of facilities lacking access to reliable electricity fails to capture the human impact of energy poverty in health-care facilities. Quantifying the number of people and facilities impacted by the lack of electricity is a helpful measure for decision-makers and other stakeholders to illustrate the extent to which a lack of simple infrastructure is preventing quality health service delivery.

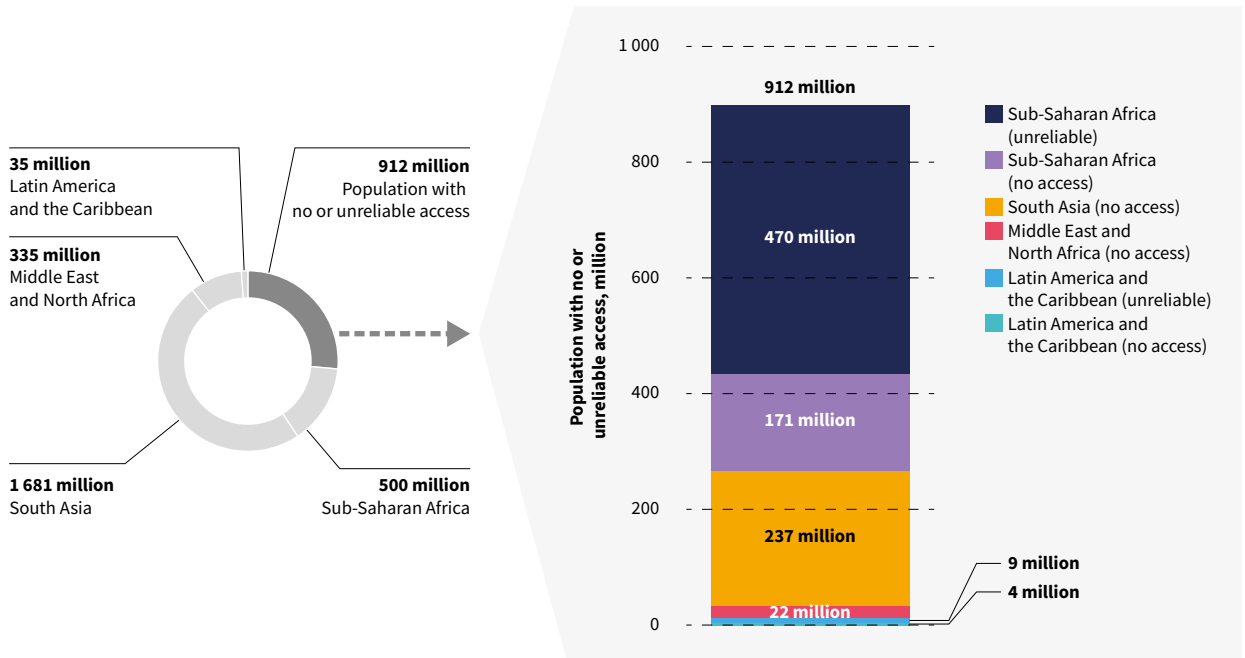
To estimate the number of people affected, the fraction of facilities lacking access to any electricity or reliable electricity was assumed to be the same as the fraction of the total population lacking access to these services. In cases where no survey data were available for a country, the regional average was assumed.⁸ Since no (or insufficient) national survey data were identified for some regions, the following “global” estimates represent only four regions: Latin America and the Caribbean, the Middle East and North Africa, South Asia, and sub-Saharan Africa. Consequently, it is likely that these figures underestimate the total number of people lacking access to facilities with reliable electricity.

⁸ Regional averages were only assumed where survey data were available for 25% or more of the regional population.

Using 2022 population figures⁹, across these four regions, it is estimated that some 433 million people rely on facilities without any electricity, and 478 million people lack access to facilities with a reliable supply of electricity. This suggests that approximately 1 billion people (at least 912 million people) across only these four regions are served by health-care facilities that do not have access to any electricity or to a reliable supply of electricity (**Fig. 2.10**). To put this in perspective, this is close to the entire populations of the United States of America, Indonesia, Pakistan and Germany combined. Globally, the extent to which people are impacted by a lack of reliable electricity in health-care facilities is likely to be even greater if one considers that the estimates presented here represent only three quarters of the population living in LI and LMI countries.

Understanding the number of facilities lacking electricity access is also a critical metric for scaling up action. However, in many places there are no censuses or rosters available which list or account for all the health-care facilities in a country, and thus different information resources must be utilized to approximate the number of facilities in a country or region. For this analysis, adequate information from different resources including survey data sources used in this chapter, the Global Electrification Platform (GEP) (ESMAP, 2022) and other secondary sources like ministry of health websites were used in combination to estimate the number of facilities lacking any electricity and reliable electricity access for the sub-Saharan Africa region. Results suggest that there is a total of around 166,720 of health-care facilities in the 41 LI and LMI countries of sub-Saharan Africa. By multiplying the total number of health-care facilities with the regional indicator averages, an estimate of around 25,000 and 68,350 health-care facilities in sub-Saharan Africa lacking access to any electricity and reliable electricity, respectively. These figures illustrate the level of energy insecurity in health-care facilities of this region, and can be used to inform the level of investment and action needed to ensure access to quality health-care service for all.

Fig. 2.10. Estimated population served by health-care facilities with no electricity access or without reliable electricity, disaggregated by region



Source: See **Web Annex B** for details.

9 Population figures according to the 2022 Revision of World Population Prospects (<https://population.un.org/wpp/>).

2.3.5 A closer look: primary supply, generators and uses of supply

Data on the availability of any electricity and reliable electricity provide a basic snapshot of the energy access situation in a country's health-care settings. However, these data do not give policy-makers much insight into the sources of electricity, the availability and operationality of primary and other electricity supplies, and other key indicators for policy and programmatic decision-making and planning. More detailed information on such factors provides details about what works and what does not work. Among the multi-country surveys identified, only the SPA and SARA surveys gather such data using a sampling method that could be considered national for this multi-regional analysis. However, other surveys, such as the MTF and PMA, also gather data that provide important insights and experience from the ground (**Box 2.4** and **Box 2.5**).

BOX 2.4.

MEASURING HEALTH-CARE FACILITY ENERGY ACCESS THROUGH THE MTF

The ESMAP's MTF is a set of assessment tools designed to support countries collect a comprehensive set of data on the current energy access situation to inform policy and programmatic decision-making, as well as monitor progress toward the universal energy access target for households, businesses, and public institutions (i.e., health-care facilities, schools).

Traditionally, electricity access in health facilities was measured using indicators such as availability of a grid connection and availability of a backup generator with fuel. Although convenient, such indicators fail to clarify important dimensions of energy access. The MTF goes beyond traditional binary measurement of energy access to capture the multidimensional nature of energy access at the end user level, and the vast range of technologies that can provide energy access, while accounting for the wide differences in user experience. It defines energy access as the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, formal, convenient,

healthy and safe for all required energy applications. The framework then defines six level of access, ranging from Tier 0 (no access) to Tier 5 (full access).

The MTF for energy access of health-care facilities questionnaire is administered to a knowledgeable staff member. It determines the type, size and hours of operations of the facility, and assesses the primary and all other sources of electricity available (grid, mini-grid, generator, solar devices, rechargeable battery), through the attributes of electricity supply (capacity, availability, reliability, quality, affordability, formality and health and safety). It also queries about the ownership and use of electric appliances, including medical devices.

Results can be compiled and analyzed to produce an energy access diagnostic for a group of health-care facility, by type, size or geographical area. To date, MTF surveys in health-care facilities have been conducted in multiple countries, including Cambodia, Ethiopia, Kenya, Myanmar, Nepal, and Niger.



Primary sources of electricity

Seven countries reported national data on the primary or main source of electricity. Grid was the common source of main electricity supply; for all countries, except Liberia and Burkina Faso, more than 75% of electrified facilities rely mainly on the grid (**Table 2.4**). Unlike earlier assessments that found on average among 9 sub-Saharan African countries, around 7% of facilities relied solely on a generator with these earlier country estimates ranging from 1% in Uganda and Zambia to some 10% and 33% in Sierra Leone and The Gambia, respectively (Adair-Rohani et al., 2013). Updated data were only available for a few of the countries from the earlier assessment; among those countries, a smaller fraction of facilities in all countries except Liberia reported 2% or less of electrified facilities relying primarily on generators.

Liberia, unlike the other countries, reported a much greater mix of electricity sources with diesel generators and solar being the most prevalent (**Box 2.3**). Senegal (ANSD & ICF, 2020) and Bangladesh (NIPORT, Ministry of Health and Family Welfare, and ICF, 2020) reported around 20% of electrified health-care facilities relying mainly on solar. A 2022 report from Burkina Faso found that, for health-care facilities with electricity, 68% relied on a solar source (IRENA & SELCO Foundation, 2022). However, the report stated that “around 30% of existing solar systems in healthcare facilities are not functioning within the first three to five years”. The report highlighted that solar power systems also need maintenance to continue to function, an issue shared with generators.

Table 2.4. Primary source of electricity among electrified facilities in seven countries with national data

Country	Year	Percentage of electrified health-care facilities by primary source (%)				Source
		Central grid	Solar	Fuel- or battery-powered generator	Other	
BANGLADESH	2017	79	19	1	1	NIPORT, Ministry of Health and Family Welfare, and ICF (2020)
BURKINA FASO	2021	31	68	-	1	IRENA & SELCO Foundation (2022)
LIBERIA	2018	24	52	22	2	Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia (2018)
NEPAL	2021	86	13	0	0	Ministry of Health and Population, Nepal, New ERA, Nepal, and ICF (2022)
SENEGAL	2019	77	21	2	-	ANSD & ICF (2020)
SRI LANKA	2017	96	0	0	0	Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics (2018)
ZIMBABWE	2015	92	6	2	0	Ministry of Health and Child Welfare (2015)

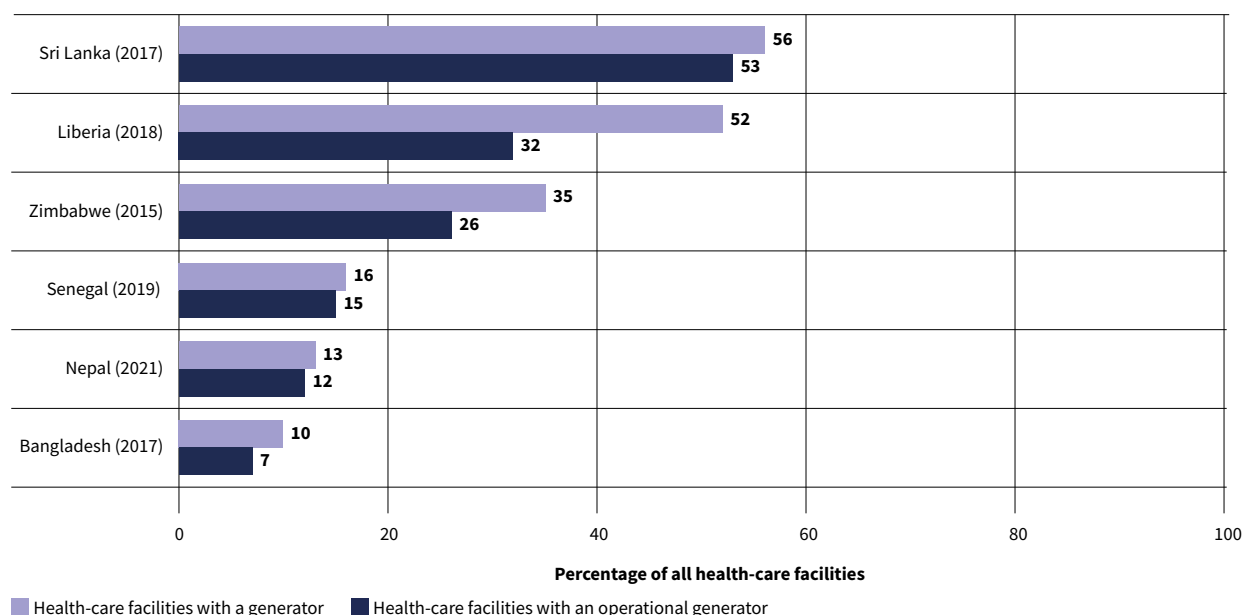
Note: Due to rounding, the sum of the percentages from various sources may not total 100%.

Source: See **Web Annex B** for details.



In many LI and LMI countries, the reliability of the electricity supply is not guaranteed. Traditionally, generators play an important role in ensuring that facilities faced with regular power cuts can maintain a constant supply of electricity for health-care service delivery. In the six countries reporting national data, the percentage of all facilities with a generator ranged from 10% to 56%, with half of these countries reporting 16% or less of facilities with a generator and the other half reporting 35–56% of facilities with generators (**Fig. 2.11**).

Fig. 2.11. Percentage of all health-care facilities with an operational generator (functional and fueled) in six countries with national data



Source: See **Web Annex B** for details.

The presence of a generator aims to maintain health-care service delivery. However, in many cases, particularly in more remote and poorer settings, generators are often not operational (i.e. lacking fuel and not functional). Looking at the data from the six countries on the operability of generators, no country reported that all health-care facilities were equipped with fueled and functional generators. The percentage of facilities with operational generators ranges from 7% to 53% (median of 21%). Estimates of number of health-care facilities with access to a generator and operational generators are also provided to illustrate the scope of how prevalent generator access and operability were in health-care facilities in each of these countries, which may not be obvious when looking at relative figures (**Table 2.5**). The data show that in some countries, such as Sri Lanka, a significant number of facilities is provided with operational generators, which are used as a back-up solution and not as a primary source.



None of the surveyed countries reported that all health-care facilities were equipped with generators that were operational, that is, being functional and with fuel or charged batteries available.

Table 2.5. Number of all health-care facilities with a generator and operational generators in six countries with national data

Country	Year	Total number of health-care facilities	Number of all health-care facilities with a generator	Number of all health-care facilities with operational generators	Source
BANGLADESH	2017	19 811	1 981	1 387	NIPORT, Ministry of Health and Family Welfare, and ICF (2020)
LIBERIA	2018	831	432	266	Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia (2018)
NEPAL	2021	5 681	739	682	Ministry of Health and Population, Nepal, New ERA, Nepal, and ICF (2022)
SENEGAL	2019	3 084	493	463	ANSD & ICF (2020)
SRI LANKA	2017	2 543	1 424	1 348	Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics (2018)
ZIMBABWE	2015	1 834	642	477	Ministry of Health and Child Welfare (2015)

Note: Total number of health-care facilities in each country was extracted from report of the same source for raw data. The absolute number of health-care facilities with a generator and operational generators were derived from multiplying the total number of health-care facilities with the percentages of all health-care facilities with access to a generator and operational generators. Generators are considered operational when they are functional and with fuel or charged batteries available, and thus ready for immediate use.

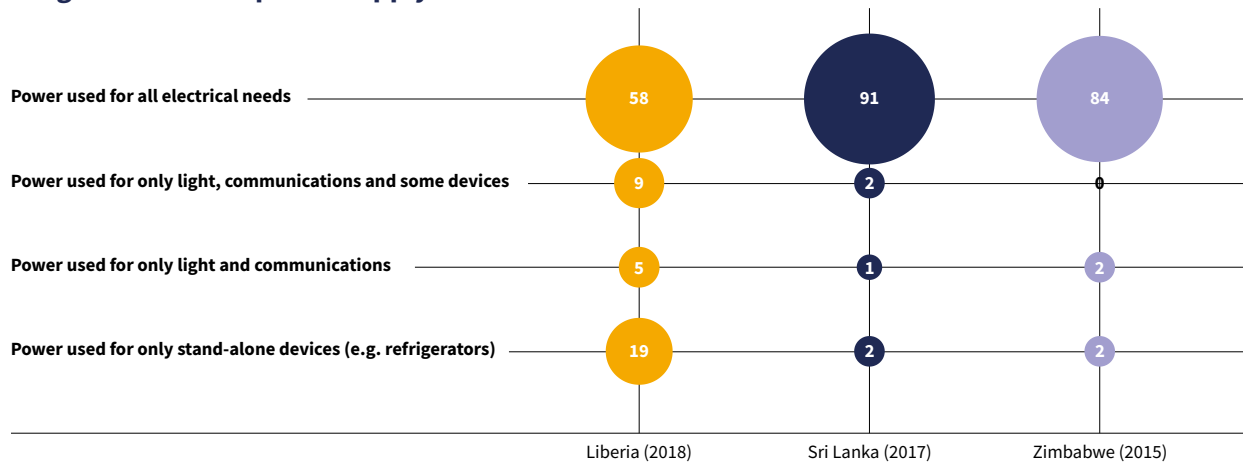
Source: See **Web Annex B** for details.

Uses of electrical supply

Electricity access in health-care facilities is not an end in itself, but rather a technology that supports effective health-care delivery. It is critical to understand how the quality of electricity access influences the services that health-care facilities can offer.

The three recent SARA surveys from Liberia (Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia, 2018), Sri Lanka (Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics, 2018) and Zimbabwe (Ministry of Health and Child Welfare, 2015) were the three national surveys identified reporting on how facilities use electricity (**Fig. 2.12**). Each survey reported four levels of power: power only available for stand-alone medical devices or appliances; power only available for lighting and communication; power only available for lighting, communication and some medical devices or appliances; and power available for all electrical needs. Sri Lanka and Zimbabwe reported 91% and 84%, respectively, of facilities with a power supply covering all electrical needs. For Liberia, only 58% of facilities reported having all electrical needs met by the electricity supply – 9% with power to only cover lighting, communication and some devices; 5% with power only for lighting and communication; and a substantial 19% with power for only stand-alone devices. Of the three countries, only Liberia relies heavily on solar power. Solar provides more than 50% of Liberian health-care facilities with electricity, in contrast to Sri Lanka and Zimbabwe where more than 90% of electrified health-care facilities use central grid for power.

Fig. 2.12. Uses of power supply for health-care facilities in three countries



Note: As the statistics apply to the full set of facilities, the sum of the percentages may not total 100%.

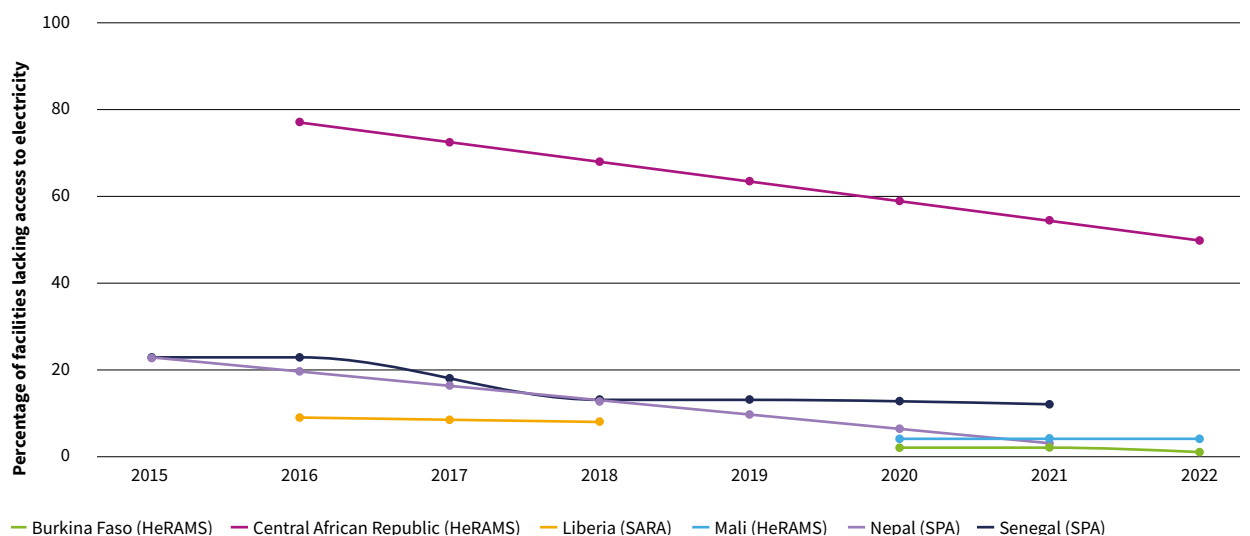
Source: See **Web Annex B** for details.

2.3.6 Tracking progress and trends

As countries work towards achieving UHC – a goal of the 2030 Agenda for Sustainable Development – an understanding of the rate of change in health-care facility electrification can be a useful way to accelerate action on the ground and ensure that much needed resources are appropriately allocated to meet country commitments.

Six countries (Burkina Faso, Central African Republic, Liberia, Mali, Nepal and Senegal) reporting on the percentage of facilities with access to any electricity have multiple data points from the same survey for different years during the 2015-2022 time frame. Looking at the changes, on average, around 2% of health-care facilities gained access to electricity (**Fig. 2.13**). Similar trends are seen in other assessments; for example, the PMA found similar results, with an average of 2–5% of health-care facilities gaining access to electricity on the day of survey each year (**Box 2.5**).

Fig. 2.13. Trends in health-care facilities lacking access to electricity among selected countries with national data from the same survey type



Source: See **Web Annex B** for details.

BOX 2.5.

AN EXAMPLE OF ELECTRIFICATION PROGRESS IN SUB-SAHARAN AFRICA BASED ON PMA

Conducting frequent full health-care facility assessments is costly and resource-intensive. Other health indicator surveys can serve as a useful resource to provide a routine snapshot of the energy access situation in health-care facilities. One such survey is the PMA project, led by Johns Hopkins University. The PMA surveys aim to regularly collect actionable data for key health performance indicators focused on family planning in eight countries in sub-Saharan Africa. The PMA surveys involve routinely interviewing a household sample of women of reproductive age, as well as the facility manager of up to three health service delivery points situated in the enumeration area.

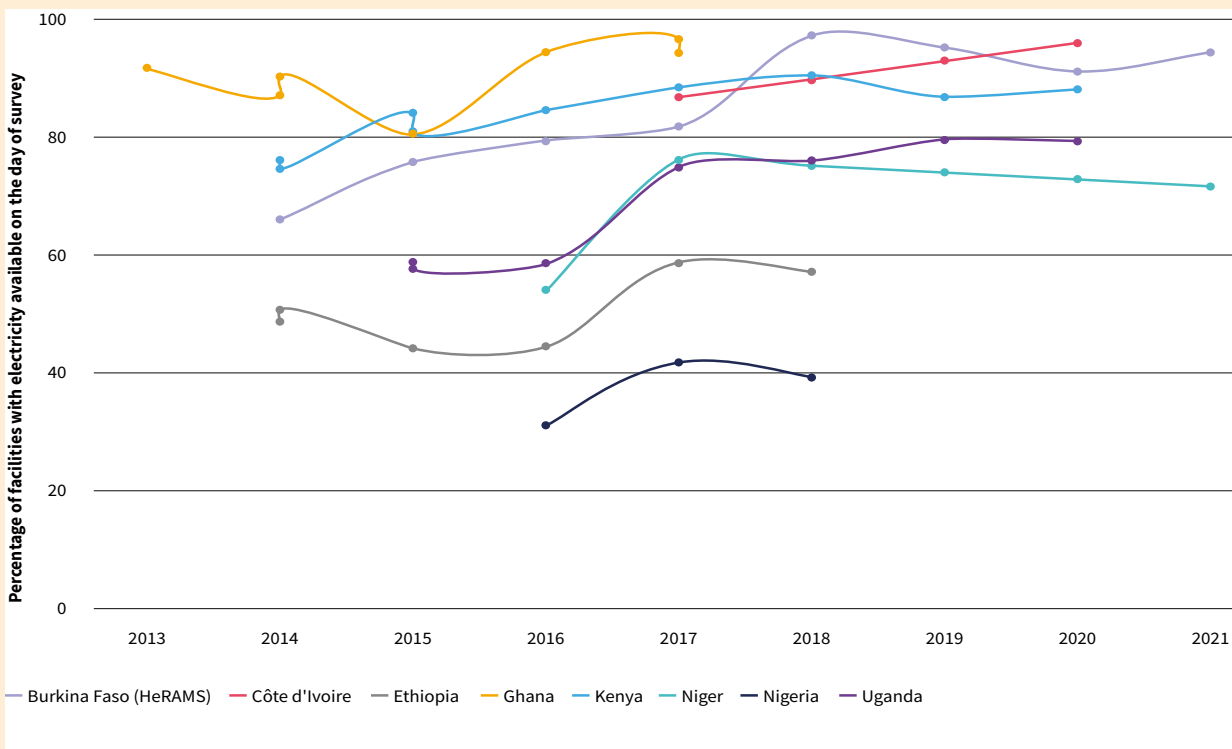
The PMA service delivery point survey includes a question about whether electricity is available at the time of the survey. Since the surveys are often conducted annually, the PMA data can provide a picture of how electrification of health-care facilities is progressing over time in the countries covered. **Fig. 2.14** shows changes in the percentage of facilities with available electricity at the time of the survey.

Across all the countries surveyed, the proportion of PMA service delivery points reporting electricity access on the day of the survey is generally increasing over time. However, the fluctuations in access indicate that more work needs to be done to ensure consistency in day-to-day electricity supply.

Taking a closer look at the PMA data by type of facility and geographic region, similar trends in access emerge. As seen with the full health-care facility assessments, access rates in rural areas lag behind urban areas. Hospitals, likewise, report close to universal electricity availability on the day of the survey.

For the eight countries for which there are PMA data, the rate of change in the percentage of health-care facilities that have electricity available on the day of the survey can be calculated. The average rate of change is 3%, meaning that, on average for these countries, each year 3% more health-care facilities had electricity available on the day of the survey.

Fig. 2.14. Percentage of facilities with electricity available on the day of survey, by country and year



Note: For some countries, PMA surveys are conducted more than once in a year.

Source: See **Web Annex B** for details.



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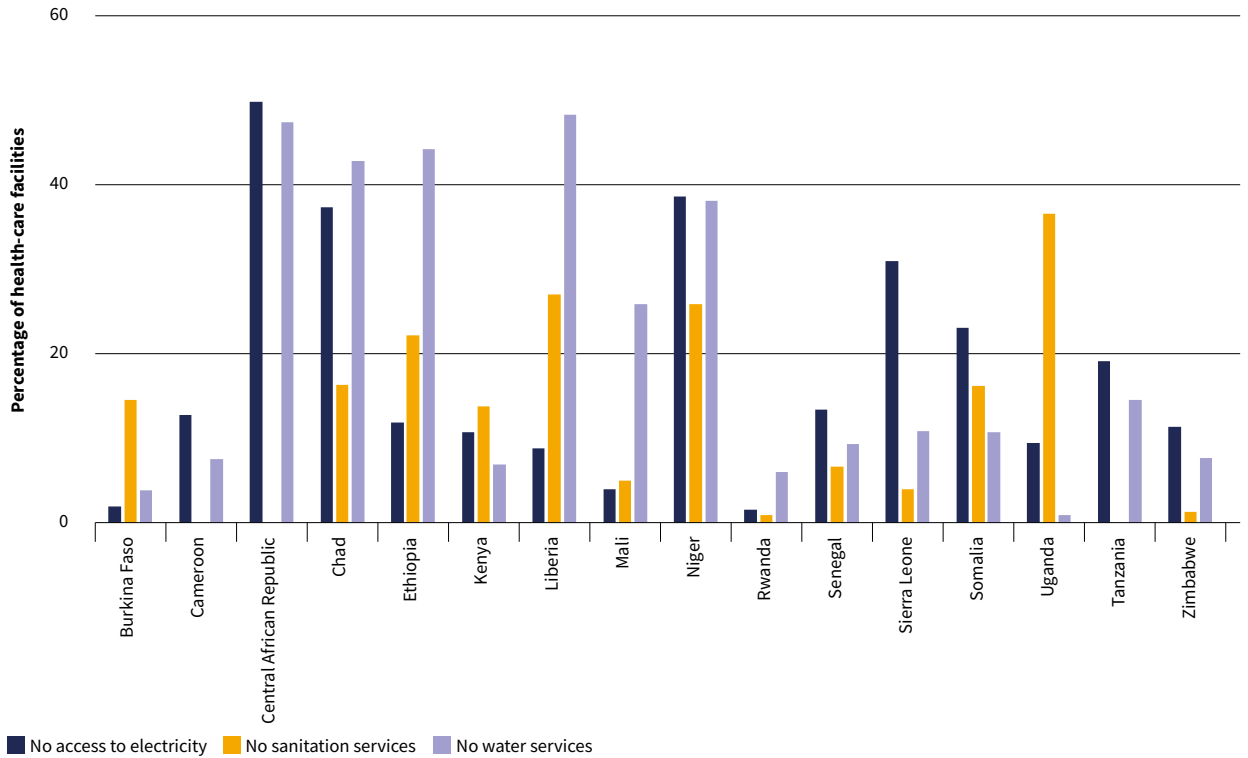
2.3.7 Electricity access compared with other facility infrastructure indicators

Infrastructure challenges for the delivery of quality health-care services extend beyond a basic power supply. Facilities without a continuous power supply are often the same facilities facing other infrastructure challenges, such as a clean water supply, effective health-care waste management systems and safe sanitation. To explore the relationship between the lack of electricity and other health-care facility infrastructure, survey data on facility electrification were paired with data on WASH indicators (WHO/UNICEF Joint Monitoring Programme, 2022). A relationship between lack of electricity access and WASH infrastructure is evident (**Fig. 2.15**).

The results of Pearson's correlation test between these variables in a set of sub-Saharan African countries clearly suggest positive and statistically significant correlation between health-care facilities with no access to electricity and water services (>0.5 ; $P = 0.03$).

Looking at the paucity of energy and WASH services in health-care facilities of LI and LMI countries highlights the need to prioritize basic infrastructure on the pathway to UHC. Furthermore, programmatic synergies and efficiencies could result from a more holistic approach to building and monitoring progress in health-care facility infrastructure for water, sanitation and energy together.

Fig. 2.15. Percentage of health-care facilities lacking electricity (2015-2022), sanitation and water services (2018-2021) among selected countries of sub-Saharan Africa



Note: National data on sanitation and water services in health-care facilities produced by the WHO/UNICEF Joint Monitoring Programme for WASH were used.

Source: See **Web Annex B** for details.

2.4 Discussion

2.4.1 Summary of findings

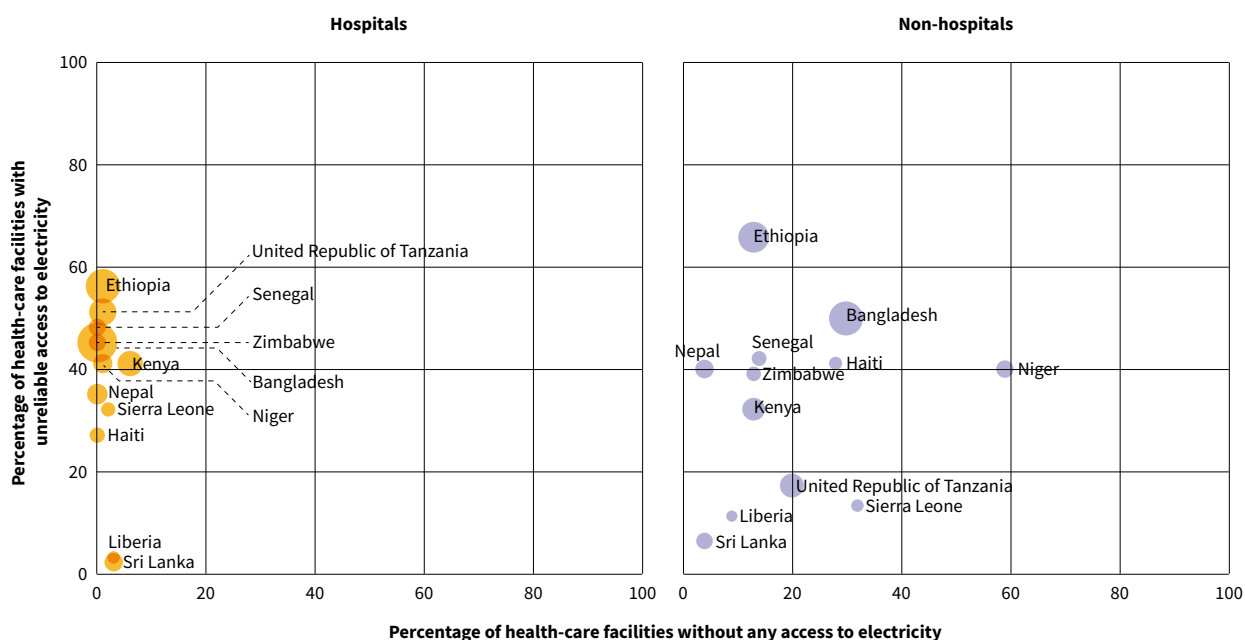
With strong commitments by countries for universal access to health coverage and modern energy services, a strong baseline and harmonized mechanism to track the energy access situation in health-care facilities is paramount. This analysis aimed to inform such a baseline by employing a robust data search, presenting updated statistics for a broad set of indicators and for more countries than previous efforts, highlighting the current strengths and weaknesses in data collection, and proposing opportunities for improving data collection efforts.

Inequity in health-care facility electricity

Although there has been progress in electrifying health-care facilities, it is estimated that close to 1 billion of the poorest people in four regions with available data are still served by ill-equipped facilities, a figure virtually unchanged since last estimated 10 years ago (Practical Action, 2013). The values presented in this analysis clearly illustrate energy poverty as a perennial barrier for the delivery of quality health-care services in LI and LMI countries, and highlight disparities in electricity access based on income and geography. Non-hospitals (e.g. primary care centres) and health-care facilities in rural areas tend to fare worse in terms of access to any electricity supply or a reliable electricity supply than hospitals and facilities located in urban areas. Non-hospitals, often the first

and last points of care, have the lowest rates of access to, and reliability of, supply (**Fig. 2.16**). Similar inequities are evident when looking at access rates by income groups: electricity access rates are lower among LI countries than LMI countries. Understanding such disparities is key to identifying where actions are most urgently needed to protect the health of the most vulnerable populations, and to prioritize the allocation of resources and investment to save lives.

Fig. 2.16. Comparison of percentage of health-care facilities with no and unreliable electricity access, disaggregated by hospitals and non-hospitals



Note: The size of the bubbles is proportional to the total country population.

Source: See **Web Annex B** for details.

Data availability and limitations

Although this analysis includes greater geographic coverage than previous assessments (Adair-Rohani et al., 2013; Cronk & Bartram, 2018), there are still a limited number of countries with recent data. Latin America and the Caribbean and sub-Saharan Africa are the regions with the greatest data coverage for health-care facility electrification when considering proportion of population represented from the three and sixteen countries reporting national data for all health-care facilities, respectively. Few surveys were found from other regions; the Middle East and North Africa and East Asia and Pacific regions had the least available country data. No national surveys were found from the Europe and Central Asia region.

Among the surveys available, inconsistencies in the instruments and sampling methods used to assess health-care facility electrification limit the comparability of data across countries and years. A standard set of piloted and validated questions and indicators are needed to better inform policy and programmatic planning, to inform estimates of needed investments and resources, and to track progress.

More consistent and robust sampling strategies are needed to provide a more accurate picture of the energy situation on the ground. Several data sources identified for this analysis did not provide clear documentation of sampling strategies used and, in some cases, data collection and reporting falls on the individual facilities themselves. Some surveys focused only on sampling facilities offering priority interventions (e.g. EmONC on maternal and child health), whereas others sampled all health-care facilities (e.g. SARA). The former may limit the external validity to the rest of the health-care facility types in the country.

The analysis disaggregated data by hospitals versus non-hospitals and urban versus rural areas; however, organizing health-care facilities into binary categories may potentially mask the on-the-ground reality and policy priorities that shape electricity access, and make it more difficult to plan and allocate resources for action. Assessment of electricity access at different levels of health-care facilities was limited by the lack of comparable definitions for different facility types. Facility classification names were inconsistent, and types of care given at different facility types were not clearly defined nor consistent. Future survey instruments should consider ways to harmonize and standardize the classification of different facility types. This would facilitate comparability between countries and years. Further, data are also needed on disparities between public and private health-care facilities in energy access.

More detailed information on the source, adequacy, consistency (voltage fluctuations) and utility of the electricity supply would help to identify strengths and weaknesses of the currently deployed energy systems being used to power medical devices and deliver care. For example, most surveys focused mainly on primary electricity sources and excluded data collection on supplementary sources, making it difficult to gauge what combination solutions are used by facilities to meet their energy needs, particularly where the grid is unreliable or unavailable. In addition, since facilities often rely on off-grid energy sources (Liberia being a notable example), better assessment by energy source and by combinations of sources is critical to forecasting needs and identifying optimal energy solutions in diverse settings.

Given the search approach of focusing on national data of less developed countries (i.e. LI and LMI countries), the analysis does not capture subnational disparity in electricity access by health-care facilities, to identify targeted areas and populations that are particularly vulnerable. This could be the case even in higher-income countries, as highlighted through the Salud Mesoamérica Initiative, which found that inadequate health-care facility infrastructure was likely to contribute to the worse health outcomes of poor, indigenous and rural populations compared with national averages (**Box 2.6**) (Mokdad et al., 2015, 2018).

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BOX 2.6.**RESULTS-BASED FINANCING APPROACH OF SALUD MESOAMÉRICA INITIATIVE TO IMPROVE HEALTH FOR THE MOST VULNERABLE IN MESOAMERICA**

The Salud Mesoamérica 2015 (SM2015) Initiative is one of the first results-based financing initiatives, which encourages regional collaboration (GHDx, n.d.; Mokdad et al., 2015). It was established to improve the health of vulnerable groups – including poor, indigenous and rural populations – in the Mesoamerica region, including Mexico and central America. These populations often have considerably worse health indicators than national or regional averages. The initiative is a public–private partnership (PPP) with the Bill & Melinda Gates Foundation, the Carlos Slim Health Institute, Spain’s Cooperation Agency for International Development, the Inter-American Development Bank, and the ministries of health in eight participating countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama.

As part of its results monitoring, the SM2015 has routine data collection activities to track health-care facility

infrastructure and service delivery. Although the sampling frame is considerably smaller than typically seen in nationally representative datasets, the data do provide insight into the energy access situation in the region, particularly for the more marginalized communities. Based on these data, 69–100% of sampled health-care facilities were connected to functional electricity in the eight participating countries (**Table 2.6**). Three countries – Belize, El Salvador and Panama – showed progress in a short time span of 18 months, with connection to functional electricity increasing by 5–22 percentage points over this period.

Results from such an initiative can inform governments and other partners on how best to invest in health systems in these impoverished areas so that facilities are equipped with clean and reliable electricity, and poor and vulnerable populations can receive optimal care.

Table 2.6. State of functional electricity connection at baseline and follow-up among health-care facilities in selected poorest regions of Mesoamerican countries

Country and income group ^a	Year	Percentage with functional electricity connection (no. of facilities sampled)	Source
El Salvador; LMI	2011	75% (65)	IHME (2011)
	2014	88% (60)	IHME (2015a)
Honduras; LMI	2013	92% (90)	IHME (2013a)
	2014	88% (60)	GHDx (2014)
Nicaragua; LMI	2013	90% (40)	IHME (2013b)
	2014	90% (59)	IHME (2015b)
Belize; UMI	2013	77% (39)	IHME (2014a)
	2014	82% (38)	IHME (2015c)
Guatemala; UMI	2013	97% (61)	IHME (2014b)
	2014	93% (60)	IHME (2014c)
Panama; high income	2013	47% (38)	GHDx (2013)
	2014	69% (39)	IHME (2014d)
Costa Rica; UMI	2015	100% (38)	GHDx (2015)
Mexico; UMI	2013	95% (59)	IHME (2013c)
	2014	95% (60)	IHME (2015d)

^aThe income grouping refers to the World Bank analytical income of economies as of 1 July 2022, based on the 2021 gross national income per capita estimates.

The harmonization exercise revealed discrepancies in survey questions that can create barriers to understanding the actual electrification status of health-care facilities on the ground. When assessing trends, inconsistencies in questionnaires and in sampling methods contribute to uncertainties as to whether a data point represents the genuine situation at that point in time or an outlier. The trend analysis is thus limited to a single indicator and a small number of countries where the same surveys were conducted over time.

Way forward

This analysis frames some of the key issues and challenges faced in defining and measuring electricity access in health-care facilities in LI and LMI countries. Indicators presented in this chapter are an important step in proposing parameters for defining key electricity access attributes for health-care facilities. They are useful in identifying access gaps and trends, and will be valuable in building the evidence base around how they affect health service delivery and population health outcomes (Khogali et al., 2022). This is a timely endeavour, given the parallel aspiration of achieving universal access to clean and sustainable energy to protect health.

There is a need for a broader interagency effort to advance a framework to measure uniformly and fully the diverse dimensions of energy access in health-care facilities. Key institutions managing facility surveys, as well as ministries of health, ministries of energy and related experts, need to work together to identify and harmonize the best survey questions and electricity indicators relevant to delivery of health services and health outcomes. Such a framework could contribute to the development of more comprehensive, routine, global energy assessments of health-care facilities by United Nations agencies and other development partners in the health and energy sectors, as well as by national ministries, to support joint monitoring and reporting of energy access in health-care facilities. The new HHFA developed by WHO and District Health Information System 2 (DHIS2) managed by the HISP Centre at the University of Oslo take steps in this direction, and might be important means to gather more robust and harmonized data (**Box 2.7**).

BOX 2.7.

OPPORTUNITIES FOR MORE COMPREHENSIVE, ROUTINE, GLOBAL ENERGY ASSESSMENTS OF HEALTH-CARE FACILITIES

Harmonized Health Facility Assessment (HHFA)

The HHFA is a new, comprehensive health facility data collection system that assesses the availability of health facility services and the capacities of facilities to provide services at required standards of quality. The HHFA contains four core modules to be used in a sample of facilities, focused on service availability, service readiness (with electricity questions), quality of care, and management and finance. Availability, quality and effectiveness of health services are integral to UHC and contribute to achieving the SDGs. HHFA data can support health sector reviews, planning and policy-making, and enable evidence-based decision-making for strengthening country health services. The HHFA builds on the WHO SARA, as well as other global health facility survey tools and indicator lists for national and subnational facility assessments.

District Health Information System 2 (DHIS2)

DHIS2 is an open-source software used by at least 70 low- and middle-income countries as a web-based platform for their national health management information system. Often used for regular reporting of disease cases, stocks of medicines and vaccines, status of health facility infrastructure and other data, DHIS2 can provide snapshots of indicators of interest at sub-national and national levels. Data on DHIS2 can be visualized spatially and are updated nearly real-time. Further, DHIS2 allows data to be reported from any health facility tier and at various frequencies, which could be useful for tracking information such as electricity reliability that may vary due to weather or other unexpected events and helping health and energy ministries, researchers, and other organizations pinpoint specific settings where electricity reliability or other issues need attention and action.

Although this chapter presents some of the most commonly collected indicators from national surveys, there are additional areas of knowledge that should be explored further. For example, studies that investigate the relationship between electricity access and population health outcomes would allow estimation of the health burden associated with the electrification status of health-care facilities and better tracking of progress towards the SDGs. Linking data on electricity access with use would provide information on the relationship between health-care facility infrastructure and medical, communications and other equipment, informing decisions on what equipment to invest in, and future designs of equipment for optimal function and adaptation. Collecting data on expenditures and affordability of various electrification options and willingness to pay for adequate

electricity would allow comparison against “coping costs” – that is, expenditures otherwise needed for health-care facilities to compensate for lack of adequate electricity. These expenditures might include staff turnover, generator and fuel expenditures, administrative time, unproductive time of health-care staff, increased cost of maintenance, and costs to replace medical appliances that are damaged by inconsistent voltage.

As our climate changes, health-care facilities are coming under mounting pressure, making it harder for health professionals to keep people healthy in the face of increasingly severe climate events and impacts (WHO, 2020). The health sector is responsible for 4.4% of global carbon emissions (Health Care Without Harm, 2019). Clear distinction between backup and secondary/complementary sources of power would allow better assessment of the extent to which health-care facilities are prepared for emergencies, and have the supply of power needed to help meet adequacy and sufficiency. Gathering information on the types of fuels used by various energy sources would shed light on access to clean and sustainable fuels over polluting ones such as coal, biomass and kerosene, and on the climate resilience of health-care facilities.

Conclusion

There is broad consensus that electrifying health-care facilities with clean and sustainable energy is fundamental for a healthier world (Khogali et al., 2022). It is also increasingly recognized as key to advancing economic, environmental and climate outcomes. There is thus an urgent need to improve the geographic coverage, quality and frequency of data collection on energy access in health-care facilities. With an integrated tracking system that routinely collects comprehensive and standardized electricity access indicators, countries will be able to monitor in a robust and cost-effective way progress towards powering health-care facilities. This, in turn, will allow assessment of the impacts of electricity access on health, climate and other development goals; forecasting of future needs; and better allocation of limited resources. Such a system would enable better knowledge sharing between the health, energy and other sectors. Common challenges across settings and opportunities to collaborate can be identified. Further dissemination of experiences with new and innovative energy solutions and other lessons learned to policy-makers and practitioners would maximize evidence-informed policies.

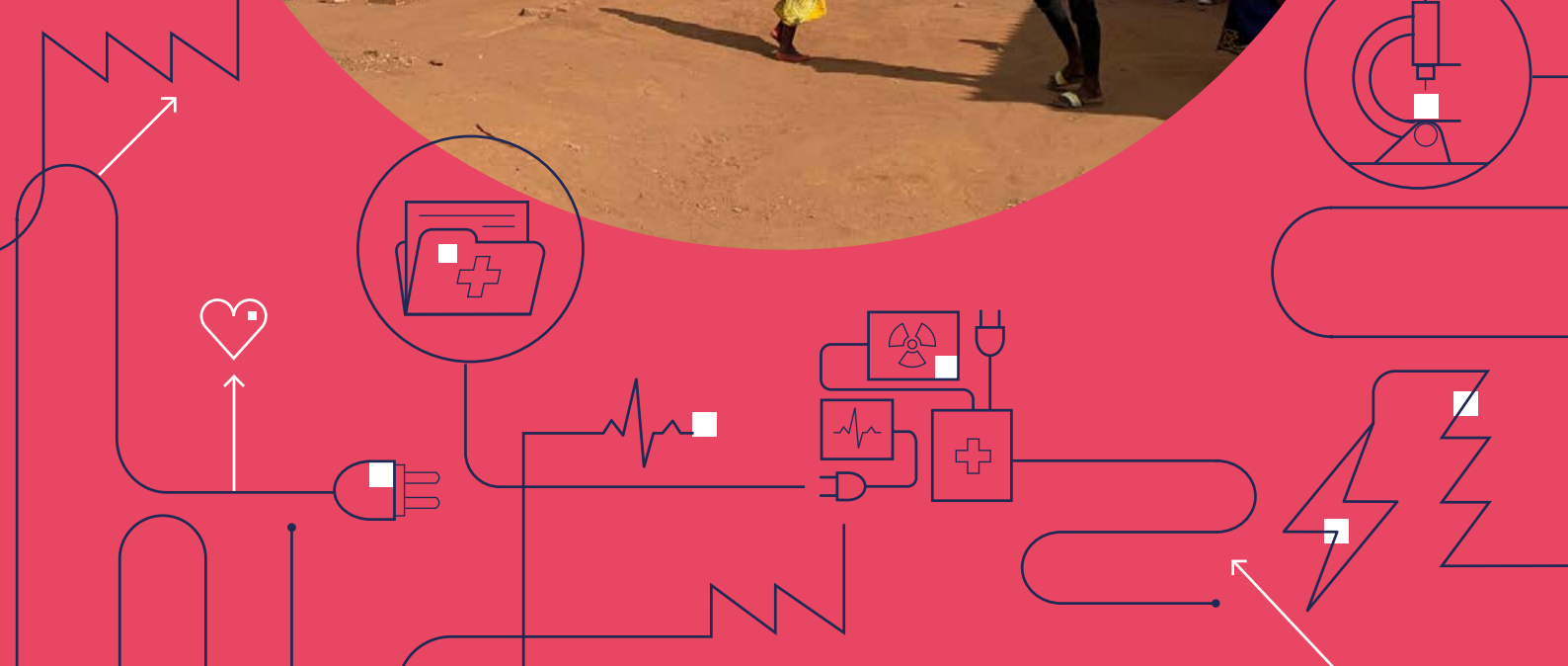
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Assessing energy needs of health-care facilities – technical guidance and tools



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This chapter describes considerations for Assessing energy needs of health-care facilities – technical guidance and tools. As highlighted in Chapters 1 and 2, electricity is required for undertaking several critical devices, including for basic diagnostics and medical procedures, for ventilation and sterilization, and to store vaccines, blood and medicines. This is in addition to the electricity requirements for water pumping, lighting, cooling and heating, sanitation, record keeping, telemedicine services and training of medical staff. Access to electricity is also important for creating a safe and conducive environment for patients and staff.

Section 3.1 provides an overview of the key energy needs for health-care facilities in low-resource settings. **Section 3.2** describes the factors that influence energy needs of a health-care facility. **Section 3.3** provides information about the energy needs assessment. **Section 3.4** focuses on the power needs of facilities based on the essential services that they deliver. **Section 3.5** describes the key thermal energy demands at health-care facilities. **Section 3.6** provides an overview of technical standards. Finally, **section 3.7** provides a brief overview of applicable energy efficiency technologies and trends.

3.1 Examples of key energy needs for health-care facilities

Clinics, 24-hour emergency services, outpatient and inpatient departments, maternity wards, operating rooms, medical warehouses, laboratories and diagnostic services rely on electricity to power the lights, refrigerate vaccines and operate life-saving medical devices. An inability to carry out these essential services puts lives at risk. Reliable electricity is essential for conducting medical procedures; monitoring community health and disease prevention; and powering operating theatres, autoclave sterilizers for instruments, microscopes, centrifuges and other diagnostic equipment. Other general needs for electricity include lights, fans, computers, mobile phone charging stations, and water pumping and purification systems. Some examples of key areas that require energy are described below.

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Basic medical equipment, lighting and communication

Electricity is required for the operation of basic amenities, including lighting, ventilation, information and communication technologies, and life-saving medical devices, and is necessary for multiple uses (e.g. laboratory, pharmacy). It enables staff at the facility to carry out basic tasks and undertake health education sessions. Energy access allows medical services to be provided at night (allowing expanded operating hours) and increases the opportunity for health clinic visits. Outdoor lighting of the health-care facility also makes the facility accessible and a positive landmark in the community.

Immunization and cold chain

In health centres, access to reliable electricity is essential for ensuring the cold chain to safely preserve and store vaccines, blood and critical medicines requiring refrigeration. Importantly, appropriate storage prevents wastage of vaccines.

Maternal and newborn care

During pregnancy and childbirth, adequate and continuous lighting, along with medical equipment such as a fetal heart rate monitor or an ultrasound, can be life-saving measures for women and children. Services that require energy to run effectively include family planning, antenatal care, care during delivery (24-hour delivery services – both normal and assisted), postnatal care, newborn care, nutrition services, immunization services and termination of pregnancies. Maternal and child health-care equipment, such as baby warmers, suction machines for deliveries, phototherapy, oxygen concentrators, lighting and fans, require reliable electricity access.

Telemedicine

Information and communication technology is a critical enabler of telemedicine strategies, which have been extremely effective in supporting activities such as remote health worker consultations, and ongoing training and education. Communication is also a critical enabler of access to public

health education and information in an era of rapid global and regional disease transmission, pandemic alerts and extreme weather. Reliable energy is needed to power computer, mobile phone and internet services required for remote consultations.

Facility operations, administration and staff facilities

Efficient management of patient records and referrals, and collection and reporting of health statistics, are greatly facilitated when computer-based services, software and solutions are available. Lights and fans are needed for the basic day-to-day operations of facilities such as offices, storerooms, administration areas, reception and registration areas, toilets, pharmacies and other supportive departments. Electricity access increases the sense of safety for patients and staff. Access to the staff quarters can contribute to attract and retain qualified health workers and to reduce employee absenteeism in health-care facilities.

Access to hot and cold water

Health-care facilities often need powered water pumps to secure the water necessary to deliver health services, and water heaters to provide patient comfort, especially in colder climates. Water purifiers are also essential in areas with poor water quality.

3.2 Factors influencing energy needs

The energy needs of health-care facilities depend mainly on the type of facility, the services provided at the facility and the patient load.

3.2.1 Type of health-care facility

Public health departments may require certain essential services and infrastructure at each level or tier of health-care facility in the public health system. At each tier, there could be multiple types of facilities based on the number of beds, the number of patients being catered to or the extent of service provision. The guidelines for each type, combined with field experience of service provision, help determine the energy needs. These can be developed as templates to aid the design of electrification solutions.

Many countries provide health infrastructure standards that define the health-care referral pyramid, medical services and respective appliances, and staffing requirements at each tier of health-care facility. Broadly, three main tiers of care and health-care facilities can be identified (Jamison et al., 2006; PMNCH, 2011; WHO, 2016).

- Health posts or clinics, at the community level, include community health and outreach workers who deliver interventions relating to safe motherhood, nutrition, and simple preventions and treatments. Depending on the country context, the level of development of infrastructure, services and socioeconomic resources, this level of care may also include treatment for the most prevalent diseases (e.g. HIV/AIDS, tuberculosis, malaria), counselling and dispensing of medicines.
- Health centres, at the first or primary level, include trained health-care professionals who offer maternity care (e.g. prenatal care, skilled birth attendance, family planning), interventions to



address childhood diseases (e.g. vaccine-preventable diseases, acute respiratory infections, diarrhoea), and prevention and treatment of major infectious diseases. These facilities include outpatient services and observation rooms for patients staying longer, and may include a labour room and outpatient surgery units.

- District, regional or provincial hospitals, at the referral level, cater to large populations and are equipped with complex facilities and medical equipment. These hospitals provide specialized services, including outpatient and inpatient departments, emergency services and surgical areas. Their health practitioners and infrastructure cover at least the following four areas of specialization: internal medicine, surgery, paediatrics and obstetric care.

However, the definition of tiers and even the number of tiers vary from country to country (as shown in **Web Annex C**), as do equipment recommendations for a given type or tier of facility (CLASP, 2021). There is no universal health-care facility classification system because the level of care varies considerably in different countries based on socioeconomic context, country-level policies and health-care budgets. Within the same tier of health care, the energy requirements of a health-care facility can be influenced by its sociodemographic profile (in terms of the population it caters for), the ownership model, the proximity to private health-care facilities (if any) and the diseases prevailing in the community. The type of terrain and prevailing climate conditions in the region can further affect technology selection, and the system size requirements to meet energy demands across seasons. The existing built environment of the facility and essential medical equipment can vary considerably, primarily due to differences in the energy efficiency of the building envelope and medical equipment. These elements, and their impact on the power system design and sizing, are discussed in detail in Chapter 4.

3.2.2 Load considerations

The loads considered for design of an electrification system should be based on the equipment requirements for each room in the facility and the services being delivered. Load assumptions can vary for specific geographic areas, based on needs. For example, if a health-care facility has a specific disease burden, certain assumptions or usage hours may need to be adjusted from the template designs.

Loads should also be assessed to identify critical and non-critical loads; critical loads require greater reliability and availability of the service. Decentralized energy systems can be designed separately for critical loads and non-critical loads. For example, lights, fans, mobile charging points, laptops and printers are considered as non-critical and consumptive loads, whereas baby warmers, oxygen concentrators and refrigerators are considered as critical loads. Usage patterns of one should not disrupt the functioning of the other. For example, overuse of lights and fans (non-critical loads) should not drain the power required for refrigerators and baby warmers (critical loads) when required. Hence, they should be designed and connected separately, if possible.

3.2.3 Typical operational hours

The design of a decentralized electrification system requires a detailed inventory of all loads and their consumption. The load assessment includes a listing of the quantity of appliances, and the power consumption and daily hours of operation of each appliance. Relevant decision-making authority should consider the expected increase in total daily load due to reliable functioning of the facilities. This can be done in a strategic manner to arrive at a system design specification higher than the currently determined daily load.

3.3 Health-energy needs assessment

Health-care facilities, even within the same tier of a public health system, vary in the type and amount of daily health services they deliver. This variation could be a function of the demand in the region, accessibility, affordability, availability of doctors and other staff, and several other reasons. As a result, a “one size fits all” approach to determining the energy requirements of a health-care facility and installing a standardized energy system would fail to note the nuances in equipment efficiency, equipment use or special needs reflecting the health conditions in different regions. To reveal the health priorities and existing challenges in delivering health services for a particular region – which are important in designing an optimal and long-term energy solution – a health-energy need assessment is needed.

Energy assessment for health-care facilities should integrate health and energy needs simultaneously for better design, ownership and use. This includes aspects from the health side (i.e. health-care services and facility profile), the nexus between health and energy (i.e. infrastructure, equipment, accessibility and environment) and the energy side (i.e. energy scenario, related impacts and systems). Benefits of an integrated assessment approach will accrue to patients, who will gain both increased access to health services and improved quality of services, and to facility managers and staff, who will experience improved well-being and productivity, as well as reduced equipment damage and financial savings.

Convergence in understanding and assessing priorities for energy access and health care can provide key insights into improving system design and consequently health-care delivery and its outcomes. Since energy is only one part of the equation, the combined health-energy need assessment can also help identify other critical and related needs, such as the need for additional staff or for appropriate equipment. A basic energy assessment focusing only of the existing energy situation would not provide these insights, which are critical in improving health-care delivery on the ground.

3.3.1 Outcomes of the health-energy needs assessment

The health–energy assessment should be a participatory exercise, carried out using a toolkit to assess the existing health services, including gaps and future service needs in last-mile health-care facilities. Tools and check lists help in gathering information about the facility and its patients’ needs systematically and scientifically, in consultation with the health staff, and subsequently aid in designing a detailed plan for improving the services available at the facility. By building understanding of the pattern of energy consumption, the assessment can also suggest actions to rationalize energy use and reduce power demand, which influences system design and enables customization of the solution. Overall, this exercise can help in:

- identifying and categorizing services and appliances in terms of critical and non-critical energy loads;
- recommending energy-efficient and suitable health-care appliances (for essential and desirable services);
- designing optimized decentralized energy systems;
- designing energy-efficient structures and built environment;
- determining additional services that could be delivered through the centre with new appliances;
- determining human resources requirements to manage the energy system and appliances; and
- planning financial or budgetary requirements.

Gaps identified in the health–energy system can allow institutions and development partners to develop and implement customized design strategies to address the gaps, resulting in a range of impacts in different parts of the health system. An example of some of these gaps, strategies and impacts is presented in **Fig. 3.1** based on SELCO Foundation (2020).

Fig. 3.1. Example of gaps in energy-health system, strategies to address them and impacts



3.3.2 Toolkits for health-energy assessments

Toolkits for the health-energy needs assessment may include a combination of interviews with staff at the health-care facility; collection of data on health-care appliances, and their power consumption and usage patterns using energy meters, data loggers and registers; observations about built environment structures; and checklists and photographs to enable design of energy systems.

Energy data loggers are plug-in devices that can help record electricity consumption from individual line wires of the electricity distribution panel, over an extended time frame. These would be useful in remote areas where regular billing of electricity is a challenge, and can also help monitor voltage fluctuations and frequency of power outages.

Chapter 4 includes more details about available online tools that could be used to facilitate a health-energy needs assessment.

3.3.3 Skills and expertise

The assessment team should include an administrator or medical officer of the health-care facility and a local energy technician. In addition to merely addressing the energy gaps, such a joint participatory assessment can open opportunities to expand health services being delivered at the centre with increased access to reliable electricity.

3.3.4 Challenges for health-energy needs assessments

The health-energy needs assessment exercise can pose some challenges. For instance, power outages in resource-constrained settings may make it difficult to estimate energy demand under a counterfactual scenario of consistent, reliable electricity. Moreover, a snapshot-in-time demand assessment does not consider seasonal or temporal variations in health service delivery, nor in lighting, heating and cooling needs. To ensure that the system is designed to provide reliable electricity throughout the year, the system sizing should take into account the busiest months in terms of service delivery due to ailments that commonly occur in the community (e.g. skin diseases, snake or insect bites) or have a high prevalence (e.g. exponential growth in malaria cases during onset of the wet season) (Hajison et al., 2017), as well as periods with the heaviest energy loads (e.g. for air conditioning). Ultimately, the outputs of a demand assessment are only as good as the inputs, especially when energy demand varies considerably over the course of a year. In addition to the health-care facility staff, it is important to involve local actors - such as local energy technicians or local organizations - in the health-energy needs assessment, system design, and future operation and maintenance (O&M), to ensure overall project sustainability.

Furthermore, supply may vary temporally and seasonally as a result of fluctuations in grid power reliability (if the facility is grid connected) or solar insolation (if solar is the primary or backup power source). Anticipating variations in supply allows planners to estimate battery backup requirements so that a facility can function with minimum interruptions due to power outages or (if solar is the main power source) overnight loads.

Finally, the demand assessment should consider future energy demands that may result from new medical equipment, and new or expanded health services, and the resulting requirements for lighting, power, heating and cooling. For example, a potential increase in number of operating hours should be considered, if the facility is currently closed at night because of lack of electricity.

Moreover, energy demand for a health-care facility can expand beyond medical services to include in-house residential accommodations or staff quarters, where amenities such as water supply, lighting and ventilation can help attract and retain skilled health workers, especially in rural and remote settings (WHO & World Bank, 2015). There is also a need to develop strategies to reduce energy generation needs through efficient equipment (Morgenstern, Raslan & Ruysevelt, 2016) and integrate reliable energy systems to power critical loads as priority.

If new loads are expected to be added in the future, their energy demands can be assumed in the assessment, to ensure that the energy system is sized for both present and future needs. Furthermore, modular sources of energy – for example, based on solar PV – can be suitable for further future expansion. Future demand may arise not just from additional equipment or population growth or migration, but also from patients choosing to come to better-electrified facilities more often rather than to other sites that have less reliable infrastructure, and to come to a fully functional clinic rather than seeking other medical care options (e.g. a midwife outside a clinic setting, a village healer). As well, the COVID-19 pandemic has shown how some new treatments and medical equipment might come into high demand if a clustering approach for testing, isolation and inpatient treatment in selected health-care facilities is followed. Energy demands might therefore reflect global, regional or local trends in diseases, and national management of such diseases.

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3.4 Power requirements in health-care facilities

Table 3.1 lists some of the medical devices in common use by both general health services and specialized health services (e.g. maternal and child health, surgical and anaesthesia, laboratory and diagnostics, and infectious diseases), and the indicative power requirement of each piece of equipment. This list provides is not comprehensive and provide an example of the electricity requirements of a health-care facility with regard to the demands of medical equipment

Table 3.1 builds upon the equipment listed in the WHO SARA¹ survey and on the list provided by WHO and the World Bank (2015). The indicative power requirements may vary based on manufacturer, equipment size and energy efficiency of the equipment; not all of these variables are captured in the table.

A major challenge for health-care facilities in resource-constrained settings is the lack of information on appropriately sized and designed medical equipment for health-care service delivery (CLASP, 2021).

In 2010, WHO (2010a) highlighted that over 50% of the medical equipment in low-income countries was not functioning, not used correctly or not maintained, with some being entirely unnecessary or inappropriate to fulfill its intended purpose. Furthermore, in sub-Saharan Africa, almost 70% of equipment was found to lie idle due to mismanagement of the acquisition process, absence of user training and lack of effective technical support.

One major problem is the poor quality of electricity supply and resulting voltage fluctuations and surges, coupled with lack of adequate protection of the equipment (e.g. from electricity surges due to lightning strikes). A university training programme that collected data from 33 hospitals in 10 low-income countries found that inadequate power supply was the single most common cause of medical device failure, with nearly a third of equipment failures occurring as a result of power problems (WHO, 2010a). Moreover, the lack of capacity to maintain medical equipment is not always given due consideration in many countries (WHO, 2010b). The World Bank (2007) estimated that, of the medical equipment it invested in between 1997 and 2001, 30% was unused, and equipment in operation faced 25–35% downtime due to insufficient capacity to repair and maintain the equipment.

Equipment breakdown due to these issues in regions with poor reliability and quality of electricity supply is rarely an active consideration for equipment manufacturers that primarily design equipment to be used in North America, Europe and East Asia, where facilities tend to have better-quality and more reliable electricity supply, and are less susceptible to highly variable climates (CLASP, 2021).



1 The SARA survey is designed to assess and monitor the service availability and readiness of the health sector by measuring, among other things, the availability of infrastructure resources, equipment, amenities, medicines and diagnostic capacities, and the readiness of health-care facilities to provide basic health-care interventions (WHO, 2015). The survey guidance and reference manual provide a list of medical equipment that is required for delivery of general health services, as well as specialized health services. The energy requirement is not an indicator that is tracked for electrical devices under the survey, apart from immunization cold chain.

Table 3.1. Typical electrical devices for health-care facilities and related power requirements

Device	Indicative power rating in operation mode (W)	AC power supply (V)	DC power supply (V)	References ^a	Services for which device is a key input
Incandescent lamp (10–15 lm/W)	25–75	110/220	12	1	GS, SA
Halogen lamp (15–20 lm/W)	60	110/220	12	2	GS, SA
Compact fluorescent lamp - CFL (45–65 lm/W)	13–15	110/220	12	3	GS, SA
LED lamp (70–90 lm/W)	10–15	110/220	12	4, 36	GS, SA
Security lighting, outdoors (LED)	40–240	110/220	12	5	GS
Mobile phone battery (charging)	2–6	110/220	5	6, 37	GS
Desktop computer	60–300	110/220	12	4, 38	GS
Laptop computer	20–100	110/220	12–20	4, 39	GS
Internet (V-Sat connection)	22–300	110/220	15–24	7	GS
Printer, inkjet	10–100	110/220	12–20	4, 8	GS
Printer, laser	300–500	110/220	24	8, 41	GS
VHF radio receiver (standby)	1–2	110/220	12	9, 42	GS
VHF radio receiver (transmitting)	6–25	–	12	9, 42	GS
Ceiling fan (AC)	30–100	110/220	–	4, 43	GS, C19
Ceiling fan (DC)	18–36	–	12	10, 44	GS, C19
Refrigerator, 165 L (for food and water) (AC)	42–180	110/220	–	4, 45	GS
Refrigerator, 165 L (for food and water) (DC)	40–80	–	12/24	11, 46	GS
Water heater, 200 L	4000	110/220	–	63	GS
Portable electric space heater	400–1500	110/220	48	4, 12	GS
Portable air conditioner (AC–DC variants)	450–1500	110/220	48	13	GS
Countertop autoclave (steam sterilizer) (19–45 L)	1400–3500	110/220	–	4, 14	GS, SA, ID, C19
Dry heat sterilizer	500–750	110/220	–	15, 47	GS, SA, ID, C19
Small waste autoclave (35–178 L)	2000–6000	220	–	16, 48	GS, SA, ID, C19
Autoclave grinder	6600	220	–	17	GS, SA, ID, C19
Small water pump – clinic	30–180	–	15–30	4	GS, SA, ID
Water pump – district health centre				18, 49	GS, SA, ID
UV water purifier	14–83	110/220	12	19	GS, SA, ID
Reverse osmosis/other water purifier	100	110/220	–	20	GS, SA, ID
Micro-nebulizer	1.5–3	110/220	2 × 1.5 V AAA batteries	21, 50	GS, MC
Nebulizer	170	110/220	12	4, 51	GS, MC
Oxygen concentrator	70–350	110/220	12–18	4, 52	MC, SA, C19
Pulse oximeter (battery operated)	<1 (20–60 mW)	110/220	2 × 1.5 V AAA batteries	4, 22, 53, 64	MC, SA, C19
Vaccine refrigerator (electric mains)	150–1000	110/220	–	23, 54	MC, ID, C19
Vaccine refrigerator (solar charged, battery driven)	50–100	–	12–24	24	MC, ID, C19
Vaccine refrigerator (SDD)	160–500 (array ^b)	–	12/24	4, 55	MC, ID, C19
LED light for phototherapy treatment of neonatal jaundice	20–180	110/220	24	4, 25	MC
Suction apparatus (AC)	70–180	110/220	–	25	MC, SA, C19
Suction apparatus (DC)	48	–	12	26	MC, SA, C19
Vacuum aspirator or D&C kit	70	110/220	3–6	4, 33	MC, SA, C19
Neonatal incubator	300–1000	110/220	12/24	4, 56	MC
Neonatal infant warmer	300–550	110/220	12	27	MC
Fetal heart monitor (Doppler)	1.5–3	–	2 × 1.5 V AAA batteries	4	MC
Ultrasound	200	110/220	–	4	MC, LD, C19
Portable ultrasound	22–28	110/220	12/24	4	MC, LD, C19

Device	Indicative power rating in operation mode (W)	AC power supply (V)	DC power supply (V)	References ^a	Services for which device is a key input
Laboratory refrigerator	40–100	110/220	11–15	4	LD, C19
Centrifuge	100–200	110/220	–	4	LD, C19
Mini-centrifuge	15–25	110/220	12	4, 57	LD, C19
Haematology analyser	60	–	12	4	MC, LD
Blood chemistry analyser	75	–	–	28	MC, LD, C19
Blood chemistry analyser (handheld)	9–18	–	2 × 9 V lithium batteries	4	MC, LD, C19
Cluster of differentiation 4 counter	100–200	–	12	29	MC, LD
Brightfield white light microscope (with LED light)	20	110/220	3–6	30, 58	LD
LED microscope (for fluorescence smear microscopy – halogen or LED light)	20 (halogen) 3 (LED)	110/220	12	29, 59	LD
Mercury/xenon fluorescence microscope	100	110/220	–	4, 60	LD
X-ray machine	600–70 000	110/220	–	4	LD, C19
Portable X-ray machine	150–300	110/220	–	4	LD, C19
Laboratory incubator	100–200	110/220	12	31	LD
Vortex mixer	15–60	100/240	12/24	18, 49	LD, C19
Sputum-smear microscopy (LED microscope with fluorescent smear)	–	–	–	4	LD
PCR diagnostic (based on GeneXpert MTB/RIF)	150–190	110/220	12/24	32, 61	LD, C19
ELISA plate reader	150–770	110/220	48	4	LD
Portable ECG	30	110/220	3–12	33	SA, LD, C19
Defibrillator with ECG	130	110/220	14–15	34, 62	SA
Blood glucose monitor	1.5–3	–	1 × 3 V or 2 × 1.5 V battery	4, 33	GS, LD
Anaesthesia machine	100–1440	110/220	–	35	MC, SA
Low-energy anaesthesia machine with DC monitor backup	50	110/220	12	4	MC, SA

AC: alternating current; C19: COVID-19 treatment; DC: direct current; D&C: dilation and curettage; ECG: electrocardiograph; ELISA: enzyme-linked immunosorbent assay; GS: general services; ID: infectious disease; LD: laboratory and diagnostic; LED: light-emitting diode; Im: lumen; MC: maternal and child; PCR: polymerase chain reaction; SA: surgical and anaesthesia; SDD: solar direct-drive; UV: ultraviolet.

^a See **Web Annex D** for full citations.

^b An SDD refrigerator is stand-alone system directly wired to a dedicated solar array.

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The steps involved in power demand assessment include listing all medical equipment required in the facility, the estimated hours of operation (including which hours or periods of the day the equipment would be powered, which is necessary for estimating peak load), and the critical nature of certain equipment that always needs to be powered. Chapter 4 and **Web Annex E** provide more details on energy demand assessment exercises.

3.5 Thermal energy needs

Apart from electricity needs, thermal energy requirements in a health-care facility can amount to a sizeable proportion of overall energy consumption. Thermal energy consumption in a health-care facility serves various end uses, including space heating, steam generation, sterilization, medical waste incineration, domestic hot water and cooking.

3.5.1 Space heating, ventilation and air conditioning

Maintaining an appropriate indoor air temperature is crucial in health-care facilities. The energy demand depends on the external temperature, as well as on the heat generated by both equipment and occupants. An effective cooling and/or heating (depending on external weather conditions) and ventilation system, along with proper insulation, is important to regulate building temperature. In addition to maintaining thermal comfort, heating, ventilation and air conditioning systems are required to regulate operating temperatures for equipment and to maintain indoor air quality.

Patient rooms often have relatively high energy consumption for heating and cooling, due to their need for high ventilation rates and stricter requirements for microclimate control (Cesari et al., 2020). The use of natural ventilation and cooling, building orientation and shading can help to provide optimal thermal performance for the building, in addition to reducing overall energy demand and increasing affordability (WHO & World Bank, 2015). Natural ventilation should be prioritized wherever climatic conditions are favourable. In most primary care facilities, fans and natural ventilation would be the most common heating, ventilation and air conditioning systems, because of their relatively low investment needs.

Using electric heaters for space or water heating consumes a large amount of electricity and has a high power load. Heat pumps or reversible heat pumps offer a more energy-efficient solution, especially in temperate climates. Heat pumps can provide both cooling and heating, using a similar technology to conventional air conditioners for cooling. Compared with electric heaters, they are also more efficient in providing heating in most climates – 1 kWh of electricity is converted to the equivalent thermal energy of 3–5 kWh from a conventional electrical heater. This implies that heat pumps are 3–5 times more efficient, and require 3–5 times less power to run, than electric heaters.

Daylight is the most desirable type of illumination for human comfort, and can save energy used for lighting if used properly. A well-designed daylight system, through proper size, orientation and positioning of windows for lighting and outside views, can lead to better psychophysical well-being of both patients and staff, reduce the need for pain medications, ease post-surgical pain and reduce length of stay in hospital (Kapoor & Kumar, 2009; Cesari et al., 2020). However, use of daylight needs to be regulated because excessive daylight can lead to overheating and the glare effects of solar radiation (Kapoor & Kumar, 2009). Access to natural light should be maximized in staff areas such as examination rooms, nurses stations, offices, corridors, reception areas and public spaces such



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as waiting areas, along with daylighting controls (Bonnema, Pless & Doebber, 2010). Passive solar design can help reduce space heating and air conditioning requirements.

Adequate ventilation, ultraviolet light and air filtration, are examples of components of infection prevention efforts in facilities to reduce the risk of nosocomial transmission of a variety of pathogens, such as the virus that causes COVID-19, the tuberculosis disease agent and varicella zoster virus.

3.5.2 Cooking and water heating

Thermal energy is also required in health-care facilities for heating water and for cooking, in clinics where food is prepared for patients on-site (or in staff quarters). Hot water is required for laundry, sanitation, bathing, washing and cooking, among other uses.

Where the health-care facility is connected to the central grid, and electricity is reliable, water heating can be provided by electric water heaters. However, electric resistance water heaters have a high power rating – typically 5000 W for a 200 L hot water storage tank (the operating time depend on the specific climatic conditions and uses, but on average it can be assumed that it operates 3 hours per day to heat water and keep it warm). The tank must reach a high temperature, typically at least 55 °C, to avoid the growth of *Legionella* bacteria in the tank and hot water distribution system (e.g. tank, pipes, shower heads). Resistance water heaters are able to convert 1 kWh of electricity to at most 1 kWh of heat, and some of this heat will be lost if the system is poorly insulated. Flat tube or evacuated tube solar water heaters can reach such temperatures, and have been successfully deployed commercially in many low-income countries. In temperate climates (provided ambient air temperatures are above about 5 °C), air to water heat pumps can achieve the water temperatures required to avoid *Legionella* growth. The heat pump can be integrated with either a hot water storage tank or a stand-alone unit with a separate hot water tank of the desired capacity.

As for cooking, the lack of access to clean cooking technologies and fuels, and the ill effects of indoor air pollution that result, is also a risk in the institutional kitchens of health-care facilities (WHO & World Bank, 2015), but little data exist on the extent of access to modern cooking technologies and fuels in health-care facilities.

Adoption of clean cooking solutions should be ensured. Just as in household settings, clean fuels and technologies for cooking (e.g. liquefied petroleum gas, biogas, electricity) and the use of thermally efficient improved cookstoves can reduce cooking time and safety risks from fuel-wood collection in many areas and should be encouraged (WHO, 2014a). The cost of cooking with electricity, in particular via solar PV systems, has decreased significantly, making it more cost-competitive with its alternatives. This cost reduction is primarily due to a reduction in the cost of solar modules and batteries of 30–50% since 2016 and the introduction of more energy-efficient cooking appliances (IRENA et al., 2020).

3.5.3 Sterilization and medical waste handling

Sterilizers and autoclaves for medical waste treatment and sterilization of equipment require thermal energy. About 85% of the waste produced in health-care facilities is not hazardous and is comparable to domestic waste that can be disposed of by standard means (WHO, 2014b). The remaining 15% is regarded as hazardous: it includes infectious, chemical or radioactive wastes, and sharp materials such as used needles, syringes, blades and broken glass. This hazardous waste needs to be managed effectively to prevent environmental and health risks, and to avoid unsafe exposure of health-care staff, patients and the general public (WHO & UNICEF, 2019).

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, and the Stockholm Convention on Persistent Organic Pollutants recommend waste treatment techniques that minimize the formation and release of chemicals or hazardous emissions. WHO recommends steam-based methods such as autoclaving, or non-incineration methods such as microwaving, to decontaminate waste. These technologies require significant energy, which can be provided by direct thermal generation (e.g. burning gas or solid fuel) or from electricity.

Although these methods are preferred, they are often not feasible in low- and middle-income countries because of a lack of reliable water, energy and solid waste collection processes (WHO, 2019). For instance, WHO considers high-temperature two-chamber incineration as a safe treatment method for health-care waste. However, health-care facilities in low- and middle-income countries sometimes only have access to simpler single-chamber incinerators, open burning or burning in pits. In some contexts, even when incinerators are installed, they are not functional or do not have fuel available to run them (WHO & UNICEF, 2019). Several types of low-cost, energy-efficient autoclaves are now presenting a viable alternative to incineration in low-resource settings (WHO, 2022).

The WHO global progress report on WASH identified that 70% of health-care facilities in the least-developed countries lack basic health-care waste management services (WHO & UNICEF, 2020). The economic consequences of COVID-19 pandemic could widen this gap. The pandemic has highlighted the need for sound waste management systems, especially in light of growing use of personal protective equipment (e.g. gloves, masks, face shields), sanitization and cleaning products (e.g. cleaning cloths, detergents, sanitizers), diagnostic and laboratory testing materials, and waste generated from vaccine injection needles (WHO & UNICEF, 2020). Countries should focus on building sustainable waste management chains through policies that guide implementation of recycling and treatment technologies.

Although it is critical to ensure that hazardous waste is safely treated and disposed of, correct segregation of non-hazardous waste from the hazardous waste stream reduces the amount of waste to be treated using costly treatment processes such as high-temperature incineration and sterilization. This best-practice waste management is crucial in regions where treatment options and safe disposal sites are limited. It also allows recovery and recycling of certain types of non-hazardous waste (WHO & UNICEF, 2019).

The long-term aim for waste treatment should be the use of non-burn technologies, such as autoclaves, through either centralized or on-site treatment. In the near term, greater segregation, and improved design and operation of locally built incinerators (that include pre-heating, dual chambers and ways to prevent overloading of units) can help achieve higher temperatures and lower emissions of persistent organic pollutants (WHO, 2022).

The energy needs associated with the usage of autoclaves and waste treatment technologies should be considered in the overall electricity demand. Over time, non-burn technologies cost less than advanced incineration and allow recycling of treated health-care waste (WHO, 2022). The savings generated can partly fund O&M to ensure sustainable operation of these technologies.

COVID-19 has exposed gaps in health-care waste management and the functioning of WASH services, which are critical to ensure patient safety and quality of care. In addition, climate change impacts on WASH and health services, gender-specific needs and equity in service provision all require adaptable tools for regular monitoring and improvement.

BOX 3.1.

INCORPORATING ENERGY AND CLIMATE CONSIDERATIONS IN THE WATER AND SANITATION FOR HEALTH FACILITY IMPROVEMENT TOOL

The Water and Sanitation for Health Facility Improvement Tool, which was first launched in 2018, is now in use in more than 40 countries. The tool provides a framework for understanding WASH and waste risks, and enables countries to develop, monitor and implement an improvement plan to address these risks (WHO & UNICEF, 2022). The second edition of the tool, launched in 2022, is now adaptable to different tiers of health-care facilities and to different contexts of national health priorities. It integrates indicators to assess and monitor WASH and climate change mitigation strategies related to health-care facilities, such as energy, vector control and occupational health. It also includes guidance on monitoring and improving climate resilience, and mitigating climate change impacts on WASH services.

Apart from developing indicators across the five primary WASH domains (water, sanitation, health-care waste, hand hygiene and environmental cleaning), the tool places emphasis on monitoring and assessment across the domain of energy and environment. This domain encompasses indicators on energy supply sufficiency and functional backup energy sources, adequate lighting,

energy efficiency, ventilation and airflow, control of vectors and other animals that transmit disease, and safe management of wastewater and stormwater (WHO & UNICEF, 2022). The tool has a particular focus on building, upgrading and sustaining WASH and energy services that are climate-resilient, equitable and inclusive. It facilitates coordination and sharing of responsibility among various stakeholders in the WASH, energy and waste sectors, such as policy-makers, district health officers, hospital administrators, engineers, waste technicians and users.

Some of the climate-smart WASH considerations and improvements suggested across the domains that have a bearing on energy demand are reinforcing infrastructure and installing backup power supplies, based on current and future climate impact risks in the region; enhancing water security through water storage, reuse and reduction; incorporating environmentally sustainable waste treatment such as non-burn technologies for health-care waste; switching to energy-efficient lighting and heating/cooling; and implementing renewable energy solutions (e.g. solar) to power basic equipment, lighting, water pumping and heating.



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3.6 Technical standards

Several national and international standards and test laboratories guide the design, manufacturing, installation, quality assurance, compatibility and safety of an energy system. These standards come in multiple forms (USAID, 2020), from determining materials (e.g. strength of rooftop mounting structure) and products (e.g. maximum power of a solar panel) to services (e.g. installation of solar PV power supply systems). Some of the common international standards are those of the International Organization for Standardization, the International Electrotechnical Commission, and the Institute of Electrical and Electronics Engineers.

The USAID has summarized some examples of international technical standards for energy system components and health system loads (USAID, 2020). Moreover, Harper et al. (2021) outlined a quality assurance framework for the design, procurement, installation, and long-term O&M of off-grid solar electricity systems at public facilities such as health clinics and schools. The approach involves quality and performance standards for equipment design and installation, along with the innovative use of digital remote monitoring technology to ensure and verify the ongoing performance of off-grid solar electricity systems against established key performance indicators.

Where international standards are relied upon for quality assurance, they need to be harmonized and adopted by relevant government agencies to meet performance requirements in various countries based on local climatic and environmental conditions. National standards complement the international standards. For example, in India, the Ministry of New and Renewable Energy adopts and develops Indian standards that are in line with international standards through creation of

research and development institutes and performance testing laboratories for energy systems. These testing laboratories are accredited by the National Accreditation Board for Testing and Calibration Laboratories and approved by the Bureau of Indian Standards. Energy system equipment needs to be registered by the Bureau of Indian Standards (MNRE, 2017).

While technical standards for energy system components exist, a recent report (CLASP, 2021) highlighted the need for more precise guidance from national health authorities on the selection of medical equipment specific to supporting electrification of health-care facilities, for example that are efficient and suitable for harsh conditions. The report highlights that such country-level guidance is often generic, with a list of all allowable medical equipment, that is not defined based on the electrification needs and the local contexts in rural areas and low-resource settings. Furthermore, national guidelines often do not take into account passive energy design interventions (e.g. building orientation, daylighting, natural ventilation) or key services where the most energy efficiency gains can be made – for example, efficient water supply, space cooling or heating, and improved cooking solutions (see **Web Annex E**).

3.7 Energy efficiency and suitability of medical devices for harsh conditions

Manufacturers of medical equipment typically focus on safety and reliability. In several cases the design takes for granted that a consistent, reliable electricity supply is guaranteed. Very few medical devices are suitable for performance in settings where the equipment is exposed to harsh conditions (e.g. hot and/or humid climates, dusty environment), or in rural or remote areas with intermittent power supply (WHO, 2010b; CLASP, 2021). Variation in the nature of energy supply in off-grid and weak-grid clinical settings is a key technical challenge.

A growing number of devices is now being developed that can use DC (such as the one generated by solar PV) without the need to convert it to AC. Furthermore, health posts and small health clinics have sometimes met specific needs by using DC-based solar packages to provide for obstetrics services or lighting. However, these small-scale solutions support only some specific electricity needs of a facility, while larger-systems (either DC or AC based) are needed to properly electrify a health-care facility and address all critical needs.

AC power supply is preferred in medium to large health-care facilities. DC power produced by solar or batteries is at a single voltage, and further voltage conversion is required to cater to voltage variations between different types of DC-powered equipment (3–34 V) (WHO & World Bank, 2015).

Where the source of power and the equipment are not compatible, an inverter is added to the system design – either at an equipment level or at a systems level – to convert DC to AC power and power AC appliances.

Some improvements have been made in energy efficiency for basic systems, such as lighting. Many lighting manufacturers now provide CFLs (13–15 W) and LED lights (10–15 W) in place of earlier-generation halogen and incandescent lights. LED lights consume less electricity than fluorescent lights to provide the same level of light, and last 4–5 times longer than CFLs (United States Department of Energy, 2009). In some cases, medical devices have become available that rely purely on a renewable energy power source, such as SDD refrigerators.



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Minimum quality and technical standards are useful to ensure that substandard or oversized equipment is not installed at health-care facilities. For medical devices used in immunization programmes, WHO has a prequalification for their suitability for use. This has led to a wide market for innovative cold chain equipment that is either energy-efficient or is powered purely by renewable energy sources – for example, SDD freezers and refrigerators (WHO, 2020).

Innovation in energy efficiency is needed in other appliances, at a wider scale and a more rapid time frame, to truly take advantage of the opportunities that different power solutions can bring to health service delivery. A comparative study by SELCO Foundation (2021) of several types of commonly used medical equipment in health-care facilities and their energy-efficient alternatives found that energy savings of nearly 55% in blood bank refrigerators, 53% in baby warmers and 75% in oxygen concentrators could be made by switching to available energy-efficient medical appliances. These energy savings directly translate to reduced energy bills from lower energy consumption, as well as a considerable reduction in the size of the decentralized energy system needed, as elaborated further in Chapter 4.

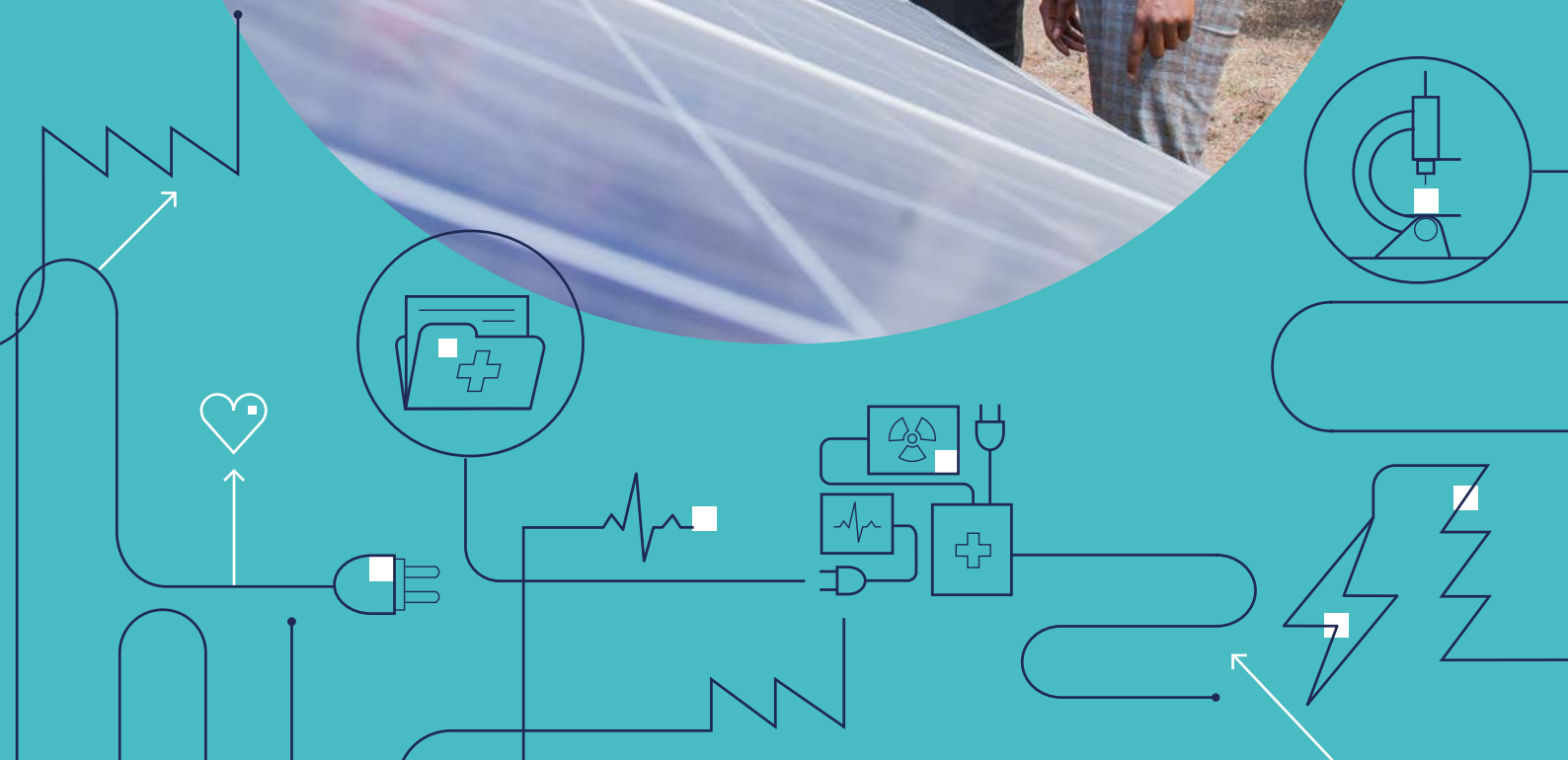
In addition to the above considerations on medical devices and appliances, energy-efficient building designs can lead to a drastic reduction in the energy consumption and carbon footprint of the facilities. For example, a well-designed building with high natural ventilation and appropriate materials reduces the energy requirement for heating, cooling and ventilation in the building.

Chapter 4

Techno-economic considerations for electrification of health-care facilities



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In resource-constrained settings where prioritisation is a requirement, the electrification of health-care facilities requires a thorough assessment of the energy needs. These needs can be quantified based on peak loads (kVA maximum demand) and energy requirements (kWh) of medical and non-medical equipment. This involves taking into account periods of use and the critical nature of certain services. The energy needs of a health-care facility will vary based on the size and tier of the facility and the respective health services offered, along with demographics and disease prevalence. Heating, cooling, lighting and ventilation requirements of a health-care facility have a large impact on the overall energy and power demand, and should be optimized by utilisation of energy-efficient equipment and adoption of building design features (e.g. passive solar design, use of daylight).

Load growth and new loads due to additional medical services being offered in future might apply to the health-care facility and must form part of the energy demand assessment; selection of appropriate and energy-efficient medical equipment will influence the daily load profiles.

Needs assessment exercises can be complemented by tools for energy system design that will help in optimization, and create a portfolio of energy system sizes and configurations that can be implemented across the existing national tiers of health-care facilities. As electrification efforts in health care are scaled up, geospatial data and tools can help combine facility-level information with demographics, location, disease rate, climate patterns and so on – factors that can help build a more robust demand assessment. These allow better extrapolation of bottom-up assessments and support integrated electrification planning.

Whereas Chapter 3 focused on the demand side, this chapter looks at energy supply options and key considerations for selecting the right energy supply option for electrification of a health-care facility. It lays out technical and economic aspects of different solutions, with a particular focus on decentralized sustainable energy solutions. **Section 4.1** documents various options for energy supply and considers factors relevant to the applicability of each mode of connection and generation technology. **Section 4.2** describe the key considerations for the implementation of decentralized solutions, describe tools for planning and for system design and includes example of design options for different tiers of health-care facilities.

4.1 Energy supply options

As noted in Chapter 3, the energy needs of a health-care facility depend on its classification or tier; the medical services it provides; the population served; the burden of disease in the catchment area served; the necessary equipment; and the requirements for preservation for vaccines, samples and other materials that require a cold chain. After evaluating the overall electricity demand – and the demand for uninterruptible power supplies for critical services– planners should weigh alternative least-cost technology solutions that could be used to provide electric power for delivering quality health-care services. If grid electricity is available, a grid connection is often the most logical choice as the primary source of power – although reliability and voltage fluctuations must be considered. Irregularities in voltage and frequency can damage sensitive medical equipment, especially if the equipment has not been engineered for operation in harsh environments. Reliability and voltage fluctuations can be especially common in rural areas, where grid electricity – even if available – often suffers from predictable and unpredictable outages and voltage fluctuations. But reliability and consistent voltage are also issues in many urban areas.

Decentralized sustainable energy sources are often the most technically and economically viable solution to provide reliable energy to health-care facilities that are not connected to the grid, or that are supplied by unreliable and expensive energy sources. In facilities that are not connected to the central grid, off-grid solutions (stand-alone systems or mini-grids) based on sustainable energy can be deployed in a timely manner. Decentralized sustainable energy solutions can also be installed in grid-connected facilities as back-up options, to ensure reliability, adequacy and affordability of electricity supply.

The right energy system configuration for a given health-care facility depends on a combination of **techno-economic factors**, including:

- **Site characteristics:** A key parameter affecting the choice of the most appropriate electrification option is proximity to the central grid, or to a local mini-grid. Other aspects include the availability of land or a rooftop area (e.g. for installation of solar panels); security of land tenure; accessibility; and the local availability of components, parts, technicians, and O&M services. In some remote areas, transport and supply chain constraints can make the required technology particularly expensive. Population density and economic activity of the community become relevant factors for mini-grids. Predictable and unpredictable events might further constrain supply chains (and budgets) – for example, extreme climate events, civil conflicts, floods, market disruptions, pandemics and security issues (including the risk of solar equipment to be stolen).
- **Size and characteristics of the electrical load:** The load on the electrical system will shape the options that can be considered. For example, sites with high electricity loads for space heating will need higher investment in the electrical/generation system unless other means of heating can be found. As discussed in Chapter 3, the proportion of loads that are high priority or critical (e.g. oxygen concentrators, vital signs monitors) will have an impact on optimized supply and storage design. Sizing considerations are discussed in Chapter 3.
- **Local energy resource availability:** The available energy resources that are currently supplying, or could potentially supply, the facility should be considered. These might include renewable energy resources, such as solar irradiance, wind potential, availability of biomass feedstock or potential for run-of-river hydroelectricity (depending on local topography and nearby water flows). They also include access to conventional energy resources, such as to the local grid or mini-grids and the cost and availability of liquid fuel supplies (in the case of fuel-based generators).
- **Environmental and climatic factors:** The terrain and prevailing climate conditions in the region can affect the choice, cost and design of the technology to be used. Climate-resilient and environmentally sustainable health-care facilities provide high-quality and accessible health-care services. The increasing frequency and intensity of many natural hazards challenges the infrastructure, support systems and supply chains that health-care facilities depend on (WHO, 2020). Designing a climate-resilient energy system will play a key role in providing fully functional WASH services, and in minimizing disruption to health services during extreme climate events.
- **Affordability and financial conditions:** Financing for health-care facility electrification efforts includes both upfront capital costs of procurement and installation of the system, and costs of system O&M and part replacement over the system’s lifetime. The combination of lifetime costs can be used to determine the levelized cost of energy for different technology options. This may require incorporation of annual O&M costs within national or subnational government budgets, long-term donor support to ensure that funds are set aside for O&M and replacement (SEforALL & ESMAP, 2021; elaborated further in Chapter 6), or targeted subsidies. In some cases, “energy-as-a-service” models can complement the traditional models where the health-care facility is the ‘owner’ of the energy system, and can facilitate the spreading of the upfront capital investment cost over the life of the equipment through payments for electricity services (in some cases, with a public sector contribution to offset a capital investment by the private sector). The ability of a health-care facility (or of the relevant ministry) to pay for the energy service, are important factors



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to consider. Price trends for energy system components (e.g. solar PV panels, inverters, batteries) will also define decision-makers' investment priorities for health-care facility electrification. Ultimately, since health is a human right and health care a public sector responsibility, solutions should be chosen in a way that ensures quality health care for all, and protects the vulnerable populations.

- **Government policy and incentives:** National policies, plans and programmes (e.g. subsidies, tax incentives, financing mechanisms), and governments' prioritization of the electrification of health-care facilities are important factors. Options for electrification of health-care facilities inextricably link to more general development plans and priorities of governments at all levels. Governments should account for energy-related costs as an essential component of existing health system costs, by including these costs in health-care budgets. Acknowledging the role of decentralized renewable energy sources for health-care facilities, several governments have promoted solar PV systems to improve access to electricity and advance several SDGs. This can facilitate financing for health-care facilities and support from development partners and donors (United Nations Foundation & SEforALL, 2019). Traditional and emerging financing approaches are discussed in detail in Chapter 6.
- **Financing sources:** Sources of finance include government budget, international development programmes, development partner countries, foundations and philanthropic institutions, NGOs, etc. Some programmes opt for co-financing approaches with mandatory user contributions to create a sense of ownership and impart greater responsibility for O&M. However, the financial sustainability of such a models depends on the user's ability to pay or obtain budgetary allocations from national and subnational government agencies, as well as manage the collection and disbursement of funds over the long run. This challenge should be thoroughly assessed in the planning phase (USAID, 2011; Alakori, 2014).

While the above-mentioned points are discussed more in detail in Chapter 6, the following subsections focus on the main energy supply options and their associated configurations, along with an assessment of their applicability.

4.1.1 Centralized grid extension

National or central grids provide high-capacity power, usually at a relatively affordable cost for the end user (often due to subsidies offered by national governments and donors). However, grid extension is usually slower and more expensive in rural and remote regions – the costs depend on the distance between the existing grid and the health-care facility, terrain, population density and the size of the load to be served, including other nearby loads (USAID, 2011). The cost of grid extension are usually borne mainly by the government or the public energy utility and recovered through electricity tariffs. In some cases, some categories of end-users, such as public health-care facilities may obtain power at a subsidized rate, depending on the specific tariff measures in the country.

Grid power in several low- and middle-income countries often suffers from predictable and unpredictable outages, and from inconsistent voltage, which threaten the integrity of health-care delivery – both by damaging equipment and by providing inconsistent power for services that need uninterrupted supply (Porcaro et al., 2017). Although grid extension (if available and able to provide reliable power) results in no additional O&M responsibilities for the health-care provider – being a responsibility of the grid distribution company – the health-care facility must still pay a tariff for electricity it uses, and this payment is often problematic when is not covered by the relevant ministries or by a development partner.

In areas where grid extensions are not planned or take too long to be realized, off-grid solutions (mini-grids and stand-alone systems) can provide the energy in a reliable and timely manner. Off-grid solutions based on renewable energy, such as solar, provide low-carbon electricity at lower operating cost and increase climate resilience (since, for example, they do not depend on fuel supply). When based on variable renewable energies, off-grid systems need adequate storage (e.g. batteries) in order to ensure continuous energy supply.

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4.1.2 Mini-grids

A mini-grid is a form of decentralized generation and distribution that provides power to several users and buildings in one or more local communities. It uses electricity produced from on-site generators using fossil fuels, renewable energy or a combination of the two (Tenenbaum et al., 2014). Users may include households, businesses and public entities, including health-care facilities. The generation source is located close to users. A crucial feature of mini-grids is their ability to operate independently from the main grid, which enables them to be set up in remote locations that the main grid does not reach (BloombergNEF & SEforALL, 2020). Another feature is that they serve multiple customers.

To date, most rural mini-grids have been designed with an installed capacity of tens to hundreds of kilowatts (kW) (ESMAP, 2022; BloombergNEF & SEforALL, 2020). Mini-grids are commonly, but not exclusively, composed of a hybrid system that combines energy storage (such as batteries) with one or more generation technologies, including solar PV, diesel generators or, occasionally, wind, biomass or small hydro. Mini-grids can be designed either to operate as autonomous grids without a connection to a national or subnational grid, or to be connected to a national or subnational grid. Service is typically provided as AC, and users can use many or all of the same appliances as a customer connected to the main grid (ESMAP, 2022; Tenenbaum et al., 2014).

Health-care facilities powered by mini-grids are usually part of a community-wide installation. Health-care facilities typically have higher power consumption than households or small shops, and their load is typically more consistent over seasons of the year (WHO & World Bank, 2015). They can also help to balance the load profile over the hours of the day, since they use power throughout the day, whereas demand among household users is often higher in the evening. This can be particularly helpful where solar PV is part of the generation portfolio, so that the mini-grid operator can sell power throughout daytime hours and reduce the overall need for (more expensive) battery storage capacity that is required to sell power at night.

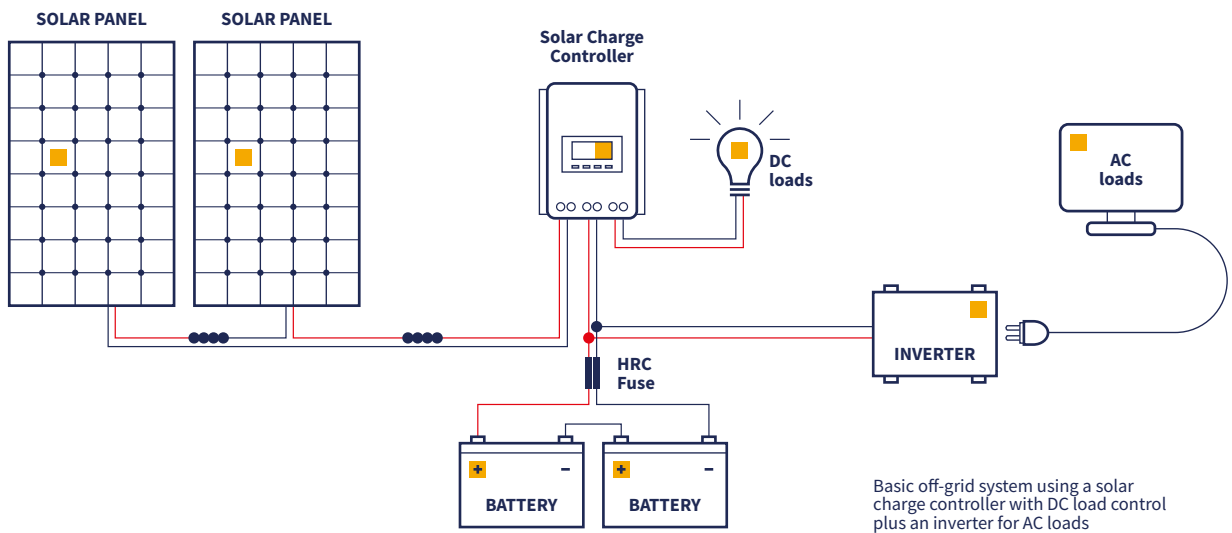
Mini-grids require significant upfront infrastructure investment (unlike stand-alone systems) which is usually partially offset by subsidies, with the remaining costs recovered through regular tariff collection over several years. Health-care facilities connected to a private sector led mini-grid typically need to pay tariffs at regular intervals, and this can be challenging in the absence of clearly allocated budget for energy services, especially for public health facilities in low-resource settings. Tariffs on renewable energy mini-grids are typically below what the same level of service would cost if provided by a standalone diesel generator (ESMAP, 2022). In many cases, health-care facilities can be provided with power at subsidized tariff rates – that is, the tariff is cross-subsidized with other large customer loads such as telecommunications towers and productive-use customers (e.g. operators of irrigation pumps and agro-processing appliances). These users together play the role of anchor customers (ESMAP, 2022; BloombergNEF & SEforALL, 2020).

Policies and regulatory frameworks (e.g. legal and licensing provisions, tariff regulation) play a critical role in influencing (or delaying) mini-grids implementation (IRENA, 2016). Absence of appropriate policies and regulations can also affect the viability of private sector mini-grids (this includes private sector risks related to the eventual arrival of the main grid). Mini-grids can play a significant role to electrify health-care facilities and local communities, however the recovery of upfront costs and the need for tailored policies and regulations have to be addressed in order to support their scale-up.

4.1.3 Stand-alone solar systems

A stand-alone solar PV system is a decentralized solution based on solar panels, not connected to the central grid or a mini-grid. The energy generated is used to power the appliances of a facility and to charge a battery bank used for energy storage. Stand-alone solar PV systems are often the fastest and most economically viable option to electrify health-care facilities in areas not connected to the central grid. Solar PV systems with battery storage can also be used as a complementary or back-up power source if the main source of power (e.g. grid power) is unreliable.

Fig. 4.1. Simplified representation of a stand-alone PV system



A stand-alone solar PV system is a versatile, modular system that can be customized to meet specific electricity demand. The size of stand-alone solar PV systems usually ranges from 500 watt peak to 20 kWp; system capacities greater than 20 kWp are often (but not exclusively) found in larger health-care facilities. Although solar PV generates electricity as DC and most medical appliances are designed to run on AC, solar PV systems can easily include an inverter to convert DC to AC, thus broadening the range of equipment that can be powered. This conversion results in some energy losses, but using inverters in stand-alone systems is relatively common practice for clinics that use medical equipment with moderate to high energy requirements (USAID, 2011). Stand-alone systems can also provide power for health staff quarters adjacent to clinical facilities, thus improving living and working conditions for health workers and their families (as described in Chapter 7).

A typical stand-alone solar PV system is composed of a solar PV array, a charge controller,¹ a battery pack, wiring, a support structure and one or more inverters. The system can be ground mounted or rooftop mounted, depending on system size, natural and built environment conditions, and space availability. **Fig. 4.1** shows a simplified representation of a stand-alone PV system.

Small solar systems have also been used to power specific appliances or devices, such as vaccine refrigerators (see **Box 6.1**), lights or communication equipment. These small-scale systems are simple to install and operate, but are not sufficient to meet all critical energy needs of a health-care facility.

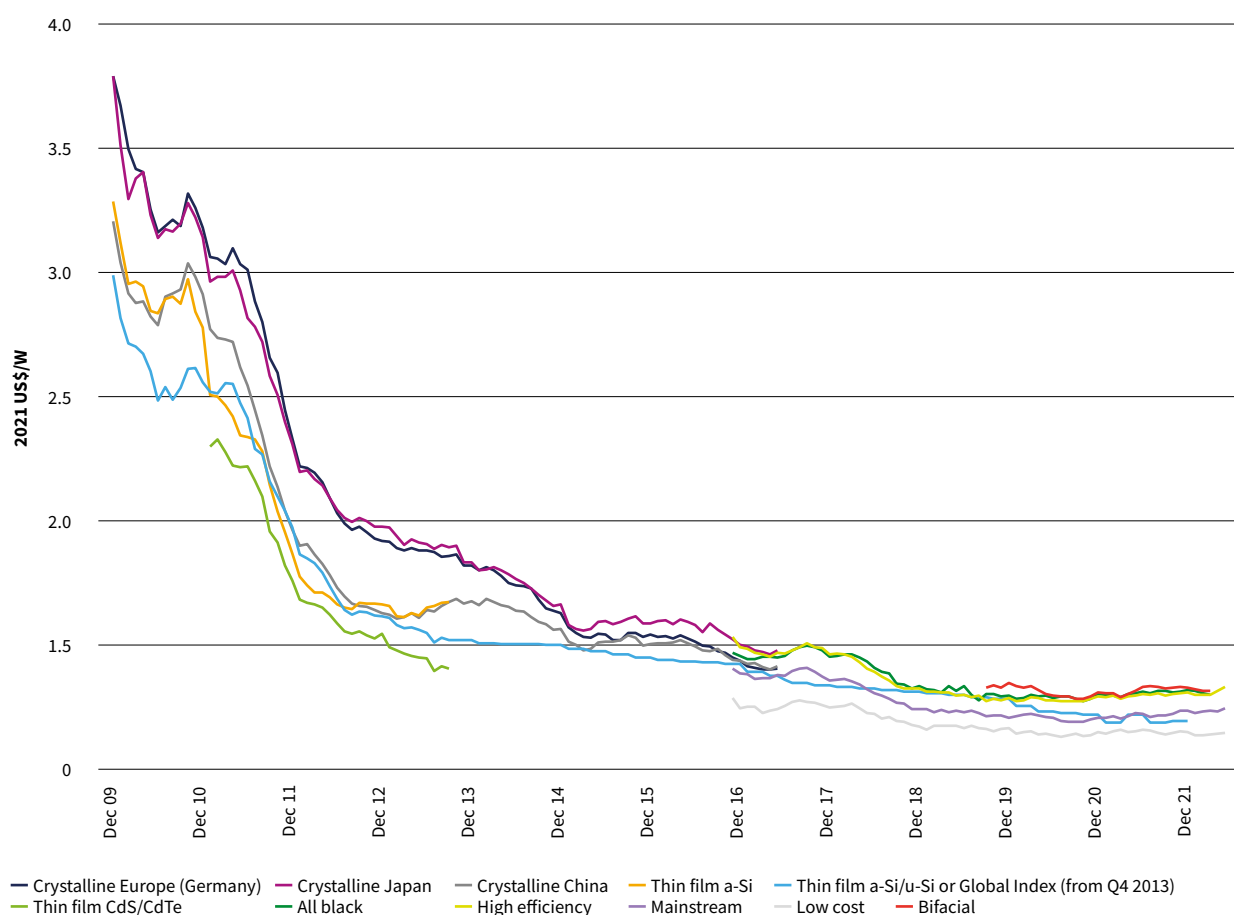
The main components of a stand-alone solar PV system (solar panels, inverters and batteries) form a sizeable proportion of the upfront costs of a solar PV solution. However, as shown in **Fig. 4.2**,

1 The charge controller regulates the power that is sent to the batteries, and protects the battery pack and equipment from damage.

the average price of solar PV modules dropped by up to 93% between 2010 and 2020; module costs ranged from US\$ 0.19/W to US\$ 0.40/W in 2020 (IRENA, 2022). The drop in the price of solar panels and batteries worldwide is projected to continue. This will make the technology increasingly competitive in future compared with other energy technologies, as well as the main grid and fuel-based generators.

A stand-alone PV system has lower O&M requirements and is more climate resilient than alternative off-grid solutions, such as diesel generators which are based on the fuel supply chain. This translates to a lower overall life cycle cost for the stand alone PV system (USAID, 2011). Although PV modules last up to 20–25 years and need minimum maintenance, it is important that the panels are cleaned at regular intervals, especially in dusty environments, to maintain optimum energy generation. It is also essential to ensure proper maintenance, repair and battery replacement services for PV systems with storage, as described in detail in Chapter 6.

Fig. 4.2. Decline in spot prices of various types of solar modules, 2010–2020



Source: IRENA (2022).

In addition, proper sizing and design are critical. An inappropriately large PV system could be underused and become too costly to maintain and repair in the future, whereas an inappropriately small system could be overloaded, affecting its lifespan or performance. The design of a larger stand-alone system should also ensure that it is grid-ready, as an added layer of redundancy, to easily integrate with the central grid or mini-grid. Being modular, stand-alone solar PV systems are customizable to contexts and equipment in a health-care facility. Sizes of standardized systems can be designed at national or subnational levels based on the health system guidelines of the country.



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Solar energy is a variable source of energy, and needs to be coupled with either other energy sources or battery storage to meet electricity needs in the evening or at night (as discussed in the next section).

Battery storage

Batteries form an integral part of an energy system that provides continuous and reliable electricity to health-care facilities, especially in off-grid systems or grid-connected facilities with frequent power outages.

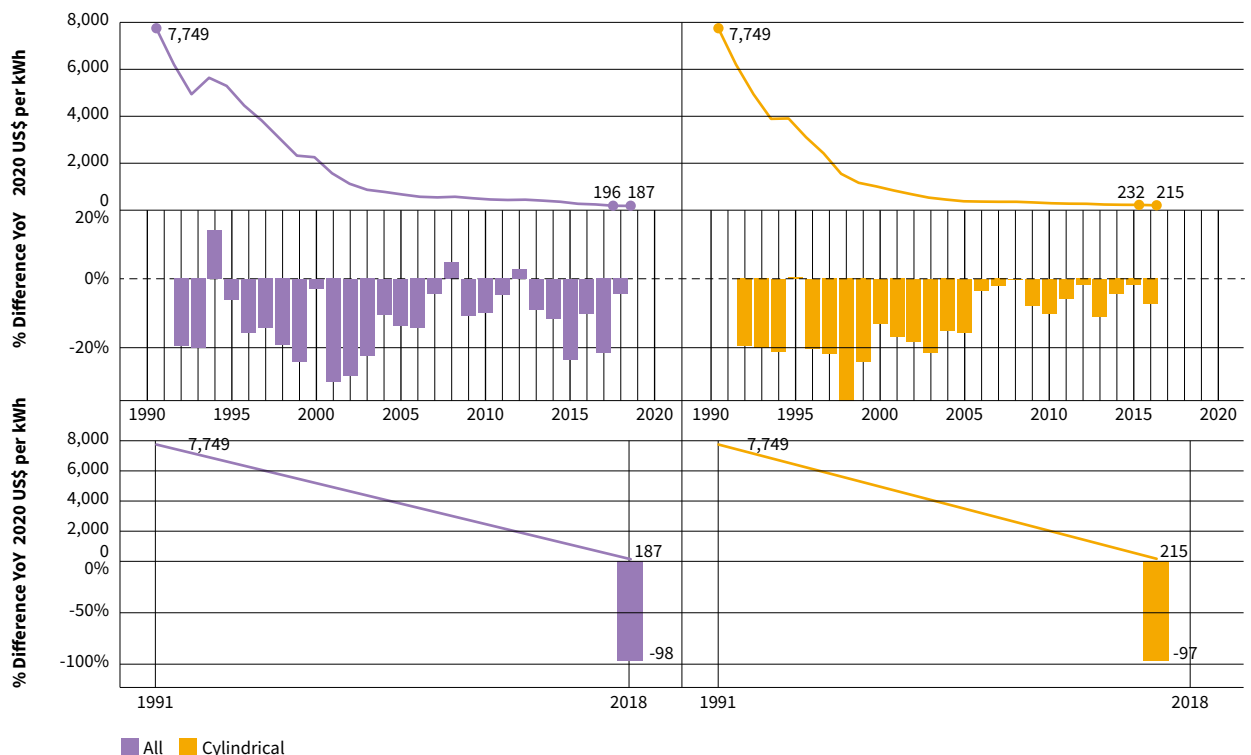
Health-care facilities relying on solar power typically incorporate battery storage as an integral part of the system. The batteries are charged using excess electricity generated by the PV panels and are then used to power critical loads when the demand is higher than the electricity production. In these systems, autonomy of the batteries ensures power availability for prolonged periods. In facilities connected to unreliable electricity grids, batteries also contribute to ensure power availability and reliability during planned and unplanned outages, and help reduce reliance on backup generation systems.

Two of the most commonly used battery storage technologies are lead-acid and lithium-ion (Li-ion), both of which exist in several types. In off-grid and mini-grid contexts, the lead-acid battery technology is comparatively mature. These types of batteries are generally readily available, have a low upfront cost, and are widely produced and used, especially in emerging markets such as Asia

and sub-Saharan Africa. However, compared with lead-acid batteries, Li-ion batteries (LFP type) offer superior operational performance, including the ability to endure approximately 2–3 times more charge/discharge cycles before end-of-life through capacity loss, can be more deeply discharged and have greater longevity in high-temperature environments (ESMAP, 2022). Lead-acid batteries typically reach end-of-life through break-down failure.

A study by Mongird et al. (2020), including an assessment of grid storage solutions (at the megawatt scale) from different industry participants and an extensive literature review, showed that the cost of Li-ion battery packs ranged from US\$ 182/kWh to US\$ 194/kWh (for different chemistries of Li-ion), in comparison to US\$ 180/kWh for lead-acid batteries, for a 1 megawatt capacity grid storage solution with 4 hours of battery backup. However, energy system installations in individual health-care facilities, which have a much smaller system capacity than this, will cost more because of the smaller scale. The greater costs also reflect the location of health-care facilities – for example, in rural areas, climate-vulnerable regions and high-risk environments. Li-ion batteries have historically had considerably higher upfront costs, but battery cell prices fell by 98% between 1991 and 2018, from US\$ 7749/kWh to US\$ 187/kWh² (IRENA, 2022), as shown in **Fig. 4.3**. Increased adoption of Li-ion batteries in electric vehicles is expected to further reduce average costs of battery packs to US\$ 58/kWh by 2030 (BloombergNEF, 2020). However, the estimated rate of fall in costs may change as a result of supply chain issues, raw material costs and other pandemic-induced bottlenecks. With falling costs and superior technology, the interest in and deployment of Li-ion battery technology has been visible in rural areas, and Li-ion batteries are currently the predominant choice for battery storage deployment in mini-grids (ESMAP, 2022).

Fig. 4.3. Cell energy density and costs of behind-the-meter battery (Li-ion cell) storage



Source: IRENA (2022).

2 The true cost of Li-ion batteries being installed in rural, resource-constrained settings would be far higher. Lower volumes of procurement, the need to import batteries, transport costs and other factors add to the overall costs of battery installation.

Disposal of batteries, in particular of lead-acid batteries can become a source of environmental contamination and human exposure if carried out without adequate standards or regulatory controls (WHO, 2017). Battery management, replacement and recycling are important to ensure the sustainability of any electrification program. Given that lead-acid batteries will need replacement 4–5 times during the lifetime of PV panels (of 20–25 years), health-care facilities need to plan for funding accordingly, since each replacement costs of lead-acid batteries is generally around 35% of the system cost (SELCO Foundation, unpublished observations, 15 June 2022). Furthermore, limitations in local access to suitable battery replacements, access to spare parts, and capacity-building to manage and maintain the battery system are important factors to consider in selection of the appropriate battery storage technology (WHO & World Bank, 2015).

With the increasing cost-competitiveness of Li-ion batteries, developers currently installing energy systems with lead-acid batteries should install battery inverters and charge controllers that are compatible with Li-ion batteries, so that future battery replacements can use Li-ion batteries, should the economics and logistics be favourable (ESMAP, 2022).

Apart from these lead-acid batteries and Li-ion batteries types, other chemical battery technologies include nickel-based, sodium-based and flow batteries. In some settings, these may demonstrate superior performance characteristics, but based on current technologies they have limited applicability for most health-care facility settings. This is because they currently incur larger investment costs (Franco et al., 2017), and some have operating requirements that are incompatible with resource-constrained settings. Nonetheless, these alternative forms of battery storage may play a larger role in future installations, as technology improvements lead to lower prices and perhaps address the issues that currently restrict their deployment in resource-constrained settings.

Batteries require regular O&M, including cleaning, topping up with distilled water (in the case of certain types of lead-acid batteries), and securing funding for battery maintenance, replacement and recycling. Accordingly, local capacity must be provided to operate and maintain batteries to achieve long-term operational sustainability.

4.1.4 Fuel-based generators

A generator is a combination of a fuelled power engine and an electricity generator to produce electricity. Generators can use various fuels, including gasoline, diesel, natural gas, propane and biodiesel. Diesel is the most commonly used generator fuel, as it is widely available, and diesel generators are typically viewed as more reliable and with longer useful lives than gasoline engines (USAID, 2011). Diesel generators can provide electricity as a stand-alone solution, or as part of a hybrid system with battery packs and solar PV. Diesel generators can also be used to provide backup for the grid, where they are turned on solely to provide electricity during outages. When used as a single system solution, the generator must be sized to handle the peak expected load.

Generator sets are available in a wide range of sizes and power rating scales, from smaller portable emergency backup generators to large stationary generators. However, deployment of several smaller units is generally preferred, as this allows the use of one or two units at full load rather than a larger unit at reduced load (USAID, 2011). This practice increases overall efficiency because engines are more efficient when operating at close to their rated power levels. The use of multiple generators in large installations, rather than a single generator, provides the ability to perform maintenance on one generator without losing the ability to generate power from another.



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As is well documented, combustion of diesel fuel results in substantial emissions of carbon dioxide, particulate matter, and oxides of sulfur and nitrogen, which contribute to climate change and local air pollution. Diesel emissions and fume exhausts are harmful to respiratory health in the vicinity of the emissions source (WHO & World Bank, 2015). Depending on ambient conditions and other nearby pollution sources, local emissions can also contribute to visual haze and increase environmental health burdens. Furthermore, although the upfront cost of diesel generators is lower than decentralized renewables such as solar PV, they are more expensive than solar PV systems in the long run, due to fuel costs and higher O&M requirement (such as engine maintenance, including major overhauls). Fluctuating fuel availability and market costs, and the costs of procuring and transporting fuels, are also key considerations that threaten the long-run affordability and resilience of diesel generators. Generators still play a prominent role in powering health-care facilities in several LI and LMI countries (as shown in Chapter 2). A study on the diesel generators used for electricity in humanitarian operations by six United Nations organizations and the International Committee of the Red Cross estimated that replacing the 11 365 diesel generators being used with solar energy would reduce fuel expenditure by two thirds, amounting to US\$ 70 million per year, and reduce greenhouse gas emissions by 126 000 tonnes of CO₂-equivalent (Sandwell, Gibson & Fohgrub, n.d.).

The supply chain to support the provision of fuel, as well as spare parts and maintenance services, is an important consideration when designing a system with diesel generators in remote areas. Public health-care facilities depend on government funds to purchase and transport fuel. However, diesel generator equipment is often non-functioning, and fuel may not be available (e.g. if the fuel supply chain is affected by extreme weather events); as a result, dependence on these generators further adds to the unreliability of electricity and therefore delivery of critical health services (Adair-Rohani et al., 2013; WHO, 2020).

4.1.5 Hybrid systems

Hybrid energy systems include a combination of energy supply options, such as diesel generators, renewable energy systems and batteries. Generators or batteries become a backup solution when the energy generated by solar is lower than the energy demand. Generators can also charge batteries during such conditions. The Nigeria Electrification Programme, supported by the World Bank and the African Development Bank, is installing such systems in 100 COVID-19 isolation and treatment centres, along with powering 400 primary health-care facilities across the country (Rural Electrification Agency, 2022).

The integration of solar PV systems with diesel generators helps reduce generator use, extends generator lifetime, reduces fuel consumption and helps reduce carbon emissions. However, with the falling costs of PV modules, battery technology and power electronics, upcoming planned systems are seeing a shift in preference from diesel to solar - or to solar-hybrid - systems (ESMAP, 2022), especially in rural settings.

4.1.6 Other forms of energy supply

Although solar PV has been the most common form of decentralized renewable energy generation in rural areas, other forms of renewable energy sources have been installed at some locations, such as small (run-of-river) hydro, wind and biomass-based systems. The ability to scale these technologies up for individual facilities is limited compared to solar PV, because of the geographic distribution of the resources. For instance, wind turbines require a relatively steady wind speed with minimal seasonal variation, such as on a ridge line, and run-of-river hydro is economically favourable only in locations near rivers that have relatively constant water flow throughout the year (Franco et al., 2017) and have a suitable head or elevation drop. These resources are less modular than PV with respect to meeting energy demands, although, in regions where the resource is abundantly available, they play an important role in bridging the energy access gap. Very few surveys that were identified for this report included specific questions about whether health-care facilities are powered by wind turbines or biomass.

4.1.7 Disposal of end-of-life batteries and solar photovoltaic panels

Off-grid solar power installations heavily rely on batteries that allow electricity generated during daytime to be stored and used when the demand is bigger than the generation (e.g. for night-time). Depending on the size of individual installations, required battery storage capacity ranges significantly. Until recently, energy access projects almost exclusively referred to the use of lead-acid batteries, because this technology is widely available, robust and cheap.

Lead-acid batteries are manufactured for various purposes, including the automotive sector and stationary power storage. It is notable that starter batteries for automotive applications are specifically designed to provide short power bursts, rather than prolonged power supply. Thus, automotive lead-acid batteries are inappropriate for use in solar power applications. For solar power applications, deep-cycle lead-acid batteries are available and commonly used. Because they contain more of the active material (lead), the purchase prices of such batteries are typically around 20% higher than for automotive lead-acid batteries. The life time of a battery used in a stand-alone PV system is commonly about 5 years. In recent years, as a result of the development of Li-ion battery technologies and falling prices, projects have started to consider the use of Li-ion-based battery technologies.

Toxicity potential and safety risks

Around 65% of the weight of lead-acid batteries is lead and lead oxide, and 10–15% is sulfuric acid. Lead is a highly poisonous heavy metal that has numerous adverse effects on various human organs when swallowed or inhaled. Exposure to elevated levels of lead can cause severe damage to the brain and kidneys, and can severely limit the development of children’s brains. Lead poisoning can cause a wide range of symptoms and can ultimately lead to death. Sulfuric acid is also of concern because it can cause skin burns and eye damage following direct contact. Inappropriate disposal of sulfuric acid contributes to acidification of the environment. During the use phase, the hazardous constituents of the battery are usually well encased so that emissions to the environment and direct contact with humans are unlikely. Furthermore, the use of lead-acid batteries is relatively safe because there is a low risk of overheating and fire. One possible safety risk is associated with overcharging of valve-regulated lead-acid batteries that have non-functioning or blocked valves. The electrolytic processes in the battery can cause a build-up of pressure and, if this pressure is not released through valves, an explosion.

Recycling of lead-acid batteries and Li-ion batteries

Because of their high lead content and the quite stable and attractive world market prices for lead, waste lead-acid batteries (AGM and GEL; 99% recycle rate) and lead scrap are collected and recycled in several countries. The recycling of lead-acid batteries involves the breaking of the batteries, capturing and separating the electrolyte, lead scrap and plastics; and processing all fractions into saleable products. Despite various plants applying high environmental standards that effectively minimize emissions of lead and sulfur to the workplace and the environment, recycling of lead-acid batteries is a severe environmental hazard in many developing countries and emerging economies. It is imperative that waste from electronic devices is recycled in a safe, appropriate and efficient manner. However, poor infrastructure and ineffective implementation of legislation mean that only a very small percentage of the total waste from electronic devices generated is recycled. Currently, waste from electronic devices in several countries is managed by the informal sector, which does not have adequate means or awareness to deal with it appropriately. This leads to ineffective waste from electronic devices management, which causes huge damage to the environment. It also poses serious health risks to the waste from electronic devices workers. Since 1990, 84–88% of the health impacts of lead exposure have occurred in middle-income countries (von Stackelberg et al., 2021).

Recycling of Li-ion batteries (mostly LFP or LiFePo₄; 5% recycle rate) is a rather new field. Although generally less toxic than lead-acid batteries, they also have a lower recycling value and are rarely disposed of properly (Manhart, Hilbert & Magalini, 2018). This is exacerbated by the fact that only a few firms collect Li-ion batteries for recycling, and basically none focus on low- and middle-income countries outside China and India (ESMAP, 2020). It focuses on the recovery of nickel, copper, cobalt and rare earth elements from Li-ion and nickel metal hydride batteries.

Lithium can be recovered from the slag phase. Other battery materials – such as iron, graphite, phosphor and organic compounds – are lost in the process. From an economic perspective, the presence and concentrations of cobalt and nickel are the main factors influencing the profitability of Li-ion battery recycling. For recycling, end-of-life Li-ion batteries need to be collected and shipped to appropriate treatment facilities. Collection and shipment are associated with additional costs and challenges, mainly linked to the need to comply with international regulations on the transport of dangerous goods. As battery recycling relies on the accumulation and management of larger battery volumes, collection and recycling (export to recycling facilities) of Li-ion batteries is still in its infancy in low-income countries and emerging economies.

An increasing number of actors and investors in the solar off-grid market are paying attention to end-of-life processes, including the Global Off-Grid Lighting Association, which promotes the

extended producer responsibility principle, in which solar companies have the responsibility for disposal. On a programmatic level, the ability to recycle lead-acid versus Li-ion batteries is a factor that should be considered when designing solar systems. If there is no suitable local management option for batteries, programme designers should consider supporting the export of retired batteries to recycling plants further afield. In all cases, batteries and systems should be designed for a long lifespan to minimize the need for replacements (Manhart, Hilbert & Magalini, 2018).

4.2 Key considerations for uptake of decentralized systems

The grid is the traditional electrification solution and can effectively and efficiently supply health-care facilities if that grid power is reliable, affordable, and of consistent voltage. However, health-care facilities operating in low resources settings and in rural areas often do not have access to a grid connection; if they do, the quality and reliability of the grid energy supply are often far from guaranteed, and grid electricity supply outages may be frequent or unpredictable. Thus, on-site or decentralized energy generation has become more important and compelling as a solution for health-care facility electrification (WHO & World Bank, 2015). Decentralized renewable energy technologies are often based on solar PV systems and battery storage.

As health-care facilities and systems consider how to provide adequate power from a decentralized system with limited budgets, they must prioritize critical loads. As noted in Chapter 3, certain types of loads, such as lighting and ventilation in surgical theatres, cold chain for laboratory samples, and oxygen concentrators and ventilators, require uninterruptible power. Critical loads must be fully accounted for during system design. For instance, Alopati Majarchar Primary Health Centre in Assam, India, was previously unelectrified, and relied on a diesel generator to meet its critical loads. For a higher degree of redundancy, the decentralized renewable energy system installed there included two inverters, so that the system could always support critical loads, even if one inverter failed (SELCO Foundation, 2020). In another instance in Jharkhand state in India, Nav Jivan Hospital installed a 10 kW solar PV system at the end of 2019 to meet a small fraction of the hospital's load. With the onset of COVID-19, the solar PV system functioned as the primary source for critical medical equipment required for treating COVID-19 patients, such as ventilators for patients in the intensive care unit (Concessao, Gupta & Deka, 2020).

4.2.1 Design of solar systems for decentralized health-care facility electrification

The following key concepts can be used when designing a decentralized solar system for health-care facility electrification.

Sunshine hours/peak sun hours

The term “peak sun hours” refers to the solar insolation that a particular location would receive if the sun were shining at its maximum value for a certain number of hours. Since the peak solar radiation is 1 kW/m², the number of peak sun hours is numerically identical to the average daily solar insolation. For example, a location that receives 5 kWh/m² per day can be said to have received 5 hours of sun per day at 1 kW/m². Being able to calculate the peak sun hours is useful because PV modules are often rated at an input rating of 1 kW/m². The peak sun hours will vary between locations and climatic conditions.

Days of autonomy

The days of autonomy is the number of days the load can operate from the energy stored in the batteries without any charging from the sun. This is an important number because the system should have enough reserve charge to be able to run even if the weather is bad on a particular day. For primary care facilities, which are often in areas with very poor or no access to electricity, a 3-day autonomy can be considered. For higher-tier facilities, a 2-day autonomy can be considered, as these facilities are often in areas with more reliable electricity access. These values can be customized depending on the context of a particular facility.

Depth of discharge

Depth of discharge indicates the charging capacity of a battery – that is, the percentage of the battery that has been discharged relative to the overall capacity of the battery. For lead-acid batteries, the recommended depth of discharge is 50%. That is, the battery should not be discharged by more than half of available battery capacity, to avoid any damage or premature system degradation. For Li-ion batteries, it is 80%.

Equipment load requirements and equipment efficiency

The load profile of a facility changes across the operating hours. The assessment of the load peaks plays a key role in the energy system sizing. In this sense, it is important to identify the critical and the non-critical devices as well the possibility to shift load with manual or automatic demand-side management. Differences in appliance efficiency can significantly change the sizing of the decentralized solar energy system – both PV panel and battery capacities. This can change the cost of powering the system and the future cost of maintenance. Recent experience has shown that the cost of powering a facility with inefficient appliances can be up to 3 times more than the cost of powering one with efficient appliances. If the cost of appliances is included in this calculation, powering a facility with inefficient equipment can still be more than 35% more expensive than powering that same facility with efficient appliances. These estimates can vary based on actual usage patterns at a specific facility. To the extent possible, energy-efficient appliances should be made available, especially to facilities being considered for solar based electrification, so that energy consumption is optimized and generation capacity needs (and relevant costs) are reduced.

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Installing more efficient equipment is an important component of energy conservation, but good management practices are equally important. These include maintaining equipment properly, insulating any areas that are heated or cooled, turning off unused lighting or equipment where possible and monitoring energy consumption. All health centre staff should be knowledgeable of the measures needed to meet the centre’s energy needs and encouraged to help conserve energy.

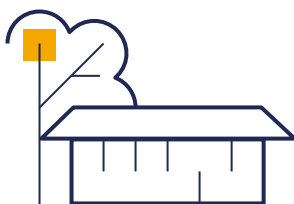
As mentioned above, energy-efficient building design also plays a crucial role in drastically reducing energy consumption and lowering the facility’s carbon footprint.

4.2.2 Factors influencing the cost of solar systems for health-care facility electrification

The costs of procuring, installing and maintaining solar systems vary from country to country, depending on several factors. **Table 4.1** breaks down the different types of costs associated with implementing health-care facility electrification programmes.

Table 4.1. Examples of costs associated with solar energy systems in health-care facilities

COST ITEM	DESCRIPTION
Capital costs	
Supply of solar equipment	This is the actual cost of system components such as solar panels, batteries, inverters, and other balance of system components. The cost of these components significantly depends on whether they are manufactured within the country or need to be imported. Costs also depend on associated taxes, import duties and currency fluctuations.
Installation costs	The cost of installing systems depends on whether reliable local vendors or energy enterprises are available near the site. Vendors’ familiarity with the area and terrain can considerably bring down the cost of installing the system, especially in remote areas, compared with flying in engineering teams from overseas to complete the installation. Installation costs also include regulatory fees and the cost of commissioning the system once installation is completed.
Transport of materials to site	Transport and storage costs can increase substantially when materials need to be ferried to remote sites. These costs also depend on the charges demanded by local transportation agencies, which can be significantly higher in conflict-prone areas or regions with other safety concerns. The need for multiple visits to complete installations at the site and future transport of spare parts can also increase the total transport expenses.
Operating costs	
Operation & Maintenance (O&M)	O&M costs include having technicians visit the site periodically (e.g. least once a year), typically through an annual (or a multi-year) maintenance contract to clean the panels, maintain the batteries and troubleshoot other site-specific issues.
Battery replacement costs	Lead-acid batteries typically require replacement after 5–6 years, depending on usage patterns. Replacement costs can be up to 35% of the solar equipment costs. If funding is not available for replacement, the entire system risks becoming dysfunctional after the initial battery life.
Remote monitoring	Remote monitoring (e.g. through a 3G network), can considerably bring down the system downtime and maintenance costs, especially for remote sites.
Soft costs	
Stakeholder convenings	Initiation of projects typically involves engaging with multiple stakeholders as well as organizing tailored meetings, e.g. with public health officials, local government officials, funders, implementing agencies and local enterprises. Other costs are associate with organizing multiple capacity-building workshops for various stakeholders.
Health–energy assessments	Comprehensive assessment involves a team of a surveyors travelling to the site, possibly more than once. It may involve additional costs for data logging to monitor usage patterns at the facility.



BOX 4.1

COST OF RENEWABLE ELECTRIFICATION OF HEALTH CENTRES IN BURKINA FASO

A study from IRENA and SELCO Foundation

In Burkina Faso, 40% of the population lives more than a 20-minute walking distance to a primary health-care facility (Moner-Girona, 2021), and less than 5% of the rural population has access to electricity (IRENA et al., 2020). Given the remoteness of health-care facilities, deploying stand-alone, decentralized solar systems to power the facilities could be a faster, cost-effective and climate-responsive option.

To address challenges of health-care facility electrification for last-mile communities in Burkina Faso, the IRENA and SELCO Foundation conducted a health-energy assessment across 40 sample health-care facilities in the country - mainly primary health-care facilities (Centres de Santé et

de Promotion Sociale, CSPS, Health and Social Promotion Centres). This involved consultations with key stakeholders and experts from the health and energy sectors, from the government and externally. The report followed an ecosystem approach to understand the challenges and suggest solutions across technology and design, local capacity-building, financing and ownership models, and policy-level action.

The study also estimated the cost of customized decentralized renewable energy system designs, for different levels of health care and service provision. Based on this, cost estimations have been developed with local clean energy enterprises. System design templates and costings for CSPS are included in the table below.

System design and requirements	Option 1	Option 2	Option 3
Maximum load connected	0.741 kW	1.5 kW	1.9 kW
Maximum units that can be used per day	3 kWh	3.9 kWh	6.5 kWh
Solar panel capacity	1.5 kWp	2.34 kWp	3.2 kWp
Number of batteries	1 500 ampere hour (Ah) 12V	1 600 Ah 12V	3 000 Ah 12V
Inverter capacity	2.5 kVA	3.5 kVA	5 kVA
Supply of solar equipment + installation cost	US\$ 5 250	US\$ 5 770	US\$ 6 300
Transportation cost in country	Depends on the distance, the climate season, and the number of facilities (economies of scale)		
Spare parts for 10 years (battery replacement)	US\$ 2 800	US\$ 2 800	US\$ 2 800
Remote monitoring (hardware with 3G network)	Unavailable in some country, because of lack of access and high-cost of internet connection		
O&M (every 3 months for 10 years)	US\$ 1 800	US\$ 1 800	US\$ 2 000
Total cost estimate 2021 (initial average costs in 2021)	US\$ 9 900	US\$ 10 400	US\$ 11 000
Estimated price 2021 (component break-up)	Capex: USD 5 250 Annual O&M: USD 180/year Replacement: USD 2 800	Capex: USD 5 770 Annual O&M: USD 180/year Replacement: USD 2 800	Capex: USD 6 300 Annual O&M: USD 200/Year Replacement: USD 2 800
Total cost estimate 2022 (including +20% inflation in 2022)	US\$ 11 880	US\$ 12 480	US\$ 13 200

Note: The options and costs mentioned in the table are indicative only. More details are available in the IRENA & SELCO Foundation (2022).

4.2.3 Integrating energy storage

Batteries can be integrated into grid-connected or off-grid systems where other energy supply options are unreliable or intermittent. Batteries can provide backup power in the event of short-duration outages, and can also provide power in the evening and at night for off-grid facilities powered by solar PV. However, the capital cost of batteries (for initial purchase and subsequent replacement) is high, and they are typically not an economical solution for providing backup power for extended (e.g. multi-day) outages; additional on-site electricity generation is usually cheaper. In the past, the specific battery technology (e.g. lead-acid, Li-ion) would vary by setting, depending on upfront cost and affordability, O&M requirements and regional availability, including availability of O&M services (see Chapter 3). Improvements in Li-ion cost and performance have now made Li-ion batteries a superior choice in almost all settings. The battery capacity should take into account power

requirements during unplanned outages, as well as in the evening and at night (if solar PV is the primary source of energy supply).

Notably, batteries are not as modular as other supply technologies, unless relevant configuration changes are made to the system. Engineers recommend against mixing batteries of different ages, capacities and chemistries. Furthermore, even when adding a new battery cell to an older battery bank with the same capacity and chemistry, the resulting composite battery pack has a lower useful life (in terms of charge/discharge cycles) than new batteries would in a stand-alone system. However, batteries of different ages and sizes can be placed on separate battery inverters to eliminate issues of mixing batteries.

Other considerations for generation or storage technology may include whether the technology selected can contribute to reduced local air pollution, or reduced carbon emissions, by displacing polluting fuels or power generation systems as the primary source of power. It is also important to consider whether the technology can be easily disposed of or recycled (Franco et al., 2017; WHO, 2017), especially for legacy energy systems that have not reached their end of life but are not running optimally. Decommissioning and replacement by better-designed and, if feasible, larger energy systems can be considered, to cover a greater number of medical and non-medical services.

4.2.4 Remote monitoring systems

One system component that is common across various energy supply options and has emerged as a critical addition to energy systems is the remote monitoring system (RMS). An RMS allows various stakeholders (health-care staff, system installers, donors and government agencies) to monitor the operation of the energy system. The RMS can provide real-time performance information to stakeholders on their portable devices, such as mobile phone and laptops. The parameters that can be monitored vary depending on the type of RMS installed, but can include energy generation and consumption at a facility level and, for batteries, storage performance, state of charge, voltage, temperature and current charging data (USAID, 2020).

Remote monitoring can complement routine maintenance checks and offline data collection. It tracks system performance information, and can help reduce risk and downtime by providing real-time information on the various parameters that can aid facility staff in troubleshooting, as well as relaying information on malfunctions to the vendor and/or implementing agencies (United Nations Foundation & SEforALL, 2019; Elahi, Srinivasan & Mukurazhizha, 2020; Ginoya et al., 2021). In the absence of RMS, engineers and technology providers spend far more time on project reporting, troubleshooting and site visits, thereby increasing their operating costs. Many manufacturers provide remote monitoring functionality that is built into the solar charge controllers or inverters. Other suppliers provide remote monitoring technology as third-party equipment with a proprietary interface (BloombergNEF & SEforALL, 2020); this needs to be compatible and interoperable with existing energy system components. Implementation of RMS in remote locations can sometimes pose a challenge in terms of mobile phone connectivity and network issues that can hinder live monitoring of operations and data transmission. In these cases, many RMS solutions provide an option of backing up data whenever the server goes down, to ensure that monitored data are captured and stored for later analysis. The data captured must be accessible if RMS is to serve its intended function – that is, supporting O&M.

In addition, RMS data can aid in monitoring and evaluating through parameters such as energy consumption and associated carbon emissions, and verification of installation and commissioning of energy systems for results-based financing payments.

4.2.5 Training and capacity-building

Sustaining decentralized energy systems requires building the capacity of various stakeholders involved in the health–energy nexus. This includes training public works department staff, contractors and vendors on energy-efficient materials and construction methodologies for efficient hospital building design. It should also include capacity-building for local clean energy enterprises on identification of critical and non-critical loads and the design of energy systems, including battery backups based on region-specific contexts (SELCO Foundation, 2020).

As the ownership of decentralized renewable energy systems in health-care facilities rests with local stakeholders, health-care staff need to be trained in effective use of energy systems and appliances. Handover documents provided to staff at project completion must include a structural report, drawings and layouts of the system design, a list of vendors who can provide energy-efficient equipment, checklists for periodic maintenance and servicing, and training manuals for basic maintenance and system troubleshooting.

4.2.6 Key role of operation and maintenance

Maintenance of energy systems is essential to ensure system sustainability and long-term functioning. In the past, limited accountability of project implementers and their lack of response after implementation have often resulted in solar energy installations becoming obsolete within a short period. Neglecting simple aspects of maintenance (e.g. replacing batteries, providing spare parts) because of the remoteness of locations has resulted in whole systems remaining unused and wasted costs for government agencies seeking to promote rural electrification.

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As mentioned above, without proper component O&M and repair, solar PV systems could become inoperative in as little as 3–5 years after installation. Assigned staff at health-care facilities should be trained to perform basic routine maintenance operations, such as keeping solar panels clean and unshaded from vegetation, and checking the water level in batteries. Responsibility for extended O&M can be provided to private contractors or developers with experience in sustaining off-grid or mini-grid systems. The costs for these maintenance contracts need to be properly budgeted for in advance. Trained facility staff should be aware of how designed loads need to be regulated during prolonged periods of power outages, to effectively stretch the capacity of batteries to power critical operations for longer durations. Vendors should be required to distribute training manuals that cover these basic system O&M protocols. They should provide contact details of system providers who can assist in the event of complex maintenance issues, to minimize the response time from when complaints are lodged by health-care staff. Troubleshooting, when parts are not working or need to be replaced, should be undertaken by trained technicians or the vendor, and contracts for these services should be established when systems are installed.

Lack of adequate funds for O&M and for replacement parts throughout the lifetime of the system is one of the most common reasons that systems fail early – especially after donor organizations leave (SEforALL & ESMAP, 2021).

One of the most common approaches on health-care facility electrification programs led by development partners has included the transfer of the O&M responsibilities (including the replacement of the batteries) to the government after a short initial period (e.g. after one or two years). However, in several cases, in the absence of clear budget allocation for the O&M, such “purchase, install and transfer” model has not been successful in ensuring the functioning of the solar system, nor in the replacement of spare parts.

Apart from having a robust O&M system in place, insuring energy system parts and structures from theft, damage due to fire, natural calamities and other unpredictable events could further buttress system sustainability. When designing tenders, funding entities should consider requesting that such insurance provisions be included in the overall quote. Health-care facilities could also approach reputable third-party insurance providers to secure the system against such events, if such coverage products are available in the country. Tenders could also request details upfront on renewal charges for O&M and insurance contracts, which would allow facilities to better plan their funding over the coming years.

A key element that should be considered in any health-care facility electrification program is training. Depending on the specific context, this can include basic training to staff of the health-care facility to undertake regular maintenance, training for the local public agency engineers, etc.

Dedicated O&M cells can be set up at different levels, which can regularly monitor the performance of all the systems installed and provide repair and maintenance services as required in their area of responsibility. Examples of tasks and roles related to maintenance for PV based systems are summarized in **Table 4.2**.



Table 4.2. Examples of maintenance tasks for solar PV based systems

System component	Lifetime (years)	Maintenance	Examples of roles and responsibilities	
			Health centre staff	Local energy provider
Solar panels	20	Clean dust on modules regularly (once a month).		
		Check PV array output current, voltage and connections (once a year).		
Batteries (lead-acid)	5–10	Clean battery terminals regularly (once a month). Check electrolyte level of battery cells (once a month). Check electrolyte level of cells (once a month). Check battery voltage (twice a month) (e.g. at noon, it should be 14 V for a 12 V battery). Fill distilled water when required.		
Charge controllers	10	Inspect connection of wiring to and from charge controllers (once a year). Check charging current and voltage.		
Inverters	10	Inspect connection of wiring to and from inverters (once a year). Check output current and voltage.		
Wiring, connections	20	Check fuse and connections between system components (once a year).		

4.2.7 Building resilient health infrastructure

The increasing frequency and intensity of extreme events associated with climate change can disrupt the existing electricity supply, leading to the need for alternative or backup electricity sources. For example, in regions where hydroelectric generation is a major source for grid power, impacts of climate change can disrupt otherwise well-established rainfall patterns. In many cases, health-care facilities are not designed to accommodate physical climate risks, such as droughts, floods, lightning, extreme temperatures or wildfires. In addition, unpredictability of water supply and water scarcity can affect the availability of water for drinking, washing, sanitation and hygiene. Clean and safe water supply is critical for effective health service delivery, and improper waste management systems can lead to local environmental contamination, and sometimes an increased disease burden. Planning for the design, installation and maintenance of energy systems should therefore be based on the local geography, the availability of supportive infrastructure and energy needs (WHO, 2020; Ginoya et al., 2021). Decentralized renewable energy systems are not dependent on fuel supplies, the shortage of which has created issues in health-care facilities in regions overly reliant on diesel as a primary source of power for running diesel generators.



BOX 4.2.
BUILDING RESILIENCE OF SOLAR ENERGY SYSTEMS FOR PUBLIC HEALTH-CARE FACILITIES IN CLIMATE-VULNERABLE AND DISASTER-PRONE REGIONS

Risk mitigation considerations for natural disasters – such as hurricanes, floods, earthquakes, lightning and high wind damage – as well as slow-onset events such as heat and humidity that can accelerate elemental corrosion are listed below. This box builds on studies of an internal ESMAP report on enhancing resilience of solar electric mini-grids and stand-alone solar power for public facilities in Haiti (ESMAP, unpublished observations, 1 December 2021), and a report on social infrastructure in climate-vulnerable regions in India (Ginoya et al., 2021).

Technical considerations:

- Conduct a structural evaluation of the roof or the soil (if ground mounted) and the racking system for the maximum sustained wind speed design.
- Ensure that PV modules are designed to withstand high wind loads at the front and back of the module. Engineer racking systems to withstand very high wind speeds.
- Use engineered, anti-corrosive materials such as anodized aluminium for structures.
- To minimize earthquake-induced damage, assess local topographical and geological conditions for appropriate site selection and follow structural design codes.
- Consider wooden covers securely mounted to modules to protect arrays from flying objects during hurricanes. If a hurricane is imminent, consider arrangements to remove modules for safe storage.
- Avoid installation of solar inverters, generators or other equipment in flood-prone areas. Elevate systems above ground based on historical flooding/waterlogging, soil data and flooding projections.
- In lightning-prone regions, ensure that the system is protected by lightning and electrical surge arrestors.
- Avoid installation of electronics such as inverters where they will be exposed to direct sunlight.
- Install lead-acid batteries in separate rooms from electronic equipment to avoid corrosion and possible fire hazard.
- Ensure that wiring meets international standards, including use of proper wire types and sizes, connectors, conduit sizes and installation practices.
- Limit exposure of wiring and distribution cables. Where financially possible, consider burying distribution networks underground in engineered underground raceways.
- Ensure that PV systems include remote monitoring to detect performance anomalies and facilitate targeted

troubleshooting before the system fails.

Organizational considerations:

- Ensure that system installations are well documented.
- Set out contractual and non-contractual roles and responsibilities of each participating organization (at headquarters or the local level).
- Enhance the ability of the government to enforce electrical codes.
- Use different contractors for system design and verification and for installation, with the design firm playing the quality control role.
- Ensure capacity-building and training of designated health-care facility staff or local community members so that they can conduct basic troubleshooting in the aftermath of extreme weather events.
- Have a proper communication protocol to engage the right organization for major repairs, with minimum time lost.
- Develop a good service maintenance schedule plan. This schedule should be followed, and a service log should be kept on site. Ensure accountability for maintaining this log.

Economic considerations:

- Have buy-in from all stakeholders expected to fund the O&M throughout the equipment's full lifespan.
- Have a funding plan in place for ongoing service and maintenance, and proper disposal of discarded equipment at the end of the system's lifetime. Factor in replacement costs for components and batteries, whose life can be affected by extreme events.

Consider obtaining insurance coverage from insurance companies present nationally, covering loss of, or damage to, the works, plant, equipment and materials, including from natural disasters and climate-related events.

Apart from building resilient structures, quick recovery and rehabilitation will require improved maintenance and management systems. Use of, and investment in, climate modelling is essential to understand future climate change impacts on building and energy system infrastructure. This should complement local environmental and socioeconomic assessments, including appropriate stakeholder consultations to mitigate or avoid any adverse impact of the electrification work on the environment and communities.

On the energy supply side, capacity, quality and reliability of power are key considerations in technology selection – this applies to various configurations such as conventional grid, off-grid, mini-grid or hybrid models. The ability of governments and health-care facilities to attract and finance upfront capital costs and O&M costs, and incorporate various service delivery models, along with the availability of trained staff to ensure system sustainability, will define the combination of power supply sources and the choice of implementing agencies. In this process, it is important to consider daily and seasonal variations in energy demand and supply; this includes grid electricity reliability during peak hours, solar or wind power production in different seasons (and day–night variations), and availability of feedstock or fuel.

4.2.8 Advantages and challenges of different models for electrification of health-care facilities based on decentralized solar systems

Reviews of health-care facility electrification based on solar systems implemented globally (SELCO Foundation, 2017; United Nations Foundation & SEforALL, 2019; Alliance for Rural Electrification, 2020) have identified three broad categories of technology models and four main typologies of ownership and financing models. Ownership and financing models are capital expenditure subsidy (with three different O&M structures), and energy as a service. Technology models are stand-alone systems, mini-grids and grid-tied systems. **Tables 4.3** and **4.4** summarize the advantages and challenges of these different models and identify the prerequisites under which specific models may be suitable for implementation. Any one model or a mix of different models may be appropriate for different countries, depending on the existing ecosystem and local conditions.

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Table 4.3. Technology models

Type	Description	Advantages	Challenges
STAND-ALONE SOLAR SYSTEM	Battery-based solar PV systems designed specifically for individual health-care facilities as a primary source of power.	<p>Simple, flexible and modular design, which can be easily tailored to the specific energy needs of the facility</p> <p>Fast deployable (can be implemented in few days).</p> <p>Not dependent on complex regulatory frameworks or tariff settings (unlike mini-grids).</p> <p>Incentivizes use of energy-efficient appliances (which reduce panel and battery capacity needs).</p> <p>Due to its modularity, the system can be upgraded in phases depending on evolving (or emergency) needs and financial outlays.</p>	<p>Need local presence of trained and reliable technicians (through vendors, public energy agencies or third-party agencies) to provide timely maintenance services.</p> <p>Requires dedicated funding (e.g. specific budgetary allocations) to cover maintenance services and battery replacement over time.</p>
MINI-GRID SYSTEM	Community-based systems that are designed to power multiple types of users.	<p>Can power different needs from private clinics to public health centres and hospitals.</p> <p>Operation, maintenance and trouble shooting is managed by the mini-grid operator.</p>	<p>More complex authorization/ regulatory process compared to stand-alone systems, which cause longer time for implementation.</p> <p>Health-care facilities typically need to make regular payments for the energy they consume. This may be challenging for public health-care facilities, unless specific budgetary allocations are made.</p> <p>Sustainability of mini-grid itself is subject to other users in the network (households and commercial/productive users) and does not depend only on the health-care facility.</p> <p>Public health-care facilities tend to be treated in a similar way to other commercial users.</p>
GRID-TIED SYSTEM	On-site solar PV systems that are mainly designed to offset the facility's power consumption from the grid, and sell the excess electricity to the grid or store it in batteries to increase backup power capacity.	Under certain conditions (e.g. high cost of grid electricity, unreliable electricity grid), a decentralized solar system in a grid connected facility can reduce the monthly electricity expenditure for larger health-care facilities and can provide back up energy.	Unless batteries are included, facilities do not receive electricity if the grid electricity interruption happens when solar panels do not produce electricity (e.g. evening/night).

Table 4.4. Ownership and financing models

Type	Description	Prerequisites	Advantages	Challenges
CAPITAL EXPENDITURE SUBSIDY + O&M PRIMARILY THROUGH LOCAL PRIVATE SECTOR OPERATORS	<p>Suitable to stand-alone systems.</p> <p>Capital expenditure typically granted through public sector or philanthropy.</p> <p>O&M financing through public sector or philanthropy.</p> <p>O&M responsibility rests with local private sector operators.</p> <p>Owned and managed by the health-care facility or a public agency.</p>	<p>Network of reliable, empanelled local private sector operators, with strong disincentives for non-compliance (e.g. blacklisting).</p> <p>Long-term O&M service contracts with committed funding.</p> <p>Credibility of health-care facility, relevant ministry or development partner to make timely payments (e.g. year-on-year) for the O&M services.</p>	<p>Entrusts O&M responsibility to local operators, who have the technical skills to provide adequate service.</p> <p>Health workers are not burdened with O&M responsibilities.</p> <p>Energy system ownership stays with the health sector (usually with the health-care facility is the owner of the energy system) and therefore energy supply does not depend on an external stakeholder.</p>	<p>When handover times (and related O&M/budget responsibilities) are short (e.g. 1-2 years) the project sustainability can be at risk.</p> <p>Risk for O&M operators without local presence of not fulfilling responsibilities, especially when installations are few and far apart.</p>

Type	Description	Prerequisites	Advantages	Challenges
CAPITAL EXPENDITURE SUBSIDY + O&M PRIMARILY THROUGH PUBLIC SECTOR ENERGY AGENCIES	<p>Tailored to stand-alone systems.</p> <p>Capital expenditure typically granted through public sector or philanthropy.</p> <p>O&M financing typically granted through public sector or philanthropy.</p> <p>O&M responsibility rests with local public sector energy agency.</p> <p>Owned and managed by the health-care facility or a public agency.</p>	<p>Presence of local/regional energy agencies with adequate capacities and that are able to secure human and financial resource to provide O&M for multiple years.</p>	<p>Energy system ownership stays with the health sector (usually with the health-care facility is the owner of the energy system) and therefore the energy supply (and the O&M services) do not depend on an external stakeholder.</p> <p>Useful model where the public agency has an internal network of maintenance technicians.</p>	<p>O&M activities depend on budget allocations and priorities of the public agency.</p> <p>Public agencies may suffer from lack of personnel and may not have the necessary human (and financial) resources to ensure a multi-year support (their human and budget capacities can change over the years).</p>
CAPITAL EXPENDITURE SUBSIDY + O&M PRIMARILY THROUGH HEALTH FACILITY STAFF OR LOCAL COMMUNITY GROUPS³ OR NGOS	<p>Tailored to stand-alone systems.</p> <p>Capital expenditure typically granted through public sector or philanthropy.</p> <p>O&M financing typically granted through public sector or philanthropy.</p> <p>O&M responsibility rests with health-care facility staff or local community groups (such as the Patient Welfare Committees in India) or local NGOs.</p> <p>System owned by the health-care facility or a public agency, and managed by health-care facility or local community groups or NGOs.</p>	<p>Existence of reliable formal community structures at local level (such as the Rogi Kalyan Samit (RKS) / Hospital Management society in India) that are capable of managing the affairs of the health-care facility.</p> <p>Sustained and focused training of health-care facility staff and community members on O&M responsibilities; best case: health agency or coordinating NGO integrates basic energy training for health staff.</p> <p>Remote monitoring capabilities to support community technicians and provide on-demand O&M support.</p>	<p>Energy system ownership stays with the health sector (usually with the health-care facility is the owner of the energy system) and therefore the energy supply do not depend on an external stakeholder.</p> <p>Active participation of health-care facility staff and local community members can contribute to create a sense of ownership of the system, which can improve its longevity.</p>	<p>Often difficult to execute at scale (local NGOs can play an important role in supporting community structures).</p> <p>Risk of unsustainable burden on health workers to also take responsibility that should be taken by specialized technicians.</p> <p>Local community groups often do not have capacity to ensure quality O&M over the years.</p> <p>Turnover of trained staff or community members can jeopardize continuity of O&M.</p> <p>Potential for misappropriation of O&M funds due to other local pressing needs.</p>
ENERGY AS A SERVICE	<p>Often tied to a mini-grid or stand-alone system, where the system is owned by the private sector operator and the health-care facility pays a fixed or per-unit cost for the electricity consumed.</p> <p>O&M responsibility rests with the private sector operator.</p>	<p>Credibility regarding the paying capacity of the health sector (health ministry or health-care facility).</p>	<p>No upfront costs/capital expenditure requirement for facilities.</p> <p>Health workers are not burdened with O&M responsibilities.</p>	<p>Public health-care facilities may not be able to make the monthly payments for the energy supply, unless funds are made available through budgetary allocations.</p> <p>If tied to a mini-grid, project sustainability can be influenced by factors outside the purview of the health-care facility.</p> <p>Since in this model the health-care facility is not the owner of the energy system (which is owned by the private sector operator), adequate risk mitigation measures need to be put in place to ensure the energy supply for the health services in all cases (e.g. in case of contract disagreements, energy company bankruptcy, etc.)</p>

3 Well-known examples of local community groups include the RKS (Patient Welfare Committee) / Hospital Management Society in India



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4.3 Tools for planning and system design

4.3.1 Tools for health-care facility electrification planning

As discussed in Chapter 2, data at the health-care facility level are often scarce, scattered, outdated or non-existent – even more so are the data concerning facility-level electrification status and electricity requirements. Furthermore, many recommended health services delivery packages and related checklists fail to assess power availability or include electricity as a necessity for facility or service readiness. Without accurate and up-to-date facility-level data, including data on reliable and sufficient energy access, it is difficult to identify opportunities and guide the prioritization and implementation of projects. This makes developing data-driven policies, programmes and plans addressing these issues a cumbersome task.

Geospatial data and technology aim to narrow this data gap, for example by estimating ranges of electricity requirements for unserved and underserved facilities. In the absence of robust usage data, more representative demand estimates for each facility can be made by combining available facility-level information (e.g. facility type, health services provided, ownership of equipment, population served, number of beds) with satellite imagery and geospatial data on demographics (e.g. population density, catchment population), facility location, disease rates, weather and climate patterns, and power infrastructure (grid and off-grid). Geospatial data can only provide a partial view of the situation, and need to be complemented and verified through proper on site assessments before moving forward with design and implementation, but they can nevertheless represent a useful tool for initial valuation and screening/planning purposes.

Among the main benefits of a geographic information system (GIS)-based approach is that it allows extrapolation of bottom-up sample data from energy audits, questionnaires and surveys at the level of the health-care facility so that ranges of electricity requirements for unserved and underserved health-care facilities with similar characteristics (e.g. type, size, location, catchment population) can be estimated. These estimates can be inputs into least-cost electrification models to examine the technology and investment implications of different supply configurations (grid extension or intensification, mini-grids, or off-grid options), as noted in Chapter 5. This requires instruments such as multi-tier framework health-care facility survey to capture the spectrum of energy services at health-care facilities based on various attributes, such as capacity, availability and reliability. Cross-sectoral coordination between health and energy stakeholders (e.g. ministry of health, ministry of energy, power utility) can improve the collection of granular information on energy access at the facility level. A better understanding of the situation on the ground will improve the assumptions and parameters used during planning to provide or expand energy services in health-care facilities.

Facility energy audits must include a statistically significant sample size for the study area (i.e. at national and/or subnational level). They must consider facility-level information, including health services delivered, electrification status, current energy supply options and quality of supply, and georeferenced locations. This ensures that the extrapolation will be representative of the electricity requirements of different health-care facilities.

Estimation of health-care facility energy demand is somewhat reliant on initial energy audits and questionnaires. Scaling up is difficult if information is outdated and not combined with geospatial data and analysis. It is essential for health and energy stakeholders to work together to consolidate representative and updated information on each health-care facility, its services and its electrification status, including available equipment, reliability and power sources. The global health sector currently uses several facility-level data resources, such as digital management platforms (e.g. DHIS2) and digital surveys (e.g. mobile tracking system), which are updated periodically, and can be used to further refine GIS-based assessments.

Development of dynamic information systems that collect and track information on health-care facility electrification and combine it with data on power infrastructure and resource availability (among other relevant datasets) can be a valuable step towards expanding health and energy services in tandem in resource-constrained settings. Standardizing data collection and reporting processes is key for the sustainability of such information systems.

Overall, geospatial data and software are becoming important tools for national-level electrification planning and performing site assessments at scale. This has been seen in countries including Ethiopia, Kenya, Myanmar, Nigeria and Rwanda, which have all adopted geospatial analysis to build their national electrification plans (ESMAP, 2022). Combining the use of GIS and non-GIS data, when available, would provide robust, dynamic, integrated and data-driven planning that can be further validated, scaled and monitored. Examples of this combined approach are observed in analyses such as least-cost electrification or multi-criteria analysis in electrification plans. Geospatial tools and methodologies that relate to health-care facility electrification and are open source include the GEP, the Energy Access Explorer (EAE) and the Multi-sectoral Latent Electricity Demand Assessment (M-LED). Important initiatives also include the open-access Clean Energy Access Tool (CEAT), the forthcoming UNICEF Solar Energy Assessment Toolkit, in addition to other proprietary tools.

All existing models, platforms and tools rely on the quality of available data to carry out analysis. For this reason, it is important to set up and agree on data standards that will facilitate both data collection and data analytics. It is also critical to provide key data providers with a dynamic information system (see the EAE content management system) that will allow them to integrate

new data or update existing data with minimal resource requirements (following data standards and automated data processing). Geospatial analysis and tools can be used to carry out an initial prioritization or pre-screening analysis to identify potential intervention areas before conducting feasibility studies or on-site assessments when implementing specific projects.

BOX 4.3.

GIS-BASED ASSESSMENT OF HEALTH-CARE FACILITY ELECTRICITY DEMAND

The World Resources Institute, in collaboration with the Uganda Ministry of Health, Politecnico di Milano and the Energy Sector GIS Working Group in Uganda, is developing a GIS-based assessment to estimate ranges of electricity requirements in unserved and underserved health-care facilities in Uganda (Fig. 4.4). It combines a bottom-up approach to assessing the electricity requirements at facility level with a top-down geospatial analysis built upon the M-LED methodology (Falchetta et al., 2021). The bottom-up approach builds load profiles for the different facility types and sizes, based on services provided, required medical equipment and number of beds. Data for the bottom-up approach come from information collected by the Ministry of Health through facility-level audits, surveys and questionnaires. The top-down approach uses geospatial data on facility location, facility type,

ownership, electrification status, electricity source and population density, among other characteristics. This top-down approach allows identification and assessment of facilities according to their specific characteristics, and estimation of the catchment population of each facility. Outputs of the analysis are then integrated into the EAE overlaid with information on current and potential supply options, and made available for a dynamic, multi-criteria prioritization analysis, and the development of customized dashboards and reports. The objective is to provide a data-driven, integrated approach to planning for the expansion of energy services in health care. The CEAT is a geospatial platform designed to support the electrification planning of rural health-care facilities in Africa. CEAT visualizes health-care energy needs and associated technology costs at different administrative levels (Fig. 4.5).

Fig. 4.4. Example of geospatial analysis in health-care facility electrification planning

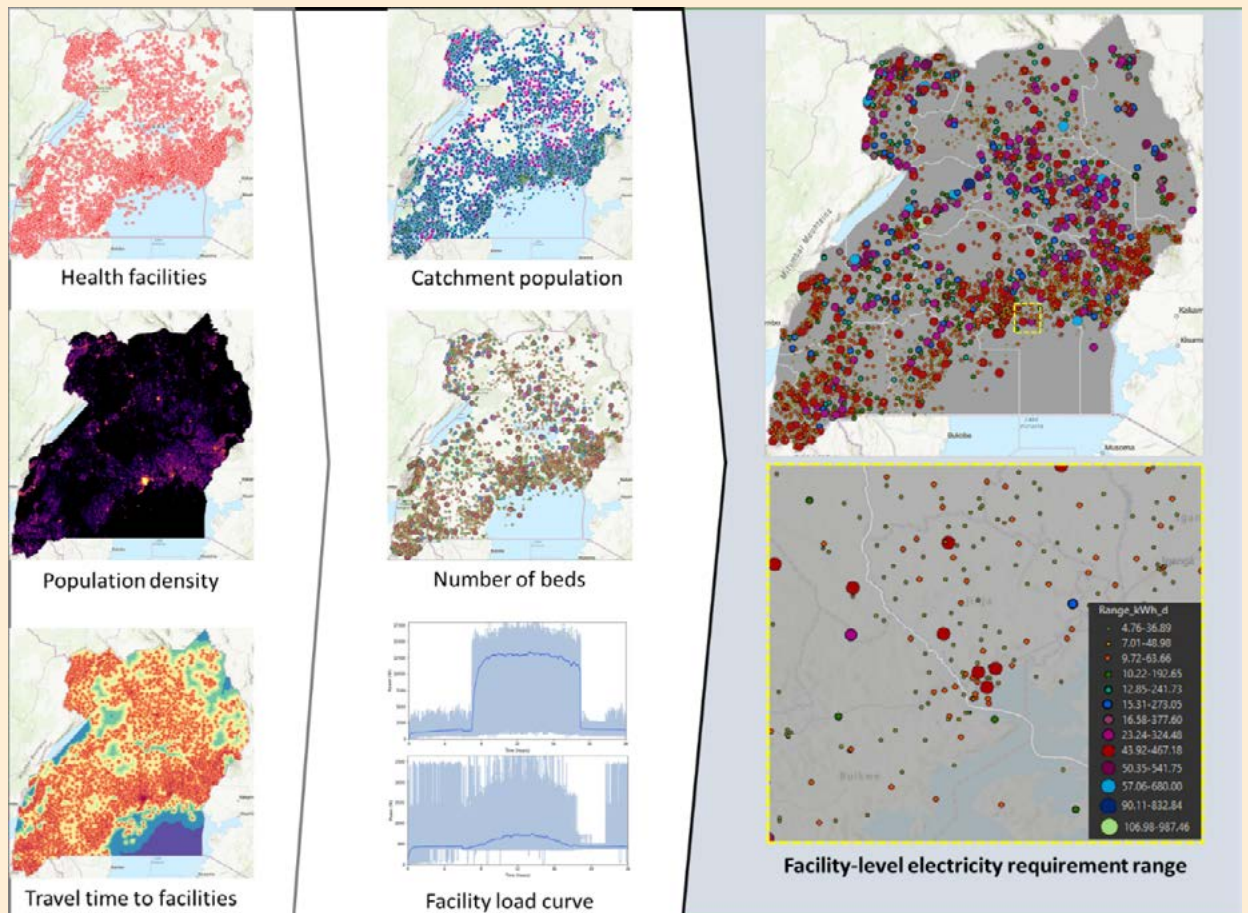
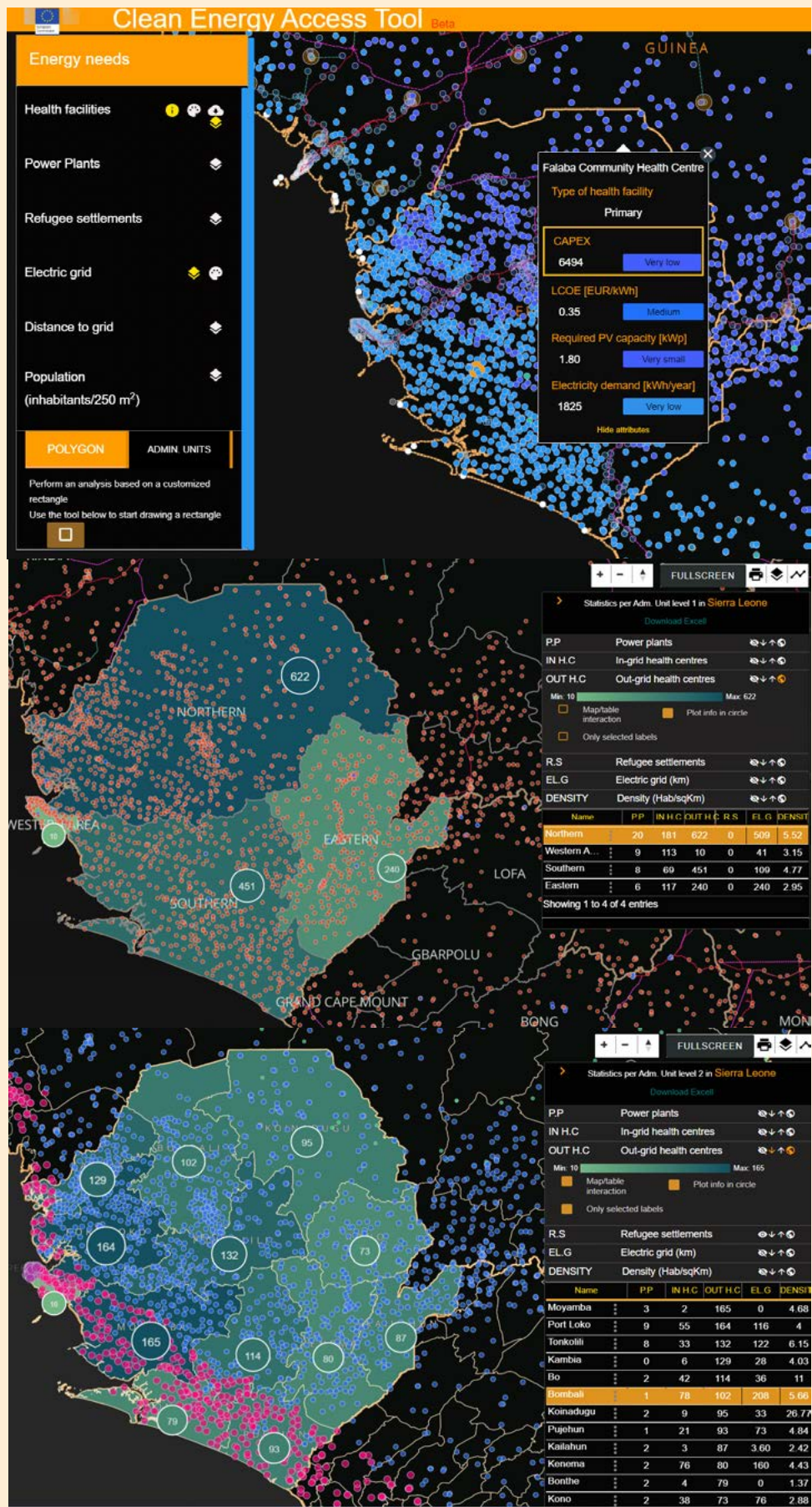


Fig. 4.5. Example of geospatial analysis on electrification of health-care facilities



4.3.2 Energy system design tools

Once the energy needs of a facility are estimated, several online tools are available to design, simulate and optimize renewable energy systems. These modelling tools are designed for different purposes, e.g. to provide inputs for analysis (such as economic evaluation), resource-specific design tools (e.g. solar PV), simulation tools, solar irradiation maps, geospatial analysis, demand assessment and other types of decision-making. **Web Annex F** provides a brief overview of some common software packages for energy system design.

Most of these software packages are not designed specifically for health-care facilities; rather, they are designed for solutions for various types of buildings (potentially including health-care facilities). They vary in their degree of sophistication and compulsory licensing. As well, they are primarily designed for energy practitioners and energy system providers (vendors), rather than for health-care staff to estimate the energy needs of their facilities.

In 2020, the USAID, in partnership with ESMAP/World Bank, HOMER Energy and We Care Solar, launched the Hybrid Optimization Model for Multiple Energy Resources (HOMER) Powering Health Tool⁴ for sizing energy systems to power health-care facilities. This tool focuses on locations where there is no access to the grid, or where the grid is unreliable or intermittent. The tool allows users to enter energy needs of a health-care facility manually, based on actual equipment use at the facility, or by selecting one of four tiers of health-care facility (district hospital, rural hospital, small inpatient facility or rural dispensary) and manually adjusting the quantity, load and usage hours. The tool has provisions to model energy needs for isolation wards and COVID-19 testing sites.

The HOMER Powering Health Tool combines energy demand data related to specific equipment with optimal combinations of power supply, based on the principle of least cost of electrification. This calculates the lowest cost per unit of electricity over a project lifetime across various energy supply configurations. The energy supply options are limited to the most-used energy sources in unserved and underserved areas: solar PV, batteries (lead-acid or Li-ion), grid and fuel-based generators. Several limitations of this tool have been acknowledged by its developers, which may restrict a user from accurately sizing their system (USAID et al., 2020).

- For a health-care facility with grid electricity, the tool can only account for power outages for a predictable and continuous number of hours each day. That is, it is not able to factor in the intermittency of an unreliable grid, or account for multiple power outages occurring at different times throughout the day.
- The pricing of grid electricity, batteries, inverter, generator, solar PV panels and fuel have been roughly estimated for Africa, and may change over time and for different geographies. Given that the tool is applicable for health centres in any part of the world, the cost estimates for equipment and fuel for other regions, including taxes on equipment, need to be manually entered based on location. These varying costs will have an impact on the least-cost system sized for the health-care facility. Users would be assisted by a cost database for different regions, to make the tool universal.
- There are limitations on the user's ability to provide customized inputs on O&M, transport and installation costs, or to change the specifications of each type of equipment (e.g. batteries, generator, PV modules), such as the useful lifetime or runtime of the equipment. These details are fixed in the tool and cannot be modified. Although these changes can be made in the HOMER Pro[®] microgrid software by HOMER Energy (a more comprehensive software package, from which

4 <https://poweringhealth.homerenergy.com/>

he HOMER Powering Health Tool was developed), HOMER Pro[®] is not free.⁵ HOMER Pro[®] can also model other energy supply options, including wind turbines and run-of-river hydro.

Overall, the HOMER Powering Health Tool provides a reasonable representation of energy requirements and can be used as a guide to optimize sizing at the facility. However, it is heavily dependent on the right inputs; assumptions made by the user on cost, local availability and reliability of existing power sources, electrical loads, respective hours of use and financing can play a significant role in the final output in terms of prioritization of the correct system size and technology configuration. Therefore, the applicability of these tools will depend on the involvement, capacity-building and use of the tools by the local ecosystem of enterprises, health-care facilities and NGOs, and should not be limited to technical specialists.

Apart from using these software-based tools, several other factors need to be taken into consideration in decision-making; these include:

- site suitability – orientation of solar PV panels on the rooftop, roof structure strength to support module mounting structure and PV panels, potential barriers on-site that prevent placement of equipment in the facility (e.g. shade-free area for solar PV panels);
- physical availability of well-ventilated space for batteries, inverters and solar PV panels;
- design of multiple available sources of power supply options;
- designing for climate vulnerabilities – for example, physical barriers, reinforcements or other adjustments in areas prone to droughts, floods, lightning or other weather conditions; and
- availability and cost of supply and installation of equipment, including PV panels, batteries and diesel fuel.

Bottom-up assessments, based on specific on-the-ground evaluations, are necessary to verify and complement the result of the energy modelling tools and to design comprehensive and proper energy solutions.

A single-sized approach may lead health-care facilities to install electricity systems that are too large or too small, which can lead to subsequent problems with affordability and effective service delivery. The system design, at a minimum, should ensure that all essential health services that the facility is designated to deliver are provided with reliable electricity. Although the minimum energy infrastructure requirements can be derived from country-specific health infrastructure standards, it is important for policy-makers and project developers to evaluate varying requirements within the same tier of health care, and design multiple system configurations and sizes through a needs assessment. After a proper assessment, standardization of system sizes relative to the different tiers of facilities in countries can eventually be used to achieving economies of scale in achieving energy access to support essential health services, and in larger-scale procurement and installation programmes (SEforALL, 2020). There is a need to collect, build and validate real-world data on clinic energy requirements and load profiles, over time, that can then be matched up with a health systems-wide approach incorporating system engineering tools.



5 The HOMER Powering Health Tool uses the proprietary optimization algorithm of HOMER, originally developed at the National Renewable Energy Laboratory, and enhanced and distributed by HOMER Energy.

4.4 Examples of solar system designs for different tiers of health-care facilities

Every country has a different way of organizing its public health system, depending on its needs, resources and historical context. From village-level clinics to specialty hospitals, the different tiers of the public health infrastructure typically include first points of care, primary care facilities, first referral units, secondary care facilities and higher-level tertiary care hospitals. The health services delivered at each of these tiers, combined with the operational hours and the size of the populations that use their services determine the facility's energy requirements.

The expected loads and indicative design for stand-alone solar PV systems are included in the sections below for all tiers up to secondary care facilities. Loads considered for each room, number of appliances and operational hours considered in this template are examples based on estimated usage, and need to be customized according to the actual usage⁶ characteristics identified during a proper health–energy assessment. For each tier, an indicative system design is mentioned for low-sunshine (3 hours per day) and high-sunshine (5 hours per day) scenarios, along with a comparison of powering traditional equipment (based on an estimated demand) versus powering efficient equipment (based on an estimated demand). As emerges from this comparison, using efficient equipment significantly reduces the needed capacity of solar panels, batteries and inverter, and therefore dramatically reduces the cost of the overall energy system.

4.4.1 First point of care

In the public sector, a health post, subcentre or clinic, is the most peripheral and first point of contact between the primary health-care system and the community. These facilities are typically tasked with providing basic services in the areas of mother and child care, family welfare, nutrition, immunization and control of communicable diseases. Well-functioning facilities at this level may also conduct deliveries and newborn care.

Type of room	Examples of loads			
OUTPATIENT DEPARTMENT/CLINIC	Lights, fans, laptop, printer			
EXAMINATION ROOM	Lights, fans, wi-fi			
WAITING AREA	Lights, fans			
STAFF RESIDENCE (INCLUDING KITCHEN, BATHROOM/TOILET)	Lights			
OUTDOOR	Lights			
STOREROOM	Lights			

Parameter	Powering traditional equipment		Powering efficient equipment	
Maximum load connected	1 380 W		678 W	
Maximum units that can be used per day	4.5 kWh		1.9 kWh	
Peak sun hours per day	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Solar system capacity required	2.8 kW	1.95 kW	1.2 kW	0.68 kW
Battery capacity	1 800 Ah 12V	1 800 Ah 12V	620 Ah 12V	620 Ah 12V
Inverter capacity equivalent to	4 kVA	2.5 kVA	2.5 kVA	1.4 kV

⁶ Examples of more detailed energy demand assessments and load profiles based on hours of operation of specific appliances are included in **Web Annex E**.

4.4.2 Primary health-care facilities

A primary health-care facility is usually the cornerstone of rural health services – a first port of call to a qualified doctor of the public sector in rural areas for the sick, and those who directly report or are referred from first points of care for curative, preventive and promotive health care. Although the specific characteristics changes between different countries, a typical primary health-care facility usually covers a population of 20 000–30 000, with 5–10 beds for inpatient admissions. These facilities are usually tasked with providing comprehensive primary health care to the community, and make the health services more responsive and sensitive to the needs of the community. The facilities also typically conduct deliveries and are often the first point of access for regular antenatal and postnatal care.

Type of room	Examples of loads	
OFFICE	Lights, fans, laptop, printer	
REGISTRATION	Lights, fans, laptop, printer	
LABOUR ROOM	Lights, fans, phototherapy, radiant warmer, suction machine, spotlight	
MENS' AND WOMENS' WARDS	Lights, fans	
NURSES ROOM	Lights, fans	
LABORATORY	Lights, fans, microscope, centrifuge	
MINOR OPERATING THEATRE	Lights, fans, nebulizer, needle cutter	
OUTPATIENT DEPARTMENT	Lights, fans	
COLD CHAIN ROOM AND PHARMACY	Lights, fans	
IMMUNIZATION ROOM	Lights, fans	
DRESSING ROOM	Lights, fans	
COLD CHAIN EQUIPMENT IN COLD CHAIN ROOM, PHARMACY, IMMUNIZATION ROOMS	Cold chain room and pharmacy – ice-lined refrigerator, deep freezer Immunization – refrigerator	
EMERGENCY ROOM	Lights, fans, mobile light, oxygen concentrator, ECG machine	
STOREROOM	Lights	
WAITING AREA	Lights, fans	
WASHROOM/BATHROOM/TOILET	Lights	
ENTRANCE	Lights	
CORRIDOR	Lights, fans	

Parameters	Powering traditional equipment		Powering efficient equipment	
Maximum load that can be connected	7 870 W		4 620 W	
Maximum units that can be used per day	18.4 kWh		10 kWh	
Peak sun hours per day	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Solar system capacity required	10.11 kW	6.6 kW	6 kW	3.6 kW
Battery capacity	6 100 Ah 12V	6 100 Ah 12V	3 300 Ah 12V	3 300 Ah 12V
Inverter capacity equivalent to	20 kVA	12.5 kVA	7.5 kVA	7.5 kVA

4.4.3 First referral units

First referral units typically provide referral health care for cases from the primary health-care facilities and for cases in need of specialist care approaching the centre directly. As an example, they may have around 30 beds and typically provide specialist care in medicine, obstetrics and gynaecology, surgery, paediatrics and dental care. First referral units are usually the gatekeepers between primary care and higher levels of specialized hospitals. These facilities are typically in grid-connected areas, but even a few hours of power cuts per day have a substantial impact on the critical services they deliver.



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Since first referral units tend to be in areas with grid connectivity, the solar power system example illustrated below is designed for backup, providing for 4–5 hours of power outages per day. Even in the case of reliable electricity, these facilities are often encouraged to offset some of their power consumption from the grid by generating power locally. This can affect the burden of recurring electricity bills over time and reduce the damage to equipment caused by voltage fluctuations where the grid-based electricity is not reliable. In these grid-connected cases, equipment such as sterilizers, X-ray machines, air conditioners and autoclaves, though they are present in the facilities, are typically not considered for solar design because of its high power consumption and surge loads. These types of equipment can be included on a case-by-case basis depending on their criticality.

Type of service	Examples of loads
ADMINISTRATION	Printer, photocopier, computer
EMERGENCY	Cardiac monitor, needle cutter, oxygen concentrator
OPERATING THEATRE (INCLUDING DELIVERIES, NEWBORN CARE)	Lights (ceiling and portable), nebulizer, suction apparatus, radiant warmers, phototherapy, oxygen concentrator, cardiac monitor, refrigerator, spotlight, examination light, needle cutter
PRENATAL CARE	Ultrasound
BLOOD TRANSFUSION (MATERIALS KIT)	Centrifuge, microscope
IMMUNIZATION	Ice-lined refrigerator, deep freezer
BLOOD STORAGE	Blood bank refrigerators, deep freezers, microscope, centrifuge
LABORATORY	Refrigerator, needle cutter, microscope, centrifuge, complete blood count machine, thyroid stimulating hormone machine, digital laboratory centrifuge, machine to conduct rapid molecular tests for infectious disease diagnostics, biochemistry machine
PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES	ECG machine, cardiac monitor
DENTAL CARE	Dental chair with equipment, needle cutter
GENERAL	Lights and fans for all rooms; refrigerators (3 units), laptops for doctors room, microscope, water dispenser, computers and printers in specific rooms, TV

Parameter	Powering existing (excluding air conditioning and X-ray)		Powering efficient equipment (excluding air conditioning and X-ray)	
	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Maximum load that can be connected	19 kW		13.7 kW	
Maximum units that can be used per day	54 kWh		39.6 kWh	
Peak sun hours per day – average from all loads	Low-sunshine hours	High-sunshine hours	Low-sunshine hours	High-sunshine hours
Solar system capacity required	32 kW	19.2 kW	23.5 kW	14.1 kW
Battery capacity	18000 Ah 12V	18 000 Ah 12V	13 000 Ah 12V	1 300 Ah 12V
Inverter capacity equivalent to	60 kVA	60 kVA	40 kVA	40 kVA

4.4.4 Secondary health-care facilities

Secondary health-care facilities provide comprehensive secondary health-care services to the people in the district, and are responsive to the needs of people and referring centres. Usually, every district or the equivalent administrative area is served by a public secondary care facility. As the population of a district is variable, bed numbers vary, for example from 75 to 500, depending on the size, terrain and population of the district.

The design templates below are examples for secondary care facilities with 100 beds, considering critical loads such as maternal and child care, laboratory, operating theatre, blood bank and administration, among other critical rooms. Since these facilities are usually located in the headquarters of a district with more reliable electricity access, the solar design illustrated below could complement the connected grid, providing 4 hours of backup for key services. However, in this example, critical equipment such as vaccine storage is considered with a full 8 hours of backup (which is the time required for the compressor to run to keep the vaccine storage running). Similar to the design shown for first referral units, equipment that has very high power consumption has not been included for the system designs example shown below.

Service	Examples of loads
OUTPATIENT DEPARTMENT, WARDS, CORRIDORS, REGISTRATION COUNTERS, ADMINISTRATION BLOCK, NATIONAL HEALTH PROGRAMMES (ROOMS), LAUNDRY, KITCHEN, STOREROOM, PHARMACY, NURSING ROOM	Lights, fans, desktop computer, printer, refrigerator, air conditioner
INTENSIVE CARE UNIT	Lights and fans, ventilator, suction apparatus, cardiac monitor, blood gas analyser, oxygen concentrator, refrigerator, needle cutter
OPERATING THEATRE	Operating table, cautery machine, suction apparatus, radiant warmer, laparoscopic set, anaesthesia unit, oxygen concentrator
MATERNAL AND CHILD HEALTH (LABOUR ROOM, FEMALE WARD, MATERNITY WARD, MATERNITY OPERATING THEATRE)	Lights, fans, radiant warmer, suction apparatus, spotlight, refrigerator
DENTAL CARE	Dental chair, dental chair compressor
IMMUNIZATION AND COLD CHAIN	Ice-lined refrigerator, deep freezer, lights, fans
BLOOD BANK AND LABORATORY	Blood bank tube sealer, blood collection monitor, blood storage refrigerator, centrifuge, cryobath, deep freezer, microplate reader, microplate washer, haematology analyser, ELISA plate reader, microscope, microscope water system, microscope printer, biochemistry analyser cuvettes, mini rotary shaker, needle destroyer, needle cutter, plasma thawing bath, platelet agitator and incubator, printer, refrigerators, serology water bath, tube sealer

Parameters	Powering efficient equipment	
Summary of services considered	Maternity care, child care, intensive care unit, operating theatre, immunization, blood bank, laboratory, administration	
Maximum load that can be connected	43 kW	
Maximum units that can be used per day	196 500 kWh	
Peak sun hours per day – average from all loads	Low-sunshine hours	High-sunshine hours
Solar system capacity required	116 kW	70 kW
Battery capacity	64 300 Ah 12V	64 300 Ah 12V
Inverter capacity equivalent to	175 kVA	120 kVA

4.5 Modularity of decentralised solar-based solutions

The sample design presented in this section focuses on powering the examples of critical loads typically present at each tier of health-care facility. Depending on the needs of a particular facility and the financial resources available, the solutions need to be further customized. They can also be modularized either to power selective loads, or to add more loads depending on the need.

Table 4.5 (based on IRENA, 2022) provides an example of how the solar design for a first point of care can be customized, based on the needs of a particular facility. This type of customization can be done for any facility at any tier of the health-care system.

Table 4.5. Example of customization of solar design for a first point of care

	Option 1	Option 2	Option 3	Option 4
EXAMPLES OF SERVICES CONSIDERED	BASIC DIAGNOSIS (CURRENT SCENARIO) + TELECONSULTATION	BASIC DIAGNOSIS + TELECONSULTATION + MATERNAL CARE	BASIC DIAGNOSIS + TELECONSULTATION + MATERNAL CARE + REFRIGERATOR FOR MEDICINE STORAGE	BASIC DIAGNOSIS + TELECONSULTATION + MATERNAL CARE + IMMUNIZATION
Example of equipment considered for all the designs as per current scenario	Lights, fans, mobile charging, printer, outdoor lights			
Examples of additional equipment considered for added services	Teleconsultations equipment	Teleconsultations equipment, 1 baby warmer, 1 suction apparatus, 1 spotlight	Teleconsultations equipment, 1 baby warmer, 1 suction apparatus, 1 spotlight, 1 refrigerator	Teleconsultations equipment, 1 baby warmer, 1 suction apparatus, 1 spotlight, 1 vaccine cold storage
Examples of loads	3 rooms, 1 dispensary, 1 maternity room, 1 toilet (9 lights, 5 fans, 2 or 3 mobile charging, 1 laptop, 1 printer, wi-fi, 2 outdoor lights)	3 rooms, 1 dispensary, 1 maternity room, 1 toilet (10 lights, 5 fans, 2 or 3 mobile charging, 1 laptop, 1 printer, wi-fi, 2 outdoor lights, 1 baby warmer, 1 suction apparatus, 1 spotlight)	3 rooms, 1 dispensary, 1 maternity room, 1 toilet (10 lights, 5 fans, 2 or 3 mobile charging, 1 laptop, 1 printer, wi-fi, 2 outdoor lights, 1 baby warmer, 1 suction apparatus, 1 spotlight), refrigerator	3 rooms, 1 dispensary, 1 maternity room, 1 toilet (10 lights, 5 fans, 2 or 3 mobile charging, 1 laptop, 1 printer, wi-fi, 2 outdoor lights, 1 baby warmer, 1 suction apparatus, 1 spotlight), vaccine SDD refrigerator (58 L of vaccine)
Indicative solar system design	1.5 kWp, 400 Ah, 48 V	2.4 kWp, 400 Ah, 48 V	3.2 kWp, 200 Ah, 96 V	2.4 kWp, 400 Ah, 48 V (and 1 kWp for vaccine SDD refrigerator)

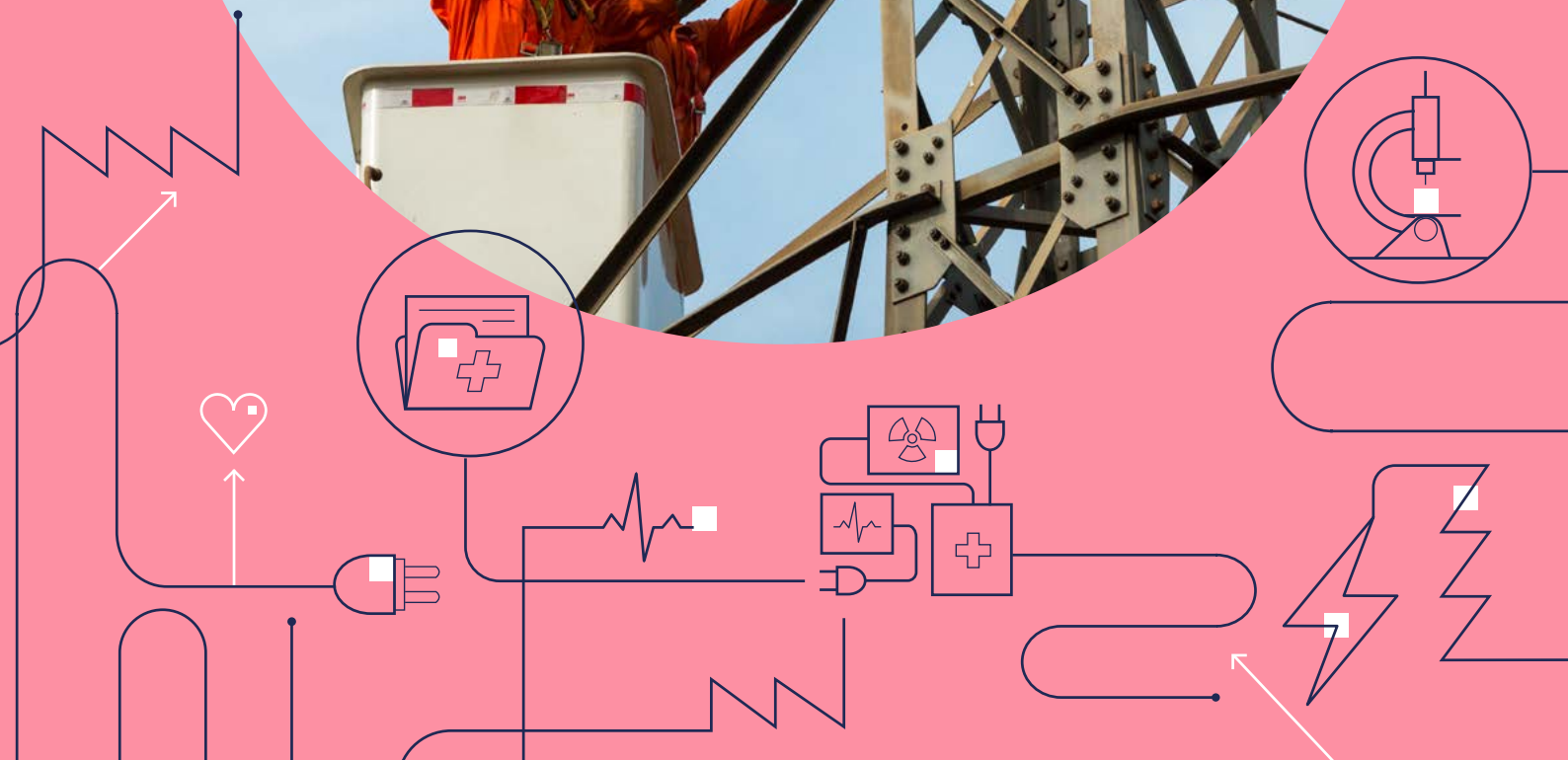




Powering health-care facilities: an investment needs assessment



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5.1 Introduction

This chapter provides estimates of the investment required to improve the electrification status of health-care facilities in 63 low- and middle-income countries. The countries included in this analysis were selected based on data availability, and compatibility between the stocktaking exercise presented in Chapter 2 and an analysis undertaken by the World Bank as part of the GEP initiative (World Bank Group, 2022). It should be highlighted that this analysis is not exhaustive, but rather a high-level estimate based on a series of assumptions that may differ between countries and between health-care facilities. However, it was based on the best publicly available (at the time of writing) data, and it can be updated should more accurate or updated input data become available.

Section 5.2 describes the methods used to collect available data and indicators, and how they were used in this assessment. Further details on methodologies are provided in **Web Annex G**. **Section 5.3** presents the findings of this analysis – that is, the total investment requirements for stepping up electricity access in currently unserved or unreliably served health-care facilities. **Section 5.4** concludes with a sensitivity analysis, and discussion of the results and limitations of the current analysis.

5.2 Methodological approach

5.2.1 The four electrification parameters

To assess the level of intervention required for electrification of health-care facilities in each country, four key parameters needed to be estimated.

- Total number of health-care facilities (THF): the total number of health-care facilities per country.
- Health-care facility electricity access rate (HFEAR): the share of health-care facilities that currently have access to any source of electricity (grid or off-grid).
- Health-care facility electricity interruption rate (HFEIR): the reliability of supply; more specifically, the share of health-care facilities experiencing frequent¹ power interruptions.
- Share of grid versus off-grid connected health-care facilities (LCHF): the share of health-care facilities that find grid (versus off-grid) as the least-cost electrification option in 2030; this was used to indicate the electrification technology for currently unserved facilities.

These parameters were not available under a single source, and thus a few different data repositories needed to be combined.

The primary source of information was the HDB from the data stocktaking exercise presented in Chapter 2. The HDB consisted of survey data and was used to extract the total number of health-care facilities, and their electrification status and reliability of supply, where available. More specifically, the indicators for electricity access (“*any_elec*”) and electricity interruptions or reliability (“*elec_interrupt*”) were used to reflect HFEAR and HFEIR, respectively. When available,

¹ The HDB in Chapter 2 comprised data from different surveys; therefore, the definition of “frequent” interruptions is loose. In most cases, this value indicates the share of health-care facilities that had access to some form of electricity, but the supply suffers from frequent outages (e.g. an outage lasting more than two hours at a time in the previous one (or two) weeks). In a few other cases, however, the length of interruption is not specified (e.g. the indicator is “Health-care facility had continuous power supply during the past 7 days” but “continuous” is not defined in available survey documents)..



the two indicators were extracted for hospitals and non-hospitals separately; otherwise, the same value was used for both types. These indicators are described in Chapter 2, with additional details available in **Web Annex A**.

For countries for which survey data from the HDB were not available (or were outdated e.g., data available from before 2015), a secondary approach was used. In these cases, HFEIR was estimated using a population-based, weighted average value of countries within the same income level group (LI or LMI).

HFEAR was estimated using data from the GEP database developed by the World Bank (World Bank Group, 2022). The GEP database contains information related to the least-cost electrification option for millions of unserved settlements in the developing world. The updated version of the database (GEP V.2.0) was officially released in April 2022. The location and type of these facilities were provided by the Maina et al. (2019) dataset for sub-Saharan Africa (98 745 health-care facilities) and the healthsites.io database (Healthsites, 2022) for countries outside sub-Saharan Africa (12 158 health-care facilities). The GEP was used to extract information relating to the electricity access status of the settlement where the health-care facility is located. More specifically, the status of electricity access refers to the probability of a settlement being connected to the grid. Using a multicriteria analysis based on key GIS data (e.g. distance to grid network, distance to functional service transformers, road availability, night light intensity, population density), the GEP model characterized each settlement as connected to the grid (electrified) or not (unelectrified). Health-care facilities located in electrified settlements were inherently classified as electrified as well. Furthermore, the status of electricity access for health-care facilities located in countries of sub-Saharan Africa was also informed by the Electricity access Health Facility Database in Africa (EHFDB), developed by the European Union Joint Research Centre (Moner-Girona et al., 2021). The EHFDB includes 126 937 health-care facilities in 58 countries in Africa and uses a GIS-based methodology (similar to the GEP) to estimate health-care facility electrification status. The GEP and EHFDB databases were used interchangeably according to data availability in each country.

It should be acknowledged that values extracted from the GEP database and the EHFDB are modeled estimates, and thus may not be totally accurate with reality on the ground. For example, some facilities may remain unconnected even if the grid network has reached the vicinity. The deployment of backup systems in areas with low reliability of supply can help avoid underestimating investment in such cases. In contrast, some facilities may have access to electricity but have been missed in the modeling exercise (e.g. being too far from the grid with low night light indication but powered via off-grid systems with such cases considered as “greenfield” sites in the modeling analysis).

LCHF was estimated using the GEP. The least-cost electrification solution refers to the technology (grid or off-grid) selected by the GEP model for each settlement. The selection was based on a comparative analysis of the lifetime costs among all technologies to cover the total load in a given settlement for a given period of time (in this case, 2020–2030²). It was assumed that the least-cost electrification option for each health-care facility is the same as for the settlement where the facility is located.

Finally, the total number of health-care facilities in each country, along with their classification as either hospitals or non-hospitals, was estimated using all sources above. Data from official statistics were also used to cross-check the numbers, when available. A full list of data sources is available in **Web Annex G**.

2 The GEP is calibrated towards the achievement of SDG 7 (United Nations, 2015) – that is, to ensure universal access to affordable, reliable, sustainable and modern energy by 2030.

By combining the collected information, a health-care facility electricity access “master list” was constructed for 63 countries. For each country, the four parameters – THF, HFEAR, HFEIR and LCHF – were estimated, separately for hospitals and non-hospitals³ (see results in **Web Annex G**).

5.2.2 Estimating intervention requirements

Once the four electrification parameters were defined, the analysis proceeded with estimating the level of intervention required per country. Two levels of intervention were defined: “new connection” for health-care facilities that do not have access to electricity, and “backup system” for health-care facilities that do have access to grid electricity but require a backup system because of low reliability of supply.

The total number of new connections for grid and off-grid powered systems in each country was calculated as follows:

$$\text{NewConnections}_{\text{grid}} = \text{THF} \times (1 - \text{HFEAR}) \times \text{LCHF} \quad (\text{eq. 1})$$

$$\text{NewConnections}_{\text{off_grid}} = \text{THF} \times (1 - \text{HFEAR}) \times (1 - \text{LCHF}) \quad (\text{eq. 2})$$

Note that $(1 - \text{LCHF})$ indicates the share of health-care facilities that find off-grid as the least-cost option.

Assuming that the reliability of supply in the grid will remain the same and that any new off-grid connections will be properly sized and operated, the total number of health-care facilities that require an additional off-grid backup system was estimated, as follows:

$$\text{Backupsystems}_{\text{off_grid}} = (\text{THF} \times \text{HFEAR} \times \text{HFEIR}) + (\text{NewConnections}_{\text{grid}} \times \text{HFEIR}) \quad (\text{eq. 3})$$

5.2.3 Estimating proxy technology costs

As described above, this methodology relied on the combination of data from different databases, with different spatial granularities: the HDB at lower granularity (national administrative level, at most) and the GEP at high granularity (health-care facility level). To make the best use of both, low granularity was used as the template, while high-granularity data were leveraged when possible.

This is particularly evident in this section of the methodology, where a detailed electrification analysis was conducted for each health-care facility in the GEP database (110 903 health-care facilities in 58 countries); however, for compatibility reasons, the investment requirements were used to create technology cost proxies per country instead. The proxy costs differ between countries and tiers of facility (i.e. hospitals and non-hospitals). A short explanation is provided below; a more detailed description of the GEP analysis for each health-care facility is available in **Web Annex G**.

- **Avg. CAPEX (\$) per kW of grid connection (Gcapex):** This proxy indicates the average, discounted, overnight cost per added kW a health-care facility would require if connected to the grid. It was calculated by averaging this cost for all health-care facilities that found grid as the least-cost electrification option in the GEP analysis, per country.

³ The classification between hospitals and non-hospitals was selected so as to reflect the granularity of the HDB data. For consistency with Chapter 3, community- and primary-level health-care facilities were considered as non-hospitals and referral health-care facilities as hospitals.

- **Avg. Net Present Cost (NPC) (\$) per kW of off-grid PV–battery–diesel connection (OGnpc):**
This proxy indicates the average NPC (capital expenditure (CAPEX) + operating expenditure (OPEX)) per added kW a health-care facility would require if connected to a PV–battery–diesel off-grid system. It was calculated by averaging this cost for all health-care facilities per country, regardless of whether this is the least-cost option or not. The PV–battery–diesel systems were modelled separately for each health-care facility, taking into account local resources and the specific electricity demand target, and maintaining high levels of supply reliability (maximum loss load <0.01%). This proxy cost was further disaggregated as:
 - Avg. CAPEX (\$) per kW of off-grid PV–battery–diesel connection (OGcapex); and
 - Avg. OPEX (\$) per kW of off-grid PV–battery–diesel connection (OGopex).

For five countries – for which GEP results were not available – these proxies were estimated based on regional averages from the GEP database. That is, for Afghanistan, Nepal, Sri Lanka and India, the South Asia region average proxy costs were used; for Viet Nam, the East Asia and Pacific region average proxy costs were used.

5.2.4 Calculating total investment requirements

Finally, when the total number of health-care facilities that require intervention and the proxy costs were estimated per country, the total investment requirements in United States dollars (US\$) of 2022 were estimated as follows:

$$\text{GridCAPEX}_{\text{newcon}} = \text{NewConnections}_{\text{grid}} \times \text{PeakLoad} \times \text{Gcapex} \quad (\text{eq. 4})$$

$$\text{Off_GridCAPEX}_{\text{newcon}} = \text{NewConnections}_{\text{off_grid}} \times \text{PeakLoad} \times \text{OGcapex} \quad (\text{eq. 5})$$

$$\text{Off_GridOPEX}_{\text{newcon}} = \text{NewConnections}_{\text{grid}} \times \text{PeakLoad} \times \text{OGopex} \quad (\text{eq. 6})$$

$$\text{Off_GridCAPEX}_{\text{backup}} = \text{Backupsystems}_{\text{off_grid}} \times \text{PeakLoad} \times \text{BPLR} \times \text{OGcapex} \quad (\text{eq. 7})$$

$$\text{Off_GridOPEX}_{\text{backup}} = \text{Backupsystems}_{\text{off_grid}} \times \text{PeakLoad} \times \text{BPLR} \times \text{OGopex} \quad (\text{eq. 8})$$

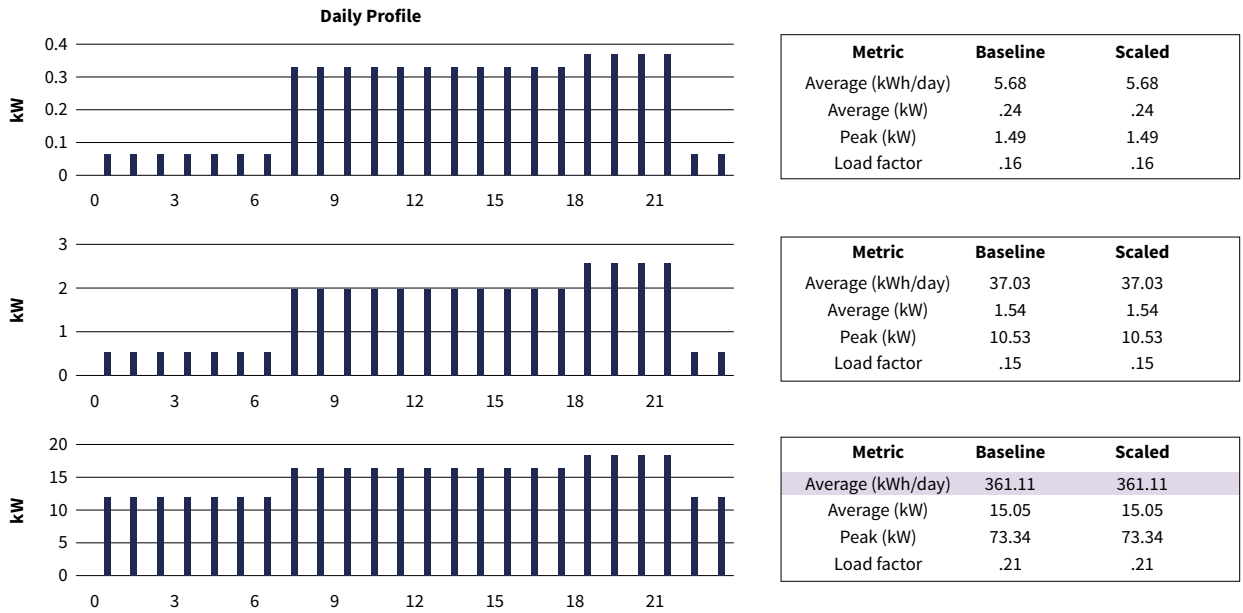
Peak Load (kW) was calculated as:

$$\frac{\text{Estimated daily electricity requirement} \times 365}{\text{Load Factor}} \quad (\text{eq. 9})$$

The estimated daily electricity requirement was set at 15 kWh/day for non-hospitals and at 500 kWh/day for hospitals, based on findings presented in Chapter 3 and an additional literature review (HOMER Energy, n.d.; USAID, 2011; WHO & World Bank, 2015; Moner-Girona et al., 2021). The load factor⁴ was set at 21% for referral-level facilities, 15% for primary-level facilities and 16% for community-level facilities (**Fig. 5.1**). It should be acknowledged that different types of health-care facilities might be subject to different load factors depending on their equipment, services and operation status (see Chapter 3 for further details). The backup to peak load ratio was set at 50% (see **section 5.4**).

⁴ Defined as average to peak load ratio.

Fig. 5.1. Indicative load profiles and load factors for a “typical” community-level (top), primary-level (middle) and referral-level (bottom) health-care facility



Note: Values were retrieved from the HOMER Powering Health Tool (HOMER Energy, n.d.), assuming the default assumptions for the reference cases of rural dispensary, rural clinic and referral hospital, respectively.

Finally, the total investment was estimated as the summary of all costs, as shown below:

$$\text{TotalInvestment} = \text{GridCAPEX}_{\text{newcon}} + \text{Off_GridCAPEX}_{\text{newcon}} + \text{Off_GridCAPEX}_{\text{backup}} + \text{Off_GridOPEX}_{\text{newcon}} + \text{Off_GridOPEX}_{\text{backup}} \quad (\text{eq. 10})$$

5.3 Results

The total number of health-care facilities included in this analysis was 459 206. About 3.9% (or 17 903) of these were classified as hospitals; the remaining 441 303 were classified as non-hospitals (see **Table 5.1**). About 22% (or 100 926) of all facilities were classified as new connections. The overwhelming majority (98.2%) of new connections are non-hospitals; there are about 1863 hospitals for which a new connection is needed. About 65.6% (or 66 166) of the new connections are expected to be achieved via grid electrification, whereas the remaining 34.4% (or 34 760) of new connections are proposed for off-grid electrification. There are 599 hospitals that were identified as new connections among the off-grid cohort.

An estimated 223 506 health-care facilities require a backup system: 5406 hospitals and 218 100 non-hospitals. The analysis also shows that about 63.9% of the recorded health-care facilities require an intervention, in the form of either a new connection or a backup power system. This rate is highest in the South Asia and sub-Saharan Africa regions, followed by the East Asia and Pacific region; the rate is significantly lower in countries in the Latin America and the Caribbean region.

Table 5.1. Breakdown of 459 206 health-care facilities in 63 countries, by region, type and intervention level required

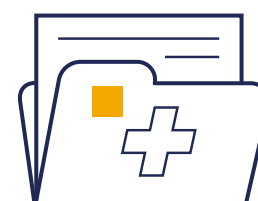
Region	Type	Total	New connections			No. of facilities that require a backup off-grid system	No. of facilities that require intervention	% of facilities that require intervention
			TOTAL	GRID	OFF-GRID			
LAC	Hospital	634	9	9	–	116	123	22.5
	Non-hospital	4 311	279	162	117	774	991	
SAR	Hospital	4 871	173	173	–	634	774	67.1
	Non-hospital	239 442	28 937	26 303	2 634	150 566	163 140	
EAP	Hospital	2 719	313	258	55	763	1 040	46.5
	Non-hospital	26 203	4 334	2 789	1 545	9 045	12 416	
SSA	Hospital	9 679	1 368	824	544	3 893	4 889	63.5
	Non-hospital	171 347	65 513	35 648	29 865	57 715	110 058	
Total	–	459 206	100 926	66 166	34 760	223 506	293 431	63.9

EAP: East Asia and Pacific region; LAC: Latin America and the Caribbean region; SAR: South Asia region; SSA: Sub-Saharan Africa region.

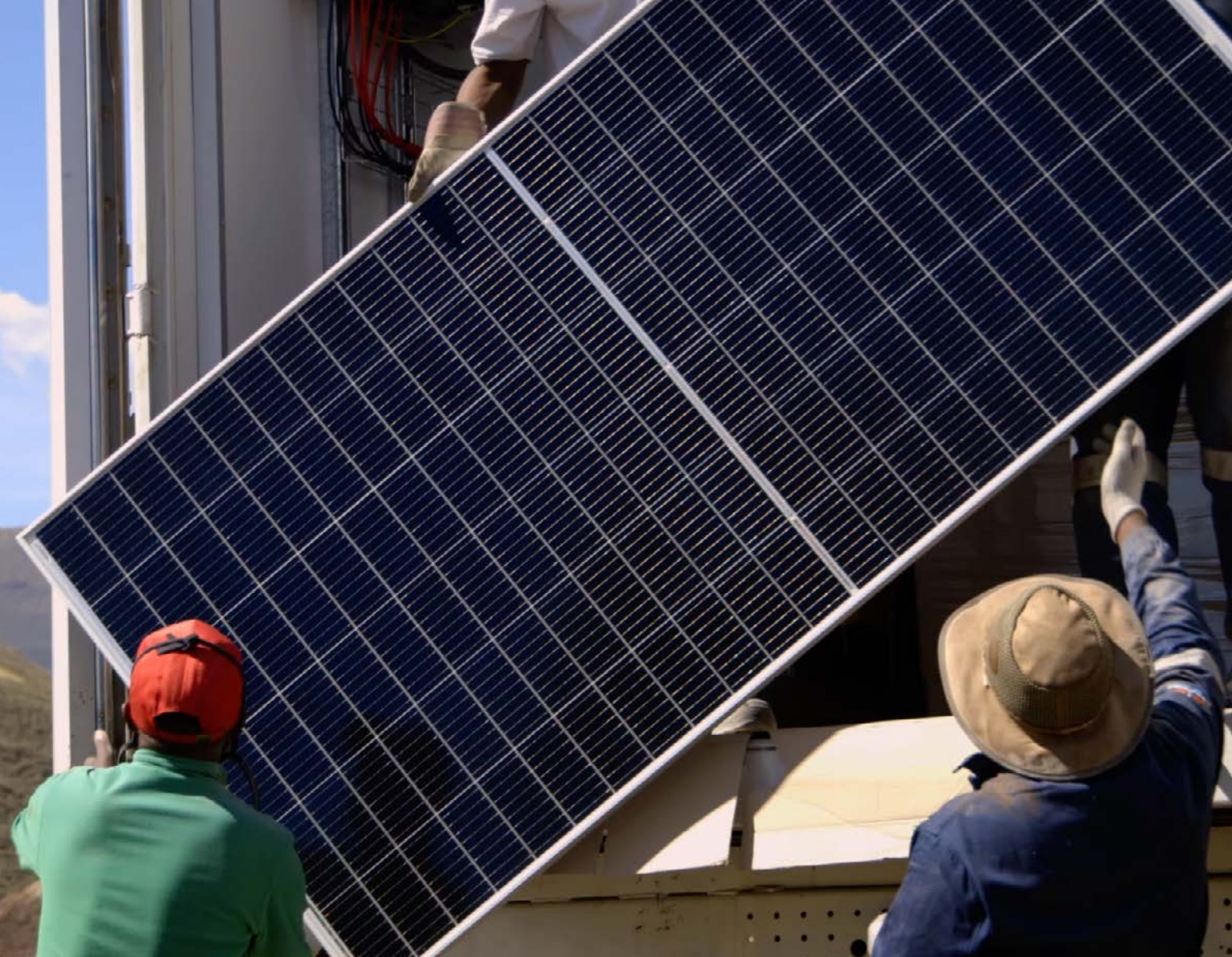
Note: “New connections” represents the number of facilities that, based on the modelling results, do not have access to electricity in the base year. “No. of facilities that require a backup off-grid system” represents the total number of facilities that are affected by supply interruptions and may require backup generation. The number of facilities included in the table may differ from the numbers mentioned in Chapter 2 due to the different scopes and methodologies used. For example, Chapter 2 focuses on national survey data from selected low-income and lower-middle-income countries, while the World Bank estimates are mainly based on GEP data for selected low- and middle-income countries. Further details on data and methodologies are provided in **Web Annexes A, B and G**.

Based on the analysis conducted, the total NPC of electrification is estimated at about US\$ 4.9 billion (**Table 5.2**). This breaks down to about US\$ 2.8 billion for supporting the deployment of backup off-grid generation in already connected health-care facilities and about US\$ 2.1 billion for new connections. The cost for grid-based new connections is estimated at about US\$ 1.5 billion and the costs for off-grid based new connections at about US\$ 476 million. Note that these costs reflect only overnight capital expenditures for grid connections, whereas both capital and operational expenditures are included for off-grid systems. All costs were discounted at a fixed rate of 8%.⁵

Geographically, sub-Saharan Africa is the region with the highest investment requirements (about US\$ 2.5 billion), with countries including Nigeria, Democratic Republic of the Congo, Kenya, Ethiopia and Tanzania ranking high in terms of total investment required. The South Asia region follows, with estimated investment requirements of about US\$ 1.9 billion; this is due to the high number of health-care facilities in India, a country that alone requires about US\$ 1.5 billion of investment. The cost of intervention is lower in the East Asia and Pacific region, and in the Latin America and the Caribbean region. A detailed list of the estimated investment requirements by country is available in **Web Annex G**.



⁵ The discount rate was set at 8% in order to be compatible with the assumptions of the GEP-based GIS analysis (Taliotis et al., 2016; Mentis et al., 2017). This may – of course – differ between countries and/or case studies. The selected rate was assumed as a good compromise between private capital rate and social discount rate.



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Table 5.2. Investment requirements for electrification of the 459 206 health-care facilities in 63 countries, by region, type and intervention level required

Region	Type	New connections CAPEX – grid (million US\$)	New connections CAPEX – off-grid (million US\$)	New connections OPEX – off-grid (million US\$)	Backup system CAPEX – off-grid (million US\$)	Backup system OPEX – off-grid (million US\$)	Total NPC (million US\$)	
							BY TYPE	TOTAL
LAC	Hospital	2.7	–	–	13.8	8.0	24.6	33.3
	Non-hospital	1.5	1.2	0.1	3.9	2.0	8.7	
SAR	Hospital	46.9	–	–	89.5	60.0	1 96.5	1 961.3
	Non-hospital	277.9	32.6	17.4	928.0	508.9	1 764.8	
EAP	Hospital	47.2	16.5	7.7	113.6	55.4	240.4	374.8
	Non-hospital	28.7	20.7	2.6	56.7	25.8	134.4	
SSA	Hospital	327.5	44.3	2.5	530.6	40.6	945.4	2 537.4
	Non-hospital	812.2	360.7	29.2	349.4	40.5	1 592.0	
Total	–	1 544.7	475.9	59.5	2 085.5	741.2	4 906.8	

CAPEX: capital expenditure; EAP: East Asia and Pacific region; LAC: Latin America and the Caribbean region; OPEX: operating expenditure; SAR: South Asia region; SSA: Sub-Saharan Africa region.

Note: Estimates are in US\$ for 2022.

5.4 Sensitivity analysis and discussion

This analysis was conducted based on the best available data at the highest available granularity. However, assumptions were made, changes in which may have a considerable impact on the results. A few important points are discussed below.

The first limitation relates to data availability, including data on both the number of health-care facilities per country and useful attributes of these facilities, such as their location, type, electrification status and power needs. Having access to this information for each facility can increase the quality of the analysis and yield more accurate investment estimates. For example, for some countries, the number of health-care facilities is almost certainly underestimated because the latest publicly available dataset was published many years ago. Another example is the HFEAR and HFEIR parameters. When missing, they were informed based on weighted averages. For the case of HFEIR specifically, data were only available for 14 out of 63 countries. That is, for most countries, the number of backup systems was simply based on the weighted average value of facilities facing frequent power interruptions, rather than a measured indicator for the country per se. These limitations need to be considered when analysing the results. They highlight the importance of data collection and dissemination at the highest granularity and consistency possible.

This analysis combined data from two different databases that contained information at different granularities. For example, in some cases, HDB data were provided at a country level and a two-fold classification (hospitals and non-hospitals) for each country. In contrast, the GIS analysis provided data at facility level but was missing important attributes such as the power availability and reliability of supply. Since the stocktaking exercise for this report significantly updated the HDB, the level of granularity follows its unit of analysis. That is, some generalizations were made to accommodate the harmonization of data.

For example, the daily electricity requirements were assumed at 15 kWh for the category “non-hospitals” and at 500 kWh for the category “hospitals”. In reality, the daily requirements vary depending on equipment available, services available and operation status; this is not captured by this binary classification. Changing the demand assumptions can have a considerable impact on the estimated investment requirements. For example, increasing the daily requirements for non-hospitals to 32 kWh/day (e.g. aiming at a minimum level of service equivalent to Tier 4; WHO & World Bank, 2015) can increase the total NPC of electrification to US\$ 8.9 billion: US\$ 5 billion for supporting the deployment of backup off-grid generation in already connected health-care facilities and about US\$ 3.8 billion for new connections. The impact of different daily electricity requirements on the results is shown in **Table 5.3**.

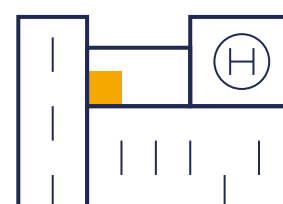


Table 5.3. Sensitivity analysis on estimated daily electricity requirements in health-care facilities, assuming all other parameters remain unchanged

Type of facility	Daily electricity requirements (kWh/day)			
Hospital	500	500	1,000	1,000
Non-hospital	15	32	15	32
Type of costs	Estimated investment (US\$ million)			
New connections CAPEX – grid	1 544.7	2 814.5	1 969.1	3 238.8
New connections CAPEX – off-grid	475.9	946.4	536.6	1 007.1
New connections OPEX – off-grid	59.5	115.3	69.6	125.5
Backup system CAPEX – off-grid	2 085.5	3 601.8	2 833.1	4 349.4
Backup system OPEX – off-grid	741.2	1 395.4	905.3	1 559.4
Total NPC	4 906.8	8 873.4	6 313.7	10 280.3

CAPEX: capital expenditure; OPEX: operating expenditure.
 Note: Estimates are in US\$ for 2022.

Notably, granularity could be improved based on the GIS data at hand; however, this would not allow inclusion of HDB data in this analysis. For example, other geospatial studies have developed higher granularity by differentiating the tier of consumption by type and location of health-care facilities (i.e. tertiary, secondary, primary and first health-care facilities; Moner-Girona et al., 2021).

It should be highlighted that the present analysis only estimates the costs of interventions required to power currently unserved facilities, and provide backup generation to unreliably connected facilities. Also, although the targeted electricity requirement aims to capture latent demand by being at the higher end of the range of typical values (e.g. greater population, higher catchment area, additional equipment), the analysis does not include new facilities that might be built in coming years. Finally, the costs reflect only the intervention required for power generation, distribution, and O&M associated with new connections and backup generation; the costs of acquiring the medical equipment in the facilities were not included.

Another important issue is the sizing of the electricity supply system. This has two components. The first is estimation of the peak load in each facility, which is based on the load factor assumption of 21% and 15% for hospitals and non-hospitals, respectively. Although these values are what we might see in a typical health post or health centre in rural settings of developing economies, the load factor is different for each facility based on the type of services provided, the available equipment, the hours of operation, and so on (see Chapter 3). The sizing of the system, and therefore the investment estimates, are very sensitive to the load factor in this analysis. Note also that optimization of the power system requires full analysis of the load profile per health facility; this was only partially done here and only as part of the GIS analysis to estimate proxy technology costs per country.





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The second component is the sizing of the backup off-grid system. As described in Chapter 4, there are different types of backup systems and strategies. Some facilities may decide to use diesel generators, which run when needed to maintain the power supply. Because of the low capital cost of diesel generators, the facility might decide to size them at 100% of the peak load, assuming that they will only be required for a few hours per year. That is, the expected net cost may be quite low. Other facilities (see the case of the Nav Jivan hospital in India, in Chapter 4) may decide to install a PV–battery system sized to meet a small fraction (e.g. 25%) of the peak load. Although it may not be able to meet the peak load at any moment, such a system can cover critical loads when the main power source is not available at low operating cost and regardless of the availability and price of diesel. In this analysis, a combined PV–battery–diesel off-grid backup system was considered. In fact, as part of the GEP analysis, additional simulations were run for all 110 903 health-care facilities for which the coordinates were available. The simulations compared the load profile (depending on type) and solar availability (depending on location) at hourly intervals throughout the year for each facility. Then it indicated the optimal share of renewable versus diesel-based generation to assure a maximum loss

of load of less than 0.01% (in share of kWh per year). The results indicated that hospitals required, on average, about 31.6% of their annual generation to derive from diesel generators; for non-hospitals, the share was lower at around 6.6%. The high share of renewable generation (and low share of diesel, accordingly) means that the costs from the GEP simulations have higher CAPEX and lower OPEX. This resembles a situation similar to the approach used by Nav Jivan hospital. Therefore, it was assumed that the backup system is sized as 50% of the peak load. The rationale is that such a system is able to cover critical loads only for the few hours that the main source of power is not available and used – when the primary source of power is available – to cover a small proportion of the facility’s requirements. Changing the sizing parameter can have a considerable impact on the total investment, as seen in **Table 5.4**. Note, however, that if the backup systems are sized at 100% of the peak load, the limitations of our approach would mean that the selected health-care facilities are addressed as “greenfield” sites.

Table 5.4. Sensitivity analysis on approach to backup system sizing in health-care facilities, assuming all other parameters remain unchanged

Type of facility	Backup sizing (% of peak load)			
Hospital or non-hospital	50	25	75	100
Type of costs	Estimated investment (US\$ million)			
New connections CAPEX – grid	1 544.7	1 544.7	1 544.7	1 544.7
New connections CAPEX – off-grid	475.9	475.9	475.9	475.9
New connections OPEX – off-grid	59.5	59.5	59.5	59.5
Backup system CAPEX – off-grid	2 085.5	1 042.8	3 128.3	4 171.0
Backup system OPEX – off-grid	741.2	370.6	1 111.9	1 482.5
Total NPC	4 906.8	3 493.4	6 320.2	7 733.5

CAPEX: capital expenditure; OPEX: operating expenditure.
 Note: Estimates are in US\$ for 2022.

Another clarification that needs to be made is that the least-cost electrification technology in the GEP analysis was identified per settlement, including all types of loads within the settlement. The aggregated residential load is usually much higher than the load associated with health-care facilities in a given settlement. That is, the least-cost solution was defined for the settlement as a whole, not for the electrification of health-care facilities as individual end targets. In scenarios where electrification of health-care facilities is a high priority (e.g. for COVID response), the deployment of off-grid systems for the approximately 32 000 facilities that find grid connection to be the least-cost approach in this analysis may serve as a more effective approach.

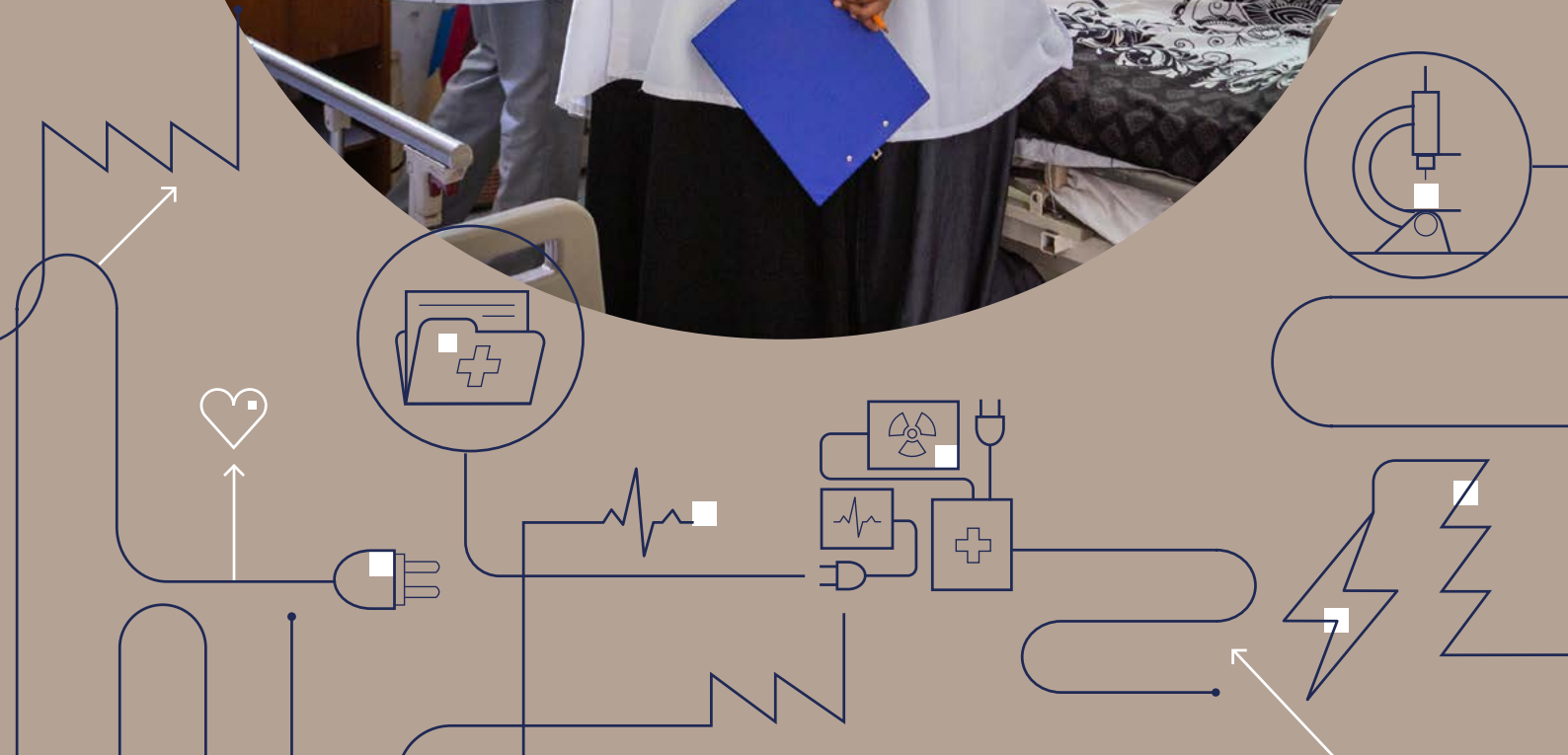
Finally, the grid-related cost proxy (Gcapex) was estimated for a given electrification scenario from the GEP database. More specifically, the “Reference” scenario was used. In this scenario, all input parameters are set so that they best reflect the current situation and targets in a given country. However, the GEP database provides 95 alternative scenarios per country (World Bank Group, 2022). Selecting a different scenario could change the least-cost mix in the country, and consequently may have an effect on the LCHF parameter indicating the least-cost grid versus off-grid share for health-care facilities.

Chapter 6

Enabling frameworks for electrification in resource-constrained settings



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This chapter reviews recent frameworks that have been proposed to link access to reliable electricity to development outcomes, including health sector outcomes. **Section 6.1** reviews challenges specific to the health sector. It provides an overview of the most important barriers to achieving health-care facility electrification, including technical, capacity, policy and financing barriers. **Section 6.2** discusses elements of the enabling environment needed to overcome such challenges. It explores the elements that facilitate sustainable electricity access at health-care facilities, including those related to policy and planning, data infrastructure, financing, institutional coordination, and capacity-building and advocacy. Finally, **section 6.3** offers concluding remarks.

In addition to collating and analysing information from various sources, a perception survey was conducted in early 2022 to understand how receptive the health and energy communities currently are to enabling greater health-care facility electrification, the feasibility of implementation, and the expected timelines to achieve electrification. To complement this survey, targeted semi-structured stakeholder consultations were undertaken to obtain richer explanations and validate the observations made in this chapter.

As reported in Chapter 2, between 50-99% (median of 88%) of health-care facilities in the countries covered in this report for which data are available have access to electricity. However, only between 19-95% (median of 54%) of health-care facilities have access to reliable electricity. Furthermore, as noted in Chapter 5, the total NPC of health-care facility electrification is estimated at US\$ 4.9 billion.¹ This would need to come in various forms of investments across a combination of electrification solutions.

Numerous challenges must be overcome if investments are to result in enduring and sustainable solutions. Some of the technical and economic challenges that need to be addressed have been detailed in Chapters 3 and 4. Beyond these considerations, the literature documents the need for an enabling environment that supports the participation and cooperation of different types of stakeholders, each of whom has a role in solving the techno-economic challenges. These may include governments, development partners, the private sector, philanthropic and financial institutions, etc. A successful enabling environment for health-care facility electrification depends on multiple factors that extend across scales of governance. Some factors may be common to all efforts to link energy to development outcomes, while others are specific to electrifying health-care facilities.



¹ The costs only reflect capital expenditure costs for grid connections but do cover capital plus operating costs for off-grid systems.

Analyses such as those of Mogelgaard et al. (2018) and Odarno (2020) present frameworks relevant to the general problem of connecting energy to development policy. Mogelgaard et al. identified five gears to help move from planning to implementation, a combination of which can be applied to address execution challenges in achieving intended policy outcomes. The five gears are policy frameworks, institutional coordination mechanisms, supportive financial processes, information and tools to enhance multi-scale capacity, and sustained and persistent leadership in critical implementation functions. Odarno (2020) has created a framework for action in linking electricity access with development outcomes, including health, in the sub-Saharan African context. This framework introduces a supportive ecosystem that links global ambition with local action, by building evidence on cross-sectoral linkages between electricity and health, and by restructuring development finance to encourage a more integrated approach to link the two sectors. Focusing more specifically on health-care facility electrification, Ginoya et al. (2021a) reviewed existing health policies in India to understand their degree of integration with electrification efforts, as well as the mechanisms required for this integration.

The enabling factors identified in this chapter build on a synthesis of this previous literature and field experience. However, it is also important for global and national players to recognize and respond to local expertise and ability to act on policy outcomes, and scale it across contexts and governance levels.

6.1 Barriers to achieving health-care facility electrification

Electrifying health-care facilities in a sustainable, affordable and reliable manner, especially in resource-constrained contexts, may face different kinds of barriers, which require structural, long-term consideration. One typical barrier in achieving health-care facility electrification is related to limited access to accurate and up-to-date data for the health-care facility, especially data on facility-level electrification status and electricity requirements. In resource-constrained settings, the data gap feeds into the other barriers, affecting the design and implementation of policy, financing and technical aspects of health-care facility electrification.² In addition to barriers reviewed in previous chapters, key technical, policy, capacity, institutional and financing barriers whose resolution requires a supportive enabling environment are highlighted here.

6.1.1 Technical barriers

Unreliability of supply

As highlighted in Chapter 2 and in previous literature, in several countries hospitals often have a poor quality of electricity supply (Welland, 2017; Devi & Deka, 2019; Schatz Energy Research Center & IFC, 2019). Reliability of supply is key, particularly for running sensitive medical equipment and therefore for delivering quality health care, including during an emergency (WHO et al., 2018). Electricity supply reliability needs to be ensured in order to avoid interruptions in critical health services. Appropriate backup needs to be factored in where electricity supply is unreliable. Furthermore, planning should consider contact and no-contact critical loads. Contact critical loads are those that can handle electricity interruptions; no-contact critical loads have a higher risk of equipment being damaged by interrupted power supply. Inadequate power supply was the single most common cause

² Based on transcripts from stakeholder interviews.

of medical device failure in developing countries, nearly one third of which were due to power supply problems (WHO, 2010). Therefore, this equipment must always be connected to reliable electricity. This consideration is especially important in health-care facilities located in areas that are vulnerable to extreme weather events, such as lightning strikes and flooding (Ginoya et al., 2021b).

Lack of supply of appropriately designed medical equipment, and poor coordination between planning of electrification and procurement of medical equipment

The medical equipment system that is fundamental to all health-care delivery becomes critical in facilities powered by off-grid electricity or by weak grid. Research to date has mainly focused on basic energy systems and electricity supply, rather than the need for specialized medical equipment that is energy-efficient (see **section 4.5**), robust, and suitable to the conditions found in many areas with unreliable electricity supply (CLASP, 2021). Moreover, electrification planning may not factor in additional equipment procurement according to required infrastructure standards, and may focus only on the status quo. Conversely, in some cases, equipment procurement is not aligned with the electricity supply situation, and do not consider the electrification status or the budget context. In such cases, equipment may not be compatible with the power characteristics, or facilities that are equipped with devices may not have the budget to pay for the necessary electricity. In these cases, facilities might be provided with equipment that sits idle, if electrification plans do not proceed according to the expected timelines.

Poor access to solar vendors and spare parts in remote areas

A challenge in remote, resource-constrained settings is the limited availability of solar vendors to service systems and provide spare parts to repair them – which affects the reliability and quality of electricity supply (Welland, 2017). Devi & Deka (2019) noted that the problem persists because there are limited incentives for solar vendors to improve channels of access in these remote areas, where electricity demand is low, and transport and logistical costs are high. More precise customer and market data, planning tools that facilitate aggregation, and incentives for servicing remote areas could help to address this challenge.

Poorly maintained systems that affect reliability of electricity supply, especially in off-grid systems

Poor maintenance of energy systems will affect the duration and quality of electricity supply. This can result, for example, in batteries not functioning, and thus the system being useful only during daytime. Another factor that affects the lifetime of the electricity system is poor adherence to quality standards in procuring equipment and installation, which can result in system components failing far before their useful lifespan. To address the concern of timely maintenance, suitable financing and budgeting aspects need to be considered to cover the costs of maintaining systems and replacing batteries (UN Foundation & SEforALL, 2019). It is also important to ensure the availability of spare parts in the initial procurement plan. Impact evaluation of previous solar PV electrification projects has shown that poor functioning of solar PV systems was due to poor maintenance, undersized components and “lack of capacity building programs in parallel to the system installation” (Al-Akori, 2014; Welland, 2017). Another challenge is the short duration of maintenance contracts, which reduces accountability and sustainability of performance (UN Foundation & SEforALL, 2019).

6.1.2 Policy barriers

Lack of understanding of linkages between electricity and health-care delivery

As described throughout this chapter, reliable electricity is a key element for providing quality health services; however, governments and development partners have not yet adequately reflected this as a development priority in institutional arrangements, or financial or policy decision-making. This challenge arises especially from the siloed approach that policy-makers adopt, as observed by Odarno (2020) in sub-Saharan Africa and Ginoya et al. (2021a) in South Asia. A mechanism is needed for linking energy and health when there is no single agency with the core mandate to lead in health-care facility electrification, including which agencies have the capacity to lead and co-lead. Health and energy agencies often do not have an incentive to collaborate because their areas of expertise are different. Health agencies are not required to report on the reliability of electricity services in health-care facilities, contributing to the gap between health delivery and electricity services.³ Much like other countries, low- and middle-income countries face challenges of knowledge translation – “a dynamic and iterative process that includes the synthesis, dissemination, exchange, and ethically sound application of knowledge to improve health, provide more effective health services, and strengthen the health care system” (Kalbarczyk et al., 2021); this is not only within the health-care system, but also between researchers, health practitioners and policy-makers. An additional challenge in understanding the linkages between health services and reliable electricity is that there is a lack of monitoring and evaluation to document the improved health outcomes that facility electrification provides.

Data challenges

Scarcity of health-care facility data, especially regarding electricity is a pivotal barrier. In many cases, data are scattered across different stakeholders and do not capture the full spectrum of the current status and reliability of electrification of facilities within an area. Policy needs to be built on and in relation to data, to understand the scope and size of the problem, and the absence of critical energy data hinders decision-making related to electrification.⁴ Health-care facilities also face the additional problem of lack of useful multisectoral data across levels of governance (Ali & Tongia, 2018). A related point is the misalignment in the jurisdictions that govern health services with administrative services that may affect integrated approaches. RMS at the facility level have sometimes struggled in remote regions where network connectivity issues persist, making it a challenge to transmit data necessary for timely troubleshooting.

Poor coordination between health and energy departments

Siloed policy-making – for example, separate national electrification plans and national health strategic plans – is a universal barrier, as seen in sub-Saharan Africa (Odarno, 2020) and Asia (Ginoya et al., 2021a). The result is that electrification of health-care facilities is not prioritized within national or subnational plans. This can be attributed to institutional lock-ins, lack of capacity to understand the linkages between electricity and health care, and non-aligned budgeting and performance criteria.

Lack of support policies and regulations

Government support policies, such as subsidies or tax exemptions for solar equipment to be installed in health-care facilities, are lacking, and should be encouraged. At the same time, laws and regulations should facilitate decentralized electrification projects, e.g. through stand-alone and mini-grid systems. Lack of predictability of grid expansion could pose challenges for private sector participation in off-grid electrification.

³ Based on transcripts from stakeholder interviews.

⁴ Based on transcripts from stakeholder interviews.



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Absence of clear standards and procedures

Lack of well-defined and comparable guidance and standards regarding the “placement, design, procurement, installation, and servicing of photovoltaic systems” (Welland, 2017), especially for electrification of health-care facilities and their medical equipment, is a challenge in several countries. This absence of clear regulations and procedures, in addition to lack of policy incentives, could also apply to multiple electrification solutions, including for stand-alone systems or mini-grids.

As noted by Maina et al. (2019), definitions of health-care facility tiers and the services they provide vary substantially between countries, which presents a major obstacle to comparing electricity access data across settings (see in Chapter 2). For example, referral health centres in Mali provide secondary-level services typically provided by “hospitals” in other countries, such as emergency, obstetric, surgical and inpatient care; community/rural hospitals in Malawi, on the other hand, only provide primary-level services (Ouma et al., 2018). These varying definitions can make it difficult to conduct a global comparative analysis of whether the electrification needs of a given tier of health-care facility are being met in a country.

A further complication is that, in many countries, the amount and type of electrification data that are collected vary between different tiers of health-care facility, which makes comparison of electricity access indicators across tiers challenging. For example, in India, community health centres (CHCs) typically collect data on connection status, electricity outage and frequency of outages. In contrast, PHCs, which operate at a more decentralized level, typically collect data that consider only the prevalence of electricity connections (**Table 6.1**).

Data attributes for data collection efforts should be consistent across health-care facility tiers and available at the most granular level, to ensure that the data are comparable and provide sufficient contextual information for decision-makers.

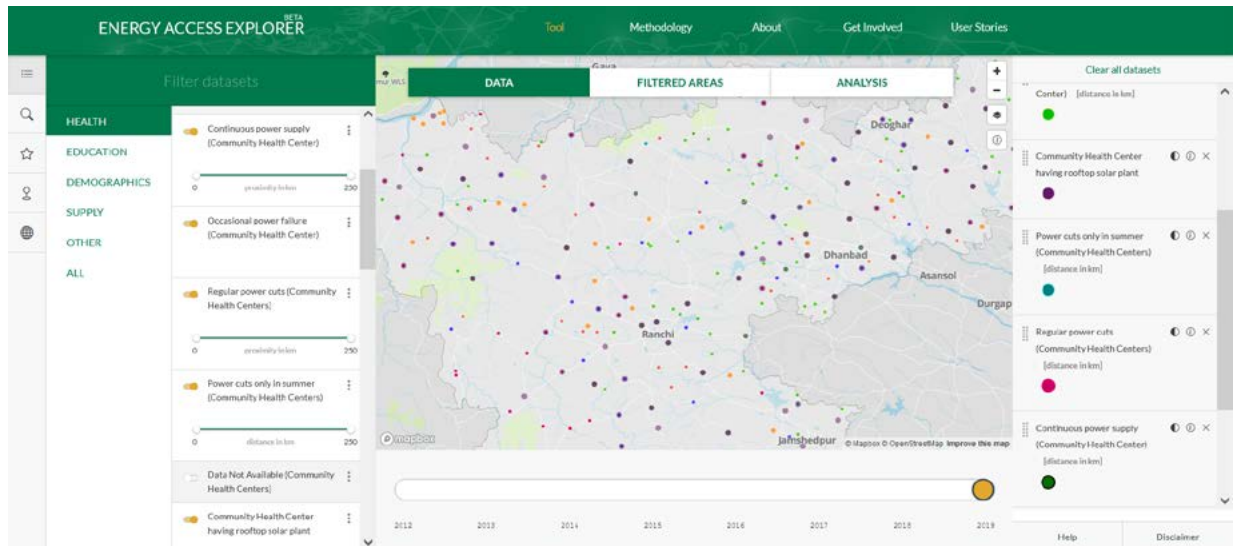
Non-standardized data between countries, within a country or between facility tiers can also increase inconsistencies in assessing electricity requirements, causing challenges in system sizing and costing, procurement efforts and supply chain development.

Online platforms can be useful tools to visualize data related to the electrification status of different facilities (see **Fig. 6.1**)

Table 6.1. Data attributes for electrification collected at the CHC and PHC levels in India

CHCs	PHCs
Continuous power supply Occasional power failure Regular power cuts Power cuts only during summer	Electrified Partially electrified Unelectrified

Fig. 6.1. Geographic distribution of health-care facilities in Jharkhand, India, with different electricity reliability attributes on the EAE Platform



6.1.3 Capacity barriers

Absence of mechanisms to nurture and sustain local capacity

Absence of mechanisms to build local institutional capacity to design and manage the implementation of electrification programs tailored to health-care facilities is a key barrier.

At the same time, the lack of local knowledge to properly operate and maintain the energy systems is one of the most common reasons for failure of health-care facility electrification programs across multiple contexts (Al-Akori, 2014; Welland, 2017; USAID & SEforAll, 2021). This also affects the accountability and sense of ownership that must be encouraged in communities where these interventions take place (Jacobs et al., 2012). Resource-constrained settings often face further challenges, such as the lack of qualified personnel trained to properly use and maintain energy systems and equipment.

6.1.4 Financing barriers

Lack of adequate funding and support measures

Funds allocated by governments, development partners, donors, philanthropic institutions, and other relevant stakeholders, for providing reliable electricity access in health-care facilities are insufficient, and do not reflect the importance of electricity for ensuring essential health services.

The need to dramatically increase funds, and to consider electrification of health-care facilities a development priority, has been highlighted in multiple occasions.⁵

In this context, government support policies, such as subsidies and fiscal incentives (e.g. tailored tax exemptions for sustainable energy equipment to be installed in health-care facilities) can also contribute to provide the necessary economic support to clean energy based electrification of health centres.

Insufficient coverage of O&M in budgets

Inability to set aside funds from public health budgets and facility-level administration or other sources for sustained O&M and replacement of old or faulty parts is a common barrier to successful health-care facility electrification. It is essential to avoid the ‘install and forget’ approach, and to ensure adequate funding for medium- and long-term O&M.

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5 See, for example, ‘Energizing health: a strategic roadmap to promote healthier populations through clean and sustainable energy’ (High-Level Coalition on Health and Energy, n.d.).



Damage to medical equipment due to unreliable electricity supply

Unreliable electricity can create significant damages to sensitive medical equipment. Nearly a third of medical devices failure globally is estimated to be caused by unreliable electricity supply (WHO, 2010). No-contact critical loads⁶ need for an instantaneous source of backup power in the event of power quality issues, such as power loss from the central grid or an on-site generator (Welland, 2017; Devi & Deka, 2019).

Challenges in selecting the right financing model for electrification

Several health-care facility electrification schemes have been focusing on procuring electricity system assets, leaving to end user (i.e. the health-care facility) the responsibility for maintaining the electricity system, but without providing it with the budget to ensure the necessary O&M. These models have been influenced by limited project cycle timelines for governments and donors, which in many cases have not allowed long-term planning for O&M. Procurement models need to be strengthened to adapt to extended programmatic time frames, and incorporate budgeting for O&M and part replacements from the start. Furthermore, health-care facility financing packages should be harmonized to that a new donor can pick up where another left off, to extend the programmatic time frame.

System sustainability can be improved also through training of health-care staff and community members on basic O&M and troubleshooting, establishing long-term O&M contracts with energy vendors (with the possibility of renewal), and contributing to O&M budgeting by switching to renewable energy and reallocating to O&M the money saved on reduced electricity bills and fuel consumption. Furthermore, service-based models (where the health-care facility is not the owner of the energy system and a private sector company is responsible for providing the energy supply), can complement the traditional health-care facility ownership approach. In these models, private sector operators can contribute to raise capital to install and operate electricity systems over a long time frame (10–15 years), and designated line ministries (either directly or through financing institutions) are responsible for raising funds and ensuring regular payments to the service provider over the project period. Adequate risk mitigation measures need to be put in place when needed, to ensure energy supply for health-care facilities and quality health services for all.

Lack of monitoring and evaluation data

More monitoring and evaluation data are needed, to track and understand the impact of investment on health-care facility electrification projects. Scarce and outdated monitoring and evaluation data mean that donors and investors cannot track the effectiveness of their investments (e.g. operation status of solar PV systems).⁷ At the same time, there is a lack of data on the track record of PPPs and related types of contracts to electrify health-care facilities. This further hinders countries in considering innovative delivery models; in some cases, for example, government permits (e.g. from the ministry of finance) are required to engage in PPPs in the health sector.

Lack of urgency in delivering solutions for reliable health-care facility electrification

Time and urgency are not being addressed on health-care facility electrification. This is true in general, but also when it comes to specific programs design, for example on the time frame before moving beyond piloting and into action. The social cost of not electrifying health clinics today is not adequately taken into account by governments as well as by development partners and donors; at the same time, health and socioeconomic benefits are not captured or monetized when identifying

⁶ No-contact critical loads are those for which any interruption in power will lead to cumulative effects and can damage the equipment or result in loss of data (e.g. laboratory instruments, X-ray machines, and data acquisition systems among others).

⁷ Based on transcripts from stakeholder interviews.

development priorities. Electrification of health-care facilities has indeed an immense impact in terms of life saving and health improvement and meet multiple SDGs in parallel (WHO & World Bank, 2015).

Lack of energy market maturity in certain countries

Without sufficiently developed energy markets, including on renewable energy, the desired electrification will not be achieved without generous support from the government or donors. Based on the United Nations Development Programme (UNDP) feasibility study for the Solar for Health (S4H) programme (UNDP, n.d.) for sub-Saharan Africa, small rural facilities located far from the grid are the most deprived when it comes to energy access, and they also serve more vulnerable and poorer populations which do not have the ability to pay. Because of their limited size and difficulty of access, energy service provided by the private sector are provided at a higher costs, unless subsidies or pooling of a larger number of facilities are put in place. Medium-sized and larger off-grid facilities provide health-care services to a larger patient base in urban and peri-urban areas, and could potentially attract energy service providers, provided the ability to pay (of the facility, the government, a development partner etc). To offer necessary services to health-care facilities, energy service providers may access additional capital (e.g. to purchase necessary equipment or expand product offerings). However, local financial institutions might be reluctant to lend money in this sector, and interest rates are often prohibitively high. In addition, foreign currency financing remains necessary for hardware. Therefore, local market maturity is an important enabler, as observed in Namibia, where local professional companies already have access to capital and are willing to service the health sector (UNDP, n.d.). In any case, it must be kept in mind that health is a human right and, as such, providing the necessary energy to ensure adequate health services for all is first of all a public sector responsibility.

6.2 Enabling environment for achieving health-care facility electrification

Despite the challenges described above, some progress in electrifying health-care facilities has been made, particularly in the past decade. As noted in Chapter 2, this has resulted partly from access to the central national grid, but also from increased deployment of off-grid technologies in rural areas – particularly solar energy. Off-grid solar systems have emerged as a solution to the absence of the electricity grid, the slowness of grid extension, and lack of affordability and reliability of the electricity grid in resource-constrained settings. Solar PV (and to a lesser degree other off-grid technologies) has attracted considerable interest in the household and light industry sectors, and has the potential to advance health-care facility electrification even further. Experiences from the deployment of solar PV systems offer instructive lessons for how best to sustain them.

Most electrification efforts for public health-care facilities need to be supported by governments and/or development partners taking into consideration that health is a public right and first of all a public sector responsibilities. In several cases, donors finance the capital expenditure of the solar PV system and short-term maintenance, while governments, local administration or the health-care facility itself are expected to support longer-term maintenance and part replacement in the future (SEforALL & ESMAP, 2021). However, donors may not appreciate how difficult integration of new technologies might be for health-care institutions and, in particular, the uptake of new items in public budgets. Whereas funds for diesel fuel have been an established line item, incorporating support for O&M of solar PV systems is unfamiliar and will require focused advocacy (Phillips, Plutshack & Yeazel, 2020). This is

especially the case where well-established networks of diesel distributors and the subsidies supporting them would be threatened. A common problem in government budgeting for maintenance of solar PV systems is that subsidies for diesel fuel may need to be shifted (this is eased somewhat in countries where donors' direct funding of diesel fuel consumption can be redirected towards more sustainable O&M). This has been a political conundrum in many regions attempting to achieve electrification in last-mile communities. The International Monetary Fund (Clements et al., 2013) has reviewed fossil energy subsidies, their financial and environmental impacts, political economy considerations, and suggestions for reforming them, but more work is needed in this area, particularly as it relates to last-mile electrification.

To rise to this challenge, development partners are considering a wider range of interventions, including (SEforALL & ESMAP, 2021):

- developing O&M planning and budget capacities within line ministries;
- planning extended-term donor-supported projects to shift the focus from upfront capital investment to sustainability; and
- designing private sector–service-based models, when feasible.

These three approaches are not mutually exclusive and, in fact, may need to be jointly pursued in some country-specific contexts. The following sections focus on the enabling environment that is necessary for success of all these approaches, especially for health sector stakeholders to take up their role as advocates of the sustainable electrification of health-care facilities.

6.2.1 Policy frameworks

Enabling policy frameworks should be developed considering electrification of health-care facilities as a social and development priority. This should then be reflected in adequate support measures and institutional arrangements.

Increase awareness of, and advocacy for, political prioritization of health-care facility electrification

Increasing awareness and advocacy at a political level to ensure that electrification of health-care facilities is considered a priority in national and subnational plans is key to ensuring a clear mandate across a country or a region. For example, the Strategic Roadmap on Health and Energy (WHO, 2021)⁸ calls on national governments, key stakeholders and the global community to change the pace and urgently undertake the following actions regarding health-care facility electrification.

- Consider access to electricity in health-care facilities as a priority.
- Dramatically increase public and private investments in electrifying health-care facilities.
- Provide the necessary human and financial resources to design and implement clean energy plans and sustainable delivery models tailored to the needs of the health sector.
- Develop tailored policy and financing schemes that can unlock the potential of clean and sustainable energy solutions, address health sector needs and mitigate climate change.
- Increase cooperation between the energy and health sectors, and collaboration with all relevant stakeholders.
- Facilitate collaboration between private, public and nongovernmental actors.

⁸ The High-Level Coalition on Health and Energy is convened by the Director General of WHO under the framework of the Health and Energy Platform of Action.

Integrate energy demand assessments for health-care facilities into electrification plans

The World Bank’s Regulatory Indicators for Sustainable Energy (RISE) framework provides a set of indicators of regulatory readiness for investment in sustainable energy. The policies that will attract investment in the full complement of energy access solutions in other sectors – grid extension, mini-grids and stand-alone solutions – can also contribute to investment in these technologies for electrification of health-care facilities. In particular, the RISE framework is clear that planning frameworks based on demand assessments are critical to investment decisions. Specialized methods have been developed for assessing energy demands of health-care facilities (see Chapter 3). The second iteration of the RISE framework acknowledges the need to include health facilities in electrification plans. Information about these facilities needs to include their demand assessments. This type of planning exercise can help electrification departments assess whether specific health-care facilities might be best served by grid extension, mini-grids or stand-alone systems.

SELCO Foundation is working with state-level national health missions in 5 Indian states to provide solar power to state health centres – primarily in rural or remote areas with hilly terrain – that have unreliable electricity access or are disconnected from the national grid. The programme involves engaging and building capacity of stakeholders at various levels: state- and district-level decision-makers, facility-level staff, local committees for untied funds (for sustaining and monitoring energy infrastructure), and local technicians and energy enterprises.

Link electrification planning to health policy

Integrating energy planning with health policy and planning supports the achievement of goals for both. Including specific health-care facility electrification targets within strategic planning creates more adoption, acceptance and alignment of these targets because they are part of the existing process and not an additional aspect that governments need to consider separately. For instance, in Uganda’s Energy for Rural Transformation (ERT) programme, the Ministry of Energy and Mineral Development secures the funds for capital expenditure and coordinates implementation of the programme; whereas the Ministry of Health conducts the electrification needs assessments of health-care facilities, procures the solar systems, maintains a budget for O&M, and collects and reports data on programme implementation. This ensures that the ministries coordinate their activities. Similarly, instances from India (Ginoya et al., 2021a) demonstrate that the sustainability of electrification efforts in health-care facilities lies in how well integrated they are into the policy and local implementation strategies of the institutions delivering health care.

Health agencies can be partners in electrification planning by prioritizing facilities based on health policy goals. For instance, health-care facility electrification in the Indian state of Chhattisgarh is driven by its state renewable development agency, Chhattisgarh Renewable Energy Development Agency (CREDA), in collaboration with the state health department, to prioritize the facilities where electrification is most required. The priority health-care facilities are identified by the state health department, and the electricity is provided by CREDA.⁹ As of March 2020, Chhattisgarh had some of the highest rates of subcentre (86.7%) and PHC (96.6%) electrification – above the national rates (subcentres: 71.6%; PHCs: 95.7%) (National Health Mission, 2020). Furthermore, as observed by Ramji et al. (2017), PHCs reported increases of 59% in outpatient services, 77% in inpatient care and 78% in institutional deliveries. Input from the health sector is critical for linking electrification to improved service delivery and health outcomes (McLaughlin & Kaluzny, 1994). A former State Electricity Regulatory Commissioner in India observed that responsibility for raising the demand for reliable electricity should lie with the health sector, whereas electricity stakeholders should be

⁹ Based on interview transcripts from CREDA.

responsible for implementation. Therefore, the health sector must be empowered to communicate its requirements to the electricity sector (Ginoya et al., 2021a).

Ensure flexibility of policy frameworks to adapt to diverse local contexts and a constantly evolving technology landscape

Policy frameworks demonstrate intent and must have necessary enforcement mechanisms. However, they also need to have sufficient flexibility to respond to an energy technology landscape that is constantly evolving. Solar PV is one technology that has emerged as a solution in resource-constrained areas, but in some contexts other technologies may be more appropriate. Factors such as no physical access to the roof (for installation and maintenance) or no unshaded space might point to battery-operated equipment as the only alternative to support an unreliable grid. Natural resource availability plays also a role on the choice of technology. For example, solar energy should in principle be the preferred option for the electrification of facilities falling within an acceptable range of global horizontal irradiance, given the higher generation efficiency.

Decentralized solar solutions play also a key role for facilities that are situated in climate-vulnerable areas. In case of extreme weather events, centralized power grids can be damaged and the fuel supply chain necessary to provide fuel for fuel based generators can be interrupted. In these situations, relying on on-site renewable energy sources, such as solar, can guarantee the continuity of the electricity supply and the energy independence.

Support regulatory standards to address the multi-dimensionality of electricity supply

Quality of power supply (e.g. duration, reliability, voltage fluctuation) as well as energy efficiency play a critical role for health-care facilities and for the functionality of sensitive and lifesaving medical devices.

As noted in Chapter 3, several national and international technical standards are available to guide the design, installation, compatibility and safety of electricity systems. The World Bank, for example, (Harper et al., 2021) outlines a quality assurance framework for the design, procurement, installation and long-term O&M of off-grid solar electricity systems at public facilities such as health clinics and schools. The approach involves quality standards for equipment, design and installation, along with the innovative use of digital remote monitoring technology to ensure and verify the ongoing performance of off-grid solar electricity systems against established key performance indicators. Furthermore, the Powering Health Program of the USAID, for example, shares resources on international standards for solar PV systems, lighting, lead-acid and Li-ion batteries, cold chain and refrigeration, uninterruptible power supply, inverters, and remote monitoring (USAID, n.d.)

However, this knowledge is not necessarily transferred to health sector stakeholders, and largely remains within the electricity sector experts. Moreover, CLASP identified that resources to select suitable equipment for health-care facilities are “inconsistent and often insufficient” (CLASP, 2021). One exception is the WHO Performance, Quality and Safety standards for cold chain equipment, which established performance specifications and standards for procurement in immunization programmes, including solar-powered medical equipment (see **Box 6.1**) in weak/off-grid contexts (WHO, 2012; CLASP, 2021). Promotion of energy-efficient medical devices that are also suitable for harsh conditions (e.g. temperature extremes, dusty environments) will be important to adequately address the energy–health-related challenges in low-resource settings.

BOX 6.1. SOLAR DIRECT-DRIVE REFRIGERATORS AND COLD CHAIN EQUIPMENT OPTIMIZATION PLATFORM

Solar direct-drive (SDD) refrigerators and refrigerator-freezers use solar energy to directly freeze water or other phase-change material, then use the cooling from that ice bank to keep vaccines, laboratory samples and other materials cold for days on end. Directly connecting a solar array to the ice bank avoids the central drawback of the previous generation of solar refrigerators. The relatively short-lived batteries used in the previous generation have a relatively short lifetime of 3–5 years, and replacements can be difficult to find (WHO & UNICEF, 2015).

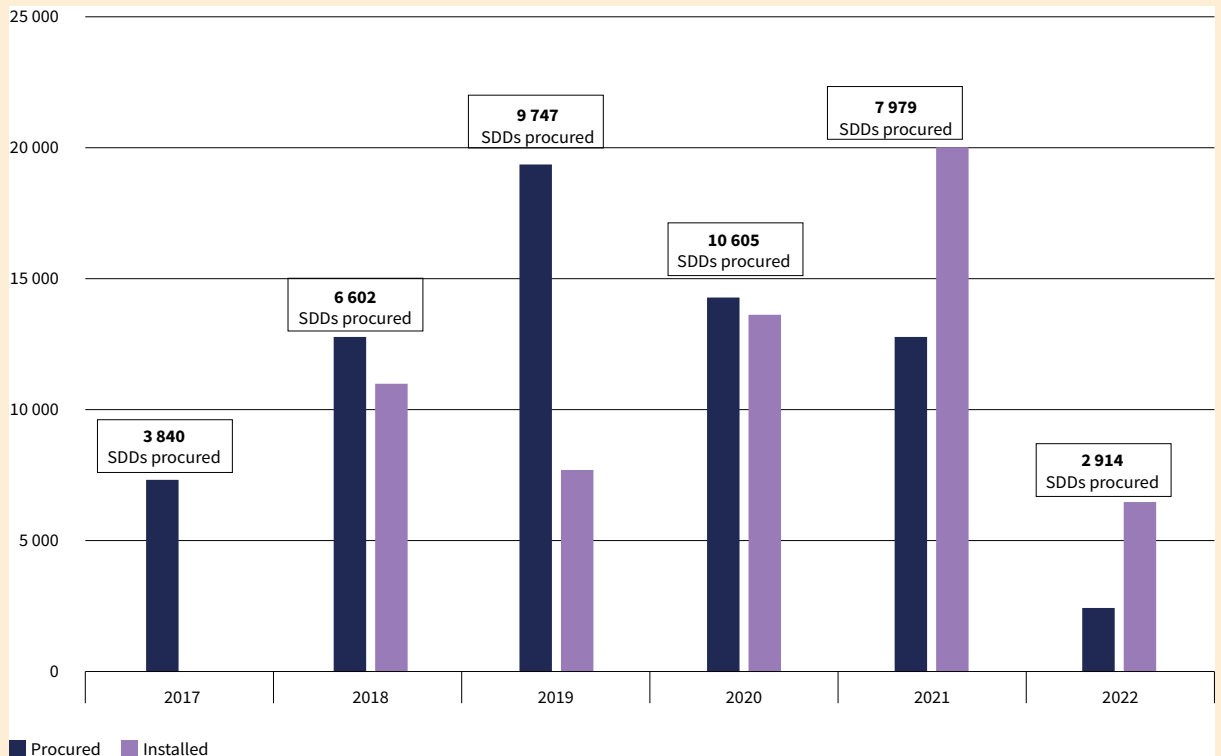
SDD refrigerators, in contrast, have rapidly gained popularity and traction by eliminating the problem of batteries altogether, and by demonstrating the ability to hold required temperatures for several days, even during periods of inadequate sunlight. Starting in 2010, WHO prequalified many SDD products from several different suppliers. Gavi, in cooperation with partners, has been supporting the deployment of SDD refrigerators since 2017; the CCEOP has steadily scaled up to procure more than 41 000 SDDs by the end of the third quarter of 2022. The technology is particularly valuable in resource-constrained areas where electricity access is unavailable or unreliable. Furthermore, SDD developers have also begun to develop mobile SDD units that help to provide cold chains for transport, not just storage (Sinai & Fetter, 2021).

As of end of September 2022, CCEOP had procured 70,540 units of ice-lined refrigerators (ILRs) and SDDs across 50 of the 52 countries with approved grants for Gavi 4.0 –59.1% of which are SDDs worth US\$ 197.5 million. Nearly 98.6% (69,578) of these units have been delivered (in 50 countries) and 90.5% (63,866) have been installed (in 47 countries) (see **Fig. 6.2**).

SDDs have proved to be robust to the constraints of low-resource areas. For example, in the Democratic Republic of the Congo, IMA World Health’s Access to Primary Health Care programme installed SDD units for vaccines, drugs and blood in 531 health-care facilities from 2013 to 2018 and found that almost 100% were still functioning in 2021. According to government staff involved in the programme, this is because the SDD refrigerators are completely enclosed, single-purpose systems with no batteries or inverters to replace. However, this benefit for continued operation is also a drawback: although SDD refrigerators provide a practical and durable solution for cold storage and cold chains, they do not address other electricity needs of health-care facilities for affordable, high-quality, reliable electricity.

Gavi, WHO and UNICEF have therefore joined forces to expand the electrification scope and cover all the electricity needs of the health-care facilities through decentralized solar systems.

Fig. 6.2. Numbers of ILRs and SDDs procured and installed under CCEOP, 2017– Q3 2022



Nodal national health-care institutions such as ministries of health need to provide clear guidance on the requirements for health-care equipment at various tiers of health service delivery. In India, for instance, the Indian Public Health Standards provide guidelines on the types of equipment required at various tiers¹⁰ of service delivery (National Health Mission, 2012). Providing specific guidance on how to select and prioritize medical and non-medical equipment for deployment in areas with unreliable electricity supply or in harsh conditions would help bridge information gaps between health-care decision-makers and equipment providers. This would contribute to ensure the selection of the most suitable options for ensuring basic health care.

Develop support policies and accountability mechanisms

Support policies and incentives play a crucial role to accelerate electrification of health-care facilities. A variety of support measures exists, from import tax exemptions for sustainable energy equipment to be installed in health-care facilities to renewable energy subsidies tailored to the health sector. The most suitable policy instrument needs to be identified taking into consideration the specific country context.

In several cases, incentives have been accompanied by tailored accountability measures. India's Labour Room Quality Improvement Initiative uses an institutional framework with focused quality improvement cycles that include financial incentives. These incentives reward the quality of the health-care facilities' infrastructure and provide monetary incentives for improved maintenance of this infrastructure.

6.2.2 Data infrastructure

Electricity planning requires robust data inputs. To address the needs of health-care facilities, planners need to know how many facilities lack electricity, lack reliable electricity, are under-electrified, where they are, their energy demands, and how much they can afford to pay, as well as other contextual information. However, data collection on health-care facility electrification status and needs is typically not institutionalized, and automated data collection is even more rare. Cross-sectional surveys are typically performed on an ad hoc basis, and the data have low temporal resolution, which is often inadequate for planning purposes since the data do not provide reliable information on trends over time. As noted in Chapter 2, trends data from national surveys showing health-care facilities lacking access to electricity are available for six of the 81 reviewed countries. These administrative surveys do not provide high-frequency information on electricity reliability, seasonal fluctuations and changes in access due to lack of O&M that result in the eventual failure of installed electricity systems. Budgetary limitations on cross-sectional administrative surveys also typically result in survey data being representative only at the national and provincial levels, which limits the usable spatial resolution of these cross-sectional surveys. Chapter 2 also highlighted that not all indicators were present across the different surveys and countries in the report. This means that careful harmonization of data from different types of surveys is needed, posing a challenge for use and comparison of the data. What is lacking is a data infrastructure, owned and managed by national actors, where data can be stored, updated, and integrated with planning and monitoring of health-care facility electrification. In this section, the types of data that need to be collected, stored and shared across agencies and administrative levels are highlighted.

In a perception survey conducted to understand the importance of data and data platforms, 93% of respondents suggested that clearly defined data parameters play a key role to achieve their outcome of health-care facility electrification.

¹⁰ Subcentre, PHC, CHC, subdivision hospital, district hospital.



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Include data with multi-dimensional attributes

Data attributes should be able to provide key information on the status of electrification (e.g. if the facility has access to any electricity, if it has access to reliable electricity, if it is under-electrified), as well as on the nature and configurations of the energy supply system (e.g. grid connected, stand-alone, mini-grid hybrid system) and the quality of electricity supply for these sources, e.g. duration and frequency of unscheduled electricity outages and voltage fluctuations. While for grid-connected facilities, electricity distribution utilities often collect data on reliability (for example, the System Average Interruption Frequency Index, and the System Average Interruption Duration Index), which provide information on the average number and duration of sustained power interruptions in a given period (Koroglu, Irwin & Grépin, 2019), for off-grid systems (isolated mini-grid or stand-alone systems) these kinds of data are often not collected. As Chapter 2 explained, access to certain data sources proved a central challenge in achieving comprehensive and up-to-date coverage.

Incorporate data on performance and use of medical equipment

When possible, public data collection efforts should incorporate information on performance and use of key medical equipment (CLASP, 2021). These data could be stored in a data logger or sent to a server for further analysis. Such information would help inform electricity demand assessments, especially in environments where the electricity grid is non-existent or weak. It can also provide information on performance standards that can eventually support the creation of a more holistic baseline and standards framework for medical equipment. Such data would also help decision-makers in the health and electricity sectors to think beyond basic energy system provisions for health-care facilities, and to include requirements for medical equipment and corresponding electricity demand in their planning processes.

Design objective data collection methods

Care must be taken to ensure that data collection templates and questionnaires are designed to ensure utmost objectivity. Given target-driven policy-making, data collection can sometimes be designed to provide a more positive picture than local realities. Guidelines such as the WHO Monitoring and Evaluation Framework or the SARA can help with writing questions and selecting indicators to support objective measurement.

Automate data collection

Some countries already have mechanisms to automatically link data on patient visits, services rendered or other health-care facility outputs to infrastructure data. For instance, Sierra Leone and the Democratic Republic of the Congo currently collect rudimentary indicators on electricity access as part of their implementation of the DHIS2 platform. DHIS2 could also be leveraged to provide additional insights on electricity access and reliability. Automatic data collection systems that are deployed regularly are invaluable in providing decision-makers with the most up-to-date information. Granular data on electricity consumption, reliability and voltage fluctuations (and other parameters) could help to improve prioritization decisions by government agencies, and funding decisions by donors, among others. Taking advantage of the fact that DHIS2 is already completed by facilities at a relatively high frequency (typically weekly, monthly or quarterly), time-series data are also important to monitor and track changes in outputs, outcomes and impacts.

Ideally, these data collection efforts would integrate data from on-grid and off-grid facilities. This is currently challenging for at least two reasons. First, off-grid facilities may suffer from disruptions in connectivity due to their physical remoteness. Second, in settings where the government agency responsible for rural electrification monitors grid-connected customers and not off-grid customers, this institutional arrangement may inhibit integrated data collection. The second issue can be addressed by providing common data platforms to facilitate cross-agency data collection and data management. This may align well with the implementation of national digital health infrastructure, under the rubric of which health ministries in low-income countries are adopting plans to transition their health systems to internet-based systems, including for information systems and telemedicine services.

Encourage common data platforms to compare and share information across government agencies and governance levels

Common platforms that facilitate data sharing between ministries or departments of health and electricity would encourage further integration and institutional coherence between the sectors. This would also provide an opportunity for local evidence to be shared at more aggregated levels, and linked with national policies and global ambition. It may include collecting and tracking data on outcomes of health-care facility electrification – that is, how health-care facility electrification affects patient outcomes and population health. The data would be shared between energy, health, finance and planning ministries, as well as with public and private finance providers and development partners, to help evaluate and prioritize programmes and interventions. In sub-Saharan Africa, Odarno (2020) observed that government decision-makers tend to use sector-specific data to inform policies and development plans at the national level that hinder integrated action. In India, the Transforming Aspirational Districts Programme aims to address this challenge of siloed information sharing and decision-making through the Champions of Change Dashboard (NITI Aayog, 2018). The dashboard provides multisector data ranging from health-care delivery to infrastructure services on a common platform for local (district-level) authorities to track and monitor progress.



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Support evidence-based planning

All of the elements in this section, either cumulatively or incrementally, would contribute to a robust data infrastructure to support institutions and planning efforts. Such an infrastructure could be managed and used by planners to explicitly incorporate ongoing data collection and analysis into planning and prioritization efforts. In Uganda, the ERT programme provided a helpful platform to start with the GIS locations of the facilities covered under the programme. The existence of an evidence base has enhanced decision-making.¹¹

Use data collection tools

Availability of correct and timely data (e.g. status of electrification, distance from the grid, global horizontal irradiance) is important for prioritizing electrification. A data repository can accompany on-ground data from surveys and questionnaires. Monitoring and evaluation tools allow users to use remote monitoring to track system performance, a facility’s electricity use and power reliability. Data platforms and tools such as EAE, SEforALL’s Integrated Energy Planning Tool for Nigeria, and the CEAT can be used to help identify the area and facilities for prioritization of electrification. Since all platforms and tools rely on the quality of available data to carry out analysis, and data are often scarce and scattered, it is important to bridge data gaps by supporting a more open-access approach to data, when possible.

¹¹ Based on transcripts from stakeholder interviews.

6.2.3 Institutional coordination

Mechanisms that encourage integration and interaction between the health and electricity sectors, across the various levels of governance and service delivery (global to local), and involving public as well as private stakeholders play a crucial role to identify synergies, ensure efficiency, and maximize impact. International initiatives and partnerships, such as the Health and Energy Platform of Action, the High-Level Coalition on Health and Energy, and the Health Facility Electrification Energy Compact, have been created with the aim to facilitate such intersectoral coordination at international level.

Examples of initiatives aiming at address the lack of coordination have also been created at country level. A recent example is the Uganda's ERT programme. The Ministry of Energy led the programmatic efforts and coordinated all the relevant utility components. The Rural Electrification Agency was responsible for the main grid connection programmes. Each component had a coordinator to manage the necessary technical support.¹²

According to Clarke et al. (2021), strategic partnerships are needed across levels of health-care leaders to lead to systemic change, and translate local evidence into national decisions and global ambitions. Coordinated efforts to address health-care outcomes fall into one of three categories (Greer & Lillvis, 2014):

- more tangible actions, such as policies and plans, that demonstrate political will;
- bureaucratic approaches, such as conducting impact assessments or reorganization; and
- advocacy through data transparency and strategic communication.

To mobilize resources and knowledge, it is important to understand the current perceptions of health-care facility electrification held by decision-makers, and to assist stakeholders to articulate and communicate the role of reliable electricity access in delivering health outcomes.

Support the creation of multistakeholder groups at country levels

Incorporating health and energy actors in multistakeholder coordination committee at country level is key to advocating for health and electricity interests in the decision-making process. It would also be important to bring together central and local actors, in order to identify the priorities on health-care facility electrification. A convergence scheme designed by the Rural Health Mission in the Indian state of Jharkhand states that “the determinants of health are varied and are spread over areas like drinking water and sanitation, nutrition, education, livelihood, environment and social justice which cannot be ignored if Health for all is intended” (Jharkhand Rural Health Mission, n.d.). The scheme encourages intersectoral coordination and collaborative fund-raising between health and allied sectors.

Ensuring coordination between health-care facility electrification programs and medical devices supply programs is also crucial. There have been examples of medical equipment being procured for health-care facilities without an assessment of the status of electrification in those facilities (and of the characteristics of electricity supply in the relevant areas). Furthermore, several health-care facility electrification programs focus only on the energy access component and do not consider the supply of essential and lifesaving power dependent medical devices. It is essential to ensure adequate coordination between actors (and departments) to avoid delays and inefficiencies.

¹² Based on transcripts from stakeholder interviews.

6.2.4 Capacity-building

Making sure that health-care facility electrification in resource-constrained settings is led and implemented by actors that can successfully integrate energy supply and demand is essential for a sustainable strategy. On the supply side, it is particularly important to understand the O&M requirements of systems. On the demand side, reflecting quality appliance and health service standards for health-care delivery is key. Transferring knowledge, train health sector staff and build capacities of all relevant stakeholders is key to ensure long term sustainability of health-care facility electrification programs.

Invest in training and capacity building activities that encourage wider understanding of electrification in health-care facilities

Capacity building should be encouraged among all actors involved in health-care facilities electrification programs, from health sector staff to local energy enterprises. In particular, institutional capacity must be strengthened to enable the public sector to design and manage health-care facility electrification programmes. Health sector stakeholders play a key role in supporting the correct assessment of the electricity demands of the facility as well as the necessary O&M of the electricity system (especially for decentralized electricity systems) and medical devices. For example, curricula for medical technicians could have a segment on electrical aspects and equipment, such as device loads, operating hours and equipment maintenance. Similarly, capacity should be built at the local governance level to ensure the integration of electricity into local health services development plans.

An example of such capacity building is UNDP's S4H programme, which aimed to build basic capacity among the staff in health-care facilities and the public works department while installing solar PV systems with batteries in 405 facilities in Zimbabwe (UN Foundation & SEForALL, 2019). Similarly, a key element in Ethiopia's Access to Modern Energy Services project is providing service contracts for local technicians, along with a 5-year system maintenance contract (Al-Akori, 2014).

In India, a PPP approach implemented by a NGO, Karuna Trust, brings community ownership through Arogya Raksha Samithi (ARS)¹³ in providing solar power to 41 public health-care facilities. This involved building the capacity of the ARS right from the planning phase – to include needs assessment, a health and energy audit, project ownership, and accountability of funding allocations for O&M and replacement of batteries – and drafting of an annual maintenance contract between ARS and the solar vendor (SELCO Foundation, 2021a). Another example of expanding capacity in energy within health agencies is in Burundi¹⁴ under the World Bank-funded Solar Energy in Local Communities project. Here, the health ministry has an existing framework to build capacity and enable its technician to take on energy O&M responsibilities without requiring external contractors. **Box 6.2** provides examples of training and capacity-building programmes in the pre-installation phase.



13 The ARS is a hospital-based management committee, constituted in every tier of public health-care facility from district hospitals to PHCs. It aims to manage use of hospital funds for smooth functioning and maintain the quality of services for patient welfare (Centre for Budget and Policy Studies & Karnataka State Health Systems Resource Centre, 2012).

14 Based on transcripts from stakeholder interviews.



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BOX 6.2.

TRAINING AND CAPACITY-BUILDING PROGRAMMES IN THE PRE-INSTALLATION PHASE

Training and skills development tailored to different stakeholders (e.g. vendors, health staff) are critical to the effective installation and use of solutions in a facility. Examples of programmes required in the pre-installation phase include the following.

Training for site assessments: To document the specific needs and site readiness for each facility, a thorough on-site assessment should be conducted. This assessment involve a mix of stakeholders, such as energy enterprises, health staff, local government staff. The training components include basic understanding of the importance of site assessment, step-by-step details of how to document site-specific nuances, and the key considerations that apply to different tiers of the health system that are being assessed.

Training for health staff on basic O&M: A specific training programme with local health staff on the management of assets and basic O&M for solar PV systems is required. The training programme can be launched in parallel with installation of the PV systems. Training of local staff on management of energy stored in batteries is necessary, including the operation of critical, important and unimportant loads. A user manual should be delivered to end users of health-care facilities and technicians.

This should be user friendly and highlight the most important elements. For example, it should include an illustration of the battery water level measurement, and should display a caution for misuse of batteries.

Training for local energy enterprises: For local vendors or energy enterprises, training on the standard operating procedures for installation should be provided. This includes creation of pre-installation checklists, installation procedures, best practices, common errors and other relevant aspects. The training should ideally include the creation of checklists and handover documents on proper use of the energy system and appliances to be given to the staff at health centres.

Awareness for communities: It is critical to conduct awareness programmes for the local community, in collaboration with local NGOs or civil society organizations, about the infrastructure upgrade at the health-care facility, highlighting how these decentralized energy solutions help the community access necessary and timely health services. Appropriate outreach to popularize the improved availability of services can increase use of health-care facilities by the community, while also building a sense of ownership of their community asset.

Collaboratively developing these narratives will also encourage wider ownership of the agenda, and tends to facilitate a series of coherent and well-coordinated interventions. As was observed in the case of the Democratic Republic of the Congo’s Access to Primary Healthcare programme, “The people who do the installation and maintenance need to be included from the very beginning, along with the people whose needs are going to be met. We need local nurses and doctors at the table and in the room when they are discussing about how many panels we need, how many plugs”. Often, the ability of villagers to understand the complexity of the electricity system is underestimated – this needs to be acknowledged, and a collaborative capacity-building environment needs to be sustained.¹⁵

The role of electrification of health-care facilities in building local capacities and driving local market has increasingly been recognized. An example is the recently launched ‘Energy Compact on accelerating the electrification of health-care facilities’ in Honduras. Based on the Compact, the country aims to a) increase access to reliable electricity to hundreds of health-care facilities through renewable energy sources and by extending electricity distribution networks, b) improve the use and management of energy in 12 hospitals through solar thermal energy for water heating, c) increase energy efficiency and implement WHO Guidance for Climate-resilient and Environmentally Sustainable Health Care Facilities and WHO/Pan American Health Organization’s Smart Hospitals Toolkit. Honduras projects that achieving these targets will provide over 400,000 Honduran people with access to better quality of health-care services, generate 13,100 new job opportunities, whilst reducing greenhouse gas emissions and strengthening the safety and climate-resiliency of Honduras’s health-care system (Ministry of Energy of Honduras, 2021)

6.2.5 Traditional and innovative financing approaches

Ensuring reliable electricity supply for all health-care facilities is essential to achieve UHC. As such, this needs to be considered a social and development priority, and financial resources need to be identified and allocated accordingly. In this sense, it is essential to dramatically increase financial commitments from governments, development partners, donors, international organizations, philanthropic institutions and private sector operators. In addition to the traditional financing approaches, innovative approaches should be encouraged, in order to leverage on a broader spectrum or resources, but always keeping in mind that health is a human right, and that the public sector has the key responsibility to ensure health for all and to protect the most vulnerable populations.

Improve existing financing models

Most health-care facility electrification financing approaches to date have been focusing on covering the upfront capital cost for procurement of the energy systems and, in some cases, the cost for short-term O&M. These approaches have often not included the long-term O&M needs nor the need for replacement of key elements after their life span, such the batteries.

This ‘short-term’ approach makes long term sustainability challenging. It is essential that health-care facilities electrification programs consider a longer term time-frame, e.g. 10 or 15 years, and include adequate financial resources to cover the relevant costs for O&M as well as for replacement of equipment and proper waste management. This change in the approach requires also an adaptation of the traditional fund disbursement by governments and development partners. For example, one problem is that, if the entire funding amount is disbursed upfront, grantees may be motivated to

¹⁵ Based on transcripts from stakeholder interviews.

use this entirely for upfront capital costs (possibly even oversizing the system), rather than saving a proportion for long term O&M. There is a need to move from this approach to either clearly laid out guidelines on use of the funds beyond capital cost or a staggered payments approach where multiple payments are undertaken during the years.

Furthermore, 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. In a phased approach, development partner funding would have a longer time horizon than a typical 4–6-year project. The World Bank has started to implement Multiphase Programmatic Approach projects for energy access, focusing on phased investment over a longer time horizon, with each phase learning from the previous ones.

Public (government) financing has played a key role over the years at both the national level and the subnational level. Subnational government initiatives across India, initiated by state nodal renewable energy agencies, have resulted in more than 90% of public health-care facilities being powered by solar in Tripura, and more than 900 public health-care facilities being powered by solar in Chhattisgarh (Ramji et al., 2017; Chhattisgarh State Renewable Energy Development Agency, n.d.). In the latter case, financing through the Chhattisgarh Health Department and long-term maintenance support from CREDA have proven crucial for sustainability of the systems.

In addition to adapting and improving the traditional financing approaches, it is also important to explore new approaches that can expand the spectrum of possible solutions, and contribute to overcome the above mentioned challenges and facilitate access to finance and affordability for energy systems. In this context, some of the emerging market-based approaches include the long-term (10–15 years) power purchase agreements between the ministry of health (or another relevant ministry) and the energy service provider, the energy-as-a-service model, or the lease-to-own/pay-as-you-go.

The Grüne Bürgerenergie (GBE, Green People’s Energy) in Benin, an initiative implemented by GIZ, is one example that includes an emerging financing approach. GBE uses energy-as-a-service delivery models for off-grid technologies deployed in social institutions, such as health-care facilities. Through this model, health-care facilities do not pay for purchase of the system (and therefore do not own the system), but pay a fee for service to a private company as long-term rental and maintenance. Additionally, GBE provides financial and technical assistance to both the supply side (private company) and the demand side (health-care facility and public sector) in the delivery model. GBE further supports implementation of this solution by providing incentives for results-based financing, as well as setting up collaborations for digital remote monitoring of the systems (SEforALL & ESMAP, 2021).

In any case, in the models where the health-care facility is not the owner of the energy system (e.g. in the energy as a service model), it is essential to put in place adequate measures to ensure that energy supply for the health facility is ensured in any case. Health services are essential services, and energy supply cannot be depended on a business based model without ensuring adequate protection for the vulnerable populations who are not able to pay.

Explore models based on energy service companies (ESCOs) involvement

In west Africa, the Regional Off-Grid Electrification Access Project aims to support electrification of health centres and schools across 19 west African countries. Governments help to identify project sites, conduct energy audits and establish required electricity service levels. Financing guarantees serve as insurance against future revenue defaults for the private sector ESCOs, help to minimize

the risk of non-payment by the government/public sector and to instill confidence in the private sector (SEforALL & ESMAP, 2021). The aim of these measures is to support ESCOs on taking up all the other components of installation, including raising capital, procurement, installation and long-term O&M. Payments to ESCOs are based on the performance of the system, which is measured and verified through remote monitoring. In this model, beyond 4–5 years, when the capital cost has been recovered, the private sector will continue to receive monthly payments for long-term O&M (SEforALL & ESMAP, 2021).

UNDP’s S4H programme focused on pure upfront capital expenditure financing for the installation of energy systems across countries through grant funding. In contrast, the new S4H programme for Liberia, Malawi, Namibia, Zambia and Zimbabwe aims to ensure sustainability of solar systems through adequate O&M over the lifespan of the procured solar system, including safe disposal of discarded equipment at the end of the system’s lifetime. This includes health ESCOs, which will install, operate and maintain energy systems through an energy-as-a-service contract. The energy service payments will be provided through a performance-based energy payment mechanism, paid partly through the Green Climate Fund and partly by governments, thereby reducing the investment risks for health ESCOs in terms of honouring of regular payments (UNDP, n.d.).

With increasing electricity bills in large hospitals and falling costs of decentralized renewable energy solutions, the state of Madhya Pradesh in India discovered unsubsidized solar tariffs of 2.18 Indian rupees per kWh, which is around one third the tariffs paid for grid-based electricity (NITI Aayog, 2018). The government was able to operationalize the renewable ESCO model for a solar power tariff agreement with the government electricity agency and a private distribution company operator. To replicate this Madhya Pradesh model, NITI Aayog under its Sun’s Blessings and Health initiative intends to set up rooftop solar projects in public health institutions. Renewable ESCO models with long-term power purchase agreements of 25 years, which are grid integrated, have been tried and tested in large-scale facilities. Use of this model would need to be more flexible for smaller, remote health-care facilities with unreliable access to grid electricity.

Blend diverse sources of finance mechanisms

Ensuring access to quality health services for all is a responsibility of the public sector, and public institutions will continue to play the key role in meeting these goals. In addition to dramatically increase government and traditional development partners commitments, it is useful to explore new and innovative financing mechanisms that can contribute to close the financing gaps.

Blending diverse sources of financing mechanisms in some cases has helped to unlock private capital for some health-care facility electrification interventions. Infrastructure Development Company (IDCOL) – a government-owned, specialized, non-bank financial institution that finances renewable infrastructure projects in Bangladesh – financed installation of 26 solar mini-grid projects, including health-care facilities, as part of community-wide installations. IDCOL provided 50% of the total cost of each 250 kWp mini-grid system as a grant, with funding sourced from development partners. A further 30% of the project cost was extended as a concessionary loan with a 10-year repayment period. The remaining 20% was invested as equity by the developer (private sector project developers or NGOs). The developers installed a prepaid metering system to ensure revenue collection as tariffs. IDCOL required the developers to provide O&M services. In addition to ensuring affordable electricity tariffs for customers, this model guarantees a reasonable return for the developer, with a payback period of 6–8 years (Alliance for Rural Electrification, 2020).

Building affordable tariff rates for the health sector is essential. Balancing this with private sector interests for a suitable rate of return and payback requires proper planning and coordination

between the various stakeholders and partners involved. It is essential to put in place adequate measures to ensure that the supply of energy for health centres is guaranteed and that health services are provided to all without being solely dependent on a private sector led business model.

Enhance PPPs

In the PPP model, a private sector entity co-invests in, builds, operates and maintains systems, while the government purchases the energy, and sets clear and measurable key performance indicators and quality standards for the operator. To unlock private sector participation in this sector, collaboration with the public sector is critical, particularly in enhancing investor confidence, by reducing the risks for their investments, while at the same time ensure that the health services are ensured for all, protecting in particular the most vulnerable populations.

National and local governments, and development finance institutions play a major role in facilitating PPP models. National governments, through either the ministry of health or the ministry of finance, can provide payment guarantees in case of default in payment by the local government. Development finance institutions can provide investment guarantees to the private sector players, as well as third-party guarantees, to further cushion the private sector in case of default by the national government.

Similar to a PPP, the energy-as-a-service model can contribute to attract private sector participation in the renewable energy segment. Under certain conditions, it can be applied to the health sector. In the energy-as-a-service model, customers pay for an energy service without having to make any upfront capital investment (Cleary & Palmer, 2019). This model allows private sector actors to take on an expanded role in the delivery of electricity to public institutions, beyond the traditional procurement and installation. It also alters approaches for payment of electricity services by the end user – by shifting from procurement of energy assets to paying for energy services (SEforALL & ESMAP, 2021). If this approach is applied to electrification of health-care facilities, however, it is essential to put in place adequate measures to address the potential risk of energy supply interruptions, taking into consideration that the health sector is not the owner of the energy system. Furthermore, guarantee for payment of the energy service by either the local government or the line ministries responsible for the health sector could further build the confidence of investors, thus reducing the burden of risks associated with procurement of the assets on the developer’s balance sheet.

Additionally, innovative approaches such as demand aggregation or pooling of health-care facilities for a contract with a provider could overcome challenges associated with powering facilities in locations where there might be insufficient interest in electrification – especially in remote areas where the cost of a private sector energy service provider could be higher.

Leverage the private sector

As mentioned in the previous sections, initiatives aimed at exploring the role of the private sector in integrating with public sector efforts have been increasing

Although service-based approaches provide new financing arrangements that can help to solve some of the challenges associated with traditional facility ownership models, they have their own challenges, which do not make them a suitable solution in several scenarios. For example, end users’ ability to pay regularly for energy services, and the private sector’s ability to raise capital for health-care facility electrification that carries a higher risk profile, are two risks that traditional financing approaches tend not to face. End users’ willingness to pay may also see a shift if the reliability of grid connection in the region improves, or if the grid is extended to areas that are currently off the grid. These changes could cause users to shift to the grid, which may provide power at cheaper rates.



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In regions where the local renewable energy ecosystem is immature, such emerging models may only be provided by international firms that can take on larger financial risks (SEforALL & ESMAP, 2021). These challenges can be mitigated by multilateral and government agencies, which could for example reduce risk by providing additional financing support and guarantees. Adequate measures should also be put in place to make sure the energy supply to health-care facilities is provided in all cases, since the health of people cannot be dependent on the profitability of a business model.

Traditional ownership approaches to financing by governments and development partners will continue to play the key role in strengthening health-care infrastructure. However, funders should be made aware of the need to incorporate O&M into financing arrangements so that system sustainability is not compromised through budgeting purely for upfront capital costs. This could include annual budgeting by relevant line ministries for O&M, or extended-term donor support (SEforALL & ESMAP, 2021). In India, RKS,¹⁶ under the National Rural Health Mission, has untied funds allocated to it by the central government for health-care facility management. SELCO Foundation (2021b) has been working with RKS across multiple states to actively engage and involve them in the O&M of energy interventions, thereby ensuring that a proportion of these untied funds can be allocated annually towards sustaining the energy system.

However, to scale up health-care facility electrification and bring in additional financing for scaling up, the right model needs to be identified based on the country-specific conditions. These include the possibility of aggregating demand, the availability of system components for installation and replacement, the availability of established vendors and O&M capabilities, the funding capacity of public institutions and multilateral agencies, etc.

16 RKS is known as ARS in Karnataka and plays the function of local health management committee, as described in **section 6.2.4**.

6.2.6 A needs-driven, process-based approach to health-care facility electrification

Every country designs the structure of its health system and health-care delivery mechanisms according to the needs of its citizens, local disease burdens, spatial constraints, and the availability of financial and human resources. Within each tier of a country's health system, there may be substantial variation in the services delivered by health-care facilities. A typical supply-driven, product-based strategy that aims to provide solar power to all health-care facilities through a standardized model carries many risks. On the one hand, one-size-fits-all energy systems may be under-designed or overdesigned for the current and future needs of the health-care facility; this misses the opportunity to use decentralized energy infrastructure to deliver health services closer to the underserved population. On the other hand, heavy reliance on external actors and insufficient leadership by local stakeholders tends to create an ownership vacuum, jeopardizing the long-term sustainability of the electrification programme.

An alternative to the supply-driven strategy is a needs-driven, process-based approach that can focus on establishing and nurturing stakeholder relationships, and on developing an enabling 'ecosystem' that can create ownership and capacity at various levels to ensure the sustainability of the programme. The mechanics of a process-based approach are best illustrated through a case study. In 10 districts across India, public health centre staff are conducting health-energy assessments, generating a grounded understanding of how the lack of adequate and reliable electricity is affecting current and future health-care needs of these facilities. Supported by the state national health missions and a suite of flexible philanthropic capital channelled through SELCO Foundation, these assessments are being used to augment the health-care facilities with energy-efficient medical equipment powered by decentralized solar technologies from reliable local vendors. The goal is for all public health centres in these districts to have access to reliable electricity and infrastructure so that they can provide improved health-care access.

The case of Meghalaya state in north-east India (**Box 6.3**) illustrates an on the ground example of health-energy partnership and offers insight into the elements of a process-based approach that can be replicated or adapted in other contexts.

BOX 6.3.

ON THE GROUND HEALTH-ENERGY PARTNERSHIP IN THE INDIAN STATE OF MEGHALAYA

In Meghalaya state in north-east India, 16 health-care facilities operated on a PPP basis by Karuna Trust and other NGOs were provided with solar power in 2016 with almost full philanthropic support (SELCO Foundation, unpublished observations, 15 June 2022). The West Garo Hills district went on to solar-power six more health centres in 2017, leveraging 50% of the cost using local government funds. These pilot projects helped convince the Meghalaya National Health Mission to solar-power 100 health subcentres in 2020–2021, leveraging 60% of the cost from state health funds. Before implementation, the health-energy assessment form was integrated into a mother and child health app that is widely used by the health centre staff. The Meghalaya National Health Mission made provisions to train staff in deploying the survey and basic maintenance of the systems.

The health centre staff conducted health-energy assessments that revealed the need to convert many last-mile subcentres into delivery and vaccination points. The public tender to procure the systems was designed with technical assistance from SELCO Foundation to attract vendors with a history of local presence and quality installations. Many of these local vendors did not exist before and were developed over the years through a dedicated incubation programme. Meghalaya has committed to solar-power the remaining 350 subcentres, leveraging more than 70% of the cost from state or local health funds. This example illustrates how partnerships were formed across need assessments, training, financing, and procurement and standards.



The health facility solar electrification programme in the Meghalaya State is a result of a process-based approach that was initiated even before the programme started. The sections below describe the four processes that created the enabling conditions to sustain the program, and that could be relevant also in other contexts.

Identify and nurture champions

Relationships should be identified and nurtured between individual “champions” within the regional health or energy departments, who can guide the design and implementation of the programme while taking realities on the ground into account. The champions in the system are as critical as the systems they are working to change. Champions are characterized by their ability to break silos and pool resources to enable systemic change. In the case of Meghalaya, champions in the health department and district administration are building energy components into existing health programmes.

For example, in Meghalaya, the O&M mechanism is proposed to be modelled along the lines of a successful ambulance call centre programme, where local health staff report problems in the solar PV system through a dedicated telephone line. In other Indian states, champions in the state energy agencies are collaborating with the health departments to integrate clean energy infrastructure. Champions can also be outside the government, in enterprises or NGOs that have a history of engaging with local governments. The bottom line is that their ownership of the programme and their motivation to persevere through the implementation process are key to sustaining health-energy partnerships.

Mobilize and deploy patient philanthropic capital

Patient and flexible philanthropic capital should be deployed to enable experimentation and demonstration of different models, rather than imposition of a predetermined “best-case” model. In the case of Meghalaya, the small number of initial pilot projects that were fully funded by philanthropy were critical to discover the needs of facilities, and develop appropriate models such as subcentres that functioned as delivery points or vaccination points. As the programme was scaled up, philanthropic money was critical in unlocking public sector money while building confidence among the public officials and sharing some of the perceived risks. Over time and through a combination of different programmes, philanthropic money was also important in building the capacity of health staff, and local vendors and enterprises, at different stages of implementation.

All funders have their own missions and focus areas for deploying their funds. SELCO Foundation’s innovation was in pooling philanthropic capital from different funders and deploying it to support different parts of a unified programme. In other low-resource contexts where domestic or international philanthropy may be lacking, foreign or multilateral aid moneys could be pooled with the same intent. Such pooling of grant capital enables the implementation of a more holistic programme rather than a project-based approach with limited scope for each funder. The whole is greater than the sum of its parts.

Build capacity of local health systems

The capacity of the local health system needs to be built at different levels. In Meghalaya, the staff at health-care facilities underwent training to conduct health-energy assessments and perform preliminary maintenance of the solar facilities. These sessions will be a part of the annual training calendar for health staff. The government data managers and volunteers identified through local non-profit organizations underwent training so that they could assist in implementing the health-energy assessments. District-level health officers were encouraged to visit the local health-care

facilities during assessments to boost the enthusiasm of local staff. Officials from the district and state administration were engaged several times at all stages of programme implementation to seek their crucial inputs in programme design.

Valuable avenues for incorporating ownership within the health sector came from these sustained engagements. This cycle of capacity-building, demonstration and sustained engagement can inculcate a sense of ownership and internalization, and eventually create champions who can sustain these programmes in the long run.

Invest in building an ecosystem for sustainable energy

An ecosystem for sustainable energy needs to be built that can support this health system transformation. Nurturing vendors with local presence and the ability to provide reliable service over a long period is important to avoid the pitfall of creating a preventable graveyard of failed solar systems. Vendors also have a larger role to play in supporting local economic development. The lack of reliable electricity that affects the health system also most likely affects the daily life and livelihoods of rural households. The vendors can also deliver, for example, solar-powered lighting or productive-use solutions that can improve the financial and social well-being of energy-poor households, which in turn contributes to the health of communities.

Enabling local vendors and entrepreneurs to provide a range of sustainable energy services can bring about long-term benefits by lowering the transaction cost of doing business, and channelling any profits to local communities rather than to overseas project developers and private investors. In addition to vendors, end users might need access to product financing through banks or other institutions, technical or business training, or market development support. A thriving local network of vendors can support the reliable upkeep of the health-care facility solar infrastructure and augment it as needed in the future. Developing each part of this sustainable energy ecosystem needs multipronged investments and long-term planning.

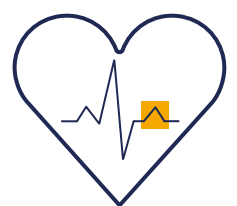
6.3 Conclusion

Several kinds of interventions are essential to ensuring electrification of health-care facilities. These range from selection of the right electrification approach – such as grid extension or off-grid – to appropriate system sizing and selection of efficient medical equipment. A proper energy supply ecosystem with local capacities helps create a robust design and implementation program and smooth O&M. Sustaining energy systems in health-care facilities is critical to ensuring quality health service delivery for all. This requires building capacity of local health-care facility staff and entrepreneurs, and creating reliable mechanisms to ensure long term O&M, backed by appropriate financing.

Reliable electrification is a key element to improve effective health service delivery. Linkages between electricity and health can be enhanced through better institutional coordination mechanisms and integrated policies. Flexibility in policy frameworks is essential to ensure that they not only evolve with time in line with technology innovation, but can devolve from national-level targets to state-level targets and objectives, based on state (or subnational) contexts, including resource availability, and the existing status of health service delivery and electrification.

Lastly, both public and private finance are critical to further push electricity access as a critical infrastructure need for health service delivery for all. Governments, development partners, donors,

and philanthropists need to dramatically increase allocation of financial resources, not just for upfront investment, but also to address the sustainability of energy solutions in the long run by covering the cost of long terms O&M. Innovation should not be limited to energy supply technology; it should include innovative financing and procurement options to ensure that the urgency of electrifying health-care facilities is supported by the availability of multiple, feasible financing options that provide effective delivery of energy to last-mile communities. Pilot projects for delivery of energy solutions should be measured, monitored and evaluated to ensure that these solutions can scale to other geographies with similar contexts. In short, how can we transition from pilots to scale, and are the existing financing mechanisms appropriate? This will require appropriate mechanisms for data collection, interpretation, evaluation and knowledge sharing, to ensure that the right solutions are being provided and transmitted across the ecosystem.

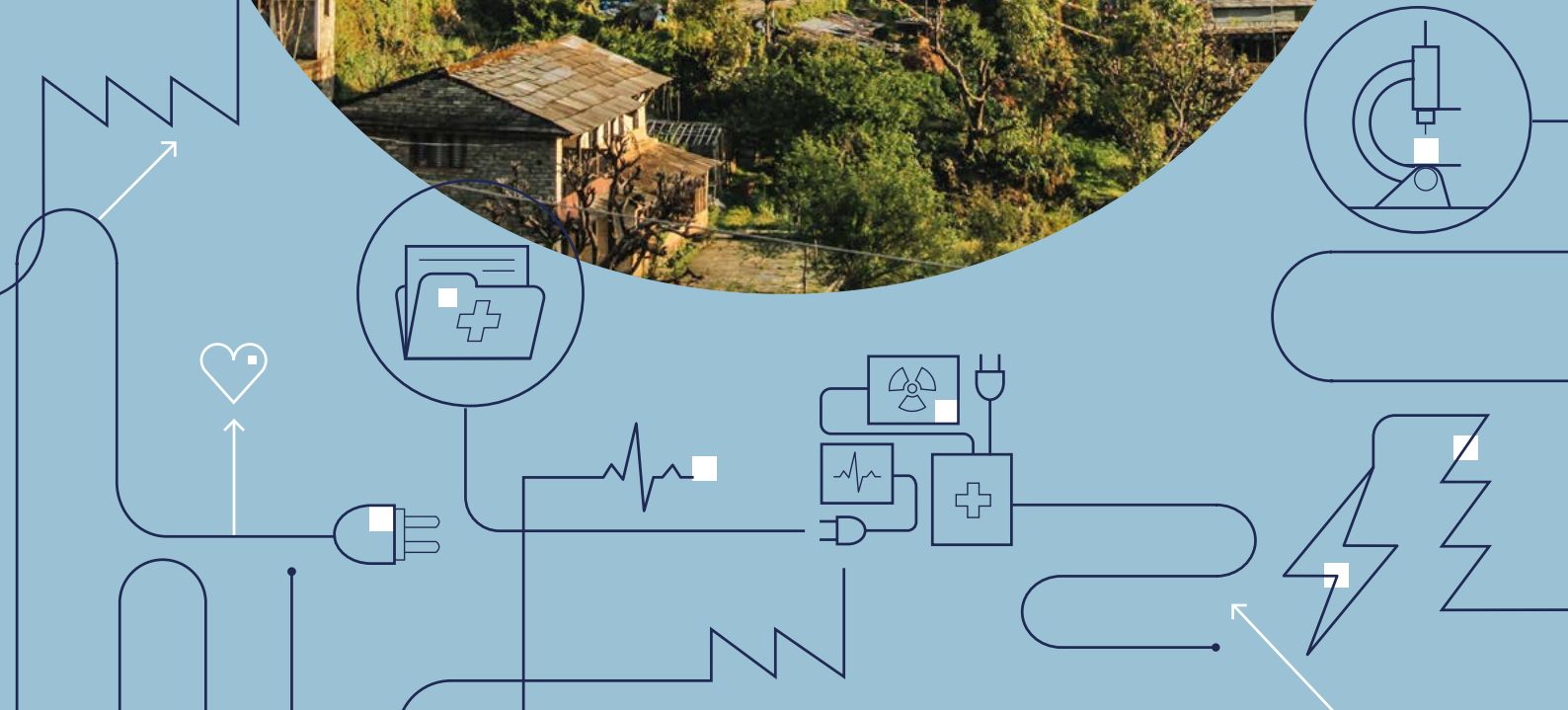


Chapter 7

Country case studies and lessons learned



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Exploring case studies of the experiences of countries can help identify lessons and insights that can be useful for future programmes. Specifically, this chapter explores programmes or projects that have been implemented in three countries: India, Uganda and Nepal. These case studies aim to provide information on risks, challenges and success factors (see **Table 7.1**), to illustrate lessons that may be transferable to other country contexts. However, context-specific factors play a key role, and therefore the transferability of lessons is always limited to some degree by the specific context.

The case study locations were selected based on an assessment of the degree to which they are likely to convey meaningful, potentially transferable lessons to other policy-makers, development partners and stakeholders, as well as the availability of detailed information, either published or through interviews with key actors. The case studies explore a range of development contexts and scales, and capture initiatives led by governments and NGOs.

The case studies illustrate specific policies or programmes implemented as well as certain principles (e.g. on decision making processes, partnership models). Many of the elements that are discussed in Chapter 6 are demonstrated in these examples. Some key themes emerge from the case studies, including the importance of multisectoral partnerships, methods for institutionalizing budgets for O&M of energy systems, and the role of data for long-term facility infrastructure planning. **Section 7.4** discusses the common issues that many of the case studies have faced, and how future interventions may mitigate these challenges by drawing upon the lessons gleaned from these Country case studies and lessons learned.

Table 7.1. Case study summaries

Programme	Period	Key actor(s)	Project size	Risks	Challenges	Success factors
COUNTRY: INDIA						
SELCO Foundation	2015–present	SELCO Foundation, state health departments	1600 public health-care facilities	Facility-level O&M budgets may have to compete with other priorities	Building local ownership	Engagement with facilities in needs assessment Decentralized O&M budgets hedge risk
COUNTRY: UGANDA						
Powering Healthcare	2016–2019	UN Foundation, SEforALL	36 facilities (health centre II and health centre III)	Insufficient provision for O&M	Building local ownership	Government support
ERT-1 and ERT-2	2002–2016	World Bank, Ministry of Health, Ministry of Energy and Mineral Development, other ministries	820 facilities (health centre II, health centre III and health centre IV)	Political and administrative changes	Multisectoral coordination Delegating O&M responsibilities	Multisectoral approach
ERT-3	2015–2022		329 facilities (health centre II, health centre III and health centre IV)			Longer-term O&M planning
COUNTRY: NEPAL						
Institutional Solar Photovoltaic Systems	2016–present	Alternative Energy Promotion Centre (AEPIC), KfW Development Bank	400 facilities	Short-term (2-year) after-sales provision Facility-level O&M budgets may have to compete with other priorities	High cost of monitoring Limited knowledge of systems in facilities	Technical training for solar companies Experienced (15–20 years) solar companies Customized 1–2 kWp systems allow quality control

7.1 India

India has made huge strides in electrification during the past decade, from an access rate of 76% in 2010 to 98% electrification through the 2017 Saubhagya Scheme of the Government of India (World Bank, 2021a). This has included recent improvements in health centre electrification. Because of India’s federal policy structure, and the health-care sector’s split between public and private infrastructure, India’s approach to electrifying health-care facilities has historically been decentralized, led by multiple, and often independent, initiatives across federal government, State governments, NGOs and the private sector.

Whereas rural household electrification in India falls under the purview of the Ministry of Power and the Ministry of New and Renewable Energy, electrification of public health-care facilities is primarily managed at the state level. Public health-care facilities are split into five categories, which have standardized guidelines for equipment: subcentres, PHCs, CHCs, subdivision hospitals and district hospitals (MoHFW, 2012). PHCs and their subcentres are the “last-mile” face of public health care and act as the first referral unit. PHCs cover on average a population of around 30 000 in rural areas and 20 000 in hilly, tribal and desert areas. Rural PHCs account for the vast majority (82.7%) of India’s PHCs, so the lack of electricity access in those facilities represents a significant challenge for India’s health-care infrastructure (MoHFW, 2020). Even facilities that do have access to electricity may struggle with expensive and polluting fuels for generators (Concessao, Gupta & Deka, 2020).

As highlighted in the previous chapters, the lack of electricity access has major implications for public health. In India, PHCs are required to provide 24-hour emergency services, referrals, inpatient services, maternal and child health care, immunizations, and basic laboratory and diagnostic services that require electricity. There is evidence from India that facilities without electricity access have 39% fewer inpatients and 38% fewer outpatients (Shastry & Rai, 2021).

The implications for women’s health in particular are well documented. Unelectrified facilities show 64% fewer deliveries, in part because women may be travelling further to reach private facilities with electricity access (Shastry & Rai, 2021). Private facilities are more expensive, and women at private facilities are 3 times more likely to undergo a caesarean section, although it is also likely that some women with complications intentionally seek out private clinics (Singh, Hashmi & Swain, 2018; Shastry & Rai, 2021). A study in Gujarat found that the probability of a functioning operating table increased by 10.3% after facility electrification, while the probability of a functioning delivery table increased by 6% and the probability of receiving a checkup in the first trimester increased by 9.5% (Chen, Chindarkar & Xiao, 2019).

Notably, data on facility electrification mainly relate to public facilities, not private or NGO-led health clinics. In India, 62.7% of hospitals are run by the private sector (Jaffrelot & Jumle, 2020; Kapoor et al., 2020). More than 65% of patient visits are to private facilities, although more private sector-run health-care facilities are found in urban areas than in rural areas (Indranil, 2020; Rajagopalan & Choutagunta, 2020). As most rural health services are government run, public funding is usually the first option for infrastructure upgrades. For health-care facilities run by NGOs or charities, corporate social responsibility funds can be tapped, although these funds are often tied to the specific area in which a corporation has operations (Jairaj & Deka, 2020).

Solar PV systems have emerged as the prominent solution for electrifying, or for providing electricity backup, for health-care facilities. India's extensive experience with off-grid solar energy through its numerous rural electrification programmes means that skilled labour for solar systems is more readily available in rural areas in India than in many other countries. As of 2019, India had the fifth highest cumulative capacity for solar PV generation installed in the world (IEA, 2020). However, upfront costs still remain a significant challenge, and new models are considering different ways to embed O&M budgets for long-term sustainability.

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Case study 1: Decentralizing ownership and O&M approach in the SELCO Foundation model

SELCO Foundation has been working with public health partners and NGOs on a decentralized model of health-care facility electrification. Since 2015, the foundation has worked with health partners in 10 Indian states – six in which the foundation works on direct implementation and four in which it works through partners. The flexibility of the foundation’s philanthropic capital allows it to demonstrate different models, and so its programmes do not use a single model but explore different options with the aim to identify best practices (Jaffer, 2022). Recognizing that solar systems are usually oversized or undersized because actual energy demand is not always aligned with the Indian Public Health Standards guidelines, SELCO Foundation takes a needs-based approach, with a focus on the efficiency, availability and functionality of medical devices and appliances (MoHFW, 2012).

SELCO Foundation currently works with approximately 1600 government health-care facilities, guiding them from needs assessment to system design and procurement to post-installation training in an integrated process that can take as little as 6 months (SELCO Foundation, 2021). State-specific programmes include 180 decentralized systems centres, PHCs and CHCs in Meghalaya through a partnership with the State Health Ministry; these systems power equipment for immunization, maternal health and childcare. In Manipur, solar systems have been installed in 80 PHCs, CHCs, and subcentres. From initial evaluations conducted by SELCO foundation, it emerges that there has been a 83% decrease in facilities reporting vaccine wastage due to poor refrigeration, 92.3% of facilities have reported extended hours of operation, and 90.3% have reported that operations were made easier by reliable energy (SELCO Foundation, 2021). Since most systems under this programme were installed less than 3 years ago, data on the status of the systems after battery replacement will likely not be available at least for another

year or two. Nevertheless, SELCO Foundation offers a particularly decentralized model that has been able to scale well across state contexts by placing greater responsibility on the health-care facility itself.

One major factor in the success of this programme was creating a sense of ownership through greater involvement of facility staff in the energy needs assessment phase. SELCO Foundation provides a health–energy audit (see also Chapter 3), and assists with procurement guidelines for health equipment and other appliances (see also Chapter 4). The health–energy audit is developed in partnership with various health stakeholders. It involves consulting with health experts to identify the energy inputs and appliance needs of each health-care facility, taking into account the Indian Public Health Standards guidelines, and offers a matrix of options for the facility based on the level of health care provided and the funds available. This was a reaction to the experience that the traditional model is very supply (energy input) focused, which can lead to incorrectly sized systems and disengagement on the part of the health-care facility staff, who have not been consulted. To address this, the assessment includes information collected through energy meters, interviews, data recorded on health-care appliances, checklists, observations and photographs (SELCO Foundation, 2020).

Another way the programme tries to address the local sense of ownership is through basic maintenance training and supporting health-care facility staff. In this model, the public health-care facilities own their solar system, with 60–80% of capital expenditure paid by state government health infrastructure funding and the remainder supplied by SELCO Foundation. The O&M costs are usually then covered by the PHC. SELCO Foundation works with the PHC’s health-care facility management committees, the RKS, to move from consultation to complete ownership and

accountability. The RKS has oversight over the annual budget of untied funds from the central government, which are the primary source of operating expenditure finance for the solar systems. Other sources can include patient fees, donor funds and grant money (SELCO Foundation, 2020). However, access to donor funds and grant money may not always be available, representing a limitation of this approach.

At the time of installation, there is on-boarding training for staff, followed up with two or three trainings over the following years, to ensure that the health centre knows to set aside some of these untied funds for O&M. The expectation is that the operating expenses will include annual maintenance costs (1–2% of the total system cost) and battery replacement every 5–7 years (up to 30–40% of the system cost) (SELCO Foundation, 2020).

In comparison, in the case of CREDA, CREDA has an O&M team and keeps a dedicated fund at the state government level to maintain the systems once the warranty has expired

(Ramji et al., 2017). That programme has been running since 2012, and the institutionalization of O&M funding at the state government level has played a key role. In SELCO Foundation's case, although there are other potential funding sources, such as fees and grant funds, annual untied funds remain the major source of O&M. There are advantages and potential risks in this approach, as in every other model. It is possible that embedding O&M at the facility level may increase the risk that facilities will fail to save appropriately for battery replacement and repairs, given other budgetary priorities. On the other side, this approach may improve the sustainability of the programme, since O&M funds centralized at the state government level could also be reallocated in future years. At this stage, insufficient time has elapsed to determine whether health-care facilities will be able to prioritize electricity reliability over the long term. SELCO Foundation is exploring additional mechanisms to secure O&M from government sources as well as philanthropic sources for long term maintenance expenditures.

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7.2 Uganda

During the past years, the effort on electrification of Uganda’s health-care facilities has increased significantly as a result of several factors: higher donor interest, commitment by the Ministry of Health, high population density and more mature solar market (World Bank, 2021a). This has also led to a rise in the number of health-care facility electrification programmes, which will require an efficient coordination mechanism to maximize impact, ensure efficiency and avoid duplication of efforts. Data and information sharing as well as coordination between relevant actors are critical in this sense.

According to a health-care facility geomapping exercise conducted in Uganda in 2019–2020, electricity access and reliability represent a significant challenge in the country (Blimpo & Cosgrove-Davies, 2019).

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Low electrification rates have had a real impact on health outcomes in Uganda. Immunization programmes in Uganda face poorly equipped facilities, including facilities without power, which adversely affects their success (Phillips, 2017; Malande et al., 2019). A recent study found that facilities that were equipped with basic electric medical equipment and mobile phone chargers had a 9.5% increase in the number of essential care actions performed (Rokicki et al., 2021). Evidence from Uganda also found that health worker satisfaction following facility electrification increased from 0% to 76%, and that community satisfaction increased from 34% to 95.4% (Javadi et al., 2020). Uganda’s maternal mortality rate is more than 5 times the target under SDG 3 of 70 per 100,000 (by 2030), and public health initiatives have tried to increase the rate of attended births, which is more likely if a mother’s local health-care facility has electricity access (Mbonye & Asimwe, 2010; World Bank, 2017a).

Health centres (facility tier below general hospital) are split into four levels in the primary health-care pyramid, which are classified by the health services available: health centre I offers preventive care and health promotion services in the communities and has no physical infrastructure; health centre II offers outpatient services, antenatal care, emergency deliveries and immunizations; health centre III offers maternity and basic laboratory services; and health centre IV is a small hospital (Javadi et al., 2020).

Since the majority of large hospitals have access to electricity, government and donor efforts have focused on health centre II, health centre III and health centre IV facilities, in order to have the largest impact on health outcomes. These programmes include the longstanding World Bank ERT project (**case study 2**), the Powering Healthcare pilot programme (**case study 3**), solar-powered maternity kits and the Uganda programme of the Clinton Health Access Initiative. Uganda has experienced an increasing interest from donors, partly because it has seen two decades of economic growth and partly because it is an anglophone country with a higher ease-of-doing-business ranking than many of its neighbours (World Bank, 2021b). On a practical level, its higher population density than many other African countries makes it easier to reach population centres with key infrastructure. Development partners also identified that having energy ‘champions’ in the Ministry of Health was key to bringing together disparate conversations. Finally, Uganda’s solar market has been instrumental in making these top-down, tender-based programmes viable, allowing sufficient bidders, ensuring that companies have spare parts inventories in the country and offering O&M services.

As the number of health-care facility electrification programmes in the country has increased, there is a risk of duplication of effort, and a need to ensure the functionality of systems covered under past programmes (which has sometimes been an issue). Whereas initially the low access rate for facilities prevented partners from needing to coordinate, stakeholders now describe concerns that they may be bringing solar technologies to facilities that have already been electrified under another programme, instead of repairing the systems already installed in the facilities. Furthermore, a number of systems electrified under earlier programmes, such as ERT-1 or ERT-2, may indeed no longer be functional, further highlighting the need for up-to-date data. Currently, multiple stakeholders responsible for electricity access, including the Rural Electrification Agency (now part of the Ministry of Energy and Mineral Development) and the Ministry of Health, collect data, but there is a need for more information sharing from all relevant actors.



Case study 2: Applying lessons learned from the World Bank-supported ERT programme

During the past decade, the World Bank's ERT programme has been the driving force for health-care facility electrification in Uganda. ERT-1 commenced in 2002, ERT-2 began in 2009, and ERT-3 runs from May 2015 to November 2022. The programme phases have included some grid connection, but most facilities have been powered through solar PV systems, initially as several small stand-alone solar systems but moving to facility-wide stand-alone systems. Although the full scope of ERT-3 also includes schools and water facilities, the programme allotted US\$ 5.1 million specifically to electrify health-care facilities. Most of this was provided by the International Development Association and the Global Environment Facility; the Government of Uganda contributed US\$ 300,000.

The objective of ERT-3 was to expand on the work of ERT-1 and ERT-2, in terms of improvements in health outcomes, increased staff retention, increased women giving birth in health centres, and increased patient use of night-time health services (World Bank, 2017b). Initially, the goal was to electrify 276 rural health-care facilities and their staff quarters, serving 5.5 million beneficiaries. As of November 2021, the programme overshot its goal, electrifying 329 facilities. As of December 2021, 98% of total solar systems installed in health-care facilities under ERT-3 were functional, however it is still early to assess the long term functionality of the systems.

Rather than installing several separate systems for different parts of the facility for health centre II and health centre III, and centralized PV/diesel/battery system only for health centre IV, which was the model for earlier iterations of the programme, the centralized solar systems were deployed throughout for ERT-3, to power all the medical buildings. This centralized approach was also taken by the UN Foundation's Powering Healthcare programme. As in ERT-2, the aim was to meet the basic needs of health services and staff, and the systems ranged in size from 130 watt peak to 1.5 kWp, with an average system size of 0.9 kWp (World Bank, 2015).

The programme has taken a multisectoral approach, since ERT aims to electrify schools and water supply projects in addition to health-care facilities. The Ministry of Energy and Mineral Development coordinates the implementation of ERT-3, while each relevant ministry (Ministry of Water and Environment; Ministry of Education, Science, Technology and Sports; and Ministry of Health) has control over the design, planning and procurement for their institutions. This ensures that the programme is responsive to the needs of the relevant ministry. In the case of the health-care facility electrification programme, the Rural Electrification Agency managed main grid connection programmes, while the Ministry of Health handled off-grid facility electrification. The first 5 years of O&M are covered by the Ministry of Energy and Mineral Development and the Ministry of Health, as described below, including battery replacements.

The role of the government was also central from the policy perspective. For example, the government implemented tax exemption policies for solar products for electrification of health-care facilities, in order to improve market conditions and reduce costs.

In earlier iterations of the programme, when designing the system, the Ministry of Health developed essential equipment lists for each health centre level (MoH Uganda, 2016). These standard equipment lists were critical for anticipating health centre energy needs, and the consultants used them to design systems of different sizes (i.e. small, medium and large) for health centre II, health centre III and health centre IV to cater to the different physical infrastructures at each health-care level. Although this approach tries to balance customization with standardization, there is always the risk of incorrect sizing of systems, which may affect the functionality of equipment. However, the longevity of the programme has allowed ERT-3 to benefit from lessons learned and led to the institutionalization of the use of centralized solar-hybrid systems to power health-care facility energy needs.

Finally, the programme used a 1+4 O&M contract approach, in which the World Bank financed the capital expenditure and the first year of maintenance, while the Ministry of Health was responsible for the following 4 years. An positive consequence of the 5-year O&M contract requirement was that international bidders were encouraged to partner with local solar companies to provide after-sales servicing, which had benefits for the Ugandan solar sector. One lesson learned from ERT-2 was that funds needed to be budgeted for to replace the lead-acid batteries at the end of every 5-year period. In ERT-3, the MEMD and the Ministry of Health agreed to increase the budget for maintenance and repair, including replacement of system parts, such as batteries, and appropriate recycling and disposal of parts (World Bank, 2015). Nevertheless, there are concerns that insufficient funds may be budgeted for these replacements.

After 5 years, the district local governments are responsible for renewing the maintenance contract. However, so far districts have preferred to fund repairs on an ad hoc basis, rather than to tender full O&M contracts (Sitra Mulepo, Ministry of Health, Uganda, personal communication, 1 December 2021). Many of Uganda’s administrative districts have been divided over the past few years, which means that districts have smaller numbers of health-care facilities, reducing the business case for signing a full maintenance contract. One option is for the Ministry of Health to re-centralize the funding for regularly replaced parts such as batteries and inverters, while allowing districts to manage other tasks such as replacing bulbs or cleaning (Sitra Mulepo, Ministry of Health, Uganda, personal communication, 1 December 2021). For example, in 2021–2022, the Ministry of Health centrally procured and replaced batteries for 280 ERT solar systems, although several districts replaced faulty batteries using their own budgets.

In response to the challenges of O&M budgeting, which are reflected in many other health-care facility electrification programmes, the World Bank is trialling a performance-based approach in its Uganda Energy Access

Scale-up Project. The Energy Access Scale-up Project supports a performance-based long-term contract with the private sector to electrify public institutions and was approved on 31 March 2022.

A major challenge has been the coordination of data sharing. In initial iterations of the programme, this was not a significant issue because there were so few electrified facilities. Now that the access rate is much higher, there is a need for better data sharing between partners, including the Ministry of Energy and Mineral Development (under which the Rural Electrification Agency now sits), the Ministry of Health and development partners on which facilities are going to be electrified by whom. This kind of data and information sharing is a challenge that we are witnessing also in other countries.

In ERT-2, the Ministry of Energy and Mineral Development decided to start mapping the facilities that had been connected through solar and grid to share with stakeholders. In the future, the aim is to incorporate the Rural Electrification Agency’s plans for grid extension, but the Rural Electrification Agency’s plans are regularly subject to change. Under ERT-3, the Ministry of Health is responsible for collecting data on health-care facility electrification, and it has recognized the need for a central database. The ERT provides access to data on the GIS locations of facilities, but some clinics are not in the database, and the data have some quality issues (e.g. some electrified clinics are listed as unelectrified and vice versa). One effort to address this is through the EAE tool, a collaboration between Uganda’s Energy Sector GIS Working Group, IKEA Foundation and the World Resources Institute (WRI, 2021). These institutions have partnered with the the Ministry of Health to create a dynamic information system that includes granular, up-to-date information on the electrification status of Ugandan health-care facilities. The health-care facility data include attributes such as facility name, level, ownership, electrification status, electricity sources and catchment population. Improved planning can effectively use limited funding and optimize improvements in health outcomes.

Case study 3: Electrification of health-care facilities and staff quarters with the United Nations Foundation's Powering Healthcare programme

In 2016, the United Nations Foundation, through its Powering Healthcare programme, initiated a demonstration project in Uganda, which electrified 36 facilities at the health centre II and health centre III levels. Uganda's nationwide ERT-2 programme had just ended, and the World Bank and the Government of Uganda were kicking off ERT-3. The Powering Healthcare programme, in coordination with the Ministry of Health, aimed to trial a more ambitious model for health-care facility electrification. Rather than meeting only the essential needs of the facility (as in the initial ERT programme), the programme intentionally oversized the solar PV systems to account for future growth. The solar systems were 2–6 kWp, and the staff quarters were also powered. In the past, the ministry had provided multiple smaller solar systems. In contrast, Powering Healthcare designed single, centralized systems for the entire facility, which improved available energy use efficiency and provided the flexibility to power any equipment, irrespective of its location. One additional aim was to improve staff satisfaction and retention by connecting staff quarters to this central system, which allowed use of televisions and radios in addition to standard lighting and phone charging.

In terms of installed capacity, these systems were intentionally designed to accommodate load growth from the addition of new equipment and staff increases over time. Stakeholder interviews suggested that, although there has been an increase in system use, the facilities have not used more than 70% of the system capacity since 2017.

To keep track of system functionality, the installed solar PV systems included remote monitoring, which allowed the developer, who also initially provided O&M, to undertake remote troubleshooting. This was key, since the sites selected were at least 5 km from the national grid, delivered maternity services and serviced critical areas (e.g. the only facilities in the neighborhood or subdistrict). Because the programme only finished in 2019, information about its long-term success and system functionality is not available yet.

Since Powering Healthcare's intervention in Uganda was a short-term donor-led project, one key challenge was building a sense of local ownership. To address this, the United Nations Foundation team formed a stakeholder group with Ministry of Health technicians, local leaders, district health officers, district administrators and the communities so that stakeholders felt that they were a part of the project development process. As a donor-led programme with 4 years of funding, there is also an ongoing risk that long-term O&M services will not be maintained. Initially, the programme included a 1-year O&M contract with the solar company, and then a 6-month extension. Once this service contract expired, the responsibility for O&M passed to the district local governments and Ministry of Health, which were already in charge of O&M for the ERT-1 and ERT-2 sites. As of 2021, new service contracts had not been tendered, which leaves the facilities at risk of losing the power on which their equipment now relies until the Ministry of Health issues new contracts.





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7.3 Nepal

Nepal is a LMI country that is divided into three geographical regions: the snowy Himal, the mountainous Prahad and the lowland Terai. Nearly 89% of rural households have access to electricity (World Bank, 2019). Access to health care is heavily influenced by socioeconomic and geographic differences in health service (Adhikari, Mishra & Schwarz, 2022). The 2016 Nepal Demographic Health Survey found that 92% of the wealthiest mothers delivered in health-care facilities, 64% in government facilities and 22% in private facilities. This compare with 36% of the poorest women delivering in health-care facilities and the majority (64%) delivering at home (Ministry of Health and Population Nepal, 2016).

The 2015 earthquake laid bare some of the challenges that the Nepalese health-care system faces in rural regions: inadequate specialized health care, infrastructure damage and power outages (Adhikari et al., 2017). Although there is limited evidence about the impact of power cuts on Nepalese health-care facilities, health concerns are always at the top of the discussion about load shedding (Gautam, 2012; Conwright, 2016). Off-grid renewable energy technologies have a large role to play in electrifying remote, hard-to-reach locations, which has been the responsibility of the AEPC under the Ministry of Energy, Water Resources and Irrigation since 1996.

Case study 4: Institutional Solar Photovoltaic Systems programme

Since Nepal's Renewable Energy Subsidy Policy of 2016, the AEPC has managed the delivery of subsidies to clean energy technologies across the country. Under that policy, public institutions in rural areas would be provided with a subsidy of up to 65% of the total system cost but not exceeding Rs 500,000 (approx. US\$ 6500) for solar PV systems. For health posts, and government and community hospitals, solar PV was expected to support a vaccine refrigerator, other electrical equipment and lighting (Ministry of Population and Environment Nepal, 2016). Since 2000, the German Development Bank KfW has committed €5.7 million to support this programme and help formalize the deployment process.

Since 2020, 1400 institutional facilities have been electrified, 400 of which are public health centres. Of the 400 electrified health-care facilities, 390 are still functioning properly. However, older systems that were installed until 2020 have not been subject to the same monitoring protocol, and it is unclear how many have been electrified or how many are still working. For those installed since 2020, there will be another inspection in 2 years.

Facilities that are electrified through this programme are predominantly public health centres and subcentres, as most hospitals in Nepal are connected to the grid. The AEPC puts out an annual public call for institutions that need support for electrification through daily newspapers, and it is the responsibility of the facilities to put themselves forward. At this stage, if there is insufficient budget to cover all the potential facilities, a selection process takes place, which considers whether the facility is connected to any form of electricity, the size of the population covered and whether there is already equipment present that could use electricity. Facilities that have access to equipment are a higher priority for electrification. When facilities apply for the programme, they provide invoices for the equipment that they already have and a commitment letter from donors or other

institutions that have promised to contribute equipment in the short term. Subsidies are only available if at least 80% of the appliances claimed in the application are on-site and operational (AEPC, 2020). Although this means that electrification can immediately improve health outcomes, it may also potentially perpetuate service inequalities – in which facilities without electric appliances do not get electrified – since the programme exclusively covers facilities that are not connected to the national grid. After being selected, the facility is then in charge of procurement. The AEPC provides a list of around 30 companies that have been pre-approved to receive a subsidy and offers the facilities procurement documents to use. However, procurement itself is entirely conducted by the facility (AEPC, 2020).

The AEPC had previously undertaken a review of health-care facility needs, and has created two standard systems, which are sized at 1 kWp and 2 kWp. The 1 kWp system is for community health subposts, village-level health posts and birthing centres. The 2 kWp system was designed for community or government (district-level) health posts, snakebite centres, PHCs or hospitals. In all cases, the health-care facility may select a different system size, but this must be approved by the AEPC (AEPC, 2020). The aim of creating these standardized designs was to ensure ease of quality control.

After installation, the AEPC monitoring team sends out a staff member to verify the installation on-site. If the installation meets standards, the AEPC proceeds with the first 90% of the total subsidy, which is paid to the solar company. The remaining 10% is held back to ensure after-sales service for 2 years, at which time it is released. After the 2-year warranty with after-sales service expires, all O&M is the responsibility of the health-care facility. The key risk of the programme is that health-care facilities may not earmark sufficient budget to maintain the systems. It is not yet known whether this has been a problem because only

systems installed in the past 2 years have been part of the monitoring process. The programme is planning another set of monitoring activities in a further 2 years, which may shed more light on this issue.

The cost of monitoring itself is a major challenge because of the remote locations of many off-grid health-care facilities. The average subsidy for a 2 kWp system is around US\$ 5000, and a single monitoring visit to confirm installation can cost up to US\$ 1000. Likewise, it can be costly and challenging for companies based in Kathmandu to undertake installations and send technicians to the field. The geographic challenges mean that health-care facilities staff are often the primary point of contact for managing the operation of

the systems, but there are concerns that they often have very limited knowledge on how the systems work and should be managed.

In contrast, the prequalified companies have a great deal of experience and training in institutional systems; this has been credited as a reason for the success of the programme. The solar companies on the prequalified list have been working in this field for around 15–20 years, and they receive several rounds of technical training, run by the AEPC, on a demonstration system set up in Kathmandu. The AEPC's own track record of experience on renewable energy systems – since 1996 – and delivery of renewable energy subsidies has also contributed to the programme's success.

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7.4 Lessons learned

The experiences described in this chapter point to several key lessons which can be useful when designing a programme.

Lesson 1: Programmes that rely on off-grid sustainable energy technologies obviously benefit from a developed local renewable energy market. On the other side, they can also provide a significant incentive for solar market growth in countries and areas where the market is not advanced. It is notable that the programmes that appear to have longer-term success, in terms of scaling up and continued functionality, are in countries with a well-developed solar market. Given that top-down procurement is still the model for most publicly driven or NGO-led efforts to electrify health-care facilities, the more competitive the solar market, the greater the potential for driving down prices. In Nepal, 15–20 years of solar experience puts the prequalified companies in a good position to deliver power in challenging geographies. In India, a mature solar market ensures that solar companies have skills and availability of in-country inventory, speeding up the implementation process and ensuring low cost for solar electrification activities compared to several other countries. The presence of a strong solar market is also important for the availability of local service agents or local trained technicians for continued maintenance.

► **GOOD PRACTICE 1.1:**

Programmes should be designed to support local market development and skills. In Uganda, the Ministry of Health supported tax exemptions for solar products to improve market conditions. The ERT-3 programme encouraged international bidders to partner with local solar companies to provide O&M services, which supported the Ugandan solar market. In Nepal, the AEPC’s long running subsidy policy has provided reliable support. These examples show that some market development falls under the purview of national governments, while other elements can be incorporated into programme design. That all these cases include partial or even complete subsidization of capital expenditure also highlights that subsidies are in most cases needed to promote health-care facility electrification in low resource settings.

Lesson 2: System sizing plays a key role for the success of any health-care facility electrification program. Incorrectly sized systems can compromise health outcomes because health-care workers come to rely on electrical equipment that is not always functional (Pakravan, 2021). The use of heavy loads at irregular intervals, such as X-ray machines, can make it challenging to adequately size a system. Systems also need to consider whether they meet current or long-term demand expectations. The cases in this chapter highlighted that system sizing is a trade-off between standardization and customization, and took different approaches to building standardization into the programme. Government institutions, such as Uganda’s Ministry of Health and Nepal’s AEPC, created standard system designs that relied on the equipment and function of each tier of health-care facility. In contrast, Powering Healthcare’s Uganda initiative customized the system according to the needs, including expected future needs, of each facility. Standardization can improve the speed of implementation for larger programmes, especially for small-scale facilities, but customization is more likely to ensure correct sizing, especially for larger facilities. There is currently no evidence that either approach necessarily offers better outcomes, and further research is needed to evaluate the trade-off between them.

► GOOD PRACTICE 2.1:

Programmes should include comprehensive health-energy needs assessments. Many countries have government guidelines on the types of equipment that should be present in health-care facilities, which can act as a good baseline for assessing the energy needs of a facility. However, as the SELCO Foundation emphasizes, a model which is only based on those standards may lead to incorrectly sized systems. A detailed health-energy audit, developed in partnership with the local health stakeholders, plays a key role. Programmes should incorporate a needs assessment of the facility to ensure that the system sizing takes in to consideration context specific aspects (such as local geografies and patient demographics), is well-designed for current activities, and meets anticipated future needs, while not being oversized.

► GOOD PRACTICE 2.2:

Programmes should link energy use to health outcomes to test the trade-offs between standardization and customization (see best practice 4.1). Greater standardization or customization in system sizing may be effective under different conditions and for different facility types. Standardization may be more effective for small scale facilities, whereas larger facilities may require greater customization, as they may have greater variation in equipment or services. Modularity – that is, designing systems to grow by adding modules – should also be leveraged when designing programs with a long-term view.

► GOOD PRACTICE 2.3:

Programmes should consider the use of remote monitoring to timely learn about functionality over time as well as to adjust their approach to standardization and customization accordingly. The degree of standardization in health infrastructure varies across contexts, and therefore the success of a heavily standardized approach will also vary. Remote monitoring can be used to check the use and functionality of systems, which can feed back into new programming decisions. Where poor mobile phone connection is a limitation, offline data collection can be used. Remote monitoring can also be installed with smaller electric devices, such as SDD refrigerators (McCarney et al., 2013; Pedersen et al., n.d.).

► GOOD PRACTICE 2.4:

Health-care facility electrification programmes should coordinate with programs related to provision of medical devices and appliances. This is necessary to avoid situations in which the health-care facility gets electrified, but it does not have devices and appliances necessary to use the electricity. In addition to the support tailored to electrification programs, facilities may need further support to acquire new equipment and appliances, and relevant stakeholders and development partners should coordinate accordingly.

Lesson 3: Sufficient O&M can be institutionalized at the government or at the health clinic level – but it does need to be institutionalized. Health-care facilities in low- and middle-income countries need to balance multiple funding needs with limited resources, and infrastructure improvements are often a lower priority than immediate needs. Although stakeholders across programmes noted that this is often because of low recognition of the benefits of decentralized electrification, the reality is that limited resources hamper what a single facility can accomplish. All the programmes mentioned in this chapter received either government or development funds for upfront costs. However, programmes regularly fail to include O&M budgets past year 5, when typical warranties expire and batteries need replacement; in some cases, this time is even less (e.g. only 2 years in Nepal’s Institutional Solar Photovoltaic Systems programme). O&M budgets can be centralized (e.g. residing with the Ministry of Health in ERT-3) or decentralized; in the latter case, as in the SELCO Foundation model, the health-care facility

uses its own budget for maintenance. Once again, there is a risk trade-off in these approaches. Decentralizing funds may make the programme more resilient to political changes, but gives the ultimate decision-making power to individual facilities. On the other hand, a more centralized approach may have more success in locating funds but, if political changes affect budget priorities, all health centres are affected.

►GOOD PRACTICE 3.1:

Maintenance funds need to be earmarked in budgets – at either the national, district or facility level. In Uganda, when districts were given responsibility for O&M, they opted to finance ad hoc repairs, rather than adopting service contracts. Both approaches are clearly a result of prioritizing limited funding, but they may adversely affect system function and the quality of health care. Another potential opportunity is for donors to transfer funds earmarked for O&M to local institutions or NGOs, who will use that funding for necessary replacements and servicing (SELCO Foundation, 2020).

►GOOD PRACTICE 3.2:

Accountability mechanisms should be created to make sure that O&M is provided. At the same time, health-facility staff should receive adequate training for the correct use of energy system and appliances. Visits from district-level supervisors combined with remote monitoring can support the timely trouble-shooting and the correct functionality of the system in the long run.

►GOOD PRACTICE 3.3:

O&M contracts should be included in the initial procurement stage and involve local companies. In addition to ensuring system functionality, Uganda’s ERT-3 programme encouraged international companies to partner with local companies to ensure that a local service agent would be available after installation. This promoted local development and investment in the country’s skilled solar labour force. SELCO Foundation has also found that working with local implementation companies – rather than companies from elsewhere in the country – produces the best outcomes (WHO, Power Africa & SEforALL, 2022).

Lesson 4: Data on the success of programmes are severely lacking, which hinders decision-making. Most programmes documents provide information about the number of systems installed, but not enough details on the number of systems still functioning after a certain number of years. Furthermore, very limited data are available to connect system functionality to health outcomes.

►GOOD PRACTICE 4.1:

Programmes should monitor system functionality over the years and connect facility electrification efforts to health outcome data. Most programmes evaluate success on the basis of number of installations, not long-term functionality. Remote monitoring can facilitate and automate collection of these data. Remote monitoring data could also be connected to other facility-specific information to help prioritize resources. It is also important to monitor health outcomes as part of these programmes, both to continue to build the evidence base on how electrification leads to better health outcomes, and to be responsive to stakeholder needs that ultimately prioritize individual, community and population health outcomes.



Conclusions and way forward



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This chapter summarizes some suggested actions, based on the discussion in the previous chapters, that governments, development partners, academic institutions and other stakeholders could take to accelerate electrification of health-care facilities. These actions also relate to a number of elements embedded in the WHO framework for building climate-resilient and environmentally sustainable health-care facilities (WHO, 2020). They are divided into those related to data collection, processing and accessibility (**section 8.1**); system planning (**section 8.2**); and programme implementation (**section 8.3**).

8.1 Data-related actions

[→ Data-related action 1:](#)

Devote resources to standardized data collection and updates, using harmonized indicators and methodologies that reflect current trends and needs. Provide georeferenced data, where feasible.

The substantial differences between the survey instruments used to collect and update health-care facility data across and within countries highlight the crucial need for standardized tools so that data can be meaningfully analysed and compared across contexts. Even widely used questionnaires such as the SPA, SARA and SDI surveys differ in how (and whether) they collect certain electrification indicators – for example, the primary energy source used by the health-care facility and whether all available sources are functional. The recently published WHO HHFA tool is a step in the right direction, as it aligns existing questions from the SPA, SARA and SDI surveys and provides a recommended minimum set of standardized core indicators. Countries can customize the tool to fit their contexts and needs by selecting from a wide set of additional questions to add to their survey instruments.

Although electricity is vital for numerous essential health services, few existing surveys collect detailed information on electricity access and reliability. Most surveys ask, at most, a few basic questions on electrification, such as whether the facility has access to any source of electricity, and whether there have been power interruptions (see **Table 2.1**). Some surveys also ask about sources of electricity, functionality and operability; a very small number of surveys ask about how power is used, or other indicators. A notable exception is ESMAP’s MTF surveys for health-care facilities. The explicitly stated purpose of the MTF surveys has been to collect nuanced information that goes beyond the “traditional binary measurement of energy access”, by measuring attributes such as end-user needs, affordability and availability of energy sources in a given local community (Bhatia & Angelou, 2015). Even so, the questions selected for the MTF surveys often have little overlap with questions in more widely implemented surveys, again hindering comparability. Future MTF surveys should ideally include questions on major indicators that can be harmonized with SPA, SARA, SDI and other mainstream surveys; more detailed questions about electrification status, reliability, affordability and use; and questions about the energy source used as the main source or backup source (e.g. solar system, solar system combined with battery storage, fuel-based generator).

In addition to data on electricity access, reliability and source, another critical category for indicators – which is rarely provided in existing surveys – is how electricity is used. Electricity access is not an end in itself, but rather an enabler for health service delivery. But information on how facilities use electricity (e.g. for appliances, stand-alone devices, lighting, information and communications technology, cold chain) is currently available primarily through a handful of SARA surveys. This indicator is particularly valuable for determining how the power source affects adequacy and utility – moving beyond assessing infrastructure for its own sake – and showing how electricity is useful for service delivery from the perspective of frontline health-care professionals.

Another notable area for which the most common set of survey questions offers little insight is mini-grid connections. When asking about type of connection, very few surveys present mini-grids as a separate response option; where the response options specifically mention mini-grids, they are typically combined with central or national grids, so that it is not possible to determine whether a facility that selects that response option is connected to a national grid or a private or community mini-grid. This makes it impossible to evaluate whether connections through mini-grids are becoming more or less prevalent, or whether they offer superior (or inferior) characteristics for reliability, affordability and so on. This is problematic given that the World Bank, International Energy Agency and other observers project that mini-grids will be increasingly important for providing high-quality electrification services in rural and even some urban areas (ESMAP, 2019). Distinguishing mini-grid connections from central or national grid connections would help to match the evidence base to projections from donors and decision-makers.

Wherever possible, data on health-care facility electrification should be provided with accompanying geospatial data, such as health-care facility geographical coordinates and facility catchment area boundaries. This would facilitate spatial analyses and more intuitive visualizations, and allow more seamless integration into geospatial-based planning tools, such as the World Bank's GEP and the World Resources Institute's EAE. Geospatial data and analyses are useful tools (see Chapter 4) for policy-makers seeking to better understand exactly which and where health system electrification interventions are most needed, and should be prioritized given limited resources.

Accessing up-to-date and standardized geospatial data that have been validated by country governments continues to be a major impediment to incorporating spatial data into analyses and tools. Different organizations and even ministries within the same country may use different geospatial datasets for important layers such as health-care facilities, facility catchment areas and even administrative boundaries, at times with little or no coordination with each other. Better coordination is needed between both in-country and international institutions to consolidate and harmonize existing geospatial datasets for countries, to maximize the impact and transferability of research findings from one sector to another.

To help address this problem, in recent years initiatives such as Geo-Referenced Infrastructure and Demographic Data for Development have begun to work with ministries of sub-Saharan African countries to take stock of, and harmonize, existing geospatial datasets for layers that are essential for infrastructure planning and development, such as administrative boundaries, population estimates, settlements and health-care facilities. In addition, open-source online platforms such as the Humanitarian Data Exchange are useful for facilitating the sharing of geospatial data and relevant documentation between organizations; they are especially valuable for quickly and easily disseminating newly updated and/or standardized datasets from organizations such as Geo-Referenced Infrastructure and Demographic Data for Development to a wide audience.

Institutions and governments can collectively help improve the accessibility, quality and impact of geospatial data and tools by routinely sharing and updating their data on open-source platforms such as Humanitarian Data Exchange, so that the data may be used in ongoing or future data harmonization efforts. Government ownership of the data and data repository may be necessary to ensure continuous updating and data sharing in the long term. Geospatial datasets such as those provided by the WHO Polio Information System offer a useful blueprint for how data can be standardized at a global scale across different countries and administrative levels, even if data from certain countries are still only operational (i.e. still undergoing validation and not "official").

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[→ Data-related action 2:](#)

Prioritize public access to data on health-care facility electrification.

Data collection is often challenging because of difficulties in accessing health-care facility data sources. This relates to the lack of a clear mechanism for making data requests, and the sometimes complex bureaucracy associated with soliciting microdata – and sometimes even summary reports – from responsible agencies. Furthermore, the process often differs from country to country and even within countries, depending on the data source. Future efforts to gather data to facilitate planning and prioritization would benefit greatly from the establishment of publicly accessible online platforms, so that survey data can be obtained by researchers on request. Good examples of such web-based portals are the Demographic and Health Survey, PMA and Integrated Public Use Microdata Series websites.

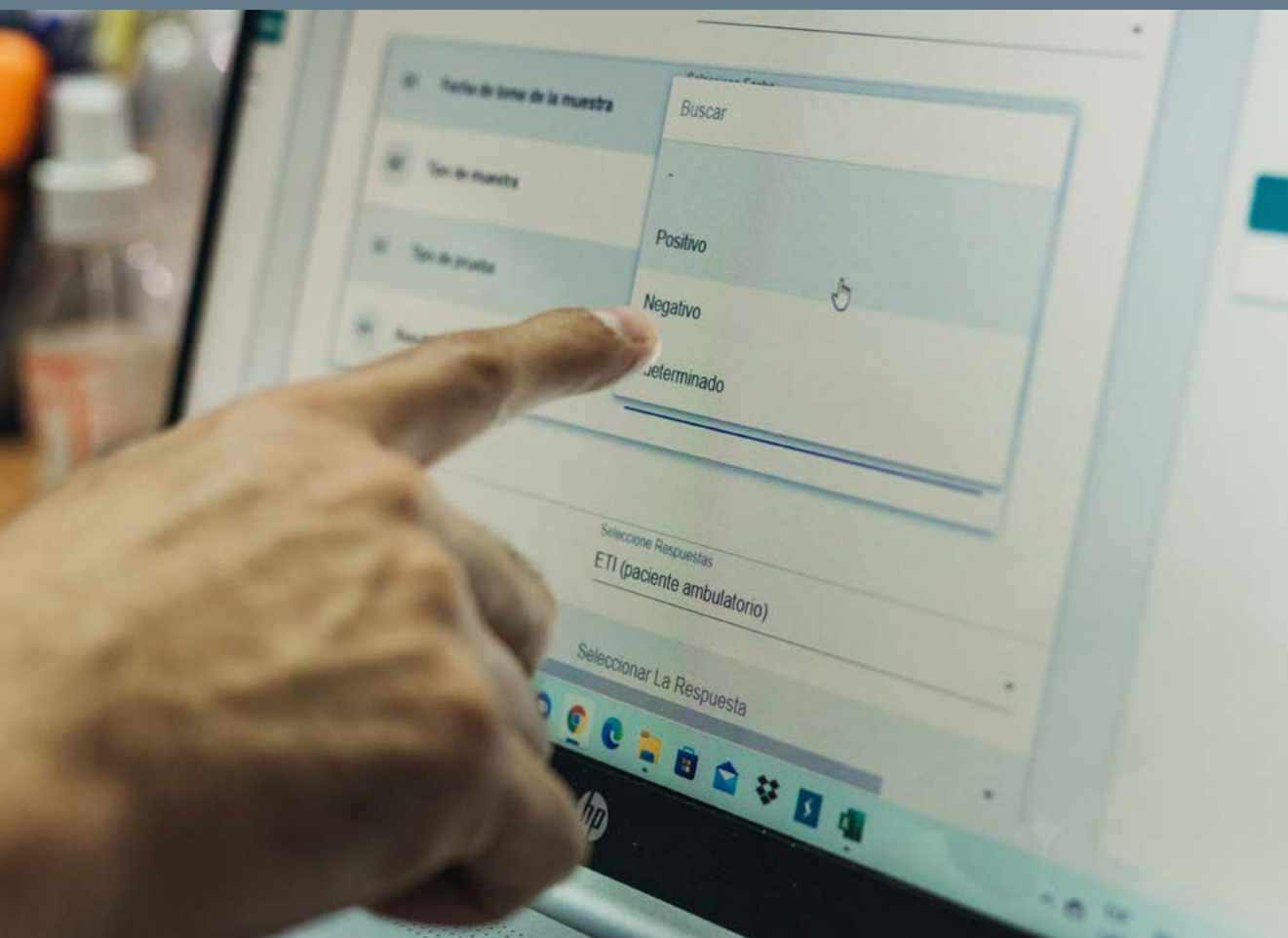
In some cases, the entities that sponsor or assemble health-care facility data may not have the resources to compile an entire programme website to make data publicly accessible. In this case, the World Bank Microdata Library could be a useful resource. This houses a number of relevant datasets, and encourages entities uploading data to include summary reports, metadata such as data dictionaries, and procedures for accessing microdata. As a pre-existing platform that can accommodate many different types of data, while still encouraging publication of questionnaires and metadata alongside output reports and microdata, the World Bank Microdata Library offers a platform to publish “one-off” surveys that are not necessarily part of an established programme such as the Demographic and Health Survey or PMA. But it can also accommodate surveys that are part of an established programme, which can then be identified through the use of keywords and dataset identifiers. Similarly, the WHO GHO is a useful resource for accessing a variety of data sources on electrification in health-care facilities, as well as other relevant information. At the country level, a good example is the Ghana Statistical Service’s data catalogue (<https://www2.statsghana.gov.gh/nada/index.php/catalog>).

In some cases, host country governments may be reluctant to publicly disclose data on health-care facility electrification – for example, for political reasons. These concerns can be partly mitigated by putting in place standard procedures for data security and facility anonymization, such as restricting access to facility names or geographic identifiers.

[→ Data-related action 3:](#)

Incorporate routine data collection and updates into national health information systems.

Ministries of health should incorporate routine data collection and update into national health information systems. Platforms already in place, such as the DHIS2 platform, could be leverage to collect spatially and temporally granular data on health-care facility electricity access, reliability, source and use or services enabled. DHIS2 (see Chapter 2 **Box 2.7**) is rapidly scaling up across low- and middle-income countries in sub-Saharan Africa and South Asia. This rapid adoption has occurred partly because the platform allows health district administrators and local health-care facility staff to submit routine data through a single streamlined interface, and partly because of its highly flexible and adaptable design. Planners can customize the platform to suit the routine data reporting needs of each country and individual health programmes. In many settings, health workers already use DHIS2 to regularly submit data on the monitoring and maintenance of essential facility infrastructure and equipment to more senior officials. Adding a few key variables to monitor facility electricity access and reliability could be a viable and pragmatic solution for collecting such data at high spatial and temporal frequency. This would also avoid the need for resource-intensive cross-sectional surveys, by leveraging the digital infrastructure and massive ongoing routine data collection efforts that are already in place.



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In its ongoing work with DHIS2 to create a set of standardized health data “toolkits” – open-source routine data entry forms and templates that countries can use to collect data on essential health programme indicators, such as for immunization and HIV treatment – WHO has created a list of core facility indicators that will play a key role in gathering standardized information on electricity access, reliability, sources or use. Some capacity-building may be required for the staff responsible for collecting these data where remote monitoring is not possible.

The development of an infrastructure-focused health-care facility data toolkit that includes electricity-related indicators would serve several functions. It would provide planners with the ability to identify, in near real time, specific administrative units and even specific facilities where electricity access and reliability are especially acute, and to understand how these may fluctuate throughout the year. Linking of data on the provision and use of health-care facility services with data on the availability and quality of electricity access (and other infrastructure) would better enable planners to direct resources, including resources for O&M, to the facilities and areas in greatest need.

Routine data are increasingly being used in scientific studies that are used to inform policy. Among other actors, researchers should be able to access routine data to help build the evidence base on how electricity access by health-care facilities promotes improved health service delivery. These data would also improve the ability of donors and other stakeholders to monitor and evaluate the results of their programmes, by providing access to consistent and timely indicators of both infrastructure and the services that it enables.

[→ Data-related action 4:](#)**Leverage automated, remote monitoring to collect data on system functionality over time.**

Monitoring the functionality of energy supply systems over time is essential. This includes monitoring power production from solar systems, the functionality of batteries or fuel-based generators, the electricity supply from a centralized grid or mini-grid, refrigerator temperatures, and so on. Automated equipment monitoring devices can assist with routine O&M (see Chapter 4), and feed back into decisions about planning and budgeting (e.g. providing better backup power in areas with frequent grid interruptions) or maintenance planning (e.g. scheduling more frequent cleaning of solar panels if power production decreases faster than would be expected from normal degradation). Once installed, these devices require little or no input from health-care facility staff to maintain their function and report critical real-time data. Although unreliable internet connections can be a limitation, remote monitors with supplementary data storage can allow offline data collection, with the data uploaded once an connection is re-established.

[→ Data-related action 5:](#)**Improve the accessibility of metadata and documentation.**

Entities responsible for survey implementation should thoroughly document and make publicly available relevant information from all steps throughout the data collection process. This includes information on questionnaire design, survey sampling frames, survey weights, data cleaning, data anonymization (if applicable), metadata (including variable definitions) and data limitations. Survey microdata and related documentation, such as the survey final report, questionnaires and metadata, should be made available upon request through public data-sharing platforms or ministry-managed portals (such as the Ghana Statistical Service’s data catalogue). As previously mentioned, publicly accessible platforms such as Humanitarian Data Exchange can also be useful for disseminating non-sensitive survey data and relevant ancillary data (e.g. facility geographical coordinates, catchment areas) to the public.

Finally, countries and entities responsible for implementing surveys could require data users to provide their resulting publications, so that these can be made available on the same data-sharing portal as microdata and related documentation. This would allow researchers and policy-makers to more easily access the research methods and findings of other users, and thereby reduce the risk of duplication of analysis efforts, leverage synergies, and facilitate increased collaboration between different institutions and disciplines. The Demographic and Health Survey data platform provides a good example of how published research can be made available on the same portal as data.

[→ Data-related action 6:](#)**Improve country-level data for systems tracking and accountability.**

Several countries have no reliable government data on how many systems have been installed in the country and how many are functioning, which makes it difficult to track the accountability of installed systems over the years. For example, there have been instances where batteries have been taken out or the solar systems no longer work. In some cases, although the health centre is the owner of the assets, it has no operational funds available for servicing, so that systems that need repair end up being idle. In several cases, electrification programmes have not allocated funds for O&M over multiple years or for replacements of damaged equipment, and the health ministry budget is too small to allocate budgets for maintaining the solar system. Systems need to be designed based on need over the years, and a detailed plan for O&M expenses should be put in place. Local stakeholders

should be involved regularly so that there is a sense of ownership. National governments should keep a registry of all electrification projects, along with the stakeholders involved, so that the responsible parties are held accountable.

8.2 System planning actions

[→ System planning action 1:](#)

Leverage the data from routine data collection and remote monitoring to feed back into policy and planning.

Time-series data on electricity availability, reliability and use, paired with information about facility infrastructure, service hours, health service delivery and available equipment, can help policy-makers and other stakeholders plan interventions, estimate demand from health-care facilities, and more efficiently and effectively electrify a greater number of facilities. Tool developers and system planners should leverage data from routine data collection platforms (such as DHIS2) and remote monitoring on system quality and use, to refine overall demand prediction (e.g. average use) and data on variations over time (e.g. seasonal trends, daily load profiles). Using more detailed data from collection tools that take minimal time on the part of health-care facility staff would reduce the burden on staff to provide information to improve demand assessment and system sizing tools. It would also allow stakeholders to assess the fit and accuracy of engineering and economic model estimates.

An important caveat is that routine data collection and remote monitoring tools cannot substitute entirely for on-the-ground, facility-level data collection. Before designing a particular solution, a physical site assessment would still be required to check the physical feasibility of the available energy supply options, wiring or re-wiring of the electricity system at the facility, and other infrastructure (e.g. checking the structural integrity and load-bearing capacity of the rooftop for solar systems).

[→ System planning action 2:](#)

Improve the availability and accessibility of customized tools for estimating electricity demand in health-care facilities.

As noted in Chapter 3, it is essential that tools to support demand assessment and other planning aspects for health-care facility electrification are tailored to the needs of each health-care facility, and are as user-friendly as possible so that they can be used by staff and planners who may not be energy specialists. The SELCO Foundation toolkit and the HOMER Powering Health tool, described in Chapters 3 and 4, are examples of how existing tools can be adapted to a target audience by providing estimates and default assumptions that relate to health-care facilities specifically. Other tools could be similarly adapted to improve intuitive accessibility for the end-user community, such as health practitioners and planners who may be unfamiliar with energy demand prediction. Such tools may also lay the groundwork for developing specialized technical guidance or training, and creating a user community that can facilitate high-quality demand assessment at lower cost.

Other capabilities could be added to existing tools to make them more useful and robust. For instance, the tools could be improved by incorporating probabilistic modelling to accommodate discontinuous or unpredictable power outages, and by increasing customization options for costs, including O&M. Tool improvement should ideally be provided in an open-source manner.

Demand assessment tools should also adjust the selection of medical devices to take into account the burden of infectious and non-infectious diseases in the country, and perhaps in regions (e.g. provinces) within a country. For instance, in countries and regions where HIV is prevalent, district hospitals may have different energy needs because cluster of differentiation 4 count machines are a higher priority. Similarly, demographic profiles affect the prevalence of noncommunicable diseases, which may drive the necessity for different devices. Software packages for assessing necessary equipment and system electrification requirements should allow users to customize accordingly. It is also key that these assessment tools account for development and availability of new, and more efficient and suitable, medical devices and equipment.

→ [System planning action 3:](#)

Improve the availability of appropriately sized and designed medical equipment for health-care facilities in resource-constrained areas.

Manufacturers should be encouraged, including through specific incentives, to design and produce medical devices designed for harsh conditions and low-resource settings – for example, devices that are efficient, are suitable for use in extreme temperatures or dusty environments, require low maintenance, and are simple and user-friendly. Furthermore, health infrastructure standards should allow adoption of such devices.

Considerable opportunities exist for mainstreaming efficient medical appliances, and ensuring that they are designed for remote settings with extreme temperature conditions and other harsh conditions, and are affordable. Integration of efficiency and other parameters in infrastructure guidelines and health infrastructure standards will help ensure better selection of medical equipment by health-care facilities and improve the uptake of suitable medical equipment.

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[→ System planning action 4:](#)

Build the knowledge base on the impacts of energy supply options for health-care facility electrification.

Building a base of evidence on impacts of health-care facility electrification allows planners and donors to evaluate the effectiveness of various delivery and financing models. Furthermore, monitoring platforms evaluating these facilities should go beyond energy generation and reduction in greenhouse gas and polluting emissions to encompass the health impacts of electrification programmes – for example, in terms of number of patients served, medical service improvement and additions, extension of operating hours, and impact on well-being of health-care staff and patients.

[→ System planning action 5:](#)

Improve coordination between key ministries in the planning process.

Improved coordination between the energy and health sectors and stakeholders is essential to accelerate electrification of health-care facilities. Global efforts to increase coordination between health and energy include the Health and Energy Platform of Action, the High-Level Coalition on Health and Energy, and the Multilateral Energy Compact for Health Facility Electrification.

In particular, breaking out of ministerial silos is critical for developing electrification plans tailored to health infrastructure. This requires cooperation across a number of actors – from the ministry of energy and ministry of health to the ministry of finance – at different levels. Coordination needs to occur in strategy and planning, budgeting, procurement and implementation. Although projects can be the catalyst for bringing together these actors, there needs to be a long-term enabling institutional framework so that coordination is a continuous, dynamic process. For instance, this might entail setting up a formal multisectoral coordination committee at country level to facilitate planning and effective investments.

An important coordination element involves coordination between electrification programmes and the choice and supply of medical devices and appliances (see programme implementation action 2). Creating the institutions that facilitate joint optimization starts at the planning level.

[→ System planning action 6:](#)

Scale up investments in health-care facility electrification.

Increased public finance and support from governments, development partners, philanthropic institutions and development financial institutions are essential for accelerating health-care facility electrification and maintaining energy supply in health-care facilities. In addition to public-led funding support, other financing sources – including from the private sector – can be leveraged to scale up health-care facility electrification. Different electrification models can better suit different contexts. For example, service-based models can complement the traditional ownership approach under certain conditions. It is essential to keep in mind that health is a human right and a public responsibility, and that the priority in all health-care facility electrification programmes is to protect vulnerable populations and ensure adequate health services. This principle must guide any collaboration between public, private and nongovernmental institutions.

[→ System planning action 7:](#)**Promote climate-resilient and environmentally sustainable technologies for electrification of health-care facilities.**

The increased frequency and intensity of extreme events associated with climate change can have a disruptive impact on electricity infrastructure, leading to the need for more climate-resilient (main or backup) electricity sources. Health-care facilities are not necessarily designed to accommodate physical climate risks, such as droughts, floods, lightning, extreme temperatures and wildfires, which can damage the central power grid or interrupt the fuel supply chain for diesel generators. Designing energy solutions that can cope with evolving climate-related risks and ensure energy supply during adverse climate events is important for all facilities. Decentralized renewable energies play a crucial role in this context.

In addition, unpredictability of water supply and water scarcity can affect the availability of water for drinking, washing, sanitation and hygiene. Clean and safe water supply is critical for effective health service delivery, and inadequate waste management systems can lead to local environmental contamination – often exacerbating disease burdens. Ensuring reliable energy supply is essential to address these challenges.

Reliability of energy supply is also key for the operation of sensitive medical equipment. In addition, more appropriately designed medical equipment is needed – with supporting technical standards, government incentives and regulatory policies – that is energy-efficient, robust and climate-resilient.

[→ System planning action 8:](#)**Ensure adequate allocation of finances and efficient management of funds.**

As highlighted in other parts of this document, ensuring appropriate O&M of energy systems in the medium to long terms is essential, and funds need to be allocated accordingly. Unfortunately, financing from the public sector is often unpredictable over the years. As well, the typical funding periods of international donors are often quite brief and not able to cover the long-term costs for O&M. There is a need to ensure a sustainable and efficient allocation and management of funds, including multi-year disbursements to cover O&M costs, to avoid the “install and forget” approach and ensure that energy systems continue to work properly.

[→ System planning action 9:](#)**Create and recommend guides and standards.**

In many areas, optimizing system design tailored to health-care facilities continues to be a challenge because of a lack of quality standards for system components, and a lack of installation guidelines and standard operating procedures. Further, since O&M procedures can be more complex in these areas, additional hardware and software innovation for remote monitoring of system performance can help in timely maintenance of systems. Guides and standards based on international benchmarks should be made available to programme designers and implementers to ensure the quality of system design, installation and maintenance.

8.3 Programme implementation actions

[→ Programme implementation action 1:](#)

Design programmes in a way that supports local markets and capacity development.

Developing local markets that can provide equipment, replacement parts and maintenance services, and strengthening local human capacities and skills (i.e. through training and capacity-building) increase the ability of health sector staff and planners to identify needs, select the best electrification options and secure O&M contracts with local providers. This increases the effectiveness of the energy systems in health-care facilities and also brings other benefits, including local jobs, related business opportunities and socioeconomic benefits for residents in local communities. Some aspects of market development are in the ambit of national ministries of economic development, but some elements can be incorporated directly into design of electrification programmes. As discussed in Chapters 6 and 7, these include tax exemptions for solar products to be installed in health-care facilities, incentives for international bidders to partner with local solar companies to provide O&M services, and long-running and transparent policies to support local service providers. The country-level case studies highlight that the countries demonstrating longer-term success in scaling up and continued functionality also have well-developed solar markets, with local providers who can offer system design and construction, as well as O&M services.

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[→ Programme implementation action 2:](#)**Coordinate electrification efforts with the provision of medical devices and appliances.**

It is important to avoid situations in which the health-care facility is not equipped with power-dependent devices and appliances even after its electrification. Energy systems need to be designed to accommodate the demand for new equipment and appliances, but facilities need additional financial and logistical support to acquire power-dependent medical devices after electrification. Energy access programmes should be undertaken in coordination with programmes aimed at providing medical equipment and relevant appliances, to ensure the health impact. At the same time, facility staff should be provided with the necessary training to properly use the new energy system and devices.

[→ Programme implementation action 3:](#)**Earmark O&M funds in budgets at the national, district or facility levels.**

All programmes should incorporate budgeting for long-term O&M from the start, along with financing for equipment replacement (including batteries) and proper management or disposal at their end of life. Although training of health-care staff and community members on basic O&M and troubleshooting can help, establishing long-term O&M contracts and developing O&M budgeting plans is essential to ensure system sustainability.

Several approaches are possible for financing O&M. Two common examples are the annual budgeting for O&M being provided by relevant line ministries at the national or district level, and O&M being financed at the facility level. There is a trade-off in risks between these two approaches. National or district-level government budgets ensure that all covered facilities have support, but this may be influenced by political changes. Facility-level O&M line items avoid that risk, but also put the onus on local facilities that are balancing competing interests vying for their resources. Another possible approach is for development partners to transfer funds earmarked for O&M to local institutions or NGOs, which would use the funds only for those services and when necessary over the years.

[→ Programme implementation action 4:](#)**Create accountability mechanisms at the facility level.**

If basic O&M is the responsibility of health-care facilities, facility staff need to be adequately trained, incentivized and accountable. Often when health-care facilities have solar power systems installed, health professionals are assumed to take charge of maintaining the systems. These programmes are often successful initially, and then fail once maintenance issues arise. Without adequate, sustained training of health professionals on how to identify basic maintenance issues and seek appropriate technical support, the systems will not be serviced, and the assets will sit idle. To build local capacity, initiatives such as a solar regional health resource centre can be set up by the government or other actors with local involvement to provide training, resources and jobs for local communities to maintain the solar facilities in the long term. Finally, visits from district-level supervisors, coupled with remote monitoring, can support accountability.

[→ Programme implementation action 5:](#)**Include O&M contracts in the initial procurement stage.**

One way to ensure the implementation of O&M is to require participants in electrification programmes to account for O&M contracts in the initial bidding proposals. In some cases,

international companies are encouraged to partner with local companies to ensure that a local service agent will be available post-installation. This can promote the development of a local skilled solar labour force and market, which will be useful to serve other commercial, institutional and residential users, and will promote a growing market and investments in the country.

[→ Programme implementation action 6:](#)

Connect system monitoring to data on health service delivery and outcomes, and use this to improve implementation.

Most programmes provide little information about how many systems still function months or years after deployment, and even less data to connect system functionality to health outcomes. This leaves planners, decision-makers and researchers with very limited data to answer essential questions about planning and implementation, such as: How can planners with resource constraints most effectively deploy limited investment funds to electrify facilities and improve health outcomes? When it comes to equipment choices, what is the trade-off between standardization and customization? Which approach to fostering health sector ownership and institutionalizing coverage of O&M costs is most effective over the long term? Collecting energy system monitoring data, and linking this to health service delivery and outcomes, would be useful for decision-makers to identify the most suitable electrification approaches in certain contexts, and ultimately to maximize individual, community and population health outcomes.

[→ Programme implementation action 7:](#)

Integrate capacity-building into programme design to ensure successful implementation.

The human resources needed to design and implement sustainable delivery models tailored to the health sector may not be immediately available in resource-constrained countries, but they are necessary to ensure the success of any programme. Developing the key knowledge and capacities requires investing in training and capacity-building activities, and creating a space for health and electricity sector representatives to collaborate, learn and disseminate insights. Capacity-building may create opportunities to identify and engage with champions of the health-care facility electrification agenda, especially among administrative staff and frontline health-care workers.

[→ Programme implementation action 8:](#)

Promote aggregation of demand.

For private sector enterprises, installing and maintaining systems can be very expensive, depending on the geographic context. If installations are few, far apart and located in remote geographies, the cost for providing the service would be significant. To provide services at affordable costs, private sector actors need to have a large enough market, which is not possible until there is aggregation of demand. Such demand could come not just from health-care facilities but also from other local energy needs, such as households, schools, government buildings and local businesses. The higher the demand and density of installations, the more likely it is that the local enterprises can maintain these energy systems effectively, and in a sustainable and timely manner.

REFERENCES

References for Chapter 1:

- Adair-Rohani H, Zukor K, Bonjour S, Wilburn S, Kuesel AC, Hebert R, et al. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability. *Glob Health Sci Pract.* 1(2):249–61. doi:10.9745/GHSP-D-13-00037.
- Apenteng BA, Opoku ST, Ansong D, Akowuah EA, Afriyie-Gyawu E (2018). The effect of power outages on in-facility mortality in healthcare facilities: evidence from Ghana. *Glob Public Health.* 13(5):545–5. doi:10.1080/17441692.2016.1217031.
- Chang W, Cohen J, Mwesigwa B, Waiswa P, Rokicki S (2022). Impact of reliable light and electricity on job satisfaction among maternity health workers in Uganda: a cluster randomized trial. *Hum Resour Health.* 20(1):30. doi:10.1186/s12960-022-00722-3.
- Chawla S, Kurani S, Wren SM, Stewart B, Burnham G, Kushner A, et al. (2018). Electricity and generator availability in LMIC hospitals: improving access to safe surgery. *J Surg Res.* 223:136–41. doi:10.1016/j.jss.2017.10.016.
- Chen YJ, Chindarkar N, Xiao Y (2019). Effect of reliable electricity on health facilities, health information, and child and maternal health services utilization: evidence from rural Gujarat, India. *J Health Popul Nutr.* 38(1):7. doi:10.1186/s41043-019-0164-6.
- Conradi N, Claude KM, Lee BE, Saleh A, Mandhane P, Hawkes M (2021). Utility of solar-powered oxygen delivery in a resource-constrained setting. *Pulmonology.* doi:10.1016/j.pulmoe.2021.11.005.
- Cronk R, Bartram J (2018). Environmental conditions in health care facilities in low- and middle-income countries: coverage and inequalities. *Int J Hyg Environ Health.* 221(3):409–22. doi:10.1016/j.ijheh.2018.01.004.
- Dhara VR, Schramm PJ, Lubner G (2013). Climate change & infectious diseases in India: implications for health care providers. *Indian J Med Res.* 138(6):847–52.
- Dholakia HH (2018). Solar powered healthcare in developing countries. *Nat Energy.* 3(9):705–7. doi:10.1038/s41560-018-0205-1.
- Duke T, Pulsan F, Panauwe D, Hwaihwanje I, Sa'avu M, Kaupa M, et al. (2021). Solar-powered oxygen, quality improvement and child pneumonia deaths: a large-scale effectiveness study. *Arch Dis Child.* 106(3):224–30. doi:10.1136/archdischild-2020-320107.
- Elahi R, Srinivasan R, Mukurazhizha T (2020). Increasing human capital by electrifying health centers and schools through off-grid solar solutions. Washington, DC: World Bank.
- Forrester JA, Boyd NJ, Fitzgerald JEF, Wilson IH, Bekele A, Weiser TG (2017). Impact of surgical lighting on intra-operative safety in low-resource settings: a cross-sectional survey of surgical providers. *World J Surg.* 41(12):3055–65. doi:10.1007/s00268-017-4293-z.
- Hawkes MT, Conroy AL, Namasopo S, Bhargava R, Kain KC, Mian Q, et al. (2018). Solar-powered oxygen delivery in low-resource settings: a randomized clinical noninferiority trial. *JAMA Pediatr.* 172(7):694–6. doi:10.1001/jamapediatrics.2018.0228.
- IRENA (International Renewable Energy Agency), SELCO Foundation (2022). Electrification with renewables: enhancing healthcare delivery in Burkina Faso. Abu Dhabi: IRENA (<https://www.irena.org/publications/2022/Oct/Electrification-with-renewables-Enhancing-healthcare-delivery-in-Burkina-Faso>, accessed 4 November 2022).
- Irwin BR, Hoxha K, Grépin KA (2020). Conceptualising the effect of access to electricity on health in low- and middle-income countries: a systematic review. *Glob Public Health.* 15(3):452–73. doi:10.1080/17441692.2019.1695873.
- Javadi D, Ssempebwa J, Isunju JB, Yevo L, Amu A, Nabiwemba E, et al. (2020). Implementation research on sustainable electrification of rural primary care facilities in Ghana and Uganda. *Health Policy Plan.* 35(Suppl2):ii124–36. doi:10.1093/heapol/czaa077.
- Khogali A, Ahmed A, Ibrahim M, Karrar K, Elsheikh M, Abdelraheem E, et al. (2022). Building powerful health systems: the impacts of electrification on health outcomes in LMICs. *Psychol Health Med.* doi:10.1080/13548506.2022.2109049.
- Koroglu M, Irwin BR, Grépin KA (2019). Effect of power outages on the use of maternal health services: evidence from Maharashtra, India. *BMJ Glob Health.* 4(3):e001372. doi:10.1136/bmjgh-2018-001372.
- Kumar S, Dansereau E, Carlo WA (2014). Supply-side barriers to maternity-care in India: a facility-based analysis. *PLoS One.* 9(8):e103927. doi:10.1371/journal.pone.0103927.
- Maboshe M, Kabinga M (2018). Facility level access to electricity and the efficiency of maternal and child health service provision in Zambia. London: International Growth Centre (S-41404-ZMB-1; <https://www.theigc.org>).

- org/wp-content/uploads/2018/06/41404-final-paper.pdf).
- Mani S, Patnaik S, Lahariya C (2021). Electricity access, sources, and reliability at primary health centers in India and effect on service provision: evidence from two nation-wide surveys. *Indian J Community Med.* 46(1):51–6. doi:10.4103%2Fijcm.IJCM_170_20.
- Mbonye AK, Mutabazi MG, Asimwe JB, Sentumbwe O, Kabarangira J, Nanda G, et al. (2007). Declining maternal mortality ratio in Uganda: priority interventions to achieve the millennium development goal. *Int J Gynecol Obstet.* 98(3):285–90. doi:10.1016/j.ijgo.2007.05.019.
- Moner-Girona M, Kakoulaki G, Falchetta G, Weiss DJ, Taylor N (2021). Achieving universal electrification of rural healthcare facilities in sub-Saharan Africa with decentralized renewable energy technologies. *Joule.* 5(10):2687–714. doi:10.1016/j.joule.2021.09.010.
- Morrissey B, Conroy N, Estelle A (2015). G260(P) Effect of solar panels on in-patient paediatric mortality in a district hospital in Sierra Leone. *Arch Dis Child.* 100(Suppl3):A114. doi:10.1136/archdischild-2015-308599.253.
- Mubyazi GM, Bloch P, Byskov J, Magnussen P, Bygbjerg IC, Hansen KS (2012). Supply related drivers of staff motivation for providing intermittent preventive treatment of malaria during pregnancy in Tanzania: evidence from two rural districts. *Malaria J.* 11(1):1–14. doi:10.1186/1475-2875-11-48.
- Owili PO, Muga MA, Mendez BR, Chen B (2019). Quality of care in six sub-Saharan Africa countries: a provider-based study on adherence to WHO's antenatal care guideline. *Int J Qual Health Care.* 31(1):43–8. doi:10.1093/intqhc/mzy105.
- Perry L, Malkin R (2011). Effectiveness of medical equipment donations to improve health systems: how much medical equipment is broken in the developing world? *Med Biol Eng Comput.* 49(7):719–22. doi:10.1007/s11517-011-0786-3.
- Reuland F, Behnke N, Cronk R, McCord R, Fisher M, Abebe L, et al. (2020). Energy access in Malawian healthcare facilities: consequences for health service delivery and environmental health conditions. *Health Policy Plan.* 35(2):142–52. doi:10.1093/heapol/czz118.
- Roos N, Kovats S, Hajat S, Filippi V, Chersich M, Luchters S, et al. (2021). Maternal and newborn health risks of climate change: a call for awareness and global action. *Acta Obstet Gynecol Scand.* 100(4):566–70. doi:10.1111/aogs.14124.
- Shastri V, Morse SM (2021). The gendered implications of energy gaps in health care: a comparative analysis of Haiti, Senegal, and the Democratic Republic of Congo. *Health Care Women Int.* Oct 12:1–23. doi:10.1080/0739332.2021.1964503.
- Shastri V, Rai V (2021). Reduced health services at under-electrified primary healthcare facilities: evidence from India. *PLoS One.* 16(6):e0252705. doi:10.1371/journal.pone.0252705.
- Turnbull H, Conroy A, Opoka RO, Namasopo S, Kain KC, Hawkes M (2016). Solarpowered oxygen delivery: proof of concept. *Int J Tuberc Lung Dis.* 20(5):696–703. doi:10.5588/ijtld.15.0796.
- US Global Change Research Program (USGCRP) (2016). The impacts of climate change on human health in the United States: a scientific assessment. Washington, DC: USGCRP (<https://health2016.globalchange.gov>, accessed 18 November 2022).
- Welland A (2017). Electrification of health clinics in rural areas: challenges and opportunities. Cambridge: Smart Villages (Technical Report No. 12; https://e4sv.org/wp-content/uploads/2017/05/TR12-Electrification-of-health-clinics-in-rural-areas-Challenges-and-opportunities_web.pdf, accessed 18 November 2022).
- WHO (World Health Organization) (2019). Maternal mortality. Geneva: WHO (<https://www.who.int/news-room/fact-sheets/detail/maternal-mortality>, accessed 18 November 2022).
- WHO (World Health Organization) (2021a). COP26 special report on climate change and health: the health argument for climate action. Geneva: WHO.
- WHO (World Health Organization) (2021b). Climate change and health. Fact sheet. Geneva: WHO. (<https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health#:~:text=Climate%20change%20affects%20the%20social,malaria%2C%20diarrhoea%20and%20heat%20stress.>)
- World Bank (2017). Implementation completion and results report. Washington, DC: World Bank (Report No. ICR00004301 for MZ-Energy Development and Access Project; <http://documents.worldbank.org/curated/en/530521514407393256/pdf/ICR00004301-12152017.pdf>).
- World Health Organization Regional Office for the Eastern Mediterranean (WHO EMRO) (2021). Solar-powered medical oxygen systems saving lives in Somalia: using innovation to accelerate impact in a fragile setting. Cairo: WHO EMRO (<https://www.emro.who.int/somalia/news/solar-powered-medical-oxygen-systems-saving-lives-in-somalia-using-innovation-to-accelerate-impact-in-a-fragile-setting.html>, accessed 12 December 2022).

References for Chapter 2:

- Adair-Rohani H, Zukor K, Bonjour S, Wilburn S, Kuesel AC, Hebert R, et al. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability. *Glob Health Sci Pract.* 1(2):249–61. doi:10.9745/GHSP-D-13-00037.

- Agence Nationale de la Statistique et de la Démographie (ANSD) and ICF (2020). Senegal: Enquête continue sur la prestation des services de soins de santé (ECPSS) 2019. Dakar, Rockville (MD): ANSD and ICF (<https://www.dhsprogram.com/pubs/pdf/SPA33/SPA33.pdf>, accessed 6 June 2022).
- Chawla S, Kurani S, Wren SM, Stewart B, Burnham G, Kushner A et al (2018). Electricity and generator availability in LMIC hospitals: Improving access to safe surgery. *Journal of Surgical Research*. 223:136-41. doi: 10.1016/j.jss.2017.10.016.
- Cronk R, Bartram J (2018). Environmental conditions in health care facilities in low- and middle-income countries: Coverage and inequalities. *International Journal of Hygiene and Environmental Health*. 221:409-22. doi: 10.1016/j.ijheh.2018.01.004.
- de Walque D, Cros M, Calonges J, Raymond S (2016). Etude d'impact sur le financement basé sur les résultats (FBR), enquête ménages - étude de base. Washington (DC): World Bank. doi: 10.48529/cv7s-wf69.
- Dornan M (2015). Renewable energy development in small island developing states of the Pacific. *Resources*. 4(3):490-506.
- Energy Sector Management Assistance Programme (ESMAP) (2022). Global electrification platform. Washington (DC): World Bank Group (<https://electrifynow.energy-data.info/about>, accessed 12 December 2022).
- GHDx (Global Health Data Exchange) (2013). Panama Salud Mesoamérica Initiative Baseline Health Facility Survey 2013 [website]. Seattle: Institute for Health Metrics and Evaluation (<https://ghdx.healthdata.org/record/ihme-data/panama-salud-mesoam%C3%A9rica-initiative-baseline-health-facility-survey-2013>, accessed 13 June 2022).
- GHDx (Global Health Data Exchange) (2014). Honduras Salud Mesoamérica Initiative First Follow-Up Health Facility Survey 2014. Seattle: Institute for Health Metrics and Evaluation (<https://ghdx.healthdata.org/record/ihme-data/honduras-salud-mesoam%C3%A9rica-initiative-first-follow-health-facility-survey-2014>, accessed 13 June 2022).
- GHDx (Global Health Data Exchange) (2015). Costa Rica Salud Mesoamérica Initiative Health Facility Survey 2015. Seattle: Institute for Health Metrics and Evaluation (<https://ghdx.healthdata.org/record/ihme-data/costa-rica-salud-mesoam%C3%A9rica-initiative-health-facility-survey-2015>, accessed 13 June 2022).
- GHDx (Global Health Data Exchange) (n.d.). Salud Mesoamérica Initiative [website]. Seattle: Institute for Health Metrics and Evaluation (<https://ghdx.healthdata.org/series/salud-mesoam%C3%A9rica-initiative-smi>, accessed 13 June 2022).
- Health Care Without Harm (2019). Health care's climate footprint: how the health sector contributes to the global climate crisis and opportunities for action. Health Care Without Harm (https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimate-Footprint_092319.pdf, accessed 12 December 2022).
- Health Resources and Services Availability Monitoring System (2019). World overview: Chad (<https://herams.org/project/33>, accessed 31 January 2022).
- Health Resources and Services Availability Monitoring System (2022a). World overview: Burkina Faso (<https://herams.org/project/31>, accessed 28 July 2022).
- Health Resources and Services Availability Monitoring System (2022b). World overview: Central African Republic (<https://herams.org/project/69>, accessed 29 July 2022).
- Health Resources and Services Availability Monitoring System (2022c). World overview: Yemen (<https://herams.org/project/34>, accessed 2 August 2022).
- IHME (Institute for Health Metrics and Evaluation) (2011). SM2015 Initiative – El Salvador: baseline health facility report, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/El%20Salvador%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2013a). SM2015 – Honduras: baseline health facility, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Honduras%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2013b). SM2015 – Nicaragua: baseline health facility survey, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Nicaragua%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2013c). SM2015 – Mexico: baseline health facility survey, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Mexico%20HF%20Baseline%20Data%20Quality%20Report.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2014a). SM2015 – Belize: baseline health facility survey, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Belize%20Baseline%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2014b). SM2015 – Guatemala: baseline health facility survey, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Guatemala%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2014c). SM2015 – Guatemala: 18-month health facility – San Marcos and Huehuetenango, final report. Seattle: IHME

- (<https://www.saludmesoamerica.org/sites/default/files/open-data/Guatemala%20San%20Marcos%20Huehuetenango%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2014d). SM2015 – Panama: 18-month health facility, final report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Panama%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2015a). SM2015 – El Salvador: 18-month final report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/El%20Salvador%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2015b). SM2015 – Nicaragua: 18-month health facility, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Nicaragua%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2015c). SM2015 – Belize: 18-month health facility, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Belize%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IHME (Institute for Health Metrics and Evaluation) (2015d). SM2015 – Mexico: 18-month health facility, data quality report. Seattle: IHME (<https://www.saludmesoamerica.org/sites/default/files/open-data/Chiapas%201st%20Operation%20Health%20Facility%20Data%20Quality%20Report%20SMI.pdf>, accessed 13 June 2022).
- IRENA (International Renewable Energy Agency), SELCO Foundation (2022). Electrification with renewables: enhancing healthcare delivery in Burkina Faso. Abu Dhabi: IRENA (<https://www.irena.org/publications/2022/Oct/Electrification-with-renewables-Enhancing-healthcare-delivery-in-Burkina-Faso>, accessed 4 November 2022).
- Khogali A, Ahmed A, Ibrahim M, Karrar K, Elsheikh M, Abdelraheem E, et al. (2022). Building power-ful health systems: the impacts of electrification on health outcomes in LMICs. *Psychol Health Med*. Published online 5 August 2022. doi:10.1080/13548506.2022.2109049.
- Liberia Ministry of Health and Social Welfare, Ministry of Health Republic of Liberia (2018). Service availability and readiness assessment (SARA) & quality of care (QOC): 2018 Final Report. Monrovia: Ministry of Health Republic of Liberia.
- Ministère de la Santé Publique de la Population et des Affaires Sociales (2020). Carte sanitaire du Niger (<https://www.cartesanitaireniger.org/data#section-info>, accessed 20 July 2022).
- Ministry of Health (2015). Emergency obstetric and newborn care needs assessment Timor-Leste 2015. Dili: Ministry of Health.
- Ministry of Health (2020). Rwanda health sector performance report 2017-2019 (2020). Kigali: Ministry of Health (https://www.moh.gov.rw/fileadmin/user_upload/Moh/Publications/Reports/FINAL_Annual_Report_2017-2019_02062020.pdf, accessed 6 July 2022).
- Ministry of Health and Child Welfare (2015). Zimbabwe service availability and readiness assessment 2015. Harare: Ministry of Health and Child Welfare (<http://zdh.uz.ac.zw/xmlui/handle/123456789/1425>, accessed 6 June 2022).
- Ministry of Health and Population, Nepal, New ERA, Nepal, and ICF (2022). Nepal health facility survey 2021 final report. Kathmandu, Nepal: Ministry of Health and Population, Kathmandu; New ERA, Nepal; and ICF, Rockville (MD) (<https://dhsprogram.com/pubs/pdf/SPA35/SPA35.pdf>, accessed 20 September 2022).
- Ministry of Health, Nutrition and Indigenous Medicine and Department of Census and Statistics (2018). Service availability and readiness assessment Sri Lanka.
- Mokdad AH, Colson KE, Zúñiga-Brenes P, Ríos-Zertuche D, Palmisano EB, Alfaro-Porras E, et al. (2015). Salud Mesoamérica 2015 Initiative: design, implementation, and baseline findings. *Popul Health Metrics*. 13:3. doi:10.1186/s12963-015-0034-4.
- Mokdad AH, Palmisano EB, Zúñiga-Brenes P, Ríos-Zertuche D, Johanns CK, Schaefer A, et al. (2018). Supply-side interventions to improve health: findings from the Salud Mesoamérica Initiative. *PloS One*. 13(4):e0195292. doi:10.1371/journal.pone.0195292.
- National Institute of Population Research and Training (NIPORT), Ministry of Health and Family Welfare, and ICF (2020). Bangladesh health facility survey 2017. Dhaka, Bangladesh: NIPORT and ICF (<https://www.dhsprogram.com/pubs/pdf/SPA28/SPA28.pdf>, accessed 6 July 2022).
- Organización Panamericana de la Salud (OPS), Organización Mundial de la Salud (OMS) (2022). Protocolo para evaluar la situación del agua, el saneamiento y la higiene en establecimientos de salud con atención a la resiliencia al clima. Washington (DC): World Health Organization (https://iris.paho.org/bitstream/handle/10665.2/55724/978927532501_spa.pdf?sequence=1&isAllowed=y, accessed 19 August 2022).
- Practical Action (2013). Poor people's energy outlook 2013: energy for community services. Rugby, UK: Practical Action Publishing.
- Rockmore C (2015). Niger - service delivery indicators health survey (SDI-H) 2015 - harmonized public use data. Washington (DC): World Bank. doi: 10.48529/ohdb-nb58.
- Shumais M, Mohamed I (2019). Dimensions of energy insecurity on small islands: the case of the Maldives. Tokyo: Asian Development Bank Institute (ADBI Working Paper 1049; <https://www.adb.org/sites/default/>

- files/publication/543261/adbi-wp1049.pdf, accessed 12 December 2022).
- Statistics Sierra Leone (2018). Service delivery indicators health survey 2018 - harmonized public use data (SDI-H 2018). Washington (DC): World Bank. doi: 10.48529/73vd-qp74.
- Tupaia (2022). Vanuatu. Beyond essential systems. (<https://www.tupaia.org/explore/explore/General>, accessed 26 July 2022).
- Wane W (2016). Tanzania service delivery indicators health survey 2016 - harmonized public use data (SDI-H 2016). Washington (DC): World Bank. doi: 10.48529/y6v3-f478.
- Wane W, Chuma J (2018). Service delivery indicators health survey (SDI-H) 2018 - harmonized public use data. Washington (DC): World Bank. doi: 10.48529/nk-dc-s217.
- WHO (World Health Organization) (2018). Climate change and health in small island developing states: a WHO special initiative. Geneva: WHO (<https://apps.who.int/iris/handle/10665/279987>, accessed 12 December 2022).
- WHO (World Health Organization) (2020). WHO guidance for climate-resilient and environmentally sustainable health care facilities. Geneva: WHO (<https://www.who.int/publications/i/item/9789240012226>, accessed 12 December 2022).
- WHO Global Health Observatory (GHO) (2022). The Global Health Observatory. Geneva: World Health Organization (<https://www.who.int/data/gho>, accessed 12 December 2022).
- WHO/UNICEF Joint Monitoring Programme (2022). Progress on WASH in health care facilities 2000-2021: Special focus on WASH and infection prevention and control (IPC). Geneva: World Health Organization (<https://data.unicef.org/resources/jmp-wash-in-health-care-facilities-2022/>, accessed 12 December 2022).
- World Bank (2021). Liberia Electricity Sector Strengthening and Access Project (LESSAP) as Phase 1 of the Multi-Phase Programmatic Approach (Report No: PAD4109). Washington, DC: World Bank (<https://documents1.worldbank.org/curated/en/127771615860080105/pdf/Liberia-Electricity-Sector-Strengthening-and-Access-Project.pdf>, accessed 12 December 2022).
- References for Chapter 3:**
- Bonnema E, Pless S, Doebber I (2010). Advanced energy design guide for small hospitals and healthcare facilities. *J Healthc Eng.* 1(2):21.
- Cesari S, Valdiserri P, Coccagna M, Mazzacane S (2020). The energy saving potential of wide windows in hospital patient rooms, optimizing the type of glazing and lighting control strategy under different climatic conditions. *Energies.* 13(8):2116. doi:10.3390/en13082116.
- CLASP (2021). Medical equipment and clinic electrification: research report. Washington, DC: CLASP (<https://www.clasp.ngo/wp-content/uploads/2021/03/MEDICAL-EQUIPMENT-CLINIC-ELECTRIFICATION-REPORT-2.pdf>).
- Hajison PL, Mwakikunga BW, Mathanga DP, Feresu SA (2017). Seasonal variation of malaria cases in children aged less than 5 years old following weather change in Zomba district, Malawi. *Malaria J.* 16(1):264. doi:10.1186/s12936-017-1913-x.
- Harper MJ, Quetchenbach T, Radecky K, Aikhuele J, Toyama S, Lam N, et al. 2021. Requirements and guidelines for installation of off-grid solar systems for public facilities. Washington, DC: World Bank.
- IRENA (International Renewable Energy Agency), International Energy Agency, United Nations Statistics Division, World Bank, World Health Organization (2020). Tracking SDG 7: the energy progress report 2020. Washington, DC: World Bank (<https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020>, accessed 18 November 2022).
- Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, et al., editors (2006). *Priorities in health.* Washington, DC: World Bank. doi:10.1596/978-0-8213-6260-0.
- Kapoor R, Kumar S (2009). *Energy efficiency in hospitals: best practice guide.* New Delhi: United States Agency for International Development ECO-III Project (https://www.keralaenergy.gov.in/files/Energy_Efficiency_in_Hospitals-_Best_Practice_Guide.pdf).
- MNRE (Ministry of New and Renewable Energy) (2017). Lab policy for testing, standardization and certification for renewable energy sector. New Delhi: MNRE (Office Memorandum 3-2/2015-2016(R & D); https://mnre.gov.in/img/documents/uploads/file_s-1582020759488.pdf).
- Morgenstern P, Raslan R, Ruyssevelt P (2016). Reducing hospital electricity use: an end-use perspective. In: 9th International Conference on Improving Energy Efficiency in Commercial Buildings and Smart Communities, Vol. 9 (https://www.researchgate.net/publication/317576984_Reducing_hospital_electricity_use_an_end-use_perspective, accessed 18 November 2022).
- PMNCH (Partnership for Maternal, Newborn & Child Health) (2011). *Essential interventions, commodities and guidelines for reproductive, maternal, newborn and child health: a global review of the key interventions related to reproductive, maternal, newborn and child health.* Geneva: PMNCH (https://files.givewell.org/files/DWDA%202009/DMI/WHO_guidelines.pdf).
- SELCO Foundation (2020). *SDG7 for primary healthcare infrastructure: draft.* SELCO Foundation (<https://drive.google.com/file/d/1gshKxWxvOYEzUw4MM7aiv-ZLE2a5ApbGO/view>, accessed 18 November 2022).

- SELCO Foundation (2021). Energy efficient appliances for decentralized healthcare. SELCO Foundation (https://selcofoundation.org/wp-content/uploads/2021/11/SF_Energy-Efficient-Appliances-for-Decentralized-Healthcare.pdf).
- United States Department of Energy (2009). Lifetime of white LEDs. Washington, DC: United States Department of Energy (https://betterbuildingsolutioncenter.energy.gov/sites/default/files/attachments/lifetime_white_leds.pdf).
- USAID (United States Agency for International Development) (2020). Technical standards. Washington, DC: USAID (<https://www.usaid.gov/energy/powering-health/technical-standards>, accessed 18 November 2022).
- WHO (World Health Organization) (2010a). Barriers to innovation in the field of medical devices: background paper 6, August 2010. Geneva: WHO (WHO/HSS/EHT/DIM/10.6; <https://apps.who.int/iris/handle/10665/70457>).
- WHO (World Health Organization) (2010b). Medical devices: managing the mismatch: an outcome of the priority medical devices project. Geneva: WHO.
- WHO (World Health Organization) (2014a). WHO guidelines for indoor air quality: household fuel combustion. Geneva: WHO (<https://apps.who.int/iris/handle/10665/141496>).
- WHO (World Health Organization) (2014b). Safe management of wastes from health-care activities, second edition. Geneva: WHO (<https://www.who.int/publications/i/item/9789241548564>).
- WHO (World Health Organization) (2015). Service availability and readiness assessment (SARA): an annual monitoring system for service delivery. Geneva: WHO (<https://apps.who.int/iris/handle/10665/149025>).
- WHO (World Health Organization) (2016). Interagency list of priority medical devices for essential interventions for reproductive, maternal, newborn and child health. Geneva: WHO (<https://www.who.int/publications/i/item/9789241565028>).
- WHO (World Health Organization) (2019). Overview of technologies for the treatment of infectious and sharp waste from health care facilities. Geneva: WHO (<https://apps.who.int/iris/handle/10665/328146>).
- WHO (World Health Organization) (2020). WHO PQS devices catalogue. Geneva: WHO (https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/index.aspx).
- WHO (World Health Organization) (2022). Global analysis of healthcare waste in the context of COVID-19: status, impacts and recommendations. Geneva: WHO (<https://apps.who.int/iris/handle/10665/351189>).
- WHO (World Health Organization), UNICEF (United Nations Children's Fund) (2019). WASH in health care facilities: global baseline report 2019. Geneva: WHO (<https://www.who.int/publications/i/item/9789241515504>).
- WHO (World Health Organization), UNICEF (United Nations Children's Fund) (2020). Global progress report on WASH in health care facilities: fundamentals first. Geneva: WHO (<https://www.who.int/publications/i/item/9789240017542>).
- WHO (World Health Organization), UNICEF (United Nations Children's Fund) (2022). Water and Sanitation for Health Facility Improvement Tool (WASH FIT): a quality improvement tool for strengthening WASH and waste services in health care facilities, second edition. Geneva: WHO.
- WHO (World Health Organization), World Bank (2015). Access to modern energy services for health facilities in resource-constrained settings: a review of status, significance, challenges and measurement. Geneva: WHO (<https://apps.who.int/iris/handle/10665/156847>).
- World Bank (2007). An overview of medical device policy and regulation. Washington, DC: World Bank (<https://documents1.worldbank.org/curated/en/568591468337916050/pdf/388190HNPBrief-801PUBLIC1.pdf>).

References for Chapter 4:

- AAdair-Rohani H, Zukor K, Bonjour S, Wilburn S, Kuesel AC, Hebert R, et al. (2013). Limited electricity access in health facilities of sub-Saharan Africa: a systematic review of data on electricity access, sources, and reliability. *Glob Health Sci Pract.* 1(2):249–61. doi:10.9745/GHSP-D-13-00037.
- Alakori A (2014). PV systems for rural health facilities in developing areas: a completion of lessons learned. Paris: International Energy Agency (https://iea-pvps.org/wp-content/uploads/2020/01/IEA-PVPS_T9-15_2014_PV_for_rural_health_facilities.pdf).
- Alliance for Rural Electrification (2020). Best practices for electrifying rural health care facilities with decentralised renewables. Brussels: Alliance for Rural Electrification (<https://www.ruralelec.org/publications/best-practices-electrifying-rural-health-care-facilities-decentralised-renewables>, accessed 18 November 2022).
- BloombergNEF (2020). 2020 Lithium-Ion Battery Price Survey. BloombergNEF (<https://www.bnef.com/login?r=%2Finsights%2F25115>, accessed 18 November 2022).
- BloombergNEF, SEforALL (Sustainable Energy for All) (2020). State of the global mini-grids market report 2020. SEforALL (<https://www.seforall.org/publications/state-of-the-global-mini-grids-market-report-2020>, accessed 18 November 2022).
- Concessao L, Gupta DK, Deka P (2020). Solar power: a rural Indian hospital's key to fighting COVID-19. Washington,

- DC: World Resources Institute (<https://www.wri.org/insights/solar-power-rural-indian-hospitals-key-fighting-covid-19>, accessed 18 November 2022).
- Elahi R, Srinivasan R, Mukurazhizha T (2020). Increasing human capital by electrifying health centers and schools through off-grid solar solutions. Washington, DC: World Bank. doi:10.1596/33276.
- ESMAP (Energy Sector Management Assistance Program) (2022). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. Washington, DC: World Bank (https://www.esmap.org/Mini_Grids_for_Half_a_Billion_People_The_Report, accessed 18 November 2022).
- Falchetta G, Stevanato N, Moner-Girona M, Mazzoni D, Colombo E, Hafner M (2021). The M-LED platform: advancing electricity demand assessment for communities living in energy poverty. *Environ Res Lett.* 16:074038. doi:10.1088/1748-9326/ac0cab.
- Franco A, Shaker M, Kalubi D, Hostettler S (2017). A review of sustainable energy access and technologies for health-care facilities in the global south. *Sustain Energy Technol Assess.* 22:92–105. doi:10.1016/j.seta.2017.02.022.
- Ginoya N, Meenawat H, Devi A, Deka P, Jairaj B (2021). Powering development in climate vulnerable areas: the role of decentralized solar solutions in India. Washington, DC: World Resources Institute. doi:10.46830/wriipt.19.00058.
- IRENA (International Renewable Energy Agency) (2016). Policies and regulations for private sector renewable energy mini-grids. Abu Dhabi: IRENA (<https://www.irena.org/publications/2016/Sep/Policies-and-regulations-for-private-sector-renewable-energy-mini-grids>, accessed 18 November 2022).
- IRENA (International Renewable Energy Agency) (2022). Renewable Power Generation Costs in 2021. Abu Dhabi: IRENA (<https://www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021#:~:text=The%20global%20weighted%20average%20levelised,%25%20to%20USD%200.075%20FkWh.>, accessed 18 November 2022).
- IRENA (International Renewable Energy Agency), International Energy Agency, United Nations Statistics Division, World Bank, World Health Organization (2020). Tracking SDG 7: the energy progress report 2020. Washington, DC: World Bank (<https://www.irena.org/publications/2020/May/Tracking-SDG7-The-Energy-Progress-Report-2020>, accessed 18 November 2022).
- IRENA (International Renewable Energy Agency), SELCO Foundation (2022). Electrification with renewables: enhancing healthcare delivery in Burkina Faso. Abu Dhabi: IRENA (<https://www.irena.org/publications/2022/Oct/Electrification-with-renewables-Enhancing-healthcare-delivery-in-Burkina-Faso>, accessed 4 November 2022).
- Manhart A, Hilbert I, Magalini F (2018). End-of-life management of batteries in the off-grid solar sector. Bonn: GIZ.
- Moner-Girona M, Kakoulaki G, Falchetta G, Weiss DJ, Taylor N (2021). Achieving universal electrification of rural healthcare facilities in sub-Saharan Africa with decentralized renewable energy technologies. *Joule.* 5(10):2687–714. doi:10.1016/j.joule.2021.09.010.
- Mongird K, Viswanathan V, Alam J, Vartanian C, Sprenkle V, Baxter R (2020). 2020 grid energy storage technology cost and performance assessment. Washington, DC: United States Department of Energy (Publication No. DOE/PA-0204).
- Porcaro J, Mehta S, Shupler M, Kissel S, Pfeiffer M, Dora CFC, et al. (2017). Modern energy access and health. Washington, DC: World Bank.
- Rural Electrification Agency (2022). About NEP. Abuja: Rural Electrification Agency (<https://nep.rea.gov.ng/about-nep>, accessed 18 November 2022).
- Sandwell P, Gibson M, Fohgrub T (n.d.). Estimating the use of diesel generators in displacement settings: preliminary results and recommendations for a solarisation programme. Global Platform for Action, United Nations Institute for Training and Research (https://www.humanitarianenergy.org/assets/resources/Summary_-_Estimating_the_use_of_diesel_generators.pdf).
- SEforALL (Sustainable Energy for All) (2020). Powering health facilities: approach. Vienna: SEforALL (<https://www.seforall.org/system/files/2020-05/SEforALL-powering-health-facilities-approach.pdf>).
- SEforALL (Sustainable Energy for All), ESMAP (Energy Sector Management Assistance Program) (2021). From procurement to performance: towards a private sector-led, service-based model to scale up sustainable electrification of public institutions. Knowledge brief. Vienna: SEforALL (<https://www.seforall.org/publications/from-procurement-to-performance>, accessed 18 November 2022).
- SELCO Foundation (2017). Sustainable energy ecosystems for decentralized healthcare. SELCO Foundation (<https://selcofoundation.org/sustainable-energy-ecosystems-for-decentralized-healthcare>, accessed 18 November 2022).
- SELCO Foundation (2020). SDG7 for primary healthcare infrastructure: draft. SELCO Foundation (<https://drive.google.com/file/d/1gshKxWxvOYEzUw4MM7aiv-ZLE2a5ApbGO/view>, accessed 18 November 2022).
- Tenenbaum BW, Greacen C, Knuckles J, Siyambalapatiya T (2014). From the bottom up: how small power producers and mini-grids can deliver electrification and renewable energy in Africa. Washington, DC: World Bank.
- UN Foundation (United Nations Foundation), SEforALL (Sustainable Energy for All) (2019). Lasting impact: sustainable off-grid solar delivery models to power health and education. United Nations, SEforALL

(https://www.seforall.org/system/files/2019-04/Powering-Health_042019.pdf).

USAID (United States Agency for International Development) (2011). Powering health: electrification options for rural health centers. Washington, DC: USAID (http://pdf.usaid.gov/pdf_docs/PNADJ557.pdf).

USAID (United States Agency for International Development) (2020). Powering health: remote monitoring. Washington, DC: United States Agency for International Development (https://www.usaid.gov/sites/default/files/documents/1865/Powering-Health_Remote-Monitoring.pdf).

USAID (United States Agency for International Development), ESMAP (Energy Sector Management Assistance Program), HOMER Energy, We Care Solar (2020). Powering health [website]. Boulder: HOMER Energy (<https://poweringhealth.homerenergy.com>, accessed 18 November 2022).

von Stackelberg K, Williams PRD, Sánchez-Triana E, Enriquez S, Serrano C (2021). Recycling of used lead-acid batteries: guidelines for appraisal of environmental health impacts. Washington, DC: World Bank (<https://openknowledge.worldbank.org/bitstream/handle/10986/36593/9781464818202.pdf?sequence=4>, accessed 18 November 2022).

WHO (World Health Organization) (2017). Recycling used lead-acid batteries: health considerations. Geneva: WHO (<https://www.who.int/publications-detail-redirect/recycling-used-lead-acid-batteries-health-considerations>).

WHO (World Health Organization) (2020). WHO guidance for climate-resilient and environmentally sustainable health care facilities. Geneva: WHO (<https://www.who.int/publications-detail-redirect/9789240012226>).

WHO (World Health Organization), World Bank (2015). Access to modern energy services for health facilities in resource-constrained settings: a review of status, significance, challenges and measurement. Geneva: WHO (<https://apps.who.int/iris/handle/10665/156847>).

References for Chapter 5:

Healthsites (2022). Healthsites.io [website] (<https://healthsites.io>, accessed 26 April 2022).

HOMER Energy (n.d.). HOMER Powering Health Tool [website]. Boulder, Colorado: HOMER Energy (<https://poweringhealth.homerenergy.com>, accessed 26 April 2022).

Maina J, Ouma PO, Macharia PM, Alegana VA, Mitto B, Fall IS, et al. (2019). A spatial database of health facilities managed by the public health sector in sub Saharan Africa. *Sci. Data*. 6(1):134. doi:10.1038/s41597-019-0142-2.

Mentis D, Howells M, Rogner H, Korkovelos A, Arderne C, Zepeda E, et al. (2017). Lighting the world: the first

application of an open source, spatial electrification tool (OnSSET) on sub-Saharan Africa. *Environ Res Lett*. 12(8):085003. doi:10.1088/1748-9326/aa7b29.

Moner-Girona M, Kakoulaki G, Falchetta G, Weiss DJ, Taylor N (2021). Achieving universal electrification of rural healthcare facilities in sub-Saharan Africa with decentralized renewable energy technologies. *Joule*. 5(10):2687. doi:10.1016/J.JOULE.2021.09.010.

Taliotis C, Shivakumar A, Ramos E, Howells M, Mentis D, Sridharan V, et al. (2016). An indicative analysis of investment opportunities in the African electricity supply sector: using TEMBA (The Electricity Model Base for Africa). *Energy Sustain Dev*. 31:50–66. doi:10.1016/j.esd.2015.12.001.

United Nations (2015). Sustainable Development Goal 7 [website]. United Nations (<https://sustainabledevelopment.un.org/sdg7>, accessed 16 January 2019).

USAID (United States Agency for International Development) (2011). Powering health: electrification options for rural health centers. Washington, DC: USAID (https://pdf.usaid.gov/pdf_docs/PNADJ557.pdf, accessed 26 April 2022).

WHO and World Bank. 2015. *Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings: A Review of Status, Significance, Challenges and Measurement*. World Health Organization. <https://apps.who.int/iris/handle/10665/156847>.

World Bank Group (2022). Global Electrification Platform [website]. Washington, DC: World Bank (<https://electrifynow.energydata.info>, accessed 26 April 2022).

References for Chapter 6:

Al-Akori A (2014). PV systems for rural health facilities in developing areas: a completion of lessons learned. Paris: International Energy Agency (https://iea-pvps.org/wp-content/uploads/2020/01/IEA-PVPS_T9-15_2014_PV_for_rural_health_facilities.pdf).

Ali S, Tongia R (2018). Energy sector data: suggestions for improving data quality and usability. Discussion paper. Washington, DC: Brookings Institution (<https://www.brookings.edu/research/energy-sector-data-suggestions-for-improving-data-quality-and-usability>, accessed 18 November 2022).

Alliance for Rural Electrification (2020). Best practices for electrifying rural health care facilities with decentralised renewables. Brussels: Alliance for Rural Electrification (<https://www.ruralelec.org/publications/best-practices-electrifying-rural-health-care-facilities-decentralised-renewables>, accessed 18 November 2022).

Centre for Budget and Policy Studies, Karnataka State Health Systems Resource Centre (2012). Differential financing for untied funds, ARS corpus and AMG funds

- in public health facilities of Karnataka. Bangalore (<https://cbps.in/wp-content/uploads/Utilization-of-Untied-Funds-RKS-Funds-and-AMG-Funds-in-Public-Health-Facilities-in-Karnataka-March-2012.pdf>).
- Chhattisgarh State Renewable Energy Development Agency (n.d.). Sustainable energy & health centers in Chhattisgarh. Raipur: Chhattisgarh State Renewable Energy Development Agency (https://www.creda.co.in/Image/Leaflet%20on%20Health_11e9a89c-c226d4a6a8b8020000057988.pdf).
- Clarke JM, Waring J, Bishop S, Hartley J, Exworthy M, Fulop NJ, et al. (2021). The contribution of political skill to the implementation of health services change: a systematic review and narrative synthesis. *BMC Health Serv Res.* 21:260. doi:10.1186/s12913-021-06272-z.
- CLASP (2021). Medical equipment & clinic electrification. Efficient for Access Coalition (<https://www.clasp.ngo/wp-content/uploads/2021/03/MEDICAL-EQUIPMENT-CLINIC-ELECTRIFICATION-REPORT-2.pdf>).
- Cleary K, Palmer K (2019). Energy-as-a-service: a business model for expanding deployment of low-carbon technologies. Washington, DC: Resources for the Future (Issue Brief 19-09; https://media.rff.org/documents/IB_19-09_EaaS.pdf).
- Clements B, Coady D, Fabrizio S, Gupta S, Alleyne T, Sdrale-ich C, editors. (2013). Energy subsidy reform: lessons and implications. Washington, DC: International Monetary Fund.
- Devi A, Deka P (2019). Powering remote hospitals with solar: overcoming the remaining challenges. Washington DC: World Resources Institute (<https://www.wri.org/insights/powering-remote-hospitals-solar-overcoming-remaining-challenges>, accessed 23 December 2021).
- Ginoya N, Meenawat H, Devi A, Deka P, Jairaj B (2021b). Powering development in climate vulnerable areas: the role of decentralized solar solutions in India. Washington, DC: World Resources Institute (https://files.wri.org/d8/s3fs-public/2021-04/powering-development-climate-vulnerable-areas.pdf?Version-Id=zM6jasv2v_9a4ajKLnfv4ybs40uRxF4y, accessed 18 November 2022).
- Ginoya N, Narayan U, Concessao L, Deka P, Mandal T (2021a). Integrating electricity priorities into health-care and education in India: a review of national and subnational policies. Washington, DC: World Resources Institute (<https://www.wri.org/research/integrating-electricity-priorities>, accessed 18 November 2022).
- Greer SL, Lillvis DF (2014). Beyond leadership: political strategies for coordination in health policies. *Health Policy.* 116(1):12–17. doi:10.1016/j.healthpol.2014.01.019.
- Harper MJ, Quetchenbach T, Radecky K, Aikhuele J, Toyama S, Lam N, et al. 2021. Requirements and guidelines for installation of off-grid solar systems for public facilities. Washington, DC: World Bank.
- High-Level Coalition on Health and Energy (n.d.). Energizing health: a strategic roadmap to promote healthier populations through clean and sustainable energy. Geneva: World Health Organization (https://cdn.who.int/media/docs/default-source/air-pollution-documents/air-quality-and-health/strategic-roadmap_final_web.pdf?sfvrsn=e2f6bb78_6&download=true, accessed 18 November 2022).
- Jacobs B, Ir P, Bigdeli M, Annear PL, Van Damme W (2012). Addressing access barriers to health services: an analytical framework for selecting appropriate interventions in low-income Asian countries. *Health Policy Plan.* 27(4):288–300. doi:10.1093/heapol/czr038.
- Jharkhand Rural Health Mission (n.d.). Convergence [website]. Namkum: Jharkhand Government (<http://jrhm.jharkhand.gov.in/nhm-schemehm/convergence>, accessed 26 April 2021).
- Kalbarczyk A, Rodriguez DC, Mahendradhata Y, Sarker M, Seme A, Majumdar P, et al. (2021). Barriers and facilitators to knowledge translation activities within academic institutions in low- and middle-income countries. *Health Policy Plan.* 36(5):728–39. doi:10.1093/heapol/czaa188.
- Koroglu M, Irwin BR, Grépin KA (2019). Effect of power outages on the use of maternal health services: evidence from Maharashtra, India. *BMJ Global Health.* 4(3). doi:10.1136/bmjgh-2018-001372.
- Maina J, Ouma PO, Macharia PM, Alegana VA, Mitto B, Socé Fall I, et al. (2019). A spatial database of health facilities managed by the public health sector in sub Saharan Africa. *Sci Data.* 6(1):1–8. doi:10.1038/s41597-019-0142-2.
- McLaughlin CP, Kaluzny AD (1994). Continuous quality improvement in health care: theory, implementation and applications. University of California: Aspen Publishers.
- Ministry of Energy of Honduras (2021). Honduras Energy Compact 9 - Promotion of Technology with Renewable Energy Sources and Energy Efficiency Actions in Health Facilities of the Republic of Honduras. New York: United Nations Department of Economic and Social Affairs (UN DESA) (<https://www.un.org/en/energycompacts/page/registry#Honduras>).
- Mogelgaard K, Dinshaw A, Ginoya N, Gutiérrez M, Preetan P, Waslander J (2018). From planning to action: mainstreaming climate change adaptation into development. Washington, DC: World Resources Institute (<https://www.wri.org/publication/climate-planning-to-action>, accessed 18 November 2022).
- National Health Mission (2012). NHM guidelines. New Delhi: Ministry of Health & Family Welfare (<https://nhm.gov.in/index1.php?lang=1&level=1&sublink-id=197&lid=136>, accessed 18 November 2022).
- National Health Mission (2020). Rural health statistics 2019–2020 [dataset]. New Delhi: Ministry of Health & Family Welfare (<https://hmis.nhp.gov.in/download>

- file?filepath=publications/Rural-Health-Statistics/RHS%202019-20.pdf).
- NITI Aayog (2018). Champions of Change platform, Aspirational Districts Programme [website]. New Delhi: Niti Aayog (<http://championsofchange.gov.in/site/coc-home/>, accessed 18 November 2022).
- Odarno L (2020). Linking electricity access and development outcomes in Africa: a framework for action. Washington, DC: World Resources Institute (<https://files.wri.org/s3fs-public/linking-electricity-access-development-outcomes-africa.pdf>).
- Ouma PO, Maina J, Thurania PN, Macharia PM, Alegana VA, English M, et al. (2018). Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. *Lancet Glob Health*. 6(3):e342–50. doi:10.1016/S2214-109X(17)30488-6.
- Phillips J, Plutshack V, Yeazel S (2020). Lessons for modernizing energy access finance, part 1: what the electrification experiences of seven countries tell us about the future of connection costs, subsidies, and integrated planning. Durham, NC: Duke University (NI Policy Brief 20-02).
- Ramji A, Patnaik S, Mani S, Dholakia HH (2017). Powering primary healthcare through solar in India: lessons from Chhattisgarh. New Delhi: Council on Energy, Environment and Water (<https://www.ceew.in/sites/default/files/CEEW-Powering-Primary-Healthcare-through-Solar-in-India-30Aug17.pdf>).
- Schatz Energy Research Center, IFC (International Finance Corporation) (2019). The dirty footprint of the broken grid: the impacts of fossil fuel back-up generators in developing countries. Washington, DC: IFC (<https://www.ifc.org/wps/wcm/connect/2cd3d83d-4f00-4d42-9bdc-4afdc2f5dbc7/20190919-Full-Report-The-Dirty-Footprint-of-the-Broken-Grid.pdf?MOD=AJPERES&CVID=mR9UpXC>, accessed 18 November 2022).
- SEforALL (Sustainable Energy for All), ESMAP (Energy Sector Management Assistance Program) (2021). From procurement to performance: towards a private sector-led, service-based model to scale up sustainable electrification of public institutions. Knowledge brief. Vienna: SEforALL (<https://www.seforall.org/publications/from-procurement-to-performance>, accessed 18 November 2022).
- SELCO Foundation (2021a). Community participation in operations and management of sustainable energy in health centres. SELCO Foundation (https://selcofoundation.org/wp-content/uploads/2021/11/SF_Community-Participation-in-Operations-and-Management-of-Sustainable-Energy-in-Health-Centres.pdf).
- SELCO Foundation (2021b). Community participation in operations and management of sustainable energy in health centres. SELCO Foundation (https://selcofoundation.org/wp-content/uploads/2021/11/SF_Community-Participation-in-Operations-and-Management-of-Sustainable-Energy-in-Health-Centres.pdf).
- Sinai C, Fetter TR (2021). Solar technologies can speed up vaccine rollout in Africa: here's how. *The Conversation*. 20 March 2021 (<https://theconversation.com/solar-technologies-can-speed-up-vaccine-rollout-in-africa-heres-how-157274>, accessed 18 November 2022).
- UN Foundation (United Nations Foundation), SEforALL (Sustainable Energy for All) (2019). Lasting impact: sustainable off-grid solar delivery models to power health and education. United Nations, SEforALL (https://www.seforall.org/system/files/2019-04/Powering-Health_042019.pdf).
- UNDP (United Nations Development Programme) (n.d.). Our flagship initiatives Solar for Health. New York: UNDP (<https://www.undp.org/energy/our-flagship-initiatives/solar-for-health>).
- USAID (United States Agency for International Development) (n.d.). Powering health. Washington, DC: USAID (<https://www.usaid.gov/energy/powering-health>, accessed 22 December 2021).
- USAID (United States Agency for International Development), SEforAll. 2021. Powering Healthcare Africa Project (2021–2023). Project flyer. USAID, SEforAll (<https://www.seforall.org/system/files/2021-08/Powering-Healthcare-Africa-Project-SEforALL.pdf>).
- Welland A (2017). Electrification of health facilities in rural areas: opportunities and challenges. Cambridge: Smart Villages Initiative (Technical Report 12; https://www.e4sv.org/wp-content/uploads/2017/05/TR12-Electrification-of-health-clinics-in-rural-areas-Challenges-and-opportunities_web.pdf).
- WHO (World Health Organization) (2010). Medical devices: managing the mismatch: an outcome of the priority medical devices project. Geneva: WHO.
- WHO (World Health Organization) (2012). PQS devices catalogue: pre-qualified equipment for the Expanded Programme on Immunization (EPI). Geneva: WHO (https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/PdfCatalogue.aspx?cat_type=device, accessed 18 November 2022).
- WHO (World Health Organization) (2021). A strategic roadmap to promote healthier populations through clean and sustainable energy. Geneva: WHO (<https://www.who.int/publications/m/item/a-strategic-roadmap-to-promote-healthier-populations-through-clean-and-sustainable-energy>).
- WHO (World Health Organization), OECD (Organization for Economic Co-operation and Development), IBRD (International Bank for Reconstruction and Development) (2018). Delivering quality health services: a global imperative for universal health coverage. Geneva: WHO (<https://apps.who.int/iris/handle/10665/272465>).
- WHO (World Health Organization), UNICEF (United Nations Children's Fund) (2015). Introducing solar-powered vaccine refrigerator and freezer systems: a guide for

managers in national immunization programs. Geneva: WHO (<https://apps.who.int/iris/handle/10665/195778>).

ingId=I3V%2Bui%2BSSQGlOtQh7XYn2w%3D%3D, accessed 15 April 2022).

WHO (World Health Organization), World Bank (2015). Access to modern energy services for health facilities in resource-constrained settings: a review of status, significance, challenges and measurement. Geneva: WHO (<https://apps.who.int/iris/handle/10665/156847>).

Jaffrelot C, Jumle V (2020). Private healthcare in India: boons and banes [website]. Paris: Institut Montaine (<https://www.institutmontaigne.org/en/blog/private-healthcare-india-boons-and-banes>, accessed 1 June 2021).

References for Chapter 7:

Adhikari B, Mishra SR, Babu Marahatta S, Kaehler N, Paudel K, Adhikari J, et al. (2017). Earthquakes, fuel crisis, power outages, and health care in Nepal: implications for the future. *Disaster Med Public Health Prep.* 11:625–32. doi:10.1017/dmp.2016.195.

Jairaj B, Deka P (2020). Improved access to finance can boost electricity access for rural healthcare in India [website]. San Francisco: Power For All (<https://www.powerforall.org/insights/asia/improved-access-finance-can-boost-electricity-access-rural-health-care-india>, accessed 18 November 2022).

Adhikari B, Mishra SR, Schwarz R (2022). Transforming Nepal's primary health care delivery system in global health era: addressing historical and current implementation challenges. *Global Health.* 18:8. doi:10.1186/s12992-022-00798-5.

Javadi D, Ssempebwa J, Isunju JB, Yevoo L, Amu A, Nabiwemba E, et al. (2020). Implementation research on sustainable electrification of rural primary care facilities in Ghana and Uganda. *Health Policy Plan.* 35:ii124–ii136. doi:10.1093/heapol/czaa077.

AEPC (Alternative Energy Promotion Centre, Nepal) (2020). Implementation roadmap for institutional solar photovoltaic systems (ISPS). Kathmandu: AEPC.

Kapoor G, Nandi A, Sriram A, Joshi J, Sriram A (2020). State-wise estimates of current hospital beds, intensive care unit (ICU) beds and ventilators in India: Are we prepared for a surge in COVID-19 hospitalizations?. *medRxiv.* 2020.06.16.20132787. doi: <https://doi.org/10.1101/2020.06.16.20132787>.

Blimpo MP, Cosgrove-Davies M (2019). Electricity access in sub-Saharan Africa: uptake, reliability, and complementary factors for economic impact. *Africa Development Forum*; Washington, DC: World Bank.

Malande OO, Munube D, Afaayo RN, Annet K, Bodo B, Bakainaga A, et al. (2019). Barriers to effective uptake and provision of immunization in a rural district in Uganda. *PLoS One.* 14:e0212270. doi:10.1371/journal.pone.0212270.

Chen YJ, Chindarkar N, Xiao Y (2019). Effect of reliable electricity on health facilities, health information, and child and maternal health services utilization: evidence from rural Gujarat, India. *J Health Popul Nutr.* 38:7. doi:10.1186/s41043-019-0164-6.

Mbonye AK, Asimwe JB (2010). Factors associated with skilled attendance at delivery in Uganda: results from a national health facility survey. *Int J Adolesc Med Health.* 22(2):249–55. doi:10.1515/IJAMH.2010.22.2.249.

Concessao L, Gupta DK, Deka P (2020). Solar power: a rural Indian hospital's key to fighting COVID-19. Washington, DC: World Resources Institute.

McCarney S, Robertson J, Arnaud J, Lorenson K, Lloyd J (2013). Using solar-powered refrigeration for vaccine storage where other sources of reliable electricity are inadequate or costly. *Vaccine.* 31:6050–7. doi:10.1016/j.vaccine.2013.07.076.

Conwright A (2016). In Nepal, a crisis “worse than the earthquake”. *Huffington Post*, 1 February 2016 (https://www.huffpost.com/entry/in-nepal-a-crisis-worse-t_b_9131410, accessed 18 November 2022).

Ministry of Health, Nepal (2016). 2016 Demographic and Health Survey: key findings. Kathmandu: Ministry of Health, Nepal (<https://dhsprogram.com/pubs/pdf/SR243/SR243.pdf>).

Gautam K (2012). Political instability blocks Nepal's hydropower potential as daily power outages continue. *Global Press Journal*, 10 September.

Ministry of Population and Environment, Nepal (2016). Renewable Energy Subsidy Policy, 2073 BS. Kathmandu: Ministry of Population and Environment, Nepal ([https://www.aepc.gov.np/uploads/docs/2018-06-19_RE%20Subsidy%20Policy,%2020273%20\(English\).pdf](https://www.aepc.gov.np/uploads/docs/2018-06-19_RE%20Subsidy%20Policy,%2020273%20(English).pdf)).

IEA (International Energy Agency) (2020). Snapshot of global PV markets. Paris: IEA (https://iea-pvps.org/wp-content/uploads/2020/04/IEA_PVPS_Snapshot_2020.pdf, accessed 1 June 2021).

Indranil BM (2020). Private healthcare industry in India: 4 common myths debunked. *Business Today*, 14 July.

MoH (Ministry of Health, Uganda) (2016). Essential medicines and health supplies list for Uganda (EMHSLU) [website]. Kampala: MoH (<https://www.health.go.ug/cause/essential-medicines-and-health-supplies-list-2016>, accessed 18 November 2022).

Jaffer H (2022). A blueprint for transforming rural health systems through sustainable energy [website] (<https://www.linkedin.com/pulse/blueprint-transforming-rural-health-systems-through-energy-jaffer/?track>

MoHFW (Ministry of Health and Family Welfare, India) (2012). *Indian Public Health Standards*. New Delhi:

- National Health Mission, MoHFW (<http://nhm.gov.in/index1.php?lang=1&level=2&sublinkid=971&lid=154>, accessed 18 November 2022).
- MoHFW (Ministry of Health and Family Welfare, India) (2020). Primary health centres (PHCs). New Delhi: Statistics Division, MoHFW.
- Pakravan M (2021). A healthcare facility with unreliable electricity access is as good as one with no electricity access at all (<https://www.linkedin.com/pulse/health-care-facility-unreliable-electricity-access-good-pakravan/?trackingId=jwqQliVaS6mZaoPvGy0e2g%3D%3D>, accessed 18 November 2022).
- Pedersen PH, Katic I, Jensen JK, Markussen WB, Moeller H, Cording C (n.d.) Direct drive solar coolers. Paris: International Institute of Refrigeration. doi:10.18462/IIR.ICR.2019.1024.
- Phillips DEV (2017). Childhood vaccines in Uganda and Zambia: determinants and barriers to effective coverage. Seattle: University of Washington.
- Rajagopalan S, Choutagunta A (2020). Assessing healthcare capacity in India. Working paper. Arlington: Mercatus Center at George Mason University.
- Ramji A, Patnaik S, Mani S, Dholakia HH (2017). Powering primary healthcare through solar in india: lessons from Chhattisgarh. New Delhi: Council on Energy, Environment and Water (<https://www.ceew.in/sites/default/files/CEEW-Powering-Primary-Healthcare-through-Solar-in-India-30Aug17.pdf>).
- Rokicki S, Mwesigwa B, Waiswa P, Cohen J (2021). Impact of solar light and electricity on the quality and timeliness of maternity care: a stepped-wedge cluster-randomized trial in Uganda. *Glob Health Sci Pract*. 9:777–92. doi:10.9745/GHSP-D-21-00205.
- SELCO Foundation (2020). SDG7 for primary healthcare infrastructure: draft. SELCO Foundation (<https://drive.google.com/file/d/1gshKxWXvOYEzUw4MM7aiv-ZLE2a5ApbGO/view>, accessed 18 November 2022).
- SELCO Foundation (2021). Sustainable energy for public health centres. SELCO Foundation (https://drive.google.com/file/d/1rmRz_lufr91OyO5XY58TH-03td-LK7ow9/view, accessed 18 November 2022).
- Shastry V, Rai V (2021). Reduced health services at under-electrified primary healthcare facilities: evidence from India. *PLoS One*. 16:e0252705. doi:10.1371/journal.pone.0252705.
- Singh P, Hashmi G, Swain PK (2018). High prevalence of cesarean section births in private sector health facilities: analysis of district level household survey-4 (DLHS-4) of India. *BMC Public Health*. 18:613. doi:10.1186/s12889-018-5533-3.
- WHO (World Health Organization), Power Africa, SEforALL (Sustainable Energy for All) (2022). Health Facility Electrification Compact Working Group meeting: delivery models.
- World Bank (2015). Project appraisal document: Energy for Rural Transformation Project in support of the third phase of the Energy for Rural Transformation Program. Washington, DC: World Bank.
- World Bank (2017a). Maternal mortality ratio (modeled estimate, per 100,000 live births): Uganda [website]. Washington, DC: World Bank (<https://data.worldbank.org/indicator/SH.STA.MMRT?locations=UG>, accessed 23 January 2022).
- World Bank (2017b). Implementation completion and results report: Energy for Rural Transformation Project in support of the second phase of the Energy for Rural Transformation Program (No. ICR4053). Washington, DC: World Bank.
- World Bank (2019). Access to electricity, rural (% of rural population): Nepal [website]. Washington, DC: World Bank (<https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=NP>, accessed 18 November 2022).
- World Bank (2021a). Access to electricity, rural (% of rural population) [website]. Washington, DC: World Bank (<https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS>, accessed 1 June 2021).
- World Bank (2021b). Ease of doing business rank (1=most business-friendly regulations) [website]. Washington, DC: World Bank (https://data.worldbank.org/indicator/IC.BUS.EASE.XQ?most_recent_value_desc=false, accessed 23 January 2022).
- WRI (World Resources Institute) (2021). Energy Access Explorer [website]. Washington, DC: WRI (<https://www.wri.org/initiatives/energy-access-explorer>, accessed 18 November 2022).

References for Chapter 8:

- Bhatia M, Angelou N (2015). Beyond connections: energy access redefined. Washington, DC: World Bank (<https://openknowledge.worldbank.org/handle/10986/24368>, accessed 18 November 2022).
- ESMAP (Energy Sector Management Assistance Program) (2019). Mini grids for half a billion people: market outlook and handbook for decision makers – executive summary. Washington, DC: World Bank. doi:10.1596/31926.
- WHO (World Health Organization) (2020). WHO guidance for climate-resilient and environmentally sustainable health care facilities. Geneva: WHO (<https://www.who.int/publications/i/item/9789240012226>).

