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Electrification with renewables: Enhancing healthcare delivery in

BURKINA FASO

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ABBREVIATIONS

AC	alternating current
Ah	ampere hour
CHR	regional health hospital
CHU	university hospital
CM	medical centre (centre médical)
CMA	medical centre with surgical antenna (centre médical avec antenne chirurgicale)
CO_2	carbon dioxide
CSPS	health and social promotion centres (centres de santé et de promotion social)
DC	direct current
DRE	decentralised renewable energy
ILR	ice-lined refrigerator
kg CO_2eq	kilogramme of CO_2 equivalent
km	kilometre
km^2	square kilometre
kVA	kilovolt-ampere
kW	kilowatt
kWp	kilowatt peak
m	metre
mm	millimetre
NGO	non-governmental organisation
O&M	operations and maintenance
OPD	outpatient department
OT	operation theatre
PCA	personal care assistance
PMA	primary medical care
PNDS	National Diagnostic and Care Protocols (Protocoles Nationaux de Diagnostic et de Soins)
SDG	Sustainable Development Goal
SONABEL	Société Nationale d'électricité du Burkina Faso
SOP	standard operating procedure
V	volt
W	watt
WHO	World Health Organization
Wp	watt peak

EXECUTIVE SUMMARY

Access to reliable energy is a prerequisite for the delivery of quality health services to all, whether that is to power incubators in maternity wards, lighting in delivery rooms and immunisation services, or basic diagnostics and administrative needs. In the context of countries and regions with high levels of poverty and an absence of reliable energy supply, decentralised renewable energy (DRE) can play a critical role in democratising essential services such as health and education. By strengthening primary healthcare infrastructure and building resilience of healthcare systems for the poor, sustainable energy can catalyse improvements in socio-economic and health indicators.

Burkina Faso has a population of 20.3 million, with more than 77% of its population living in rural areas. However, only 5% of people in-country have access to electricity. The country has 2 330 healthcare facilities, of which 1 800 are primary healthcare facilities that serve mostly rural communities. As in other developing country contexts, these communities travel longer distances and incur out-of-pocket expenses to access reliable healthcare. The government of Burkina Faso is focused on addressing these challenges and providing more accessible healthcare to the poor in a reliable and resilient manner.

Today there is a clear opportunity to leapfrog the traditional grid and equip health facilities with DRE technologies to meet community needs in a sustainable manner. The implications are not only for service delivery and costs of healthcare provision and access, but also carbon dioxide emissions reduction and environmental considerations. The International Renewable Energy Agency (IRENA) and SELCO Foundation have partnered with the Health and Energy Ministries of Burkina Faso to assess the opportunities for integrating DRE and energy-efficient appliances to strengthen the healthcare sector of the country.

The report provides an overview of the approach that uses Sustainable Development Goal (SDG) 7 (or universal access to modern, reliable and affordable energy) as a catalyst to enable SDG3 (aimed at universal health coverage). It draws on primary data from health-energy assessments across 40 sample health facilities in Burkina Faso, across levels, key stakeholder consultations and meetings with health and energy experts from the government and outside.

In order to break away from silos and enable a more nuanced understanding of each sector for stakeholders from both sides – energy and healthcare sectors – there is a need to work closely together and bridge skill and knowledge gaps. The key steps and processes, as spelled out in the report, to enable better planning, design and implementation of energy-health nexus solutions are outlined below.

- **Energy-health assessment:** Clear understanding of the energy needs in the facility given the specific health situation, disease burden and human resource capacity.
- **System design and costing:** Developing customised DRE system designs, including efficient medical and electrical appliances, based on the assessments conducted and templatising these designs for different levels of healthcare and service provision. Based on this, cost estimations can be developed with local clean energy enterprises.
- **Procurement and installation:** Using procurement guidelines that incentivise quality and timely after-sales service, and strengthen local entrepreneurship; installing energy solutions with efficient equipment based on energy system design.
- **Ownership and maintenance:** Establishing clear and customised financial and ownership models that ensure maintenance and proper utilisation of the energy system, including maintenance contracts with local energy enterprises.
- **Capacity building and training:** Equipping staff to utilise the medical appliances for service delivery and manage the energy system, including aspects of basic maintenance.

This process needs to be supported by improvements in the overall energy-health ecosystem across technology and innovation, financing, capacity building and skills, health service delivery, and policy. The report provides an effective approach for implementing an energy-health programme and building or strengthening the ecosystem to enable better integration of DRE solutions and energy efficiency for healthcare provision in Burkina Faso, and ensure their long-term sustainability and operations.

This initiative seeks to push the needle on South-South co-operation through sharing of learnings, models and processes that can be adapted and replicated to transform the lives of the poor across developing country contexts.

METHODOLOGY

The development of this report follows an ecosystem approach to understand the challenges and suggest solutions – across technology and design, local skill development, financing and ownership and policy-level action. The process included both primary and secondary research components, as per the phases below.

PHASE 1

In-depth understanding of the health-energy landscape in the country via secondary research and primary inputs provided by regional and local health and energy stakeholders:

Through the documents and information shared by the energy and health ministries of Burkina Faso, the overall understanding of the health-energy nexus in the country was developed as a foundation for the further activities. Consultations with regional (for the purpose of the document, representations from five regions of the country: Centre, Centre-East, Centre-West, Hauts Bassins and North) health and energy representations were held to map the needs, challenges and opportunities. This was done particularly to strengthen the Health and Social Promotion Centres (Centres de Santé et de Promotion Social [CSPS]).

PHASE 2

Selection of sample facilities for assessments based on key criteria

Based on the understanding developed from phase 1 on the overall healthcare infrastructure of CSPS, 50 centres across the five regions were chosen, based on the following criteria:

- **i.** Type of infrastructure within CSPS (CSPS upgrading to Medical Centre [Centre Médical (CM)], basic CSPS, maternity, etc.).
- **ii.** Urban or rural geographies.
- **iii.** Provision of health services.
- **iv.** Proximity to the nearest CM.
- **v.** Different electrification scenarios (off-grid, powered by Société Nationale d'électricité du Burkina Faso [SONABEL], powered with solar).

Some of the CSPS were located in conflict zones and were inaccessible.


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PHASE 3

Training of local health and energy personnel to conduct the assessments

In order to conduct detailed health-energy assessments of CSPS, the local staff from the health and energy departments were trained by the SELCO Foundation on the overall process. The virtual training session was conducted with an objective of providing the resource personnel a detailed understanding of how to assess energy needs in the healthcare facility, along with obtaining regional-level understanding of the needs and challenges of the health-energy nexus from the health and energy ministry representatives.

PHASE 4

On-ground assessment of CSPS with the support of local personnel

The on-ground assessment for the sample sites were conducted by the local personnel in Burkina Faso, and the data from the centres (the majority of them being CSPS) were received for Centre-Centre East, Centre West, Hauts Bassins, and North regions. With the limitations of remoteness, travel restrictions related to pandemic and other constraints, around 40 centres were assessed from the perspective of the need for health-energy nexus. These data were analysed with the complementary information from the primary consultations and secondary research towards developing the system design.

PHASE 5

Decentralised renewable energy (DRE) solution and efficient medical equipment design

Based on the analysis of different levels of assessments and landscaping along with the set of assumptions on design considerations (described in the next section), solar system design templates were developed for CSPS. These solution templates consider the existing and futuristic needs recommended by the ministry in order to strengthen the CSPS (and last mile public health infrastructure) across the country.

PHASE 6

Developing overall DRE-health ecosystem-based recommendation

Along with the technology design templates, overall recommendations (expanded in Chapters 2 and 3) are developed from a holistic DRE-health nexus perspective towards strengthening the DRE-health implementation programme.

UNDERSTANDING SUSTAINABLE ENERGY FOR HEALTHCARE

1.1. SUSTAINABLE ENERGY FOR UNIVERSAL HEALTH COVERAGE

Background

Stronger primary healthcare systems are essential to achieving Sustainable Development Goal (SDG) 3, which aims to ensure healthy lives and promote well-being for all age groups through universal health coverage. The health of the population as conceived under SDG3 is key to the attainment of many other goals beyond health, including those on reduction of poverty, better education, attainment of gender equality, provision of clean water and sanitation, creation of employment opportunities, economic growth and so on.

When viewed regionally, sub-Saharan Africa and South-East Asia's health indicators, such as under-5 mortality and maternal mortality, perform lower than the global average, with both regions combined seeing 86% of global maternal deaths in 2017 (UN Foundation, and SEforALL, 2019). Primary healthcare systems, especially in the developing world, lack the resources and facilities integral to provide adequate, accessible and quality healthcare. The onset of COVID-19 and its successive waves have further posed a challenge to already overburdened healthcare systems.

These regions with underdeveloped health infrastructure are also those most affected by energy poverty. Studies have shown that one in four health facilities in sub-Saharan Africa has no access to electricity (WHO, 2015). A survey of 78 countries found that only 41% of health facilities in low- and middle-income countries have reliable electricity access (UN Foundation, and SEforALL, 2019). As highlighted in previous reports (IRENA, 2019), over a billion people globally access healthcare in facilities that are unelectrified. Most of these facilities are located in remote areas and 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" providing the full range of medical services but dependent on diesel generators for reliability, with economic and environmental implications.

Role of energy in healthcare delivery

Access to reliable energy catalyses the delivery of health services and when combined with appropriate medical and electrical appliances, contributes to improving the efficacy and impact of healthcare provision.

Waiting area at the Clinic Wolobougou near Bobo-Dioulasso, in Burkina Faso.
Photo: SELCO Foundation (2021).

Given below are some of the key services in primary healthcare that are dependent on reliable energy access:

- basic administrative services: general needs including lighting, fans, laptops, computers and printing services, mobile charging for staff and patients;
- maternity and childcare: powering diagnostic equipment used in identification of high-risk pregnancies, and those used during and post delivery including suction machines, radiant baby warmers, operation spotlights, phototherapy and so on;
- immunisation: cold chain and refrigeration using deep freezers; ice-lined refrigerators for storing medicines, drugs and vaccines;
- basic diagnostics, laboratory and medical care: lighting for operations, energy for microscopes and centrifuges, instrument sterilisers and noncommunicable disease kits; and
- COVID-19 preventive and therapeutic care: energy and built environment for space heating, cooling; basic energy for testing, quarantine facilities; cold chains for vaccine storage and delivery.

Why decentralised energy for health delivery?

With more than 50 000 primary health facilities (Moner-Girona *et al.,* 2021) spread across sub-Saharan Africa without reliable energy access, it is critical to accelerate the process of electrifying these facilities using the most appropriate energy systems that can offer reliable, affordable and quality electricity. It is also important that primary healthcare infrastructure be made more resilient, ensuring more independent, reliable and sustainable power supply in facilities that can better serve last-mile communities and reduce financial, social and environmental costs.

Studies show that in some of the least-developed countries, an unreliable grid results in almost 70% of medical devices failing or not being procured at all (Moner-Girona *et al.,* 2021). As noted by previous reports, decentralised solar energy systems can offer a clean, reliable and cost-effective solution, considering the avoided investment on grid expansion, time involved, and ongoing operation and maintenance costs that would be needed to power these facilities (IRENA, 2015). By powering critical medical equipment and basic energy access needs with decentralised solar energy, along with appropriate training and maintenance mechanisms, there is an opportunity to improve healthcare service delivery, contribute to improving health outcomes and strengthen the healthcare system as a whole.

The integration of decentralised energy enables more effective universal access and reach of healthcare by equipping primary healthcare facilities to provide all the services required by last-mile communities. In countries with relatively low levels of existing grid infrastructure, solutions powered by decentralised energy can provide an opportunity to leapfrog the grid and create infrastructure that is more climate-resilient and socially, economically and environmentally more sustainable from the outset (Corentin, 2021). It would also strengthen the ability of last-mile communities to have more control over their energy generation, supply and consumption (UN, 2018).

Moreover, the decentralised nature of solar systems offers the opportunity to maximise the socio-economic benefits of energy access by engaging local capacities along different segments of the healthcare value chain. Many of the skills needed to install, operate and maintain off-grid systems can be developed locally, providing access to training and employment opportunities, especially for youth and women (IRENA, 2019). Along with that, over a span of 20 years, one estimate finds that powering all the public health facilities with decentralised renewable energy (DRE) solutions in West Africa alone would avoid more than 80 000 tonnes of carbon dioxide (CO_2) being emitted (Moner-Girona, *et al.,* 2021).

Decentralised energy planning for Burkina Faso

Burkina Faso has more than 1800 primary healthcare facilities providing key health services to communities. In accessing healthcare, more than 60% of its population live within a 20-minute walking distance and more than 90% of population live within 60 minutes' travel distance of a primary health facility (Moner-Girona, *et al.,* 2021). However, less than 5% of its rural population have access to electricity (SEforALL Africa Hub, 2022). Given the remoteness of these health facilities, deploying stand-alone, decentralised solar systems to power the health facilities could offer a faster, cost-effective and climate responsive option for the government of Burkina Faso to strengthen the already existing last-mile health delivery infrastructure. It would avoid the costs of centralised electricity generation plants and grid extension otherwise required to facilitate electricity access. Deploying decentralised energy solutions would also require strengthening various aspects of the health-energy ecosystem, including technology supply chains, installation capacities and skill development, local entrepreneurship for installation and maintenance, funding for capex and opex requirements, healthcare system linkages and policy frameworks.

In this context, it was recognised by the Ministries of Energy and Health of Burkina Faso as urgent and important to develop a larger country-level energy approach for deploying decentralised sustainable energy systems and efficient equipment to strengthen last-mile health facilities. This roadmap can be bolstered by a policy framework that outlines the enabling ecosystem components for the design, implementation and sustainability of health-energy nexus programmes. In order to accelerate this effort and set the foundation for a country-level DRE-driven health-energy nexus programme, this document provides a framework for the Ministries of Health and Energy of Burkina Faso along with the recommendations to strengthen the enabling ecosystem for long-term sustainability of the programme.

The schematic below outlines the expected impacts of such a health-energy nexus programme that links SDG7 for SDG3 (modern energy access for improved health and well-being) to benefit last-mile communities across Burkina Faso.

Figure 1 **Expected impacts of a health-energy nexus programme**

Service delivery:
- Prolonged hours of operation
- Reduced out-of-pocket expenses for patients
- Wider range of services
- Better utilisation of medical devices
- Telemedicine and remote care

Reduced operational expenses:
- Reduced electricity bills (efficiency + alternate energy source)
- Avoided costs of diesel fuel and generator
- Reduced damage to equipment due to voltage fluctuations

Types of services:
- Immunisation and cold chain facilities
- Maternal care and safer deliveries
- Neonatal care
- Laboratory and diagnostics
- Digitisation and better administration

Health workers retention:
- Enhanced safety and hygiene
- Greater comfort in providing healthcare
- Improved accommodation and well-being (in staff quarters adjacent to the facility)
- Functional systems → increased motivation and better morale among healthcare workers

Gender considerations:
- Enhanced safety and hygiene among women
- Increased confidence to access healthcare
- Reduced risk and convenience for women accessing maternal care

SDG7 + SDG3
Economic, social environmental benefits

Reduced long-term costs for country:
- Avoided grid extension or diesel usage bringing reduction to the health/energy systems as a whole in the long-run
- Improved health outcomes and well-being of population

Job creation and local entrepreneurship:
- Involvement of local individuals, technicians and enterprises in design, installation and after-sales services
- Opportunity to strengthen local manufacturing and entrepreneurship on energy-health nexus needs

Avoided CO_2 emissions:
- Offset the use of (largely fossil fuel-based) grid, diesel
- Reduced energy consumption with efficiency increase
- Avoided need for future fossil fuels as health services grow

Increased climate resilience:
- Increased use of active and passive cooling to reduce health complications due to heat stress
- Reduced downtime on energy systems in disaster contexts (flood/cyclones) - ability to repair and maintain locally

1.2. HEALTH AND ENERGY NEXUS CONTEXT IN BURKINA FASO

Public health system in Burkina Faso

Burkina Faso, a West African country in the Sahel, covers an area of 272 960 square kilometres (km^2) and has an estimated population of 20.3 million with an annual growth rate of 2.8% (World Bank, 2021b). A large majority of the country's population (77%) lives in rural areas (Ministry of Health of Burkina Faso, 2018). Women represent 51.7% of the total population, while women of reproductive age constitute 23.56%. Young people under 15 years of age account for 46.4% and children under five years of age for 17.38% of the total population. Some of the key indicators critical to the country's health status point directly to the health challenges faced by these segments of the population. The table below provides an overview of the key health indicators in Burkina Faso alongside the global average and the targets established for SDG3 on universal health care.

Table 1 **Key health indicators of Burkina Faso**

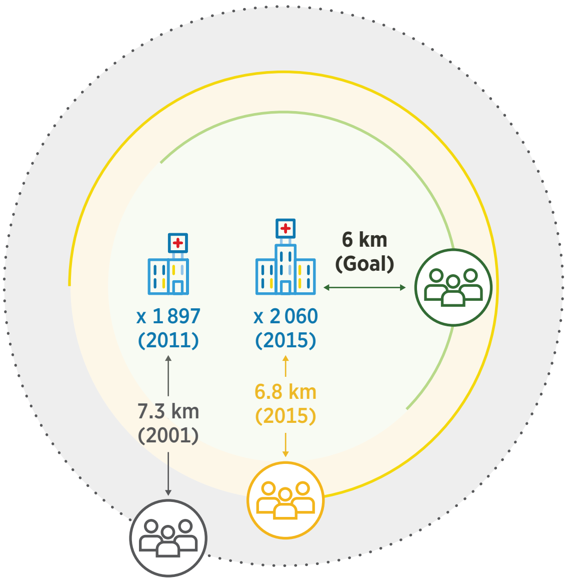
Health indicators	National level (year)	Global level (year)	SDG3
Maternal mortality rate/100 000 births	320 (2017)	211 (2017)	70
Neonatal mortality rate/1 000 births	26 (2019)	17.5 (2019)	< 12
Infant mortality rate/1 000 births	54 (2019)	28 (2019)	< 25
Births attended by skilled health staff	80% (2015)	70% (2015)	/
Pregnant women receiving prenatal care	80% (2018)	86% (2018)	/

Source: Compiled using information from the ministry of health of Burkina Faso (Ministère de la Santé du Burkina Faso 2015, 2018 [national level]).

Over the last decade, the government has been focusing a great deal of effort on reducing the expenditures incurred by households in accessing the health system and on achieving free health care for all in the long term (Ministry of Health of Burkina Faso, 2016). Towards this effort, numerous free and subsidised measures are being put in place, such as coverage for pregnant women and children under five years of age, as well as antenatal care and provisions for case management during pandemics.

On this path, to achieve universal access to healthcare services, between 2011 and 2015, the Health Ministry of Burkina Faso increased the number of healthcare facilities from 160 to over 2100 public facilities (of which 1800 are primary healthcare facilities catering to last-mile populations). This has led to a clear improvement in the accessibility to the healthcare facilities, by reducing the average distance to the first point of health care to 6.8 kilometres (km) in comparison with 7.3 km in 2011 (Ministry of Health of Burkina Faso, 2016) (as outlined in Figure 2).

Figure 2 **Representation of the average distance to primary point of care and the changes in ministerial efforts**



Source: Compiled using information from the ministry of health of Burkina Faso (Ministère de la Santé du Burkina Faso 2015).

Given below is a summary of the various tiers of healthcare provision in Burkina Faso with an indication of the services delivered and the human resource and infrastructure requirements at each level. The list of equipment and devices for each tier/level of health facility can be found in the load assumptions of the solar system designs in Figures 4 to 7. The specific equipment for each facility and decisions on which option to choose are to be determined by the Ministry of Health and its related authorities based on the services being delivered through the facility and the capacity/skills of medical staff in that facility.

Figure 3 **Distribution of healthcare facilities in Burkina Faso**

	Centre type	Services delivered	Human	Infrastructure	Quantity
National	**Health Universitaires Centre (CHU)**	**PMA** + **PCA** support + **Specialised** care + **Academic** training/research	5+ Doctors (1+ specialised doctor) 2+ Midwife 5+ Nurses 2+ Administrative officer	Infrastructure which does have CSPS standards, with labour room and medical research office	6
Regional	**Health Regional Centre (CHR)**	**PMA** + **PCA** support + **Pre-specialised** care		Infrastructure which does have CSPS standards, with labour room	8
District (200 000 population max.)	**Health District Hospital (HDS)**	**PMA** + **PCA**: Surgery, para-clinical, general and specialised medical consultations	1+ Doctors 1+ Midwife 2+ Nurses 1+ Administrative officer		45
	Medical Centre (CM/CMA)				57
	Health and social promotion Center (CSPS)	**PMA**: Curative, preventive, rehabilitative and promotional care	1+ Midwife 1+ Nurse 1+ Administrative officer	1 dispensary with beds; 1 maternity ward (delivery room); 1 basic pharmacy; 1 latrine for each maternity ward and dispensary; 1 kitchen; 1 incinerator; 3 accommodations for medical staff	1 839
	Community Health Centre/Dispensary (PSC)	Maternal and promotional care		Infrastructure which does not complete CSPS standards	PNDS Goal

Notes: PMA = primary medical care; PCA = personal care assistance; PNDS = National Diagnostic and Care Protocols.

In 2018, the Health Ministry of Burkina Faso launched the National Strategy for Community Healthcare for the period from 2019 to 2023 (Ministry of Health of Burkina Faso, 2018). Extending the efforts of the previous phase, decentralisation was identified as a key component of enabling universal healthcare access (SDG3). As part of this, there has been a focus on the development and strengthening of CSPS which are the last-mile first points of care. There is currently a total of 2 000 CSPS deployed, including isolated dispensaries and maternal units (1 839 CSPS, 136 isolated dispensaries and 8 isolated maternity units) (Ministry of Health of Burkina Faso, 2015).

These centres provide primary medical care (PMA) that is composed of curative (*e.g.* curative nursing consultation and minor surgery), preventive (*e.g.* vaccination and HIV testings), promotional (family planning and nutritional education) and maternal care (*e.g.* prenatal care and assisted normal childbirth).

For communities to get the most value from this increased number of health facilities and reduced distance to the first point of care, strengthening basic infrastructure and improving service delivery at the CSPS plays a very important role. Enabling energy access and efficient medical equipment can help transform the quality and affordability of healthcare services being provided by primary healthcare facilities to last-mile communities.

Challenges and need of (renewable) energy for health in Burkina Faso

While electricity is critical for quality healthcare, Burkina Faso has one of the lowest electrification rates: less than 20% of the population of Burkina Faso (Moner-Girona, *et al.,* 2017), and 5% of the country's rural population (World Bank, 2022b) has access to electricity. In comparison, the average rate of sub-Saharan African countries is around 50% (World Bank, 2022a)

Regarding electrification of healthcare facilities, efforts invested by public authorities over the last decade have brought great impact as now 84% of health centres have access to electricity. Out of these, 30% are connected to the grid and 70% are using decentralised solar systems (Ministry of Energy of Burkina Faso, 2020). However, as detailed in Table 2 below, around 30% of healthcare facilities lack electricity access in Burkina Faso (779 facilities out of 2 330 assessed).

Table 2 **Overview of health facilities electrification in 2021**

Regional overview of current health facilities electrification (2021)							
Region	No. of health facilities	Powered by SONABEL	Powered by solar	Powered by other source	Functioning facilities	Non-functioning	Un-electrified
Boucle du Mouhoun	297	79	157	2	182	56	59
Cascades	102	30	71	0	53	48	1
Centre	128	55	54	1	103	7	18
Centre-East	123	49	58	0	60	47	16
Centre-Nord	182	40	123	2	131	34	17
Centre-Ouest	248	65	164	0	196	33	19
Centre-South	148	42	88	0	102	28	18
East	159	28	98	0	110	16	33
Hauts Bassins	219	71	114	7	164	28	27
North	261	49	150	7	178	27	56
Plateau Central	176	39	113	1	120	33	23
Sahel	145	28	81	6	72	28	45
South-West	142	28	59	0	80	7	55
Total	**2 330**	**603**	**1 330**	**26**	**1 551**	**392**	**387**

Note: SONABEL = Société Nationale d'électricité du Burkina Faso.

Although the electrification rate for healthcare facilities is high, 16% of facilities remain without electricity access. Furthermore, electrified healthcare facilities face the following challenges which need to be addressed by developing a strong ecosystem for decentralisation of health and sustainable energy infrastructure:

- Standardised solar kits of 500 watts (W) and 1 kilowatt (kW) have been deployed in healthcare facilities. These primarily power lights and fans, and do not prioritise health delivery as laid out under PMA (that is composed of curative, preventive, promotional and maternal care) as per the National Strategy for Community Healthcare by the government of Burkina Faso. Currently, energy access remains a challenge for critical medical equipment such as cold chains (ice-lined refrigerators and deep freezers), baby warmers and suction apparatus even in centres that have been provided with solar energy systems.

- Around 30% of existing solar systems in healthcare facilities are not functioning within the first three to five years (Ministry of Energy, 2020), due in part to a lack of maintenance (UN Foundation, and SEforALL, 2019). Therefore, appropriate training and ownership modelsare required. In chapter 3 and subsequent annexes, the report provides recommendations for developing and implementing effective operations and maintenance mechanisms for energy-health programmes.[1] An effective and sustainable energy access model for healthcare facilities (technology, finance, delivery and maintenance) is essential to improving healthcare services, and building a strong health-energy ecosystem around these solutions is a critical component of the strategic development plan.

To meet the dual challenge of energy and health access (as laid out above), the way forward necessitates integrated planning efforts from Health and Energy ministries in Burkina Faso. This would require following a systems approach, involving different stakeholders from both energy and health sectors, resulting in a comprehensive process to assess, design, implement and manage renewable energy solutions for healthcare.

1.3. POTENTIAL IMPACT OF THE HEALTH-ENERGY NEXUS PROGRAMME

The expected impacts of integrating sustainable energy for improved healthcare are experienced across different levels – the end-user level, the health facility level and the system and community level. Given below is an overview of the key metrics used to measure these impacts and includes testimonials from health staff and patients at the Clinic Wolobougou.

End-user level impact

- **Timely and reliable access to health services:** Reliable energy can equip the healthcare facility to provide service 24 hours a day, 365 days a year. In regions that are remote, rural and poorly connected in terms of the transport and road network, decentralised energy solutions can play a critical role in strengthening primary healthcare, thereby strengthening the access to good quality and reliable healthcare service for last-mile communities. Adding new or complementary efficient medical appliances results in additional service provision for these communities – be it for maternal and childcare or immunisation and COVID-19 vaccination efforts.

  The unreliability of power and restricted service provision due to power outages meant people had to travel farther away to access the first point of care. Timely access, especially in maternal and childcare, can reduce risks and complications and avoid mortality.

- **Improved maternal and childcare:** Strengthening the capacity of last-mile facilities can ensure higher immunisation rates and early identification of high-risk pregnancies. Both of these contribute to reducing lives at risk and mortality rates, and improving the well-being of mother and child. Basic lighting can also increase the sense of safety and security among women seeking to access care.

[1] See chapter 3, section 3.2, "Ownership, maintenance and monitoring", as well as Annex 2, "Operations and maintenance guidelines".

As outlined in the Clinic Wolobougou case study, the clinic was earlier ill-equipped to provide quality maternal care, and was unable to provide childbirth at night, forcing patients to travel more than 15 km to access the nearest medical centre. Since the intervention at the facility, the number of patients has increased by 25% from 300 to 400 patients per month, and the number of childbirths has doubled from four to eight per month. Reliable and quality electricity access with the decentralised solar system, combined with good quality medical equipment, has increased patients' trust and extended operating hours.

- **Reduced out-of-pocket expenditure:** Typically, end users accessing healthcare farther away are forced to lose a day's income and pay for transportation to the nearest point of service delivery, which may be closer to a town or city. At times, they are forced to use private healthcare facilities. Strengthening access to reliable healthcare closer to patients' households helps end users/patients reduce time and out-of-pocket expenses typically spent on accessing healthcare.

- **Improved patient well-being and safety feeling:** Powering healthcare facilities improves patients' well-being by lighting and ventilating waiting rooms, operation theatres and resting rooms. Reliable and sufficient electricity access also enables patients to charge their phone, and thus keep in touch with their family. As discussed above, even basic lighting significantly enhances the sense of safety at night.

With the introduction of reliable energy, "In the evening, we don't worry anymore, there is no more stress, the lights can be seen from a distance, people are less afraid; it improves the confidence and the feeling of security", says Honorine Soma (midwife and director at the Clinic Wolobougou).

Health facility-level impact

This primarily captures the impacts of the intervention from the perspective of the facility itself and the need/role of energy to deliver the mandated services. These sets of indicators capture a mix of the facility-level improvements such as services in the centre, savings due to the intervention, environmental aspects and improvements in staff comfort and their ability to provide services.

- **Staff retention levels:** There are a number of challenges faced by healthcare staff in the absence of reliable electricity. They are unable to carry out their activities – deliveries, diagnostics and administration. Their own well-being and comfort also become an issue (especially if they are staying within the premises of the facility). This tends to affect morale and results in lower levels of staff retention in facilities that are more remote. However, an improved working facility with proper equipment and reliable power can help staff to better care for the patients, which can contribute to greater work satisfaction and confidence. Greater safety with better lighting and comfort of health staff can also be improved, thereby contributing to better retention levels and willingness to work in remote areas.

- **Improved service delivery** (UN Foundation and SEforALL. 2019. Lasting impact – Sustainable off-grid solar delivery models to power health and education. Page 22): With reliable power availability, wastage of vaccines and other temperature-sensitive commodities can be reduced. The number of hours of operation, of outpatients and inpatients and of institutional deliveries can be increased. The quality of service provision also can be improved. Referrals for more basic primary care can be reduced, thereby lowering the burden on higher tiers of healthcare.

- **Energy costs/savings:** The money spent on grid electricity and procurement of diesel fuel can be avoided and reallocated for the maintenance and service cost of the solar energy system. There is likely to be lower damage to medical equipment caused by frequent power outages and voltage fluctuations, thus reducing costs spent on spare parts or new equipment. As mentioned above, the facility is also likely to see savings from avoided wastage of vaccines and essential medication.

Previously, the clinic had to turn off all appliances at night to save power for the refrigerator storing medicines, drugs and vaccines. When their old solar energy system stopped functioning, they were forced to use a diesel generator. The fuel cost approximately USD 40 per month.

Since the installation of the solar energy system, the critical loads such as refrigerators can run 24 hours a day, seven days a week. It has also avoided the use of the diesel generator and brought savings that can now be used for staff well-being and accommodation.

"Before, I had to go outside the clinic to read the results of the malaria tests or give injections because my consultation room was not well lit. Today, thanks to the solar system, I can conduct the entire consultation in the consultation room" Honorine Soma (midwife and director at the Clinic Wolobougou)

System-level impact

Through the decentralised energy for health approach, the public health system will be able to improve its efficiency and quality of health in a manner which is reliable, resilient and equitable.

- **Improvements in societal/community health outcomes:** By strengthening the ability of healthcare facilities to provide better services, particularly for maternal and child care, energy solutions can contribute to reducing the risks faced in conducting deliveries at the last mile, or enabling better cold chains for vaccination and immunisation efforts. Through this, the solutions can catalyse improvements in health outcomes associated with maternal and child mortality, immunisation rates and so on.

Lighting the Clinic Wolobougou at night increases the feeling of safety within the community, and they are more inclined to come and seek services as needed. Earlier, people used to wait until morning to receive care. Patients are also more confident of good-quality healthcare knowing that there is electricity reliability and quality equipment.

- **Reduced or avoided CO_2 emissions:** With little to no access to electricity, rural communities are forced to rely on diesel to power the most basic services. By replacing existing energy systems or reducing usage from traditional sources (including the largely fossil fuel-powered grid), including through energy-efficient appliances, decentralised sustainable energy systems can reduce CO_2 emissions within the healthcare sector.

As outlined in the Clinic Wolobougou case study, the solar energy system resulted in avoiding more than 800 kilogrammes of CO_2 equivalent (kg CO_2eq) per year (given the diesel consumption of 0.8 litres of diesel per day in the facility). If diesel was being used to power all of the services currently being provided through the new solar energy solution, it would have resulted in more than 2 341 kg CO_2eq per year.

- **Job creation/local entrepreneurship ecosystem:** Local entrepreneurship and job creation can be strengthened through this approach by involving local clean energy enterprises in the design, procurement and implementation or solar energy systems; by engaging with technology enterprises for medical equipment; and by working with local technicians for regular maintenance and service of the system (UN Foundation, and SEforALL, 2019).

  Furthermore, improving facility delivery at the health centre can increase staff recruitment and retention within the healthcare sector (IRENA, 2018).

As explained by the UN Foundation and SEforALL in their joint report "Lasting impact: Sustainable off-grid solar delivery models to power health and education", clean energy enterprises play a critical role in solar energy system installation and maintenance. In India and sub-Saharan Africa, private solar enterprises are mostly involved in system installation and maintenance, reflecting important opportunities of powering healthcare facilities for local clean energy enterprises. (UN Foundation, and SEforALL, 2019).

1.4. CASE STUDY OF DRE – HEALTH IMPLEMENTATION IN CLINIC WOLOBOUGOU

The case study presented below details the pilot implementation of a DRE solution with efficient equipment in a rural maternal health clinic in Burkina Faso. The study aims to provide a concrete demonstration of the approach described above and its impact at a micro level.

Background

The Clinic Wolobougou was established in 2015 by Ms Honorine Soma. It is located 15 km away from the second-biggest city of Burkina Faso, in a rural off-grid area. It provides maternity and emergency services mainly, but also preventive-promotion activities such as contraception and detection/testing. The Wolobougou team serves 200 patients per month: one-third are women who come for prenatal care and assisted childbirth and one-third are infants who come for diarrhoea, malaria or bronchitis. Furthermore, the clinic provides emergency care for all and pharmacy services. The electrification of the clinic was critical to ensure good-quality health services and good working conditions for the clinic team.

Solution

Load requirements	Basic loads: 14 lamps and 14 fans Medical equipment: Ecograph, Scialytique lamp, Suction machine Pharmacy: Vaccine and medicine fridge storage Administrative devices: Printer, laptop and mobile charging Worker well-being: Fridge and coffee machine
Assumptions	Sunshine hours: 5 hours per day Maximum energy use per day: 6.04 kWh Autonomy: 2.5 days
Solar system design	Power capacity: 3840 W Maximum loads that can be connected: 1785 W System Voltage: 48 V
System components	Solar panels (320Wp, 24V): 12 units Battery (Acid, 220Ah, 12V): 8 units Solar inverter (5kVA, 4kW, 48V): 1 unit

Impacts

a. The solar energy system significantly improved the quality of healthcare services. Because of the reliable energy, the facility is able to avoid delays in administrative work, as well as medical operations.

b. Since the clinic has reliable energy access, quality has improved and attendance has significantly increased. The staff reported that the number of patients has increased by 25% from 300 to 400 patients per month, and the number of childbirths has doubled from four to eight per month.

c. The Clinic Wolobougou is able to completely avoid the use of diesel generator, and is able to save approximately USD 40 per month.

d. The administrative manager had to travel for about two hours daily to procure diesel or fuel from the city. This time can now be saved and used for critical work at the health facilities, and also improves comfort and efficiency of the health staff.

e. The use of the solar energy system prevented up to 65 kg CO_2eq released in the atmosphere per month, on a base of 2.5 kg per litre.

f. Access to reliable electricity has resulted in an increased feeling of safety and comfort for healthcare workers and patients.

ASSESSMENT-BASED DECENTRALISED RENEWABLE SYSTEMS FOR HEALTH FACILITIES IN BURKINA FASO

2.1 OVERALL IMPLEMENTATION APPROACH FOR ENERGY-HEALTH PROGRAMME

Addressing energy issues for decentralising healthcare in an effective and impactful manner requires an integrated approach. It is imperative that we break away from siloes and bring together both health and sustainable energy stakeholders for a nuanced understanding of the gaps in each sector and work closely to bridge these knowledge, technical and skill gaps.

The design, implementation and management of energy solutions for healthcare delivery are guided by certain key processes. These processes are detailed in this chapter and aim to ensure efficiency, efficacy and sustainability of the solutions developed and deployed under the nexus of Sustainable Development Goal (SDG) 3 and SDG7. The processes are designed to enable convergence of expertise from the health and energy sectors.

Installation of solar panels at the Clinic Wolobougou, near Bobo-Dioulasso, in Burkina Faso.
Photo: SELCO Foundation (2021).

The chapter begins with an overview of each stage of the approach to effective planning and implementation of the health-energy programme. This approach is based on the work of IRENA, SELCO Foundation and its partners for health-energy nexus programmes since 2019. The approach is structured across five major stages, with some overlap. The table below outlines the rationale and outcome of activities undertaken at each stage, which need to be scaled up through key stakeholders within the ecosystem to strengthen existing rural healthcare infrastructure.

Table 3 **Approach to effective planning and implementation of the health-energy programme**

#	Stage	Details and rationale
1	**Energy-health assessment**	**Outcome: Clear understanding of the energy needs in the facility given the specific health situation, disease burden and human resource capacity.** · Understand local health needs and concerns, including gaps in current levels of health service provision, climate related risks and considerations, human resource capacity and so on. · Use a participatory and consultative approach that brings together ecosystem stakeholders working across both health and energy sectors. By understanding the health needs and disease burden, the appliances considered and energy system can be designed to ensure it is well-suited to serving healthcare needs in the region. Involving both health and energy sector stakeholders helps to create a strong sense of ownership during planning and can ensure proper utilisation and maintenance post implementation.
2	**System design and costing**	**Outcome: Customised DRE templates system designs are developed based on the assessment conducted and obtain cost quotations from local clean energy enterprises**. · Develop the design of the decentralised solar system, based on the energy gaps and future health needs/services identified through the health-energy assessment. · (Using the designs), estimate the indicative costs for energy system deployment with efficient appliances. These costs should include material, transportation, installation, operations and maintenance costs. Developing the system design also provides the evidence for efficiency drives by comparing energy systems with and without efficient medical and electrical equipment. It ensures that the system accounts for sunshine hours and autonomy based on the context in the region, the number of rainy days, remoteness of the facility and so on. Furthermore, costing of solar system model solutions is then needed, and must be collected from at least three different local clean energy enterprises.
3	**Procurement and installation**	**Outcome: Energy systems are installed based on procurement guidelines that incentivise quality and timely, after-sales servicing, and strengthen local entrepreneurship**. · Develop procurement guidelines, based on the design, that include efficient equipment, quality of energy system components, installation and aspects of maintenance and servicing

3	**Procurement and installation**	· Procure and install energy systems and appliances through local clean energy and technology enterprises Procurement guidelines are critical to ensuring quality components and timely after sales service and maintenance for long-term sustainability of the solution. These guidelines could also strengthen local energy and technology entrepreneurship and facilitate local employment.
4	**Ownership and maintenance**	**Outcome: Establish clear and customised financial and ownership models that ensure maintenance and proper utilisation of the energy system.** · Based on initial assessment and health facility ownership structures and budgets, develop ownership model to ensure accountability on maintenance of the energy system · Ensure Annual maintenance contracts between health facilities and local enterprises for maintenance and servicing; Allocate financial resources to provide for annual maintenance and battery replacements By institutionalising aspects of maintenance and fund allocation for it, the sustainability and utilisation of the decentralised renewable energy system can be better ensured.
5	**Capacity building and training**	**Outcome: Staff are well equipped to utilise the medical appliances for service delivery and maintain and manage the energy system.** · Training and capacity building for health staff on utilisation of medical appliances, that can also be integrated into regular departmental skill upgradation programmes for healthcare workers · Training of staff for efficient use of energy systems and basic troubleshooting and maintenance, · Training and support of local technicians to undertake more complicated maintenance and replacement needs This aspect also strengthens ownership of energy systems; It plays a critical role in better service delivery as healthcare workers have greater confidence using equipment. With better usage of energy systems, training also ensures better performance of the system and longer asset life.

The following sections in this chapter detail each stage of the approach. The DRE solution designs proposed for public health centres of Burkina Faso have been developed based on the inputs gathered from the primary and secondary data. These have emerged from the overall mapping of the health-energy landscape, consultations with health-energy ministries personnel and primary assessments of health facilities. It is to be noted that based on the priorities recommended by the ministries (and other insights gathered during the consultation period), detailed guidelines for energy and health planning for Health and Social Promotion Centres (CSPS) have been developed. The following sections lay out the process of how these guidelines were developed and the assumptions behind the system design, which can be applied to design energy systems for other levels of health facilities as well, including Medical Centre (CM), Regional Health Hospital (CHR) and University Hospital (CHU).

2.2. ENERGY NEEDS ASSESSMENT OF THE BURKINABÉ HEALTHCARE SYSTEM

With the two levels of assessments conducted – primary consultations of the regional health representatives from the five regions of the country and the assessments conducted at the health facilities – key details were identified towards developing the DRE designs for the last-mile facilities. The on-ground assessment for the sample sites were conducted by the local personnel in Burkina Faso, and the data from the centres (the majority of them CSPS) were received for Centre-East, Centre, Plateau Central Region, Hauts Bassins and North regions. After the training session with the staff from both health and energy sector sides, the assessment for around 40 centres from the five regions were conducted to understand the health-energy nexus needs.

General insights

The current structure of CSPS suggests that the centres mainly have four to six rooms, though they can vary between five and eight rooms, with the majority of the centres consisting of: one dispensary, one maternity ward, one pharmacy, one toilet, one admin block and three other rooms. The physical conditions and provisions for solar panel installations vary from region to region.

Disease burdens

The consultations and the primary assessments with the centres showed that certain diseases are prevalent across the regions of the country. Vector-borne diseases such as malaria, respiratory infections such as pneumonia, neonatal disorders, diarrheal diseases and hypertension are some of the key diseases that the CSPS have to treat with more frequency. The availability of appropriate vaccine and medicine storage and basic facilities at the CSPS are critical in order to treat these diseases. Thus, design templates are developed with these disease burdens in mind.

Maternal care as priority

The health ministry does recognise the priority of providing quality maternal and child care at the last-mile health facilities, which can be seen from the efforts of upgrading the CSPS to have an infrastructure for improved prenatal care and institutional delivery services.

Regional representatives have opined that lack of lighting access for delivering babies (which is mostly done with headlamps) and lack of equipment management due to the absence of guidelines have been key issues that could be addressed with access to energy and the right technology and ownership models. Lack of confidence among the mothers in visiting the centre at night was also cited as one of the reasons for lower institutional births.

Deliveries conducted in CSPS assessed varied from 50 to 700 per year, with over 30-40% of them happening at night. Thus, it is important that guidelines for energy and health are developed in a manner that recognises this and allocates medical equipment, energy infrastructure and human resources in a manner that is catering to this need. Considering this, a modular design has been developed in Chapter 2 which allows for infrastructure upgrade from basic diagnosis services to delivery points. Additionally, it is to be noted that the CSPS have community healthcare workers associated with them. These community health workers provide doorstep services and reach out to vulnerable mothers in the surrounding villages. Portable solutions such as solar-powered maternal kits, with battery charging stations in the CSPS, have also been included in the designs, where needed.

Distance from the nearest referral hospital

Considering the remoteness and tough terrains of rural Burkina Faso with challenges around transportation, the government's initiative towards strengthening CSPS with critical services is a key aspect in the delivery of health services for Burkinabé communities. The assessments showed that the nearest CM (next referral level) for the CSPS varies between five kilometres (km) and 50 km, with an average of 15-20 km. Thus, in the majority of the cases, the immediate point of healthcare delivery is the CSPS, in both rural and periurban areas. The government's efforts towards upgrading CSPS (to decentralise the services for improved access) to CMs to provide quality maternal and laboratory services would greatly benefit from DRE solutions. This would also strengthen the country's initiatives in improving universal access to healthcare, and reduce the transaction costs on rural and periurban communities in traveling to CMs for critical care.

Welfare of staff is key in strengthening CSPS

In the key primary consultations, it has been recommended that the access to improved housing and energy access for the centre's staff would benefit the overall situation of CSPS, and could be considered as a priority. The CSPS layouts mentioned in the primary assessments show the presence of resting rooms for the staff in the clinic's premises, and stand-alone buildings for staff housing. However, lack of energy access has been a key challenge in ensuring safety and comfort for the staff in order to stay in these premises. Thus, the CSPS design templates have considered basic lighting and fans for these rooms, and a generic specific design for staff housing has been added in Annex 1.

Climate risk burdens related to health

With its geographical position, Burkina Faso is characterised by a dry tropical climate which alternates between a short rainy season and a long dry season. However, due to the results of climate change and its proximity to the Sahara, the country faces strong seasonal and annual variation, and specifically is prone to chronic drought, flash floods, windstorms and disease outbreaks from impacts of climate change. The primary consultations with the regional representatives showed that excessive heat, flooding, heavy windstorms and dust, and sudden rains result in not only blockage of access to health centres but also increases the stress on the facilities. Thus, DRE solutions, which allow for them to function independently, implemented with appropriate bolstering to face the effects of these challenges would strengthen the last-mile level.

2.3. SYSTEM DESIGN AND COST

System design

Based on the needs identified from the assessments and the details gathered from the consultations, along with the following considerations, the DRE system design has been developed.

- **Sunshine hours/peak sun hours**
  The term "peak sun hours" refers to the solar insolation which a particular location would receive if the sun were shining at its maximum value for a certain number of hours (PV Education, 2022). Since the peak solar radiation is 1 kilowatt per square metre, the number of peak sun hours is numerically identical to the average daily solar insolation. For the designs in the document, sunshine hours are considered as four hours based on the geographical presence and climatic conditions of the country in the tropical region, with average peak sunshine hours varying between four and five hours a day (World Bank, 2020).

- **Days of autonomy**
  The days of autonomy is the number of days the load can operate without any charging from the sun. This is an important number because despite bad weather on a particular day, the system should still have enough reserve charge to be able to run the system (PV Education website).

  For CSPS, a three-day autonomy has been considered (due to the higher probability of being in areas with very poor or no access to electricity).

  For CMs, CHRs and CHUs, a two-day autonomy has been considered (as often these areas have more reliable electricity access).

  While the above assumptions have been made for the purpose of this document, customised designs are encouraged for specific geographical areas, based on requirements.

  The designs provided in Figures 4 to 7 indicate the system sizing. However, the capacity of each component including individual battery/panel size needs to be based on the availability and access to that specification in the local market (as well as servicing and spare part provision). There also needs to be adequate consideration of safety requirements and avoidance of theft. Additional provisions such as separate rooms with batteries and energy components under lock and key and specific responsibilities to staff at the facility can also help mitigate against theft.

- **Designs based on the current and future suggestions**
  The current structure of CSPS suggests that the centres mainly have four to six rooms, but in some cases vary between five and eight rooms, with the majority of the centres consisting of: one dispensary, one maternity ward, one pharmacy, one toilet, one admin block and three other rooms.

  The system design templates are developed based on the key requirements highlighted from the ministry along with the basic services requirements at CSPS. Following are the key options that are considered in the design templates:

  Basic design considers the lights, fans, mobile charging, printer and outdoor lights due to the remoteness and nonavailability of the grid in the surrounding areas; many of the CSPS centres are located in places which are not well-lit. One of the key requirements that emerged from the consultations was to improve the safety and security of the surroundings with outdoor lighting for the centres. Thus, two outdoor lights are considered for the design in order to create a better environment for the visiting patients. The quantity of each of them being considered based on the need in CSPS.

It should be noted that the use of telemedicine is contingent on a reliable internet connection/ network connectivity. To ensure reliable access, it is recommended to connect with relevant public authorities and private internet network distributors.

Option 1 (Basic diagnosis + teleconsultation):
This option considers equipment needed for teleconsultation services as the Health Ministry is keen on adding this to support nurses and CSPS staff with the doctors and other specialists from other centres. Thus, the equipment such as laptops and internet devices are also considered for the load designs.

Option 2 (Basic diagnosis + teleconsultation + maternal care):
Additionally, considering the role of CSPS as an important point for delivery of maternal and childcare, this system and equipment design option includes key maternal equipment, such as radiant warmers, suction apparatus, spotlights and maternity kits.

Option 3 (Basic diagnosis + teleconsultation + maternal care + refrigerator for medicine storage): This design option includes a refrigerator for medicine storage (currently present in some of the CSPS) along with the above loads.

Option 4 (Basic diagnosis + teleconsultation + maternal care + immunisation): This option considers an efficient vaccine cold storage solution with a separate solar system associated with the unit. This would strengthen the CSPS to store necessary vaccines catering to the disease burdens in the regions.

Design templates for CSPS

Based on the assessments and considerations above, the following design templates are recommended for CSPS. As mentioned, the detailed assessments and consultations were conducted for the CSPS, with which the designs have been derived from the current and future needs of the centres as per the recommendations of the ministry. For the other levels of healthcare facilities such as CM, CMU, CHR, CHU, design templates have been developed from analysis of secondary information supported with inputs from the consultations.

Figure 4 **DRE designs templates for CSPS**

CSPS	Option 1	Option 2	Option 3	Option 4
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 + immunisation**
Equipment considered for all the designs as per current scenario for basic diagnosis	Lights, fans, mobile charging, printer, outdoor lights			
Additional equipment considered apart from the above - for the added service	Tele-consultations equipment	Tele-consultations equipment, 1 Baby warmer, 1 suction apparatus, 1 spotlight	Tele-consultations equipment, 1 Baby warmer, 1 suction apparatus, 1 spotlight, 1 Refrigerator	Tele-consultations equipment, 1 Baby warmer, 1 suction apparatus, 1 spotlight, 1 Vaccine cold storage
Rooms and loads	3 Rooms + 1 dispensary + 1 maternity ward + 1 Toilet (9 lights + 5 fans + 2-3 Mobile Charging + 1 Laptop + 1 Printer + Wi-Fi + 2 outdoor lights)	3 Rooms + 1 dispensary + 1 maternity ward + 1 Toilet (10 lights + 5 fans + 2-3 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 ward + 1 Toilet (10 lights + 5 fans + 2-3 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 ward + 1 Toilet (10 lights + 5 fans + 2-3 Mobile Charging + 1 Laptop + 1 Printer + Wi-Fi + 2 outdoor lights + 1 Baby warmer + 1 suction apparatus + 1 spotlight) + (Vaccine Solar Direct Drive Refrigerator 58L of vaccine)
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 Solar Direct Drive)

Design templates for CM/CMA

Below are a few options considered for using solar to power (medical centre with surgical antenna) CMAs, which basically covers primary medical care (PMA) services (curative activities, preventive activities, promotional activities and supportive activities) and (PCA) services (surgery, paraclinical, generalised and specialised medical consultation).

Figure 5 **DRE designs templates for CM/CMA**

CMA	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
	Basic Lighting	**Basic Lights & Fan**	**Basic light, fan & Critical medical loads**	**Primary Inverter System for Critical Loads**	**Primary Inverter System for an ideal CMA**
Equipment (energy efficient)	Only Lights	Lights + fans + mobile charging	Lights + fans + mobile charging + labour room + immunisation room + pharmacy + OPD (Outpatient department) + laboratory Toilet, kitchen, corridor	Lights + fans + mobile charging + labour room + immunisation room + pharmacy + OPD Toilet, kitchen, corridor	Lights + fans + mobile charging + labour room + immunisation room + pharmacy + OPD + laboratory Toilet, kitchen, corridor
No. of rooms and loads	8 rooms 10 lights (1-6 hrs.) (Direct current [DC] system)	8 rooms 10 lights (1-6 hrs.) 5 fans (3-4 hrs.) (DC system)	8 rooms 10 lights (1-6 hrs.) 5 fans (3-4 hrs.) (DC system) Baby warmer + suction apparatus + focus light + centrifuge + microscope + refrigerator (Alternating current [AC] system)	7 rooms 10 lights (1-6 hrs.) 5 fans (3-4 hrs.) Baby warmer + suction apparatus + focus light + refrigerator (AC system)	8 rooms 10 lights (1-6 hrs.) 5 fans (3-4 hrs.) Baby warmer + suction apparatus + phototherapy + focus light + centrifuge + microscope + refrigerator (AC system)
Solar system	(150 Wp, 150 Ah, 12 V DC system – 3 days of autonomy); 1 unit	(400 Wp, 400 Ah, 12 V DC system – 3 days of autonomy); 1 unit	(400 Wp, 400 Ah, 12 V DC system – 3 days of autonomy) X 1 No (1.2 kWp, 200 Ah, 48 V – AC system – 2 days of autonomy) 1 unit	(1.5 kWp, 200 Ah, 48 V – AC system – 2 days of autonomy) 1 unit	(1.8 kWp, 240 Ah, 48 V – AC system – 2 days of autonomy) 1 unit

Design templates for CHR

Below are a few options considered for solar powering CHR, which includes PMA services, PCA services and prespecialised care.

Figure 6 **DRE designs templates for CHR**

Burkina Faso CHR	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
	Basic lighting	**Basic lights & fan**	**Basic light, fan & critical medical loads**	**Primary inverter system for critical loads**	**Primary inverter system for an ideal CMA**
Equipment (energy efficient)	Only Lights	Lights + fans + mobile charging	Lights + fans + mobile charging + labour room + immunisation room + minor operation theatre (OT) + ladies & gents ward + laboratory + dressing room + doctor's room + nurse room + cold chain room + waiting area + storeroom + reception + office room + telemedicine room + toilet, corridor, entrance	Lights + fans + mobile charging + labour room + immunisation room + minor OT + ladies & gents ward + laboratory + dressing room +doctor's room + nurse room +cold chain room +waiting area + store room + reception + office room +telemedicine room + toilet, corridor, entrance	Lights + fans + mobile charging + labour room + immunisation room + minor OT + ladies & gents ward + laboratory + dressing room +doctor's room + nurse room +cold chain room +waiting area + store room + reception + office room + telemedicine room + toilet, corridor, entrance
No. of rooms and loads	22 rooms 33 lights (1-6 hrs.) (DC system)	22 rooms 33 lights (1-6 hrs.) 15 fans (3-6 hrs.) (DC system)	22 rooms 33 lights (1-6 hrs.) 15 fans (3-6 hrs.) (DC system) Baby warmer + suction apparatus + spotlight + centrifuge + microscope + refrigerator + deep freezer + ice-lined refrigerator (ILR) + laptop printer (AC system)	22 rooms 33 lights (1-6 hrs.) 15 fans (3-6 hrs.) Baby warmer + suction apparatus + spotlight + centrifuge + microscope + refrigerator + deep freezer + ILR + laptop printer (AC system)	22 rooms 33 lights (1-6 hrs.) 15 fans (3-6 hrs.) Baby warmer + suction apparatus + spotlight + centrifuge + microscope + refrigerator + deep freezer + ILR + laptop printer (AC system)
Solar system	(300 Wp, 300 Ah, 12 V DC system – 3 days of autonomy) X 2 Nos	(400 Wp, 400 Ah, 12 V DC system – 3 days of autonomy). X 3 Nos	(400 Wp, 400 Ah, 12 V DC system – 3 days of autonomy) X 3 Nos. (2.97 kWp, 300 Ah, 48 V AC system – 2 days of autonomy) X 1 No	(2.97 kWp, 360 Ah, 48 V – AC system – 2 days of autonomy) X 2 Nos	(6 kWp, 300 Ah, 96 V – AC system – 2 days of autonomy) X 1 No

Design templates for CHU

Below are a few options considered for solar powering CHU, which includes PMA services, PCA services and prespecialised care.

Figure 7 **DRE designs templates for CHU**

Burkina Faso CHU	Solution 1			Solution 2			Solution 3	Solution 4
	Lighting			Lights and fans			OT block	Labour and cold chain block
Equipment (efficient loads)	Only Lights			Lights + fans + mobile charging			Lights + fans + mobile charging	Lights + fans + mobile charging
List of equipment/ appliances.	49 rooms X 169 lights			49 rooms x 169 lights + 24 fans + 5 exhaust fans + 1 stand fan			28 rooms x 109 lights + 12 fans + 4 exhaust fans refrigerator, water purifier, baby warmer, focus lights, air conditioners, suction machine, cautery machines, OT table, defibrillator, needle cutter, laparoscopic display, pulse oximeter	6 rooms x 17 lights + 5 fans + 5 exhaust fans + 1 stand fan. ILRs, baby warmer, oxygen concentrator, suction apparatus, air conditioner, baby warmer, deep freezers
Usage hours	Regular Usage	8 hrs. max/ day	4 hrs. max/ day	Regular Usage	8 hrs. max/ day	4 hrs. max/ day	Regular Usage	Regular Usage
Solar system design	(7.5 kWp, 200 Ah @ 240 V, 10 kVA, 240 V) 2 units	(4.5 kWp, 360 Ah @ 96 V, 6 kVA, 96 V) X 2 Nos.	(4.5 kWp, 360 Ah @ 96 V, 6 kVA, 96 V) X 1 No.	(10 kWp, 300 Ah @ 240 V, 12.5 kVA, 240 V) X 2 Nos.	(5.94 kWp, 360 Ah @ 120 V, 7.5 kVA, 120 V) X 2 Nos.	(5.94 kWp, 360 Ah @ 120 V, 7.5 kVA, 120 V) X 1 No.	(12 kWp, 400 Ah @ 240 V, 20 kVA, 240 V) X 2 Nos.	(12 kWp, 400 Ah @ 240 V, 20 kVA, 240 V) X 1 No.

System cost

The detailed pricing for the design templates is obtained for the CSPS, where the indicative pricing includes the following:

- System cost (capex): Cost of system components (including solar panels, batteries, inverter, charge regulator, wiring, mounting structure, etc.), installation and commissioning costs. The transportation cost is not considered as its variation is highly dependent on the geographical location, remoteness, proximity to Ouagadougou (the capital city, where the majority of the suppliers are located) and accessibility to the region.

- Operations and maintenance (O&M) cost: This cost is considered for ten years, with servicing visits once every three months. Since the issue of sandstorms is prevalent in the region, regular clearing of panels and batteries is paramount – thus the local installers need to visit the centres often.

- Battery replacement cost: Lead acid batteries (considered for designs in this document) come with a warranty of five years; depending on usage and maintenance, the life of the lead acid battery could be extended to seven to eight years; one-time battery replacement cost is considered for ten years.

- Equipment cost (not included): Since the designs that are being recommended include medical equipment such as baby warmers, suction apparatus, and cold chain solutions such as vaccine refrigerators along with efficient lights, fans, laptops and internet access solutions, the overall cost of the programme would include these aspects as well. It is to be noted that the pricing provided below doesn't include these costs, so more localised market research is recommended for the same.

Moreover, inflation from early 2022 on energy prices has been taken into account and incorporated in the last line of the pricing below, as per an average increase of 20% added to the initial cost. Interviews with local clean energy entrepreneurs reported an average increase of 15% for photovoltaic solar panels and batteries, 30% for solar inverters, and 20% for transportation.

Figure 8 **DRE designs templates and costings for CSPS**

System designs and requirements	Option 1: 1.5 kWp, 48 V	Option 2: 2.4 kWp, 48 V	Option 3: 3.2 kWp, 96 V
Number of solar Panels	260 Wp, 6 Nos	260 Wp, 9 Nos	320 Wp, 10 Nos
Number of batteries	200 Ah, 8 Nos	200 Ah, 8 Nos	200 Ah, 8 Nos
Inverter capacity	2 kW, 2.5 kVA, 48 V	3 kW, 3.5 kVA, 48 V	4 kW, 5 kVA, 96 V
Supply of solar equipment + installation cost	USD 5 250	USD 5 770	USD 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 (Batteries replacement)	USD 2 800	USD 2 800	USD 2 800
Remote monitoring hardware with 3G network	Unavailable in some country, because of lack of access and high-cost of internet connection		
Operations & maintenance each 3 months for 10 years	USD 1 800	USD 1 800	USD 2 000
Total estimate 2021-costing (initial average costs in 2021)	USD 9 900	USD 10 400	USD 11 000
Estimated costing 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 estimate 2022-costing (incl. +20% inflation in 2022)	USD 11 880	USD 12 480	USD 13 200

Notes: The options mentioned here are from the design templates discussed in section 2.3, and are indicative only.
The increase in cost estimations for 2022 is based on insights from local clean energy enterprises based in-country.

In addition to the inflation, the cost might vary from 10% to 20%, depending on the transaction costs and geographies. It is to be noted that the indicative costing mentioned for each of the designs is an estimation and based broadly on the present-day scenario (as of June 2022).

Further recommendations for solar system design

Given below are certain key considerations and recommendations to optimally design the decentralised solar energy solution, while incorporating energy efficiency and healthcare requirements.

i. **Modular designs for health facility levels:** Similar to the CSPS, it is recommended that detailed modular designs be developed for other types of health facilities, as outlined in the National Plan for Health Development published in 2016 by the Ministry of Health of Burkina Faso. A further detailing of the guidelines to include essential medical equipment as per the services and human resources allocated, as well as their specifications, would also help authorities in implementing integrated packages of health service, human resources, appliances and solar energy.

ii. **Customisation of solar energy system for improved optimisation:** While a standardised modular system design has been detailed in the previous section of the report, local factors could be considered to make it more robust and reliable. These factors require in-depth training of the technical and assessment staff. Some of these factors are:

- **Operational hours of specific services and disease bur den:** Loads and their criticality are identified based on health services to be offered. The total energy consumption, based on footfall or population served – relating to the amount of time health appliances are actively in use.

- **Critical and noncritical loads:** Designs can be locally customised to categorise into:

  - Critical medical loads – Ones that can have severe medical implications if not available at certain critical times (*e.g.* baby warmer, phototherapy, OT light) ; and loads that need reliable energy to function continuously with no interruption (*e.g.* ILRs and deep freezers for vaccine storage), which need to maintain a specific temperature at all times or can result in vaccine spoilage.
  - Lights, television, printers are defined as consumptive loads and can be prioritised according to the needs of the local health facility.

- **Terrain, geography and transportation infrastructure:** Based on the terrain and road accessibility for the health facility, solar energy systems can be designed with a higher capacity battery, *i.e.* allowing for higher autonomy. This autonomy is also needed in areas with multiple rainy or cloudy days and limited sunshine hours

- **Multiple systems at the local level:** It is recommended that all loads at a particular health facility not be connected to one battery load. Splitting the battery bank into multiple systems will help increase the reliability of the overall system. Even if one part fails, the other parts would be functioning. Such designs are critical for remote areas, where technical staff might take time to reach for repair.

It is also to be noted that in health facilities where there is an existing solar system design, efforts should be made to integrate the current system with the new system, as per the system specifications mentioned in this document.

iii. **Criticality of energy-efficient appliances:** Often, energy costs at a local health facility are high because of the power consumption of most of the appliances, both critical and noncritical ones. The inefficiency of the appliances has not only driven the usage of diesel up but also led to higher solar power needs than actually required. Thus, it is strongly recommended to replace the inefficient appliances with efficient ones, thus reducing the costs of solar systems. A study done by SELCO Foundation in 2018 showcases efficiency improvements up to 40-60% resulting in savings.

A design that entails efficient appliances reduces the annual cost of maintenance and servicing which could be 2-5% of the system cost, as well as reduces battery replacement cost (to be allocated every five to seven years), which is approximately 35-40% of the total system cost.

03 STRENGTHENING ECOSYSTEM FOR ENERGISING HEALTHCARE IN BURKINA FASO

Along with system design, it is critical to consider the energy efficiency of the built environment. Inefficient building design leads to an increased usage of lights during the day and active cooling measures (such as fans, coolers, air conditioners) for thermal comfort, particularly in heat stress regions. This further increases energy consumption at the facility. Efficiency in built environment design can bring 40-80% of savings in energy consumption when coupled with energy-efficient appliances (SELCO Foundation, 2021a). Below are basic recommendations for an energy-efficient built environment, and practical recommendations have been added in Annex 3.

i. **Basic Infrastructural Improvements for energy system installations:** In order to ensure that components of the decentralised energy system can be installed and managed properly, basic infrastructure of the facility, for example the roofing and walls, need to be in good condition. The primary assessments indicate that in several cases of CSPS, the gaps in physical infrastructure would need to be addressed to effectively install and manage systems. strengthening the roof to allow for solar panel mounting, having a leak-proof room dedicated for battery storage, and strengthening walls or adding basic aspects to allow for wiring and casing.

ii. **Improved built environment design for health facilities:** Facilities that don't use climate-responsive materials or have layouts that are poorly planned also affect recovery of patients and the well-being and productivity of the medical practitioners. There is growing evidence to demonstrate that energy-efficient building designs, layered with efficient appliances powered by clean energy sources, can lead to a considerable reduction of energy consumption. For example, a well-designed building with high natural ventilation reduces the requirement of fans in the building. This coupled with efficient appliances and solar-powered cooling and lighting technologies could make the health facilities highly resilient and energy efficient.

- **For existing facilities,** built environment improvements could include renovations and improvements to integrate cool roofing, ventilation or increased natural lighting or to add materials for increased insulation of walls.

- **For new facilities**, given the health ministry's plan to expand services and increase the number of CSPS, it would be extremely beneficial to ensure that from the outset, the design and construction of the built environment consider aspects of lighting, ventilation, thermal comfort and temperature control - through appropriate building materials, guidelines on fenestration, shading devices and complementary efficient appliances (SELCO Foundation, 2021c).

- **In labour rooms and facilities** catering to women and maternal care, gender considerations are equally important in structuring the space to ensure it is safe, hygienic and temperature-controlled, taking note of services such as checkups, deliveries and follow-up care.

3.1. PROCUREMENT AND INSTALLATIONS

Once the design templates are finalised and the budget allocation has been established for the programme, installation processes, both for the DRE solutions and the medical equipment, would have to be initiated.

Vendor identification for DRE and procurement of solar and medical equipment

Vendors for installing the solar energy systems and efficient medical equipment, can be identified through a tender process. The tender should pertain to specification of the medical equipment as per national and World Health Organization (WHO) guidelines, keeping in mind the energy efficiency aspect. The specification can further be reviewed by health experts, energy efficiency experts, etc. It is also suggested that the Ministry of Energy initiate a programme or schemes with a focus on promoting setting of standards for energy efficiency for medical equipment.

The finalisation of vendors can take place as per the National Health Ministry tender procurement guidelines. Since there's a possibility that the equipment might not be available locally and procured from a supplier from other countries, it is critical to establish the technical capacities of local personnel to provide servicing and maintenance.

Criteria for vendor/supplier selection

The implementers of the energy-health solutions, whether they are local energy enterprises, local construction agencies or contractors, are extremely important to the functioning of a system. The government of Burkina Faso has already taken initiatives in installing DRE solutions for health facilities. However, there are opportunities in further strengthening the utilisation and performance of these systems. Strengthening systems around maintenance (for example, replacement of batteries or provision of spare parts) because of the remoteness of these locations can result in improved sustainability of the health-energy infrastructure being established.

It is also suggested that certain criteria are built into the selection process of the vendor. Some of these could be as follows:

- proof of local presence of the vendor (either directly or through associated local technical agencies), showcasing their ability to provide timely, quality service in the project area;
- availability of local supply chain for spare parts for servicing and maintenance; and
- past performance of the vendor with respect to providing design, installation and postinstallation service, especially on similar decentralised rural energy projects.

Way forward for mapping and strengthening the local supply chain for solar components and efficient medical equipment

i. **Technology mapping and benchmarking:** To start, it would be critical to review and benchmark existing technology for healthcare in Burkina Faso. It should involve the energy system components, models of electrical and medical equipment, and the healthcare needs in the country. The benchmarking should take into consideration efficiency, quality and pricing of appliances and map the companies.

ii. Supply chains and after-sales networks: The expansion of programme on deploying DRE on health facilities would require a strong ecosystem of suppliers of solar components and efficient medical equipment. A mapping of the relevant vendors (for energy systems and efficient medical and electrical appliances) should also be conducted. The exercise would help understand the supply chain within Burkina Faso and in the neighbouring West African region.

Based on this mapping, vendors can be identified and supported to ensure a strong after-sales network across the country for maintenance and equipment repair. Additionally, the recommendations recognise that early pilots would involve importing technologies into the country. In such scenarios, the procurement process should account for measures that account for the local servicing network and spare part availability.

3.2. OWNERSHIP, MAINTENANCE AND MONITORING

Building a clear ownership model

It is critical to integrate a decentralised ownership model either at the centre level or at the local governance structure level for the DRE solutions and equipment, as this is the only way in which the systems would be operated and maintained with long-term sustainability. After the installations are complete, regular and annual maintenance are essentially required for the sustenance of the systems. For this, the health centre staff and community members must be trained on the basic technicalities and O&M of the systems by the technician, as per Annex 2.

Institutionalising the operations and maintenance activities

A dedicated O&M cell is recommended in every region, which can regularly monitor the performance of all the systems installed and provide repair and maintenance services as and when required in their area of responsibility. Further, it is critical to integrate the annual maintenance contract process for the installed services from the local enterprises with an option of battery replacement after five years or as and when found dysfunctional.

It is important to have resources unlocked for the maintenance of the systems either through untied funds present in the local or regional governance structures or including it in the installation contract for the enterprises. Following are the ways in which the operational and maintenance models could be established.

- **O&M expenditures built into health system budgets allocated for use by the local administration:** This would bring in local ownership of systems, and thus, timely maintenance activities and appropriate utilisation of health system funds available at the local level. This would require the local government structures to be enabled and monitored closely.

- **O&M expenditures and responsibility built into tenders to local energy enterprises as part of DRE installation programme**: This would ensure the availability of service as part of the long-term contract itself. However, it is important to consider that the vendors without local presence may need incentives to undertake O&M responsibilities, especially when installations are few and far apart, as the transaction costs are higher for them to provide these services.

Budgeting for DRE in healthcare facilities

i. **Budgeting for DRE to be included in the infrastructure costs while setting up or upgrading a health facility:** It is recommended that the Ministry of Health makes it a practice to account for DRE costs as capital infrastructure of the health facility, along with efficient appliances. Such an approach would save the ministry expenses in the long run.

ii. **Budgeting for maintenance costs and battery replacement:** In numerous cases around the world, decentralised solar systems have failed because of lack of financial resources to maintain the system and replace the batteries after five years of operation (UN Foundation, and SEforALL, 2019). Thus, it is critical to plan out the financial outflow for maintenance and replacement during the planning phase by allocating resources from savings or other available funds. For example, a contract between the local regional-level authority and local energy enterprises is set up which lays out the conditions of the servicing and maintenance contract (SELCO Foundation, 2021b).

Monitoring for better understanding and planning

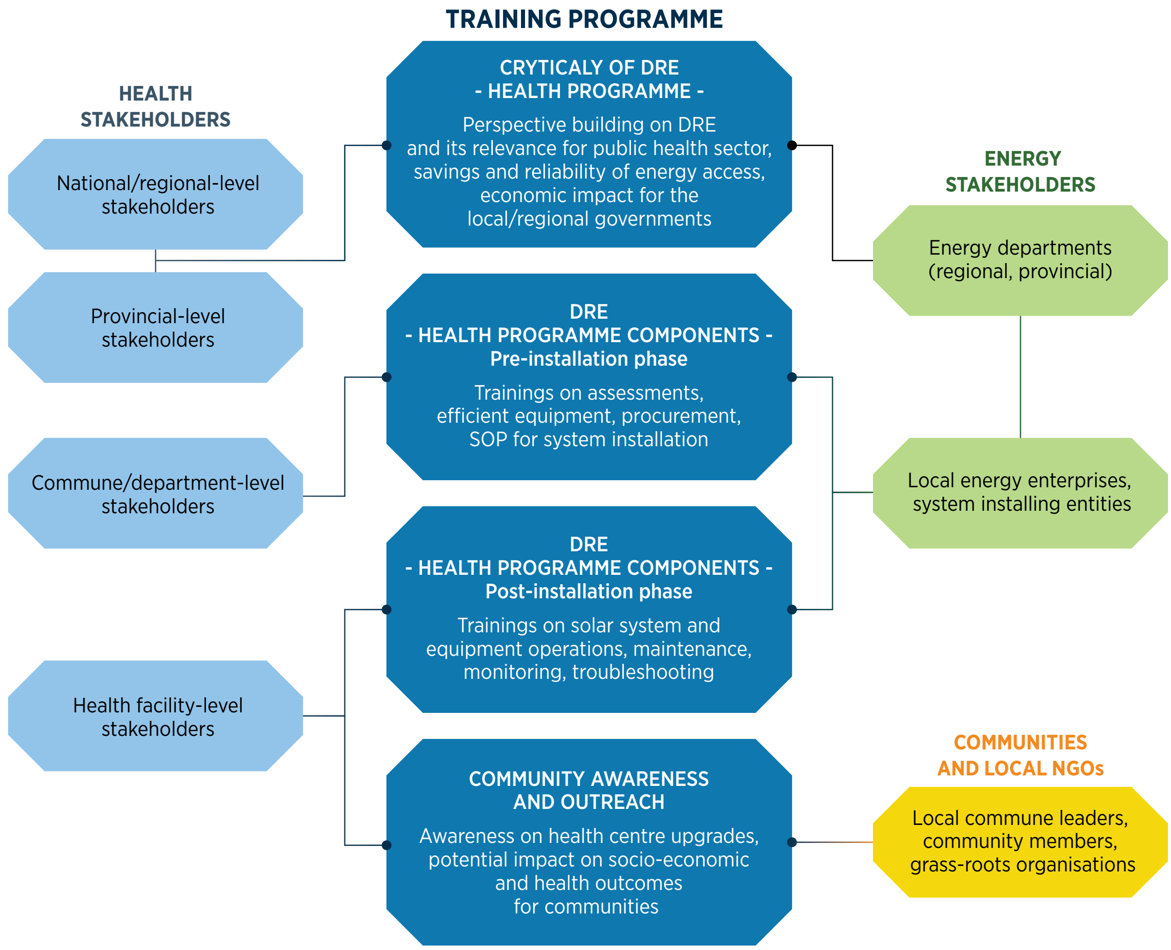
Once the installation is completed, an immediate implementation of a robust monitoring and evaluating process is necessary to constantly follow up on the utility and impact and develop steps towards rectification if necessary. Concurrent monitoring systems need to be in place to monitor the service uptake of health centres, postinstallation. This should be done in coordination with the National Health Ministry and regional/provincial authorities. Meetings with all personnel from regional/district authorities should be conducted once the installation of DRE and deployment of medical equipment is done. Further, field-level champions such as local health workers at each centre could be created, to speak on the value addition of the DRE system in improving the services uptake. It is critical to create documentation of case studies from each region focusing on the end user to share their experience of accessing services from the improved health centre. Along with champions at health facility level, creation of champions from the regional community-based organisation or individuals, civil society organisations, etc. who would speak on the value addition of DRE solutions would help in expanding the outreach of the programme's impact.

3.3. TRAINING AND CAPACITY BUILDING

Overall training and capacity-building map

Building capacity of the health and energy stakeholders is a key requisite for effective planning (resources), implementation and utilisation (O&M) of the energy and health infrastructure. These training programmes across the implementation phases are critical for overall sustainability of the programme. Thus, the health ministry is recommended to develop and integrate the following skill- and awareness-building components within the DRE-health programme implementation design.

Figure 9 **Map of common training needs for health and energy stakeholders**



Note: SOP = Standard Operating Procedure; NGOs = non governmental organisations.

Table 4 **Training needs identified across the implementation phases in Burkina Faso**

Phase of implementation	Key stakeholder	Details
Programme conceptualisation	National, regional-level health and energy department personnel	**Larger level awareness and perspective-building exercise with regional, provincial-level energy and health stakeholders in Burkina Faso.** This is to be done by the relevant ministry in order to have key buy-in from the nodal entities at regional and provincial levels. This could include the introduction of DRE and its potential to improve the delivery of SDG3, how solar integration into public health facilities resolves critical problems associated with energy access challenges and health service delivery without compromising on climate change agenda; socio-economic impact that the DRE integration would bring in terms of savings in electricity or fossil fuel cost for the local governments, economic impact due to improved health of communities, etc.
Assessments	Local health department field staff, local co-ordinators, NGOs	One of the key components that has to be implemented in the initial stage of the DRE-health programme is the detailed assessment of the healthcare facilities to develop system design and implementation pathways. The training components include basic understanding of importance of site assessment, step-by-step details of how to document the site-specific nuances, and the key considerations in terms of not only the energy aspect, but also the gaps in healthcare services that could be addressed through the programme.
Procurement	National, regional and provincial health and energy departments	Procurement of both medical equipment and services of clean energy enterprises in installing the systems are critical in the programme. The training programme of the implementing entity needs to include the best practices such as tendering (with adhering to national/WHO guidelines for medical equipment for example); energy efficiency aspects during the procurement of technologies; selection of local enterprises on certain key criteria of ability to procure, install and provide the maintenance and service.
Installation of solutions	Local clean energy enterprises and installing entities	It's critical to train the local energy enterprises (installers of the solar systems for the health facilities) on **the standard operating procedure for the installations of DRE in health facilities.** The two main components of the trainings: · On the detailed aspects of installation, key activities such as checklist and handover documents, providing initial training to the healthcare staff on the operation/service/maintenance aspects of solar to the **technicians and operation personnel of local enterprises.** · On the general attitude towards the health sector, establishing partnerships with health sector stakeholders to develop contracts on service and maintenance, constant monitoring of the systems, for the **leads of local energy enterprises.**
Post-installation O&M	Local health centre staff, community health workers, operation personnel within CSPS	After the system installation, the health centre staff and community members must be trained on the **basic awareness, technicalities, and O&M of the solar and medical equipment.** These training programmes with the community-level and health facility-level staff would have two main objectives: · improving the utilisation of new medical equipment powered by DRE by the facility level staff to provide better services to communities · incorporating basic O&M practice for solar components among the health facility-level personnel.

Way forward to provide effective training and build capacities

To enable the above-mentioned training activities, it is critical to develop training modules and institutionalise the training process within relevant ministries, among health facility staff and in local technical training institutes.

i. Strengthen training departments in the Health and Energy Ministries

It is important that a training department be created to facilitate implementation of these guidelines under the Ministry of Health and Ministry of Energy.

ii. Developing training modules

Following are some of the key modules that need to be incorporated along with the implementation programme within the training departments under the Health and Energy Ministries.

- **Healthcare practices:** This training should cover the regular theory and practical training of healthcare practices for various services to be offered by the staff. It should cover emergency care, mother and childcare, specialist care, etc. As part of this training, the healthcare staff should be taught the basics of operating and maintaining different medical equipment.

- **Basics of renewable energy and its criticality in the healthcare sector:** This training should cover the basics of renewable energy uses, types, technologies and their operation, the role of sustainable energy for better healthcare facilitation, and its various impacts on the health care system, on the staff and on the end users – patients. It also covers the basics and selection of energy-efficient medical equipment and its impacts on energy requirements for powering it as well as the broader aspects of savings from a solar-powered healthcare facility and how it can be budgeted (capex and opex) for a new or existing healthcare facility.

- **Role of DRE in various healthcare models**: This training should cover various types of healthcare models where energy can play a role. For example, solar powering various health facilities such as hospitals, health clinics and health posts; solar powering various mobility-based health care – mobile clinic, health boat, portable health kits etc.; addressing various types of health needs such as geriatric care, speciality care (dental, ophthalmic etc.); diagnosis; preventive care etc. This session covers examples of various interventions globally.

- **Health-energy nexus programme implementation guidelines:** This training module should cover the guidelines for implementation of health-energy nexus programmes. It covers the approach, tools at various stages, stakeholder mapping and their roles, procurement guidelines, standards and certifications, implementation SOPs and best practices, service and maintenance, monitoring and evaluation, capturing learning and sharing knowledge etc.

- **O&M of renewable energy systems:** This training should cover the O&M and troubleshooting (weekly, monthly, yearly) of the solar energy system. It covers the dos and don'ts and safety measures to be taken while using the system.

- **Usage of new technologies and medical equipment:** This training should provide hands-on training to healthcare professionals on existing and new medical equipment to carry out various medical procedures. The practice sessions will enable them to use the equipment with ease in the time of need.

iii. Upgrading local technical training institutions

The government should upgrade local technical institutes to facilitate training in:

- **Load assessments, site survey and system designs:** Development of standard guidelines and approach to design system suitable to local needs.

- **Technical capacities for quality installation and servicing in local areas:** Development of the standard operating procedure for the local solar enterprises or technical agencies involved in installations will have to be put in place. These will complement the already existing training initiatives undertaken by the government of Burkina Faso.

3.4. DEVELOP ENERGY-HEALTH INTER-MINISTERIAL PLAN

Delivery of healthcare services across the country is inherently linked to availability, reliability and good quality of energy access. It would be detrimental to view the energy needs in a silo without considering healthcare sector plans for establishing new facilities, upgrading existing ones, increasing services provided, and expanding and training human resources.

Given this, it is crucial that government departments, private-sector stakeholders and NGOs across the health and energy sectors come together to coordinate for long-term sustainable planning. Within the larger goal of integrated planning, ministries would need to include certain aspects within each of their mandates. Recommendations shared below outline which aspects could be taken on by health ministries and departments and which ones could be led by energy sector government agencies.

Health-side planning to include:

- Budget planning and allocations of the health ministry and related departments should include the costs of DRE systems and efficient appliances. It would also be important for this planning to include the costs of battery replacement over a five-to-eight-year period for each of the facilities.

- Planning (budgets, human resources, technologies, etc.) for future expansion or upgrade of health services needs to include the component of energy systems and appliances.

- Capacity building and training programmes planned by the health department for health staff, healthcare workers and government health officials need to take note of energy needs. The energy training can be planned in convergence with existing skill and capacity building to include utilisation of appliances and basic maintenance.

- Basic infrastructure and water access can be planned for by the health department for their health facilities, keeping in mind the infrastructural requirements to install decentralised solar systems.

Energy-side planning to include:

- **Development of policies** that encourage adoption of DRE solutions for use in healthcare facilities. This will include the following:
    - benchmarking of energy-efficient technologies and solar components
    - certification of technologies
    - empanelment of energy enterprises that are trained for assessments and quality installation and have the capacity to service
    - benchmarking design specifications and costs for different service levels.

- **Strengthening service networks:** Use an empanelled list of enterprises to develop after-sales networks by encouraging training of local technicians for repair and maintenance and building stronger supply chains for spare parts. Obviously, this activity must be liaised with health departments to create a plan for servicing and maintenance in health facilities currently powered by solar and grid-based electricity. Furthermore, it is advised to include frameworks for annual maintenance contracts to be in place that can ensure after-sales support on solar-powered energy systems.

- **Data and evidence building:** Evaluate the performance of existing facilities in Burkina Faso that use solar energy systems and SONABEL's (Société Nationale d'électricité du Burkina Faso's) electricity systems to understand what works well and the key gaps and challenges, and determine ways to address them, including through other aspects outlined in the recommendations section.

Others (taxes, supply chains and manufacturing)

- **Tax exemptions and concessions:** Certain tax exemptions exist for solar energy in Burkina Faso, such as for materials import. In addition to solar energy, the tax regimes for components such as batteries, inverters, and medical and electrical appliances can be developed in a manner that incentivises greater efficiency and modernisation.

- **Support for the development of local manufacturing**: In addition to tax concessions and exemptions, the government can engage with bilateral and multilateral agencies to lead the effort in creating conducive conditions to support local entrepreneurship and manufacturing capabilities through incubation and business development services, low-cost credit lines taking note of inflation and regional financial fluctuations, technology innovation linkages, human resource development, and so on.

CONCLUSION

Strengthening primary healthcare systems is essential to achieving SDG3, which aims to ensure healthy lives and promote well-being for all age groups through universal health coverage. In this effort, SDG7, on enabling access to reliable and modern energy for all, plays a critical role by powering health service delivery and affording last-mile communities access to such basic care.

In the context of Burkina Faso, to overcome the dual challenge of energy and health access, it is critical to use an integrated energy-health nexus and ecosystem approach. This report outlines how this approach can be customised and applied to developing a sustainable energy-health programme in Burkina Faso, by understanding the needs, developing solar energy system designs that integrate energy efficiency, and creating systems for effective O&M, alongside capacity building for health and energy stakeholders on planning and implementation.

Moving forward, it is imperative to break away from siloes and bring together both health (SDG3) and sustainable energy (SDG7) stakeholders for a nuanced understanding of the gaps in each sector. This can facilitate action towards bridging these knowledge, technical and skill gaps, with the larger goal of improving health outcomes for rural and last-mile populations across developing country contexts.

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ANNEXES

Solar system maintenance at the Clinic Wolobougou, near Bobo-Dioulasso, in Burkina Faso.
Photo: SELCO Foundation (2022).

ANNEX 1 SOLAR ENERGY DESIGN TEMPLATES FOR STAFF HOUSING IN CSPS

Figure 10 **DRE design template for staff housing in CSPS**

Staff housing for CSPS	
Rooms assumptions	1 Common/resting room 2-3 bedrooms 1 bathroom 1 storage room 1 outside walk
Loads assumptions	In the common/resting room: 1 light + 1 fan + 1 phone charging + 1 refrigerator In each bedroom: 1 light + 1 fan + 1 phone charging plug-in Outside: 2 lights
Energy requirements	**524 W, 3.7 kWh, 48 V**

ANNEX 2 OPERATIONS AND MAINTENANCE GUIDELINES

Ensuring sustainability of energy-health programmes

Building in-country capacity for health-energy deployments

+

Building and transfer O&M capacity to local systems

+

Choosing appropriate O&M models

+

Good and bad O&M practices

Building in-country capacity for health-energy deployments

STEP 1.1

Capacity building pre-empanelment

Capacity building for health departments	
Health and energy assessments Procurement of assets O&M needs	Content and purpose
3-5 members of the health department	Target
1 time training	**How often?**

Capacity building for local energy enterprises	
Energy audits and system design Procurement and installation Servicing and maintenance	Content and purpose
3-5 enterprises or service providers	Target
1 time training	**How often?**

STEP 1.2

Capacity building post-empanelment

Post-empanelment for local energy enterprises	
System installation quality Safety standards	Content and purpose
3-5 enterprises or service providers	Target
1 time training	**How often?**

STEP 1.3

Capacity building post-implementation

Capacity building for local energy enterprises	
Energy audits and system design Procurement and installation Servicing and maintenance	Content and purpose
3-5 enterprises or service providers	Target
1 time training	**How often?**

Building and transfer O&M capacity to local systems
Setting up a bridging initiative and team for O&M regularisation, with the end outcome of long-term practice transfer to local authorities **Key focus areas**
System strengthening and mechanisms for helplines, triage and troubleshooting in case of technology breakdown/low performance
Identifying mechanisms for energy enterprise and service provider linkages to local health staff **(based on local health system/context of regions)** at facilities and regularising such mechanisms
A three-member team comprising a Sr. Co-ordinator and two x junior co-ordinators who report to the health department of the country for a period of 1.5 to two years. (Managing assets deployed in 300 facilities in remote contexts with low population densities)

Choosing appropriate O&M Models
OPTION A
o&m expenditures and responsibility bundled into **tenders to local energy enterprises** as part of state-level scaling programmes
Long-term O&M service contracts (Between national/state govt. and vendors) are budgeted and accounted for during the initial procurement stage itself
Step 2 considering transfer of practices over a longer hand-holding period would continue to be required to ensure O&M
OPTION B
O&M Expenditures built into **health system budgets allocated to the local government or institutions**
Formal local government or public institutional structures that are capable of channeling public finances and procuring technical components and services as and when needed
These groups should have a history of channeling available funds towards health facility upkeep.
O&M expenditures towards solar energy systems deployed are added into these funds with year-on-year expenditures as well as savings for battery replacements are accounted for
In the two-year transfer of practice period, it should be ensured that either savings for battery budgets are taking place and any expenditures towards maintenance is taking place
This model would require pre-investments into local health system governance systems

OPTION C
O&M Expenditures carried out by **regional or national renewable energy development authority or department**
Energy departments manage assets deployed and ensure systems are functional and utilised
In the two-year transfer of practice period, it should be ensured that appropriate flow of communications, grievance redressal and recording of common challenges, standard operating procedures and best practices
This model would require pre-investments into local renewable energy development authorities, departments and systems

Photo: SELCO Foundation.

Good and bad O&M practices	
How to maintain the solar panels?	
Cleaning solar panels	**Good practices**
Every 2 weeks, debris and dirt should be removed from the panels using a sponge/cloth and cold water	
Prevent wear and tear on the panels	
Note and report wear and tear on the panels and cables	
Avoid shade on the panels	
Remove (or cut back) vegetation that shades the panels	
Do not disconnect the cables	**Bad practices**
Do not remove labels and certifications	
Do not walk or sit on the solar panels	
Do not place anything on the panels	
Do not illuminate the panels with strong direct light	
Do not move the panels	
Do not clean the cables with water or other wet products	
Do not use detergents or anything other than cold water	

How to maintain the batteries?	
Clean the surfaces of the batteries	**Good practices**
Every 2 weeks, using a dry cloth, clean debris and dirt from the batteries and around the ventilation grilles	
Prevent wear and tear on batterie	
Check and report wear and tear on the batteries and cables	
Ensure ventilation of the battery storage room	
Check the electrolyte level	
If the level is below that required, distilled water should be added	
Do not disconnect cables	**Bad practices**
Do not remove labels and certifications	
Do not place anything on the batteries	
Do not smoke or light fires near the batteries	
Do not clean the cables with water or other wet products	
Do not use detergents or other cleaning agents, only dry cloth	

How to maintain the inverter?	
Clean the surfaces of the inverter	**Good practices**
Every 2 weeks, using a dry cloth, debris and dirt should be cleaned from the inverter and around the ventilation grilles	
Prevent wear and tear on the inverter	
Note and report any damage to the inverter and cables	
Ensure ventilation of the uninterruptible power supply storage room	
Check the wiring	
Check that the wiring is intact	

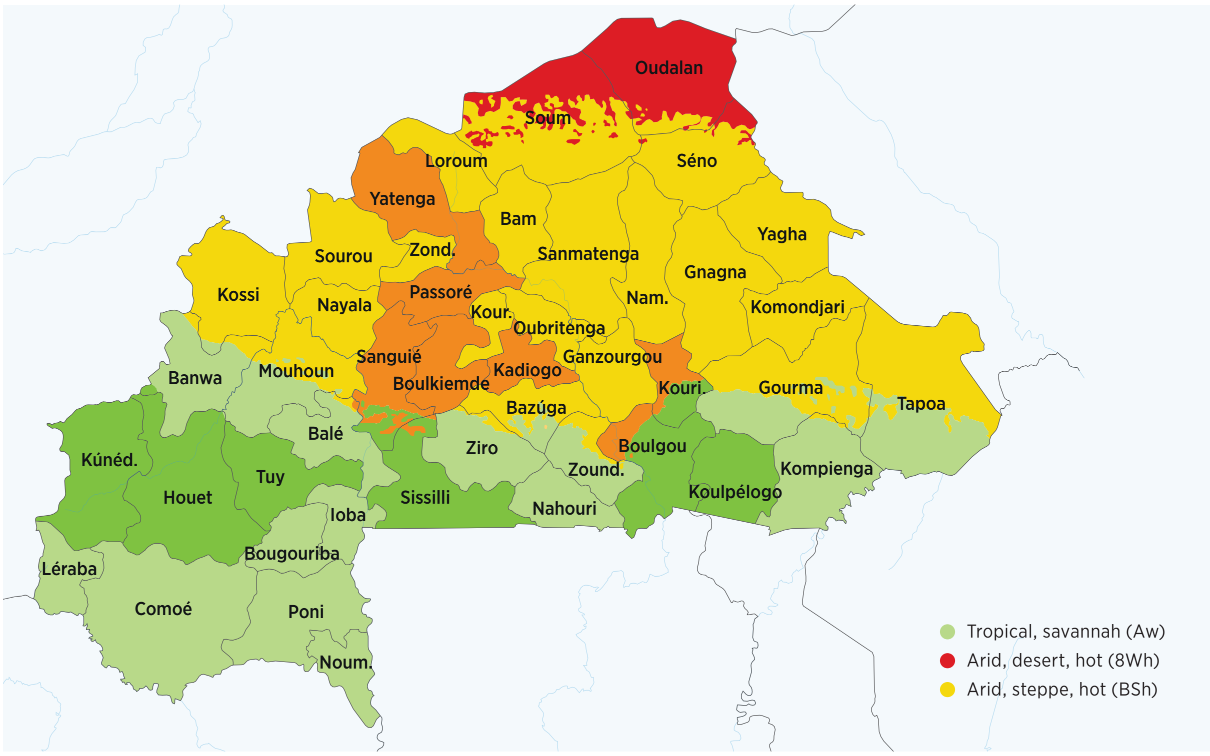
Do not disconnect cables or touch anything	**Bad practices**
Do not remove labels and certifications	
Do not place anything on the inverter	
Do not smoke or light fire near the inverter	
Do not clean the cables with water or other wet products	
Do not use detergents or other cleaning agents, only a dry cloth	

ANNEX 3 EFFICIENT BUILT ENVIRONMENT GUIDELINES

Context of Burkina Faso

- **Climatology**

  Burkina Faso is divided into three major climate zones according to the Koppen-Geiger climate classification: tropical savannah, arid desert (hot) and arid steppe (hot). The temperature and relative humidity vary according to the season with high variation between the daytime and night-time conditions as well. The rainfall is very variable and irregular and decreases from the southwest towards the north.



Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Source: Ministry of Environment and Sustainable Development, 2014.

Table 5 **Characteristics of classified climate areas**

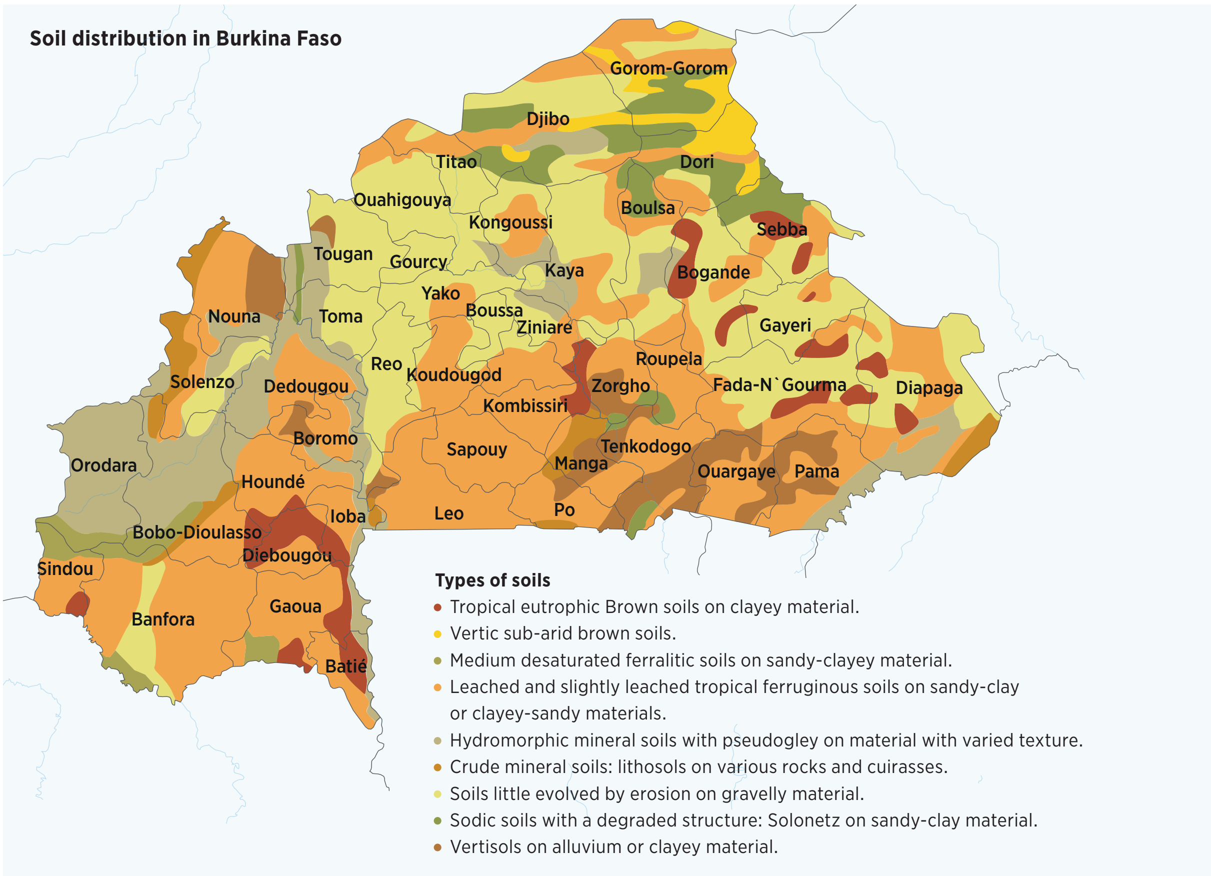
Characteristics of climate areas	Climate Areas		
	Tropical Savannah (South Sudanese)	**Arid Steppe (hot)** (North Sudanese)	**Arid Desert (hot)** (Sahel)
Annual rainfall	>1 000mm	600-1 000mm	<600mm
Duration of rainy season	180-200 days	150 days	110 days
Number of rainy days	85-100 days	50-70 days	<45 days
Annual temperature	20°C (Jan) - 43°C (April)	14°C (Jan) - 44°C (April)	8°C (Jan) - 45°C (April)
Dry season (Oct - Apr)	25%	23%	20%
Moist season (May - Sept)	85%	75%	70%

Source: Ministry of Environment and Sustainable Development, 2014.

- **Terrain and soil conditions**

There are nine types of soil present in Burkina Faso. Of these, the most dominant soil types are leached tropical ferruginous soils and lightly leached (39.78%), slightly eroded soils on gravelly materials (26.03%), and hydromorphic pseudogley mineral soils (12.70%). In general, the soils in Burkina Faso are rather unstable, having a poor level of fertility and high structural fragility (Ministry of Environment and Sustainable Development of Burkina Faso, 2014). Therefore, based on the location and the building design, deeper pile foundations are preferred.

Soil distribution in Burkina Faso



Source: Ministry of Environment and Sustainable Development (2014).

Due to the condition of the soil, the foundation and superstructure of the buildings must be designed to prevent the sinking of the structure as well as uprooting during floods or sandstorms. Structures need to be lightweight and not heavily loaded.

- **Climate and other stresses**

Burkina Faso has been confronted with many challenges due to climate change-related disasters. With varying rain patterns, the country experiences drought conditions. Over the past 30 years, severe flooding has occurred, causing the destruction of many poorly constructed informal settlements and infrastructure services and degrading the landscape. The flooding is succeeded by drought periods which are most pronounced during November and December when the humidity is extremely low (World Bank, 2021a).

The country also receives strong wind from the north that can reach speeds of up to 200 kilometres per day. Especially during the dry season (November to April), a hot and dry wind blows from the Sahara called the harmattan. The harmattan creates desert-like weather conditions within the country by lowering humidity, dissipating cloud cover, preventing rainfall, and bringing in dust storms or sandstorms.

Furthermore, due to the hot and dry climate of the country, the health of the people can also be negatively affected. For example, during the harmattan months, some people get spontaneous nosebleeds due to heat stress, which further spreads epidemics such as meningitis and cholera (World Bank, 2021a).

- **Architectural practices and materials generally followed**

The modern architecture of Burkina Faso can be described as a product of ingenuity born from reimagining traditional building materials and techniques. More than two-thirds of the people live in rural villages, and as such the designs and material palette of health infrastructure need to reflect them physically and physiologically.

Common house in Ouagadougou.
Photo: Clouis (2020).

Primary school in Gando
Photo: Kéré Architecture (2016).

- **The need for energy-optimised built environments in healthcare**

  An indoor environment that experiences high temperature and humidity fluctuations and has poor ventilation systems can have negative effects on the health of the users. These kinds of spaces have to be avoided in hospitals or healthcare centres so as to promote better comfort for health workers and a faster recovery rate in patients (Ormandy and Ezratty, 2015).

  Energy-optimised buildings are designed to utilise the energy supplied to them in the most optimised and economic way by taking steps to reduce energy loss. They are also used to be less expensive to operate during the life cycle of a building, to be more comfortable to reside in, as well as to be more environmentally friendly.

  Case 1: A study conducted by the SELCO Foundation showed that after providing energy-optimised spaces for recovery in rural areas, the health of the residents of the nearby villages improved significantly. The costs for operating the health centre in terms of providing electricity and cooling are also reduced. This is clearly seen in the cases of the health centres in Keba, Arunachal Pradesh, and in YK Mole, Karnataka, both in India.

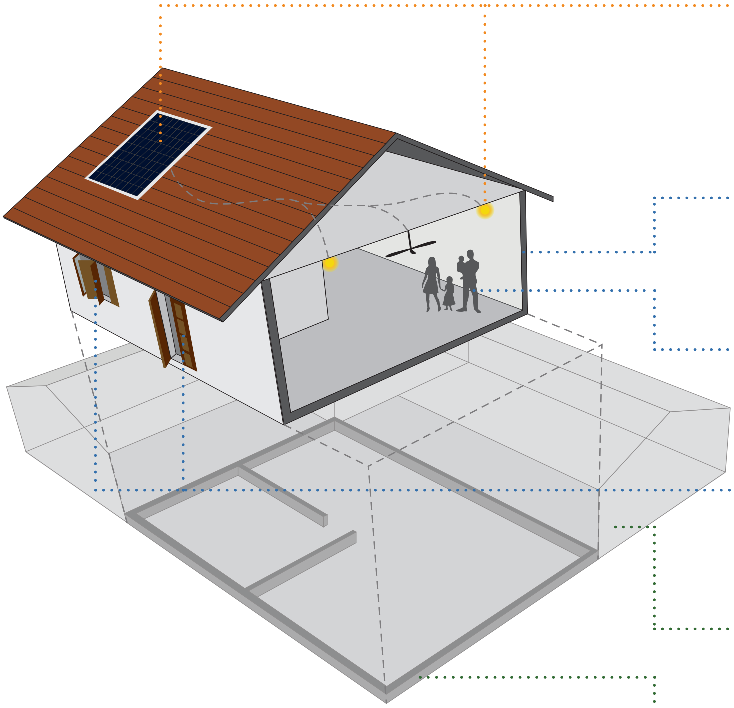
  Case 2: A study conducted in four wards of a general hospital in Nigeria to test the relation between indoor environment quality and patient recovery showed that a good indoor environment in terms of thermal comfort, air quality, lighting and acoustics has a positive influence on the patients. This improved the recovery rates (Alfa, 2019).

  Energy-optimised built environments can be achieved by means of passive (without energy consumption) and active interventions. Inclusion of passive interventions can improve the indoor environment of the building, hence reducing the amount of energy required to create a comfortable space. Active strategies are used to supply comfort conditions when passive strategies aren't sufficient. These mostly include lighting equipment such as bulbs and tube lights and cooling equipment such as fans and air conditioners. In energy-optimised buildings, the amount of active equipment can be reduced and low-energy solutions can be used to reduce the building energy demand. Energy-optimised buildings balance these active and passive systems to provide an ample amount of comfort with lesser energy consumption.

Passive interventions include:

1. optimised spatial design to limit or enhance solar heat gain and capture air movements
2. design of fenestration to increase daylighting and natural ventilation in the space
3. material and insulation: building and insulating with materials which have appropriate U-value in response to local climatic conditions to ensure comfort in extreme heat and cold conditions.

Figure 11 **Efficient built environment**



Energy efficient appliances and austainable enegy Integration

Wattage, location, type, reflectors and products to optimise the active and passive system designs

Material and Insulation

Building and insulating whith materials which have appropriate U-value in response to local climatic conditions

Physical, physiological and psychological benefits to occupants of the space

Design of Fenestrations

Size, location, type and accessibility of doors, windows, ventilators etc.

Adaptability local social contexts and needs

Efficient Spatial Design

Planning, shape, orientation and shading - to limit or enhance solar heat gain and capture air movements of the microclimate

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Solutions

- **Optimisation benchmarks for various rooms**

  Indoor temperature, relative humidity and lux levels can differ based on the function of a space. Based on this, the design of the form of the building, the layout, window placement and circulation as well as various active technology integrations can be defined. The following table lists the different functions in a health centre and their indoor environment requirements:

Table 6 **Optimisation benchmarks for various rooms**

	Function	Dry Bulb Temperature (°C)	Relative Humidity (%)	Minimum Illumination (lux)
A	**Health Centre**			
1	Entrance, Waiting Areas, Corridors, etc	24-26°C	45-55%	150
2	Consultation and Examination Room	24-26°C	45-55%	200
3	Labour and Delivery room	17-27°C	45-55%	PHCs: 300-500 CHCs: 500
4	Recovery / Wards	24-26°C	45-55%	150
5	Operation theatres	17-27°C	45-55%	500
6	Auditorium	Summer: 23-26°C Winter: 23-24°C	Summer: 50-60% Winter: 40% min.	250
7	Washroom/ Passage	24-26°C	45-55%	100
8	Pharmacy/ Storage	17-27°C	45-55%	100
B	**Accommodation**			
1	Kitchen	24-26°C	45-55%	200-300
2	Living Room	24-26°C	45-55%	150-200
3	Bedroom	24-26°C	45-55%	100-150
4	Bathroom	24-26°C	45-55%	70-100

Note: PHC = Primary Health Centre; CHC = Community Health Centre.

- **Recommendation for energy optimisation**

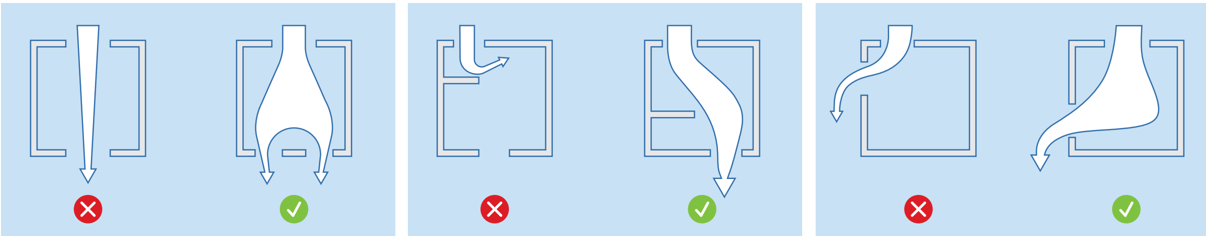
  There are three distinct climate types in Burkina Faso: tropical savannah, arid steppe (hot) and arid desert (hot). Designing for the climate is extremely important for ensuring energy optimisation because approximately 40% of the building energy consumption occurs due to active solutions for thermal comfort.

a) **air movement through cross-ventilation:** window placement to improve spread of incoming air in the space (Figure 12)

b) **air movement through stack effect:** provision of openings at a higher level to promote hot air rising and being replaced by cool air (Figure 13)

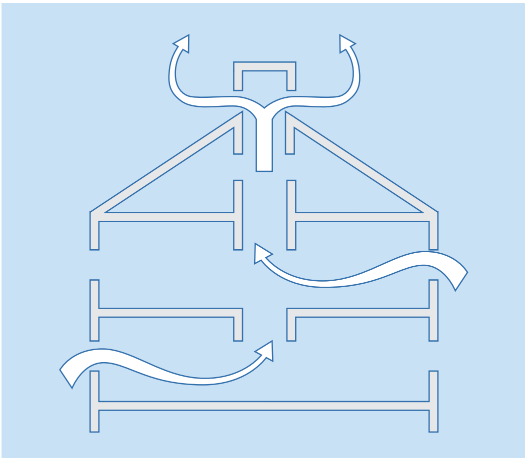
c) **humidification:** wind towers or wind scoops with provision of water to improve the humidity of the space and make it more comfortable (Figure 14).

Figure 12 **Air movement through cross-ventilation**



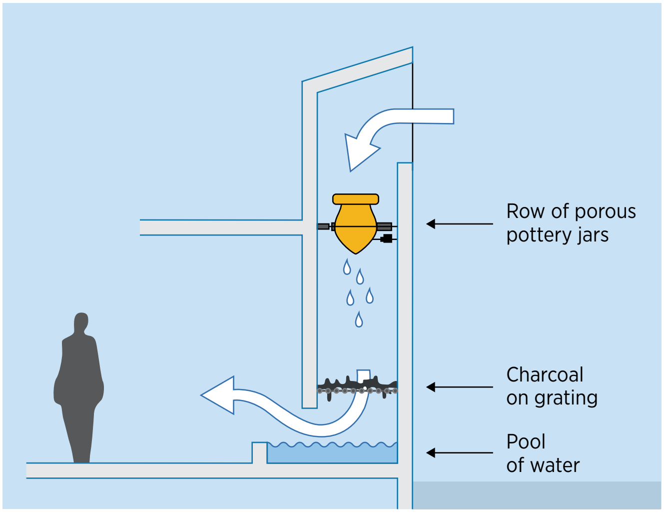
Distribute air throughout the room | Keep partition away from window | Locate window position for distributing air

Figure 13 **Air movement through stack effect**



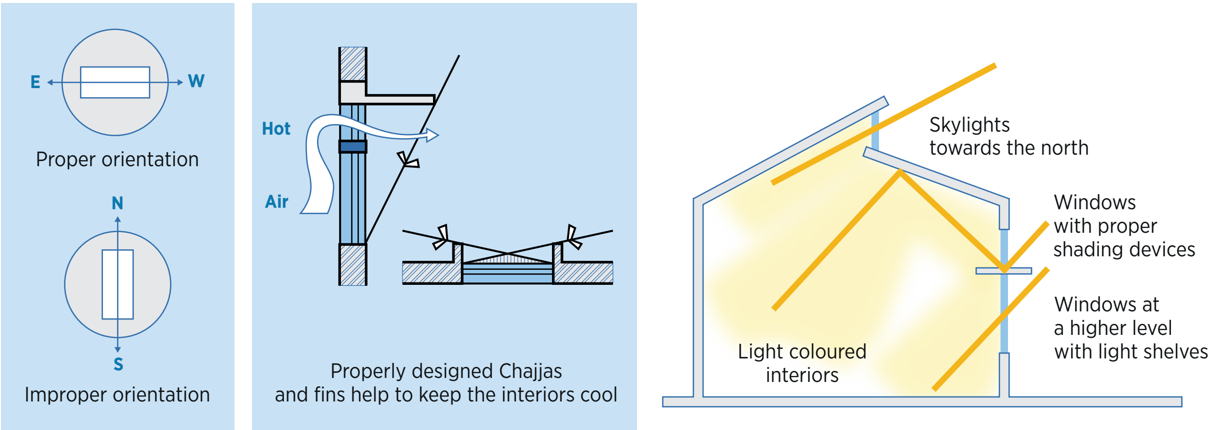
Windows at high level to vent hot air

Figure 14 **Humidification**



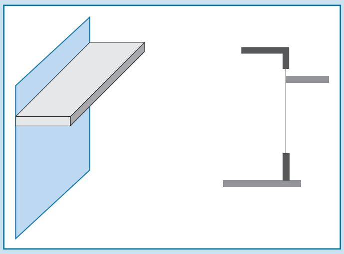
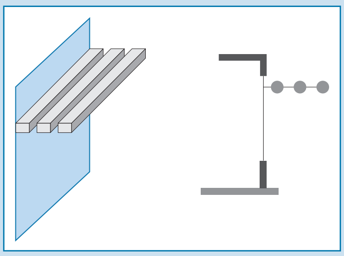
d) Daylighting and shading guidelines: Longer face of the building to face the north-south direction as the walls are easier to shade than east and west walls. Horizontal and vertical shading devices to be provided based on the orientation and size of the window.

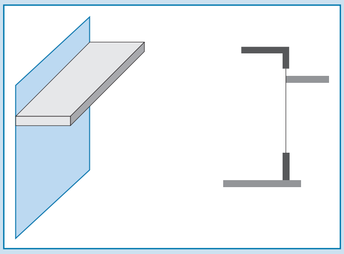
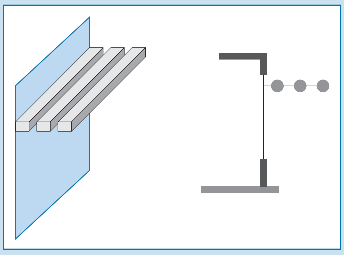
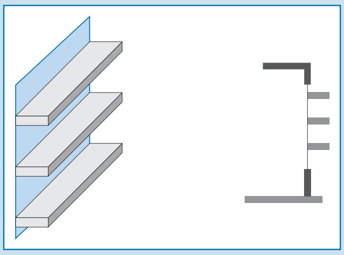
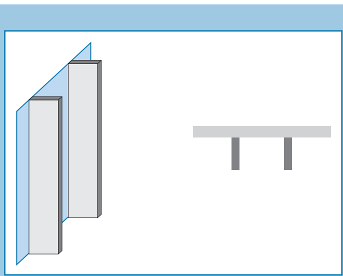
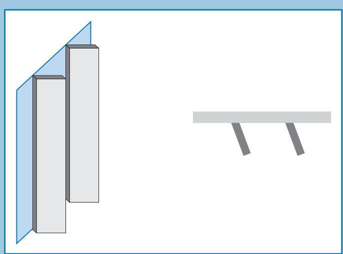
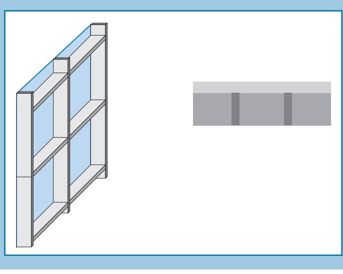
Figure 15 **Daylighting and shading guidelines**



Interior surfaces should be finished with light colours to improve light reflection within the space. Provision of light shelves and skylights improve daylighting. Adding internal shading devices such as curtains and blinds can further control heat and light entering the room

Table 7 **Shading guidelines**

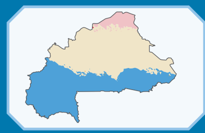
Orientation	Guidelines		
	Shading devices		Daylighting
North		Single horizontal shade - solid	· Larger windows for daylighting on north side as lesser incident radiation and glare · More numbers of individual windows preferred over single ribbon windows · Provision of skylights and light shelves towards north · Preferable orientation for spaces which require more lighting
		Single horizontal shade - perforated	

South		Single horizontal shade - solid	
		Single horizontal shade - perforated	· More numbers of windows for daylighting can be provided on the south with smaller dimensions - to increase daylight and reduce radiation · More numbers of individual windows preferred over single ribbon windows · Preferable orientation for spaces which require more lighting
		Multiple horizontal shades	
East		Vertical fin - 90º	
		Vertical fin - angled	· Lesser number of windows - glare during the morning · Lesser number of windows - glare and heat during the evening
West		Egg crate shading device	

Summary of energy optimisation requirements according to climate classification

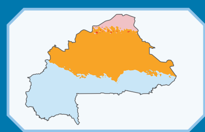
Table 8 **Resilience parameters for preparedness during disasters**

Climate type:
Tropical Savannah (Aw)



Climate characteristics	Building intervention	Description	Energy demands
High temperatures and high humidity levels	Shading	· Shading devices to be provided for all windows and door to prevent solar radiation from entering **Minimum 0.6 m sunshade to be provided** - especially in the south and west orientation · Shading of walls also preferred	Cooling Mechanical Ventilation Dehumidification
	Maximising cross ventilation for dissipation of humidity	· Providing windows on windward and leeward sides to promote air movement - **total window area to be 30% of the floor area. Height of the windows to be at least 1 m** **Sill height to preferably be at 1 m or lower**	
	Increased thermal capacity	· Providing walls and roof with insulation · Air gap can be provided as insulation in walls. In roof, air gaps can be given in the form of false ceiling · Providing thicker walls	
	Reducing effect of incident radiation	· Using lighter colours for external surface · Rough plaster finish for external surfaces	

Climate type:
Srid steppe (hot) (BSh)

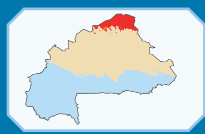


Climate characteristics	Building intervention	Description	Energy demands
Mix of high and low temperatures and high and low humidity levels, cold winds during winter and hot winds during summer	Shading	· Shading devices to be provided for all windows and door to prevent solar radiation from entering **Minimum 0.6 m sunshade to be provided** - especially in the south and west orientation · Shading of walls also preferred	Cooling Mechanical ventilation Humidification (depending on the season)
	Controlled ventilation – increased ventilation during monsoon	· Provision for operable windows that can be opened and closed based on the season **Total window area to be 20% of the floor area - height not exceeding 1 m size –** windows to be relatively closed during dry seasons and opened during wet season **Sill height to preferably be at 1 m** · **Provision of wind towers are preferred**	

Climate type:
Srid steppe (hot) (BSh)

Climate characteristics	Building intervention	Description	Energy demands
Mix of high and low temperatures and high and low humidity levels, cold winds during winter and hot winds during summer	Increased thermal capacity	· Providing walls and roof with insulation · Air gap can be provided as insulation in walls. In roof, air gaps can be given in the form of false ceiling · Providing thicker walls	Cooling Mechanical ventilation Humidification (depending on the season)
	Reducing effect of incident radiation	· Using lighter colours for external surface · Rough plaster finish for external surfaces	

Climate type:
Arid desert (hot) (BWh)



Climate characteristics	Building intervention	Description	Energy demands
Solar radiation, glare, hot winds and low humidity levels	Shading	· Shading devices to be provided for all windows and door to prevent solar radiation from entering **Minimum 0.6 m sunshade to be provided** - especially in the south and west orientations · Shading of walls also preferred	Cooling Humidification
	Controlled ventilation	· Smaller windows to be provided to prevent entry of dust and sand **Total window area to be 10% of the floor area – height not exceeding 1 m height** **Sill level if the windows are preferred to be 1.5 m or higher** · Provision of wind towers preferable	
	Increased thermal capacity	· Providing walls and roof with insulation · Air gap can be provided as insulation in walls. In roof, air gaps can be given in the form of false ceiling · Providing thicker walls	
	Increasing humidity within the space	· Provision of water bodies in the windward direction · Wet clothes can be placed over openings in the windward direction to increase the humidity of incident wind	
	Reducing the effect of incident radiation	· Using lighter colours for external surface · Rough plaster finish for external surfaces	

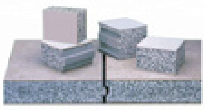
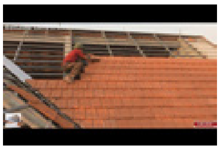
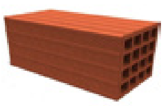
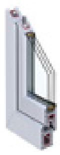
Resilience parameters for preparedness during disasters

	Disaster Type	Damages	Resilience measures (%)
A	**Flood and Flash Flood**		
1	Site Selection	Building Location	· Conduct a site-level hazard/risk assessment. · Avoid low-lying areas and flood-prone zones while selecting location for health centre. · Road transport and access routes should not be cut off due to flooding. Roads to be built on embankments. Access routes such as bridges need to be reinforced. · Site must be elevated from road levels. · Build site-level protections such as embankments, earth mound raising or elevating the plinth or lower floor, landscaping, and/or building flood walls along the site boundary to divert floodwater or reduce the impact.
2	Orientation	Building Layout	· Orientation of the building along the flow of the flood to reduce resistance and impact.
3	Orientation of the building along the flow of the flood to reduce resistance and impact	Foundation	· Flood impact and duration to be considered and its effect on soil properties and bearing capacity ground settlement due to flood (among other factors). · Uplift (buoyancy) pressures on the building foundation to be considered.
		Plinth/ Floor level	· Ground-floor plate needs to be located above flood levels. · Ground-floor rooms should be waterproofed. · Construction joints must be made watertight.
4	Envelope	Walling	· Impermeable construction materials and waterproofing at least up to 3 feet above flood levels. · Waterproofing additives to be added to cement mixture.
		Roofing	· Providing waterproofing of the rooftops. · Minimum 3-foot roof overhangs to protect the built envelope from torrential rains.
5	Openings	Windows and Doors	· Providing waterproof, watertight and impact-resistant window and door frames. · Openings on the ground floor should be above flood level and provided with impact-resistant glazing. · Shading or chhajjas of 2 feet to be provided over windows, ventilators and doors.
6	Services	Solar Systems	· Providing rooftop reinforced solar panels to power all critical loads (*e.g.* emergency lights, mobiles, fans, water pumps).
		Electricals	· Diesel generator sets as backup systems to be avoided.
		Water Storage	· Below-ground infrastructure (tanks, plumbing) should be designed to prevent leakage or contaminations. Overhead tanks recommended.
		Sanitation	· Backflow prevention valves to be installed to prevent leakages. · Plumbing to be located above flood levels.
B	**Drought and Heat Stress**		
1	Site Selection	Building Location	· Planting of local indigenous shade trees that consume less water and naturally shade/cool the building.
2	Orientation	Building Layout	· Linear along the east-west axis to reduce the impact of the harsh low sun altitude.

3	Structural System	Foundation	· Reduce usage of cement in the foundation.
4	Envelope	Walling	· Promotion and use of less-water-intensive construction methodologies (reinforced concrete is water-intensive). · Prefabrication and pre cast technologies are more optimised and have a faster pace of construction, reducing site usage of water.
		Roofing	· Insulated roofing technologies and cool roof paints to be used.
5	Openings	Windows and doors	· Deep chhajjas and shading on the southern and eastern facades. · Insulated glazing to be used.
6	Services	Solar systems	· Air-conditioning and cooling systems to be solar integrated for optimisation in energy consumption.
		Water storage	· Promoting rainwater recharge of ground water and/or harvesting of rainwater for utility purposes.
		Sanitation and plumbing	· Usage of low-flow taps and flushes. · Biodigesters to be used for sustainable management of sewage. · Greywater and blackwater recycle and reuse for utility and gardening.
C	**Sandstorm and locust infestation**		
1	Site Selection	Building Location	· Conduct a site-level hazard/risk assessment. · The area behind a mound or a hillock should be preferred to provide for natural shielding. · Indigenous trees can be planted to provide a shield from the wind and sand. · The road transport and access routes should not be cut off due to storms. Roads to be built on embankments. Access routes (*e.g.* bridges) must be reinforced. · In hilly areas, construction along ridges should be avoided since they experience an accentuation of wind velocity whereas valleys experience lower speeds in general. Though sometimes in long, narrow valleys wind may gain high speed along valley.
2	Orientation	Building Layout	· Orient the building along the flow of the wind to reduce resistance and impact. · Rectangular or circular, symmetrical and compact buildings are preferable in terms of form.
3	Structural System	Foundation	· Suitable foundation to be provided so as to prevent uplifting of the building during windstorm. · Pile foundation is preferable for sandy soil, the depth of which will be have to be determined based on site conditions.
4	Envelope	Walling	· Walls should be impermeable with minimum number of openings on the external side. · Diagonal bracing to be done for extra stability.
		Roofing	· Hipped roof (for rectangular plans) and conical (for circular plans) are most preferable. · Slope should be between 30° and 45°.
5	Openings	Windows and Doors	· External openings to be minimised. · Windows and doors should be provided with operable shutters that can withstand the effect of the high winds.
6	Services	Solar Systems	· Providing rooftop reinforced solar panels to power all critical loads (*e.g.* emergency lights, mobiles, fans, water pumps).
		Electricals	· Diesel generator sets as backup systems to be avoided.
		Water Storage	· Below-ground infrastructure (tanks, plumbing) should be designed to prevent leakage or contaminations.

Materials

Table 9 **Optimised material alternatives and its application**

Optimised Material Alternatives		Application
External Envelope		
	Cool roof paint	For galvanised iron sheet as well as reinforced concrete (RCC) slab on the exterior surface of the roof for reflecting incident solar radiation
	Precast cement/ferrocement sandwich insulation (with foam or expanded polystyrene) slabs	Flat roof slab alternate for RCC
	Clay or laterite aggregate in RCC slab	Alternative for RCC aggregate
	Clay tile roofing with metal framework	Alternate for RCC roof in heavy rainfall zones
	Fly ash or autoclaved aerated concrete cement blocks	External and partition walls
	Laterite blocks, compressed stabilised earth blocks or adobe blocks	External walling material
	Hollow clay blocks	External and partition walling material
Fenestrations		
	Unplasticised polyvinyl chloride or fibreglass frame windows and ventilators	Fenestration
	Window glazing material (low emissivity)	Fenestration

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