Executive summary

1. Introduction

Universal health coverage and universal access to efficient modern energy services are both global development goals. Rarely, however, have they been explored in tandem. This document sets out key issues, opportunities and synergies for further exploration. The report is intended to inform the *Sustainable Energy for All (SE4All)* initiative, which aims to achieve universal access to energy by 2030 as well as double the rate of improvement in energy efficiencies and the share of renewable energy in the global energy mix. This report is particularly relevant to SE4ALL's new *High-Impact Opportunity (HIO) on Energy for Women's and Children's Health*, which aspires to improve availability and quality of essential maternal and child health care through the scale-up of energy access in health facilities. This report lays the groundwork for further work and consultations leading to: the development of tools for better assessment of the state of energy access in resource-constrained health facilities; design of interventions; and measurement and monitoring of progress. Although household energy access has been a focus of increasing attention, access to energy for health facilities has received much less emphasis. Health facilities are community institutions where access to adequate, reliable and sustainable energy is particularly important. Energy access is a critical enabler of access to medical technologies, and thus an important determinant of the effective delivery of essential health services. Without energy, many life-saving interventions simply cannot be undertaken. This poses barriers to the attainment of universal health coverage as well as to key health-related Millennium Development Goals (MDGs).

Reliable data on energy access in health facilities is currently very sparse. WHO and other international and bilateral agencies support limited monitoring and measurement of energy access in health facilities in the context of facility infrastructure surveys. Some studies by the World Bank and other agencies have looked at indicators of health-sector energy access in community development contexts. But a better understanding of the multidimensional linkages between energy and health service delivery is needed. This report examines the energy needs of health facilities in resource-constrained settings most commonly found in low-income countries or emerging economies. The report considers available evidence about inadequate energy supplies' impacts on health services as well as trends in the use of energy technologies. These are used to develop a rationale and approach for tracking and monitoring energy access in health facilities.

This report's findings are most relevant to clinics and health centres at the primary and secondary tiers of health systems, many of which struggle to access sufficient energy to power lighting, refrigeration and a few basic medical devices. Access to reliable electricity, however, is also a severe problem at higher levels of the health services chain, including large urban hospitals. While the energy needs of larger facilities are inevitably more complex, many of the messages and findings presented here are relevant for hospitals. The broader aim of this report is to support better measurement, monitoring and design of energy interventions that optimizes delivery of health services at all levels.

2. Energy as an enabler of universal access to health care

Why energy is important for delivery of health services

Good health is integral to attainment of the Millennium Development Goals (MDGs). The health-related MDGs have focused the world's attention on the need for expanded access to skilled care, essential medicines and medical technologies for priority diseases and health conditions. Comparatively less attention, however, has been given to energy's vital role as an enabler of health care delivery, and particularly the lack of electricity access in many resource-constrained health facilities. Yet available data and anecdotal examples indicate that even the most basic modern energy services are often unavailable in thousands of facilities across the developing world, including lighting for child delivery and emergency night-time care, refrigeration for blood and vaccines, sterilization facilities, and electricity for simple medical devices.

The growing need to fight noncommunicable diseases that require complex interventions will drive additional energy requirements (for example, imaging equipment for cancer detection). Besides playing a key role in delivery of health services, facilities that have access to electricity may be better positioned to attract and retain skilled health workers, especially in rural areas. Electricity also enables mobile- and tele-health applications, and facilitates public health education and information. Modern energy provision is therefore a critical enabler of universal access to health care and universal health coverage.

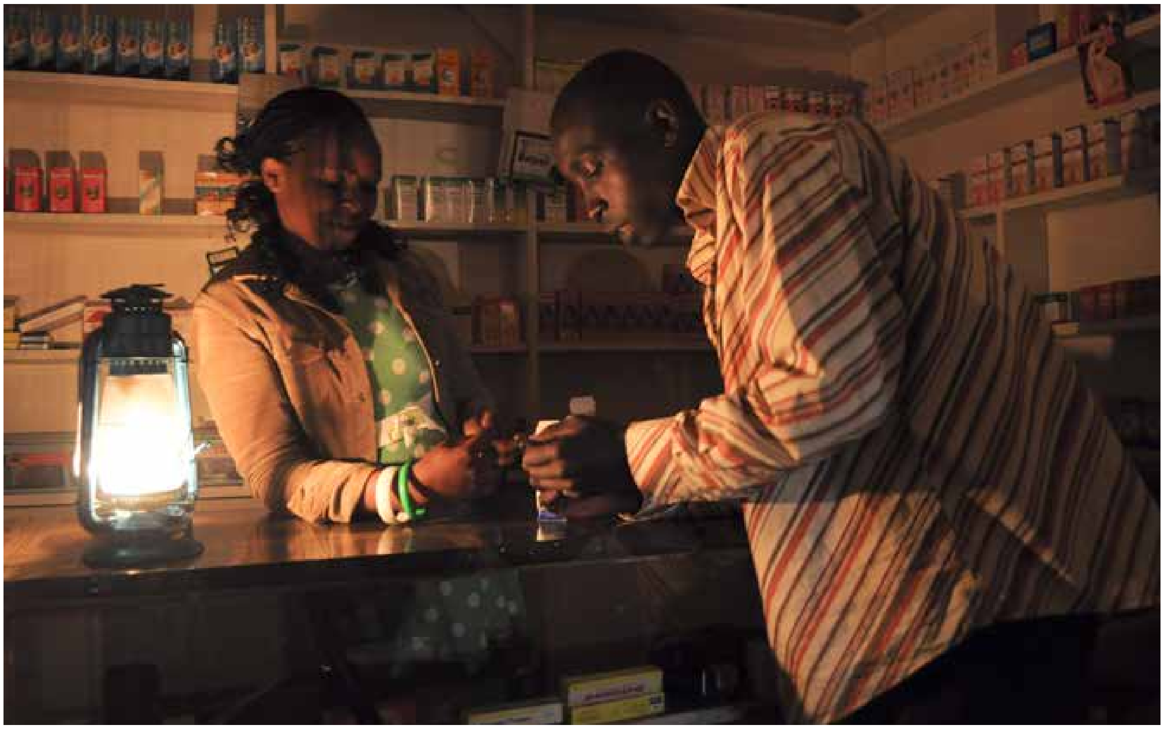
Current status of electricity access in health facilities: measurement and available data

Reliable data is sparse. A WHO-led review found nationally representative data for only 14 developing countries globally, 11 of them in sub-Saharan Africa. Even this data set, however, yields striking results. On average, one in four sub-Saharan health facilities had no access to electricity (Adair-Rohani et al, 2013). Only 28% of health facilities and 34% of hospitals had what could be called "reliable" access to electricity (without prolonged interruptions in the past week). WHO's new Service Availability and Readiness Assessment (SARA) provides a consistent methodology for country-led monitoring of health service delivery, and has supported over a dozen surveys in Africa. Other health partners, such as the GAVI Alliance and the Global Fund to Fight AIDS, Tuberculosis and Malaria, have recently joined WHO to expand the survey base further in Africa and South-East Asia. These surveys have refined data collection on electricity access, reliability, and major sources of supply (e.g. grid, generators, solar). However, further improvements in energy survey tools would support more refined analyses of energy issues.

Research into links between energy access and health services provision

The very few studies that have been conducted indicate that electricity access may have a significant impact on some key health service indicators, such as: prolonging night-time service provision; attracting and retaining skilled health workers to a facility; and providing faster emergency response, including for childbirth emergencies. This report analyses the available evidence.

Few studies, however, have systematically examined the impacts of energy access at health facilities on health services provision – and fewer still have looked at treatment outcomes. Impacts on health outcomes are particularly difficult to measure due to the many confounding factors, including staff skills and knowledge, availability of medicines, proximity to treatment and time lag before measureable improvements. Better data collection can help facilitate research into the linkages between reliable electricity access and major health-care priorities such as improving maternal and child health and reducing mortality.



A kerosene lamp *illuminates a community pharmacy in Nigeria. Despite the impacts of kerosene smoke on both health and climate, such lamps remain the only lighting option for countless health clinics as well as homes in the developing world. (Photo: World Bank)*

3. Energy requirements in health facilities: a closer look

Electricity needs for health services and medical equipment

Health facilities may provide a wide range of health services, such as obstetric care, immunizations, basic emergency treatment and surgical services. Each of these may require specific equipment, trained staff and medicines. Defining essential energy needs in relation to all aspects of health service delivery has yet to be undertaken systematically. WHO's SARA and similar infrastructure survey tools are used by national health ministries, as well as multilateral and bilateral agencies, to conduct detailed monitoring of equipment available in health facilities in relation to their provision of specific services. Better definition of device electricity requirements is needed to help drive appropriate design of energy supply-side solutions. The recent emergence of more energy-efficient medical devices that can operate from low-power battery and solar panel sources creates exciting new opportunities to improve energy access using demand-side measures. Examples range from obstetrics devices such as fetal heart monitors to LED microscopes for TB smear microscopy and a new generation of WHO-pre-qualified solar-powered "direct-drive" vaccine refrigerators. Direct-drive refrigerators use solar electricity to power a cooling system that freezes ice or some other phase-change material rather than storing energy in a battery. This keeps the refrigerator at a stable temperature when solar power is not available while eliminating the expense of battery replacement. More systematic review and continuous updating of the energy performance requirements for essential technologies is thus important.

Thermal energy needs of health facilities

In addition to electricity for medical devices, appliances and facility support functions (such as lighting and water pumping), health facilities have thermal energy needs for cooking and water heating, sterilization, space heating and incineration of medical waste. Such needs are more significant in larger health facilities delivering more complex health services or offering inpatient services. Among high-income and grid-connected health facilities, thermal energy needs may be met using electricity and increasingly by high-efficiency co-generation of heat and power (CHP) systems. More commonly, thermal energy needs are supplied through direct combustion of fossil fuels (diesel, gas, coal and biomass) using on-site boilers; inexpensive thermal solar panels also can provide hot water for hygiene and space heating. Improving the energy efficiency of buildings can greatly reduce thermal energy needs as well as electricity requirements.

4. Electricity supply in health facilities: trends and opportunities

Grid-based electricity supply and on-site electricity production

Hospitals and clinics located near an electricity grid connection have traditionally relied on grid power as a primary energy source. Yet power failures or outages during periods of peak demand are a problem even in grid-connected cities and regions. This forces clinics to rely on expensive backup generators – or to remain without power.

In off-grid settings, stand-alone diesel-powered generators have been the most common solution, backed up mostly by kerosene lamps, candles or flashlights. Generators, however, are expensive to operate due to the increasingly high cost of fuel and its transport and storage. As equipment maintenance also may not be locally available, the unreliability of generators is thus a major issue. In a recent WHO survey of data from six large sub-Saharan African countries, less than 30% of stand-alone diesel generators were functional with fuel available on the day of the survey.

Generators also produce significant waste heat, which is essentially wasted energy. Small on-site diesel generators tend to be particularly inefficient. They produce high proportions of health-harmful particulate matter (PM) and CO_2 emissions per kWh of power generation, contributing to air pollution exposures as well as to climate change. Conventional thermal grid power generation is also an energy-inefficient process, generating significant waste heat during power production and thermal losses during transformation and long-distance transmission. More than two-thirds of input energy may thus be wasted in a conventional coal- or oil-fired power plant. Finally, grid power access does not alleviate the need for on-site generators, because all health facilities that offer emergency care, childbirth management or surgical procedures also require backup power. Regulatory or accreditation requirements typically make on-site power mandatory for such facilities.

Overall, energy and fuel costs in many developing countries are high compared to per-capita income levels. While few reviews of health-sector energy costs have been undertaken, these costs appear to consume a significantly larger proportion of operating budgets than in comparable developed-country settings. Such stresses have been exacerbated by fossil fuel price increases over the past decade.

Increasing role of solar power in health facilities

As the costs of renewable energy technologies fall, they are more affordable for health facilities, both as a primary or backup energy sources. This is particularly true in the case of photovoltaic (PV) solar power. The recent WHO-led review of sub-Saharan African health facilities found a trend towards increasing use of on-site PV solar either as a primary or backup electricity source. In Uganda, some 15% of hospitals used PV solar to complement grid electricity access, and in Sierra Leone, 36% of all health facilities and 43% of hospitals used solar systems in combination with other electricity sources (Adair-Rohani et al, 2013). In Liberia, a country with little grid coverage beyond the capital city, the pace of solar electrification has outstripped that of other power sources; in 2012, more first-line public health clinics used PV solar than generators as their primary energy source. While PV systems are limited in capacity, they appeared to offer somewhat greater reliability: more solar-equipped clinics reported having electricity available on the survey day compared with those using diesel generators as their primary source.

The interest in solar has been stimulated by the increasing range of direct-current (DC) medical devices and appliances that can be charged from PV solar panels. Major donors, such as UNICEF are making solar refrigerators a major procurement item for vaccine refrigeration. Solar systems are also being purchased in bulk by the Global Fund to Fight AIDS, Tuberculosis and Malaria, often to power TB diagnostics. A number of NGOs have developed inexpensive portable solar systems designed for off-grid health clinics' basic lighting and communications needs, particularly to support childbirth and emergency services.

Emerging solutions: Hybrid systems to limit fuel costs, climate-changing emissions and pollution

Hybrid energy applications are of increasing interest among energy experts. For small and mid-size health clinics, well-managed hybrid solar-diesel systems can achieve lifetime fuel savings on an order of 75–80% while ensuring reliable electricity supply. Small-scale energy management systems can shift efficiently between different energy sources so clinics harness sunlight during most operating hours, but benefit from automatic generator backup in peak periods or when solar storage has been depleted. Insofar as diesel fuel use is reduced, such systems reduce CO_2 as well as particulate emissions that are harmful to health. Diesel particulate emissions also contain considerable amounts of black carbon, a short-lived climate pollutant whose mitigation can reduce near-term climate change impacts.

High capital cost barriers to initial solar energy investments

Despite their potential long-term appeal, renewable or hybrid energy systems still require greater capital investments by health facilities than conventional generators. This poses a significant barrier to change.

Other barriers to effective uptake of PV solar include security issues, inadequate budgets in small clinics for replacement of solar system batteries and spare parts, and lack of technical capacity to troubleshoot and perform equipment maintenance. More advanced and robust battery technologies also are needed; the lead-acid batteries most commonly available have short lifespans in hot climates and present waste disposal issues. Health-care facilities have not traditionally viewed energy services as a "core function" – although increased recognition of its role in modern health care can open up new opportunities for innovation. Finally, innovative financial solutions are needed to overcome capital cost barriers to the deployment of clean, energy-efficient systems in health facilities that harness renewable energy capacities.

Health facilities as energy providers

With better access to new technologies and financial models to ensure system sustainability, health facilities can become "anchors" for distributed energy generation in their communities, stimulating even wider development co-benefits.

While small and mid-size clinics are the major focus of this report, hospitals, which have a very large and constant need for energy, can also benefit from investments in efficient on-site energy systems. Combined heat and power systems (CHP), increasingly common in the hospital sectors of the United States of America and Europe, also are attracting interest in emerging economies such as India and Brazil. When these are fuelled by natural gas, CO_2 and PM emissions are very low, and use of energy inputs is extremely efficient since waste heat is captured for building use. On-site hydroelectric power systems have also been developed by some African hospitals. When such systems produce electricity at a lower lifetime cost and higher rate of reliability, resource use and service delivery are both improved.

However, business models suitable for health facilities in resource-constrained settings need to be devised for making and maintaining investments in energy-efficient hospitals and in reliable and efficient energy systems.

In grid-connected areas, "feed-in" tariffs can facilitate the sale of surplus electricity produced on-site by a health facility to the grid; other forms of incentives can make energy efficiency investments more attractive. To finance new investments, more and more hospitals in North America and Europe have become partners in "power purchase agreements" (PPAs) whereby energy utilities or other investors pay to construct and operate a CHP, wind or solar installation on the hospital premises. The health facility receives a guaranteed supply of power at a fixed rate in a long-term lease arrangement – and any surplus (e.g. from off-peak periods) is sold by the utility. In off-grid settings, some NGOs have supported health clinics to create micro-enterprises that mimic such arrangements on a very small scale. In this approach, the clinic is equipped with a solar system and a small proportion of the power generated is used to charge community cell phones. Fees collected are used to finance system maintenance, including replacement of critical spare parts such as light bulbs and batteries – ensuring long-term operational sustainability.

Stimulating investments in power solutions

Decisions about which on-site energy solutions are needed are based on a wide range of factors. These include: electricity and other energy requirements; reliability and quality of grid supply (if available); local availability of other energy technologies or fuels; and the capital and operating costs of grid versus on-site supply options.

Partnerships between the health and energy sectors are mutually beneficial in overcoming barriers to new modes of energy provision. Partnership models that are becoming increasingly common in developed countries need to be considered and adapted for resource-constrained settings. Health services may thus gain more reliable and less expensive energy sources, and investors can secure from health facilities an institutional commitment to long-term repayment of capital investments. These arrangements can be supported by public policies such as grants and soft financing to mitigate high cost barriers, as well as by structured products that securitize budgetary allocations for diesel fuel procurement towards repayment of capital investment loans on energy-efficient alternatives.

A proposed energy results chain for appropriate energy delivery

Energy initiatives in health facilities may range from stand-alone off-grid and micro-grid solutions using a mix of renewable and/or fossil fuel-based technologies to large-scale grid expansion around centralized power plants. In all cases, the principles of effective energy delivery remain similar. Fuel distribution systems (for fossil fuel-based power generation), availability of spare parts and skilled staff to maintain all energy systems are critical for sustained operation. Effective delivery of energy also requires a strong energy supply ecosystem encompassing laws, policies, regulations, markets and institutions to support equitable access to energy, its efficient use and a transparent payment system. Finally, within the facility itself, an appropriate suite of medical devices and appliances, as well as skilled staff to maintain and operate equipment, are required.

An *energy results chain framework for health services* (see figure below) illustrates the pathways by which modern energy investments enable improved health services delivery. Of course, improved electricity supply and use is not a panacea. Effective health services delivery and ultimately health outcomes depend on many variables, including: an appropriate mix of preventive and curative services; availability of trained health-care personnel; access to medicines; and medical equipment and support systems. In a world of increasingly complex medical technologies, access to modern energy services, particularly electricity, can certainly enhance the range and quality of health services provided.

Energy results chain framework for health services

IMPACT: Progress towards public health goals and MDGs

MDGs

4: Maternal delivery in health facilities with skilled caregiver • 5: Childhood vaccines and emergency treatment
6: TB and other infectious disease diagnosis • 7: Safe drinking water access for health-workers and patients

Post-2015 SDGs

Universal access to health services • Non-communicable disease diagnosis and treatment capacity
Clean, modern energy services for health facilities

RESULT LEVEL AND PARAMETER	POTENTIAL INDICATORS (EXAMPLES)*	
	Improved preventive health initiatives and disease management	
INTERMEDIATE IMPACT: Improved health services delivery • Expanded health-care services • Expanded diagnostic services • Improved hygiene and environmental health conditions	• Operational hours • Emergency response time • Health worker retention and attendance • Health worker and patient safety and hygiene • More rapid and accurate diagnosis	HEALTH SECTOR PERFORMANCE
	Improved healthworker capacity, access to medical devices and medications	
OUTCOME: Improved health-care facility uptake of energy • Electricity-driven equipment is available and functional • Increased/improved use of electrical equipment for medical services • Energy-efficient devices and appliances are available • Building infrastructure uses energy efficiently • Systems maintenance requirements are fulfilled	• Lighting, communications, refrigeration and sterilization always available • Appropriate medical technologies functional as measured through infrastructure surveys (SARA) • Devices have good energy performance • Piped, clean drinking-water available	HEALTH SECTOR PERFORMANCE
	Provision of trained medical staff, information and operational funds	
INTERMEDIATE OUTCOME: Health-care facility access to modern energy services for electricity and thermal requirements • Increased capacity, availability, reliability, quality, affordability, operational sustainability, convenience and health and safety of energy supply • Increased compatibility of energy supply with medical-use requirements • Availability of stand-alone medical devices with built-in energy supply	• Capacity and duration of energy supply • Electricity quality (voltage and stability) • Affordability and sustainability of energy supply • Convenience, health and safety aspects of energy • Multi-tiered metric/index of access to energy	ENERGY ACCESS
	Provision of trained workers, fuel, spare parts, operating funds, maintenance budgets and control equipment	
OUTPUT: Enhanced elements of energy supply ecosystem • Assets for on-grid and off-grid energy production and supply • Back-up energy storage / generation • Capacity to operate, maintain, repair and replace energy equipment	• Availability of grid or off-grid power connection • Expansion of energy generation, transmission and distribution, as well as management capacities of the energy supply utility • Availability of back-up generator energy storage	ENERGY-RELATED PERFORMANCE
	Effective implementation of projects and programmes, as well as policy and regulatory inputs	
INPUT: Increased financing for energy interventions, including: • Energy sector projects and programmes • Energy investments at health-care facilities • Energy and health sector policies • Capacity-building on energy aspects	• Investments in energy systems and efficient buildings • Health-care facility energy costs and emissions • Tracking supportive policies	IMPACT FINANCING

* Note: Further research is needed to define the health outcome indicators most closely related to sustainable energy provision.

5. Improving measurement of electricity access in health facilities

The need for improved measurement and monitoring of electricity access

Traditionally, electricity access in health facilities was measured using only a few basic indicators, such as: a) availability of a grid connection and b) availability of a backup generator with fuel. Although convenient, such indicators fail to clarify important dimensions of energy supply issues, as illustrated in this report and summarized in Fig. 1, *Energy Results Framework*. As a next step forward, Chapter 5 considers a more refined measurement framework to systematically capture the key characteristics of a cost-effective and sustainable electricity supply for health facilities. Such measurement and monitoring should capture a wide range of valuable indicators and information useful for assessing energy needs and gaps, effectiveness of different energy interventions, and progress in improving access against defined baselines.

Defining the main attributes of electricity supply

Improved measurement and monitoring of energy supplies should yield data on whether facilities have sufficient power capacity to run all critical support functions (e.g. lights, water pumping) and available appliances during all working hours while maintaining stable voltage and without significant power outages (reliability). In addition, the system needs to have sufficient funding and personnel for operation and maintenance. The key attributes of electricity supply might be summarized as: (i) power capacity (including peak power capacity and daily energy capacity), (ii) duration (including daily duration of supply and evening supply), (iii) power quality (minimal fluctuations in voltage, current and frequency), (iv) reliability of supply, (v) affordability, and (vi) sustainability (operational and environmental).

Enhanced health clinic surveys and data collection tools

Measuring electricity access based on these attributes of supply requires improved data collection parameters in health facility surveys. One way to accomplish this is by integrating more energy indicators into routine annual health facility infrastructure surveys performed by ministries and donors. The World Health Organization's recent SARA surveys have already been undergoing refinement in this direction, capturing a wider range of electricity sources (e.g. solar) and some basic indicators of power capacity and reliability. In addition, a comprehensive stand-alone "energy survey module" is proposed here as a means of baseline energy measurement and regular tracking of energy issues (Annex 1). This approach can help to advance more refined measurement of the electricity supply performance in relation to the energy requirements of the health facility.

6. A 'multi-tier metric' to track electricity access in health facilities

This chapter describes a method for aggregating the data on different attributes of electricity supply, as gathered from improved survey tools, into a standardized *electricity access tier* for the health facility, which is then comparable across groups of facilities or countries. Such a rating would represent the cumulative impact of deficiencies in different attributes on the usability of such supply for various needs. The approach is based on a *multi-tier framework* (Tiers 0–5) that specifies the minimum levels of attributes at each tier, with higher tiers representing progressively greater access to a larger, more reliable and more sustainable power capacity. The system permits systematic assessment of the proportion of health facilities with differing degrees of access to energy supplies and comparisons among groups of health facilities within and across countries. A weighted aggregation of the proportion of health facilities falling into each of the tiers can yield an *index of access to electricity in health facilities*. Such an index collapses the tier ratings across multiple health facilities into a single indicator, allowing easier comparisons of electricity access status across countries and of progress in improving electricity access over time.

Limitations of the multi-tiered approach

Monitoring access to energy in terms of attributes of electricity supply has limitations. The system does not consider thermal energy demands. Nor does it define at what threshold levels health facilities of various sizes have "adequate" access to electricity or adequate access for night-time or 24-hour services. Issues related to electricity access in high-end facilities are not as well reflected in the tier system. While certain health and sustainability factors are captured in terms of PM and CO_2 emissions from the power systems, building-related energy efficiencies are not comprehensively reflected.

Tracking demand-side factors in relation to supply

Ideally, electricity supply should be tracked in relation to electricity requirements (for both essential building functions and medical appliances/devices). This is challenging due to the wide diversity in health services between countries as well as differences in access to medical technologies. Health systems have varying national priorities and funding for procurement of medical equipment. Demand-side energy efficiencies, ranging from higher-performing energy systems to more energy-efficient buildings, as well as improved user behaviors (e.g. turning off lights, computers on standby), can significantly reduce building energy demands and improve overall access to energy. As a result, no universal prescriptive standard exists for the minimum capacity of electricity or thermal energy systems that should be available to health services at different levels of the health system. Future work should lead to a more comprehensive analysis of demand-side energy factors that defines thresholds for such minimum energy provision.

7. Next steps and conclusions

Going forward, two parallel tracks can be envisaged for further improving health facilities' access to energy.

I. Improved monitoring of energy access

- Effective tracking of energy access requires piloting, validation and broader application of a measurement framework, such as the multi-tiered metric described here. Harmonization of approaches, indictors and data collection efforts is another important aspect. Better monitoring data also is important to research and scale-up of energy access.

II. Scaling up energy access

- **Research:** Additional research is needed to refine tracking tools and better define the optimal energy technologies suitable for health facilities in resource-constrained settings. More research is also needed to better establish the benefits of energy access to improved health services delivery. This would support prioritization of energy investments towards facilities and services most in need.
- **Policy and finance innovation:** Health and energy sectors need to design new policies, standards and regulations to support procurement, installation, and sustainable operation of energy technologies, as well as innovative financing structures to catalyse investment in modern energy systems. Policies should also foster research and development (R&D) into efficient medical technologies.
- **Capacity-building:** Health systems need to strengthen capacity of health facility managers to procure, implement and operate energy systems.

An overarching theme of this report is the need for closer cooperation between health and energy sectors. Greater awareness of the serious gaps in energy access that currently exist should stimulate policymakers to action. SE4All initiatives, especially the *High Impact Opportunity on Energy for Women's and Children's Health* can help catalyse collaborations between energy actors and mainstream health sector programmes on maternal and child health, as well as in other critical areas of disease prevention and control. This joint WHO and World Bank report aims to sow the seeds for such fruitful cooperation in this long-neglected domain.