



SMART VILLAGES
New thinking for off-grid communities worldwide

Electrification of health clinics in rural areas: Challenges and opportunities

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Smart Villages

We aim to provide policymakers, donors, and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries—technological, financial and political—and how they can be overcome. We have chosen to focus on remote off-grid villages, where local solutions (home- or institution-based systems and mini-grids) are both more realistic and cheaper than national grid extension. Our concern is to ensure that energy access results in development and the creation of “smart villages” in which many of the benefits of life in modern societies are available to rural communities.

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INTRODUCTION

The Smart Villages Initiative aims to provide policy makers, donors and development agencies concerned with rural energy access with new insights into the real barriers to energy access in villages in developing countries and how they can be overcome.

This report provides an overview of the status of, and challenges facing, the electrification of health clinics in rural areas in the developing world. In addition, it considers the opportunities provided by telemedicine and the barriers to this, along with some examples of innovation and work in this field. The content of this report has been drawn from a review of the literature and will be used as a starting point for Smart Villages workshop discussions with experts in the field.

The focus of this report is primarily on the electrification of health facilities specifically. However, the complementary benefits of community-wide electrification are considered in the section of the report dealing with the challenges of electrification, and the requirements

for thermal energy in health clinics (for example, for sterilisation, cooking, water and space heating, etc.) are briefly reviewed.

The report finds that the benefits of health facility energy provision are multi-fold and that off-grid renewable systems in remote, resource-poor settings can enable 'basic electricity for life-saving procedures that might not otherwise be feasible' (WHO, no date). In addition, it finds that technology and telemedicine enabled by electricity provision and connectivity can further enhance the quality of care in remote settings. Yet neither of these areas is without its challenges.

The report is divided into two main chapters. The first considers the energy requirements of rural health clinics, the benefits of electrification, and the challenges as well as opportunities (for example, clinics as mini-grid anchors). The second focuses on innovation in energy-enabled technologies and telemedicine, and the barriers to such innovation. The report ends with some concluding remarks.



Masougbo Chiefdom Primary Health Unit in Bombali District, Sierra Leone. Midwife Zainab Manserray (white uniform) is in charge of the clinic and is currently training male midwife student Sahr Philip Sheku (purple uniform) from The Midwifery School in MAsubu, Makeni. They have recently received a solar lighting system funded by UNFPA which enables them to see what they are doing both during the rainy season and at night. H6Partners/CC BY-NC-ND 2.0

CHAPTER 1: THE ELECTRIFICATION OF HEALTH FACILITIES

This chapter first notes the status and trends in provision of electricity services to health facilities, including the move to solar power. It then outlines the requirements of small, medium and large health facilities before analysing the benefits of electrification, other related concerns and the challenges faced in electrifying health facilities. Finally it highlights the possibility of electrification via a mini-grid.

Section 1.1 key points:

- *There is a lack of reliable data across developing countries relating to the status of electricity access in health facilities. However, a sub-Saharan Africa-focused study found that on average one in four health facilities in this region had no access to electricity.*
- *Isolating the impact of electricity access on health outcomes can present difficulties.*
- *Solar power is increasingly being used as an affordable alternative to the common solution of diesel-powered generators. There have also been advances in the use of hybrid technologies.*
- *Reliability of energy access presents a key issue with numerous negative knock-on effects for medical service delivery, including those relating to lighting, refrigeration and sterilisation.*

1.1 Status and trends in electricity access for health facilities

Data are relatively sparse regarding the status of electricity access in health facilities in developing countries. A World Health Organisation (WHO)-led review obtained ‘nationally representative data for only 14 developing countries globally, 11 of them in sub-Saharan Africa’. From these data, on average ‘one in four sub-Saharan health facilities had no access to electricity’; also only 28% of health facilities and 24% of hospitals had ‘reliable’ access (‘without prolonged interruptions in the past week’) (WHO, 2015). However, improvements have been occurring. For example, ‘Electricity access in health care facilities increased by 1.5% annually in Kenya between 2004 and 2010, and by 4% annually in Rwanda between 2001 and 2007’ (Adair-Rohani et al., 2013).

There is an urgent need to improve the ‘geographic coverage, quality, and frequency of data collection on energy access in health facilities’: standardised tools need to be used for data collection (Adair-Rohani et al, 2013). The WHO and its partners have worked to extend data collection through the new Service Availability and Readiness Assessment (SARA), which ‘provides a consistent methodology for country-led monitoring of health service delivery’ (WHO, 2015).

In off-grid settings, standalone diesel-powered generators are often the most common solution, complemented by kerosene lamps, candles and flashlights (WHO, 2015). However, the shortfalls of such generation include high operating and high fuel costs, as well as transport and storage issues (WHO, 2015). In addition, such generators emit CO₂ and can produce particulates and

fumes which are harmful to health (WHO, 2015). In contrast, the negative effects on health of electricity generation from renewable sources appear to be small—although these effects have not been assessed as fully as with traditional sources (Wilkinson and Markandya, 2007). In these respects, renewables are a positive solution to the dearth of electricity access for health clinics.

A key trend is the increasing role of solar power as it becomes more affordable (WHO, 2015). A WHO-led review of sub-Saharan African health facilities identified a trend towards increased use of ‘on-site PV solar energy either as a primary or backup electricity source’ (WHO, 2015). In Sierra Leone in 2013, ‘36% of all health facilities and 43% of hospitals used solar systems in combination with other electricity sources’ (WHO, 2015). Furthermore, in Liberia in 2012 ‘more first-line public health clinics used PV solar than generators as their primary energy source’ (WHO, 2015). Countries like India, which are ‘abundantly endowed’ with renewable energy sources such as solar and small hydro-electric energy, are well placed to leverage these for a decentralised approach to enable the ‘proper running of health centres’ (Climate Parliament, no date). The focus on solar energy is reflected in the examples throughout this report. However, this is not to say it is the only option: this can only be decided in light of the specific context and the size and priorities of the health facility.

In addition to straight solar energy there have been advances in ‘modern forecasting, storage and hybrid technologies’ that allow renewable sources to be used in conjunction with each other to provide a ‘reliable solution to power in the rural areas (Climate Parliament, no date). Powering Health (a knowledge portal/forum that is a product of USAID’s energy team) has recommended that hybrid systems are a particularly feasible option for medium to large loads (see the Energy Requirements section of this report for definitions), with reduced operating costs offsetting ‘high initial capital costs over

time’ (USAID, no date). However, we should bear in mind that the increased complexity of the systems demand sound ‘maintenance programs and trained technicians’ (USAID, no date). Whilst the different electrification options are not the focus of this report (in light of this needing to be determined on a case-by-case basis) a detailed breakdown of the different electrification options for rural health centres can be found in ‘Powering Health: Electrification Options for Rural Health Centres’ (USAID, no date).

The move to renewables is complemented by an increasing range of direct-current medical devices/appliances that are chargeable from solar panels (WHO, 2015). ‘Solar systems are also being purchased in bulk by the Global Fund to Fight AIDS, Tuberculosis and Malaria, often to power TB diagnostics’ (WHO, 2015). Several NGOs have also ‘developed inexpensive portable solar systems designed for off-grid health clinics, basic lighting and communications needs, particularly to support childbirth, and emergency services’ (WHO, 2015). The ‘solar suitcases’ developed by We Care solar (We Care Solar, no date) are a good example.

We should bear in mind that even for facilities powered by the grid, on-site generation is still important and relevant; many of the solutions we consider for off-grid renewables are transferable. Regulatory and accreditation requirements often make such backup and onsite generation mandatory due to the emergency care, childbirth management and surgical procedure offerings (WHO, 2015). Even if the health centre has a grid connection, the electricity supply is often unreliable. If there is no back-up generator present, in the context of off-grid renewables, then the ‘battery must be sized appropriately to provide power after several days of overcast weather’ and this then also influences the cost (USAID, no date).

Reliability is a key issue for rural health centres, as a lack of electricity can be catastrophic

(EnergyPedia, 2014). For example, ‘if the cold chain is inoperable when supplies arrive, vaccines, blood, and other medicines may go to waste. If a clinic is without lights, patients arriving at night must wait until morning to receive care’ (EnergyPedia, 2014). Reliability is an issue that will be explored in the Challenges section of the report.

A lack of reliable energy access (including thermal energy as well as electricity) has numerous negative impacts, which include:

- ‘Poor storage facilities for vaccines and medicines requiring refrigeration;’
- ‘Poor facilities for sterilisation of medical tools;’
- ‘Poor lighting conditions for performing operations;’

- ‘Inability to provide clinical services after sunset;’
- ‘Difficulty in deploying health officers in remote rural areas;’
- ‘Inability to power laboratory equipment to diagnose patient’s disease;’
- ‘Poor ability to communicate with medical specialists or to call for transport to a health facility with a higher degree of specialisation;’
- ‘Limitation to traditional cooking facilities—resulting in inefficiencies, poor air quality and possible inadequate food intake of patients.’

(Source: European Commission, 2006)

1.2 Energy requirements of health facilities

Section 1.2 key points:

- *Further research is needed to define energy needs in relation to all aspects of service delivery; however, there are high-level needs and characteristics that have been developed for small, medium and large clinics.*
- *Despite such guidelines, a needs assessment is still required on a case by case basis to ensure the plans for electrification of the health facility are contextually relevant. Research is also being done to better understand how energy is consumed in rural health facilities.*
- *A small health facility has an average electricity consumption of 10 kWh/ day, a medium size facility 10-20 kWh/ day, and a large facility exceeds 20 kWh/day.*
- *Health facilities also have thermal energy requirements for activities such as cooking, water heating, sterilisation and incineration of medical waste.*
- *The WHO has proposed a multi-tier framework system for categorising access.*

‘Defining essential energy needs in relation to all aspects of health service delivery has yet to be undertaken systematically’ (WHO, 2015). In addition, ‘better definition of electricity device requirements is needed to help drive appropriate design of energy supply-side solutions’ (WHO, 2015). STG (a non-profit organisation focused on sustainable energy technologies for communities in the developing world) is currently monitoring power usage at a number of rural health and education facilities that already have access in order to help improve this picture (STG, no date). For example, they have been designing software that can help to better understand the energy demands of clinics and schools (STG News, 2015). In addition, as of May 2015, they launched a campaign ‘to measure energy consumption at a number of clinics in Lesotho’ to aid the understanding of ‘minute-by-minute energy consumption at these facilities on different days of the week, months of the year and as the number of patients visiting and the weather changes’ (STG News, 2015). Such data can help the organisations designing systems as well as government ministries to improve designs and ‘allocate funding for capital and recurring expenditures for each of their clinics’ (STG News, 2015).

A needs assessment includes an inventory of equipment and the power required for each device, as well as allowing an understanding of the average daily load (Energypedia, 2014). Understanding the need will enable the consideration of electrification options as well as the ability to make up a realistic budget (Energypedia, 2014). In addition to analysing day-to-day energy requirements, it is also important to consider whether demands are likely to change. For example, there may be an increase of patients and their regularity (Energypedia, 2014).

Such needs assessments are something that should be carried out for each facility due to different levels of need and consumption, different health priorities depending on the surrounding services,

social context, etc. and different services offered (for example, if they take in-patients).

However, the following three sub-sections summarise some of the key characteristics of small, medium and large health facilities that indicate the energy potentially required. They are followed by a summary of thermal energy requirements of clinics, and the WHO multi-tier framework for ratings for health facilities.

1.2.1 Small/Health clinic or post

Small clinics would be those most typical of the remote communities that the Smart Villages Initiative is particularly concerned with. These posts tend to cater to primary health, with treatments provided for most common diseases such as malaria and TB, in addition to ‘maternal and child health services and first response to emergencies’ (WHO, 2015). The clinic may also offer ‘special clinics for mother/child care, HIV/AIDS counselling and treatment, or dispensaries to provide antiretroviral therapy, blood pressure medicine, anti-malarials and TB treatment’ (WHO, 2015). Such clinics would also only have a few staff, and the services outlined here will vary; for example, some health posts are focused primarily on first aid.

Key characteristics to bear in mind when deciding energy requirements:

- ‘Average daily energy consumption up to 10 kWh/ day;’
- ‘Capacity ranges from 0 to 60 beds;’
- ‘Limited health services provided such as first aid and limited surgical services;’
- ‘Equipped with one or two vaccine refrigerators;’
- ‘Temporary working team, such as doctors and nurses.’

(IEA, 2014)

When analysing the load profile for a small clinic in Cambodia, the IEA found that ‘the lights are the most significant load and consume about 35% of the total energy’ (IEA, 2014). A vaccine refrigerator, where present, can also be a large consumer of electricity.

The IEA describes a ‘typical’ electrical load distribution of such a facility (based on PV provision) as 35% lights, 14% fans, 34% lab equipment and 17% other, with the load curve increasing gradually to a midday peak and then decreasing gradually (IEA, 2014).

1.2.2 District/Medium-sized health centres

These facilities will tend to offer a wide range of health services, catering to larger populations than rural health posts (WHO, 2015). They will have patient beds, and more advanced medical services may include: dental procedures, blood testing, obstetric procedures, ‘injury response and diagnosis and treatment of serious infections and fevers’ (WHO, 2015) (IEA, 2014).

Typical characteristics of medium-sized health facilities:

- ‘Average daily energy consumption within 10- 20 kWh/ day;’
- ‘Capacity ranges from 60 to 120 beds;’
- ‘Equipped with several medical appliances that do not exist in small size health facilities, such as diagnostic and surgical equipment;’
- ‘Maintains a cold chain for vaccines and blood supplies;’
- ‘May have an additional refrigerator for food;’
- ‘Provision of sophisticated surgical and emergency services such as dental health surgeries;’

- ‘Equipped with advanced equipment, such as small size X-ray machine.’

(IEA, 2014)

In a typical load profile of a medium-sized facility, ‘the highest energy consumption within day time is by laboratory equipment, while lighting systems and fans consume more within the night time’ (IEA, 2014). However, in terms of electricity distribution the main consumers are the lighting systems/fans (IEA, 2014). It is important to take into account consumption patterns for a health facility in order to design an ‘efficient operational plan’ (IEA, 2014).

1.2.3 Large-sized health facility/District or Regional hospitals

Large facilities will cater to large populations with a ‘more diverse range of services including more specialized services, surgical centres, intensive care and noncommunicable disease treatment’ (WHO, 2015). Unlike the previous health facilities discussed, these will tend to be located in urban areas/cities, with ‘several wards and include nursing school, staff house etc.’ (IEA, 2014). As such the make-up of these facilities is more removed from the smart village context. Staff houses for larger-sized facilities can sometimes contribute the largest share of energy consumption, as found in a hospital in Tanzania, although this is not true in all cases (IEA, 2014).

Typical characteristics of large-sized health facilities:

- ‘Energy consumption is high and exceeds 20kWh/day;’
- ‘Capacity over 120 beds;’
- ‘May contain advanced equipment (e.g. X-ray, CD4 counters, blood typing equipment).’

(IEA, 2014)

1.2.4 Thermal energy requirements

As well as electricity provision for powering medical devices such as diagnostic tools and refrigerators, healthcare facilities also have thermal energy requirements. Such energy will be required in relevant cases for 'cooking, water heating, sterilisation and space heating/incineration of medical waste' (WHO, 2015).

Food in rural health centres tends to be predominantly for staff. 'Most rural health centres do not provide meals for the patients, even if they have in-patient facilities' with meals being prepared by patient guardians who tend to use make-shift three-stone fires using firewood or biomass (as they have to provide the fuel and utensils) (EnergyPedia, 2014).

For well-funded grid-connected facilities, thermal needs tend to be met with electricity and 'increasingly by high-efficiency co-generation of heat and power (CHP) systems' (WHO, 2015). However, more commonly these needs are met through fossil fuels with on-site boilers (WHO, 2015). There is an opportunity to use 'inexpensive thermal solar panels' that can provide hot water for hygiene and space heating functions (WHO,

2015). The use of solar energy for sterilisation is noted in the latter half of the report.

It is also worth bearing in mind that in designing energy provision for health facilities the energy efficiency of the building itself can be improved to reduce the demands for thermal energy and electricity (WHO, 2015).

The WHO has also developed a multi-tier framework for rating health facilities. We should bear in mind that the multi-tier methodology requires 'further expert review and pilot testing for fine-tuning and validation' (WHO, 2015). There are several limitations we should consider when assessing quality of healthcare provided along these lines: Energy access is 'one of many elements in the health system', 'High-end health facilities likely require a separate customised metric', 'Thermal energy produced by non-electrical sources is not reflected' and 'energy-efficient facility design' is not fully reflected (WHO, 2015).

Due to the village-level focus of Smart Villages, smaller health posts are of particular importance for the rural context, as the first port of call for isolated communities. As such, this report is slightly weighted towards this first point of care, although still referencing the broad range.

1.2.5 WHO multi-tier framework for ratings for health facilities

The WHO have proposed a multi-tier framework system for health facilities specifically that mirrors the ESMAP approach (those for ESMAP are focused on community centres more broadly).

Tier 0 (no access): 'The health facility does not have access to any electricity supply (except dry-cell batteries with a peak power capacity of less than 5 W). As a result, the facility has to rely on kerosene lamps or candles for lighting and a dry-cell battery-powered radio. '

Tier 1 (minimal access): 'The health facility can access at least 5 W of peak available capacity for at least four hours during the day, typically for electrical lighting. It is also

possible that the facility faces issues of inadequate evening supply, quality, reliability and operational or environmental sustainability.' Daily Energy Capacity 20-279 Wh per day.

Tier 2 (basic access): 'The health facility can access at least 70 W of peak available capacity for at least four hours per day, including at least two hours after nightfall if required. The supply is capable of meeting additional applications beyond lighting such as blood analyzer, UV water purifier, jaundice light, VHF receiver, LED microscope, air circulation, printing, ultrasound and vacuum aspirator. The facility may experience reliability issues and/or voltage problems, as well as difficulties with operational and environmental sustainability.' Daily Energy Capacity of 280-1599 Wh per day.

Tier 3 (intermediate access): 'The health facility can access an electricity supply of least 200 W of peak available capacity for at least eight hours during the day, of which at least two hours are in the evening. In addition to applications mentioned in Tier 2, the health clinic is able to use most medium-capacity equipment, such as suction apparatus, vortex mixer, CD4 counter and centrifuge. While the facility does not face issues of supply quality or reliability, it may face environmental and operational sustainability problems.' Daily Energy Capacity of 1600-31999 Wh per day.

Tier 4 (advanced access): 'The health facility has access to an electric supply of at least 2000 W and can operate most applications, though it may be constrained to use a large number of these applications simultaneously (for example, in a large clinic with multiple high-capacity applications). Supply is available for at least 16 hours per day, including all of the evening hours. Voltage is adequate and interruptions are infrequent. The facility has sufficient funds to pay for fuel and electricity bills and to cover any maintenance costs. Also, the electricity source does not cause negative environmental or health impacts in the local area around the health clinic.' Daily Energy Capacity of 32-220 kWh per day.

Tier 5 (full access): 'Health facilities can access virtually unlimited amounts of power at all hours of the day and night without any deficiencies in quality or reliability of supply. Additionally, the health facility has sufficient funds to pay for fuel and electricity bills and to cover any maintenance costs. The electricity source does not cause any negative environmental health impacts in the local area around the health clinic.' Daily Energy Capacity of >220 kWh per day.

Details and values of the multi-tier framework and the kinds of application that may be present at each tier can be found on pages 54-57 of the WHO 2015 report 'Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings: A Review of Status, Significance, Challenges, and Measurement'.

Source: WHO, 2015

1.3 Benefits of electrification

Section 1.3 key points:

- *The benefits of electrification have the potential to be profound and to improve health services and potentially impact key health outcomes. However, more work is needed to examine the impacts of energy access in terms of health services provision and treatment outcomes.*
- *The provision of energy access to remote health facilities can help in attracting and retaining medical professionals by improving living conditions and communications links.*
- *The quality of the service can be heightened through the extension of opening hours and the enablement of cold-chain storage. In particular, maternal health can be improved by enabling night-time deliveries, aiding the safety of obstetric care.*
- *Productive enterprise can also receive indirect benefits with the potential for reduced sickness absenteeism in light of better quality healthcare provision.*
- *Access to communication links can enable life-saving referrals and emergency care.*

The benefits of electrification have the potential to be profound. For example, 170 rural clinics provided with PV systems in Cuba saw improvements in both quality of life and infant mortality (GVEP, 2013). The systems provided included lights, a vaccine refrigerator, and other key pieces of equipment including electrocardiographs and X-ray machines. In Uganda, in the World Bank's Energy for Rural Transformation Project, solar energy was used to electrify health centres. 'Standard Solar energy packages installed in medical buildings and Health Centres have resulted in improved health services, and have had a positive impact on decreasing diseases such as Measles, Polio and Typhoid' (GVEP, 2013). However, GVEP noted that there was a lack of evidence in the relevant report to back this up.

Indeed, few studies have systematically examined the 'impacts of energy access at health facilities on health services provision – and fewer still have

looked at treatment outcomes' (WHO, 2015). From the few studies that have been made it can be seen that electricity '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' (WHO, 2015). Impacts are difficult to measure as a result of the numerous 'confounding factors', such as lack of skills/ knowledge, medicine availability, 'proximity to treatment and time lag before measurable improvements' (WHO, 2015).

The distinctive link between healthcare and energy is that provision of any real standard of healthcare in this modern age is not possible without energy. By contrast, whilst it can contribute to the improvement of education, this is not to say teaching cannot take place in its absence (although it eases the process).

‘Without electricity for refrigeration, health clinics cannot safely administer vaccines or a number of other medicines. Without a constant source of good lighting, which is not achievable using candles or other non-electrified sources, doctors cannot safely perform operations or even adequately examine a patient at night. Many doctors and nurses simply won’t serve at health clinics that don’t have outdoor lighting to provide for their safety. Thus, it is difficult, if not impossible to establish a safe and efficient health clinic that provides quality health care services without electricity or more modern energy sources’(Brenneman and Kerf, 2002).

The benefits explored in the sub-sections below are: attracting doctors, improving the quality of service, health and productive enterprise, and communication.

1.3.1 Attracting doctors

One of the recommendations made by WHO to assist in the attraction and retention of healthcare workers for rural areas is to ‘Improve living conditions for health workers and their families and invest in infrastructure and services (sanitation, electricity, telecommunications, schools, etc.) as these factors have a significant influence on a health worker’s decision to locate to and remain in rural areas’ (WHO, 2010b). Health facilities with electricity may be ‘better positioned to attract and retain skilled health workers, especially in rural areas’ (WHO, 2015).

‘A study of South African doctors listed better accommodation as one of the three most important factors that would influence them to remain in a rural area’ (WHO, 2010b). ENSOL (a solar PV company based in Tanzania) found that ‘health workers prefer to stay in places where electricity is available’ (IEA, 2014). In Tanzania ‘there are health facilities with no single health worker... and one of the contributing factors is the unavailability of energy’ (IEA, 2014). ‘Recorded cases show that health workers choose to even quit employment when they are assigned to work

in remote rural areas where energy is a problem’ (IEA, 2014).

In Zambia, a bank-supported social fund provides solar power to all the clinics it constructs, and also ‘constructs a house with solar power for the health worker’ (IEG, 2008). The second addition adds to the potential role of energy in staff retention. Another study in Zambia found that solar energy has been seen as a ‘morale booster for health staff’ due to the improvements rendered to their working/living environments (Mfune and Boon, 2008). In one study in the Lundazi district all ‘the health staff interviewed expressed happiness and indicated that the environment was clearly more motivating than before, staff could gain access to TV, video, radio and light for reading (Mfune and Boon, 2008).

However, another impact study on the solar electrification of health centres in Uganda found that while the ‘availability of solar energy is not a decisive factor for the deployment of health staff, it is likely to increase motivation and morale of health staff whose living standards are improved by access to cheaper and quality light’ (Energypedia, 2015).

In Bangladesh, the average number of job vacancies for healthcare providers in rural health centres is 26%, with vacancy rates being higher in poorer areas (Chaudhury and Hammer, 2003). The absentee rate for doctors at larger clinics is 40% ‘but at the smaller sub-centres with a single doctor, the rate is 74%’. The study found that ‘Whether the medical provider lives near the health facility, access to a road, and rural electrification are important determinants of the rate and pattern of staff absentee rates’ and ‘The proportion of households with electricity is a strong encouragement for providers to live in the village. This may be due to electricity being a proxy for wealth or it may be the direct benefit of living with access to electricity’ (Chaudhury and Hammer, 2003). ‘Anecdotal data reinforce the results of studies indicating that the lack of appropriate housing,

electricity and phone service, and inadequate schools, all act as disincentives for rural service.’ (WHO, 2010b).

Overall it appears there is a clear potential for electricity to contribute to attracting and retaining doctors to rural areas, although this is not to say it is the deciding factor.

1.3.2 Improving the quality of the service—The evidence

Poor energy infrastructure can affect the quality of service: for example, reduced operating hours resulting in an un-served population, reduced capacity for lab tests, night-time safety concerns and decline in staff morale (USAID, 2012). Energy can, as a result, work in multiple ways to improve the quality of the service, as well as the ability of health workers to provide certain services in the first place.

The majority of the benefits for health tend to either arise by way of extended opening hours or through having equipment that requires electricity (IEG, 2008). For example, a project in Columbia provided PV systems for four rural communities ‘to provide health care services by powering vaccine refrigeration, lighting, communications, and medical appliances’ (GVEP, 2013). Services were noted to have improved with increased vaccine coverage, more rapid malaria diagnosis and improved lighting for night visits (GVEP, 2013). However, as with many projects in this area it was unclear how it was measured.

A World Bank study ‘concluded that renewable energy benefits the quality of health services and lowers costs by extending opening hours and significantly strengthening the cold chain for vaccines—though it does not increase the extent to which such services are offered’ (GVEP, 2013). For example, ‘Opening hours were increased in Bangladeshi and Kenyan clinics with electricity’ (GVEP, 2013). In the case of Bangladesh this was

7.1 hours with electricity and 6.1 without, and in Kenya, 15.1 hours with electricity and 11.0 without (GVEP, 2013).

In the impact assessment for rural health centre electrification for Uganda, it was found that the use of solar energy at health clinics ‘enhances the delivery of medical services through the provision of quality light for use during treatment of night time emergencies, emergency deliveries and for security purposes’ (EnergyPedia, 2015). The provision of light helps procedures to be carried out safely. In addition to being more dangerous, low-quality light sources including paraffin lamps and candles are actually more ‘expensive per unit of energy than electric lighting’ (Practical Action, 2014). We Care solar suitcases provide portable power for lights and mobile phones, and feedback from clinicians is that it is ‘easier to see at night and repair lacerations, making obstetric care safer’ (GVEP, 2013). Maternal health is often cited as a key beneficiary of energy provision.

In a study by Mbonye et al in Uganda, it was found that only a few health clinics had electricity, although having electricity, running water, and an operating theatre had a ‘protective effect on maternal deaths’ (Mbonye et al, 2007). ‘Women delivering in health facilities without electricity are 39 times more likely to die than the ones in facilities with electricity’ (GVEP, 2013). In Eastern Uganda the Italian non-profit Medici con l’Africa (CUAMM) has been using solar suitcases to help with the issue of lighting in maternity wards (NewsHub 2015). As a result, in Kaabong in the Karamoja region, ‘the average number of night-time deliveries per month jumped from three to 18’ whilst day deliveries remained constant (NewsHub 2015)—the idea being that women are more comfortable delivering in health facilities with light than previously (NewsHub, 2015). A relatively simple intervention in this case helped to have a profound impact statistically.

However, better data collection could ‘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’ (WHO, 2015).

1.3.3 Health and productive enterprise

‘An improved health status in the population impacts positively on productivity which has positive implications on, for example, agricultural outputs and educational results’ (European Commission, 2006). And vice versa, ‘Labour-intensive and inefficient farming systems, due to a lack of mechanisation and low fertiliser inputs play a role in malnutrition, poor health, and low productivity’ (European Commission, 2006). The impacts are not linear but a positive impact in one can have knock-on effects for others, and vice versa.

‘Sickness absenteeism is the major occupational health problem in developing countries where the majority of the working population are engaged in hazardous sectors, such as agriculture’ (Tadesse et al, 2015). This can lead to loss of working hours, a reduction in productivity and even workplace disputes (Tadesse et al, 2015).

‘According to International Labor Organization 2008, more than 317 million accidents and diseases occurred on the job annually; and about two-thirds of them caused employees to be away from work for four working days resulting in economic effects and loss of labor time in both developing and developed countries’ (Tadesse et al, 2015). In the case of sub-Saharan Africa, ‘42 million work-related accidents caused at least three days absence from work in which agriculture plays the major role. About half a million accidents caused at least four days off work in Ethiopia’ (Tadesse et al, 2015).

Whilst improved healthcare access cannot prevent accidents, it can help access to relevant treatment which we may assume can improve recovery

time. When it comes to disease, the benefits for health to productive enterprise can be increased not only by effective and timely treatment (e.g. access to vaccines enabled by cold-chain) but also by extending clean energy access to the wider community.

Indoor air pollution from the use of traditional fuels can result in ill-health, which can affect schooling and can also result in ‘reduced ability to be involved in farming or other income generating activities’ (European Commission, 2006). For example, ‘The losses incurred because of cooking fuels, including work days spent, expenditure on illness and lost working days due to illness are Rs. 29 billion per year in the rural areas of Rajasthan. By minimizing these losses even by some fraction, one can give a boost to the rural economy and improve women’s welfare’ (Laxmi et al, 2003).

1.3.4 Communication

Communication can play an integral role for remotely situated health clinics.

Solar powered radios have been used in locations like Zambia to improve communication and can be used for ‘important information on emergencies such as ruptures of uteruses where pregnancies are concerned’ (Mfunne and Boon, 2008). Radios can also be used for referrals and consultations, and to request transport from larger centres for referred patients (Mfunne and Boon, 2008). In one district in Zambia of all ‘cases in health centres, one out of two uterine rupture preventions is due to the direct use of radio messages’ (Mfunne and Boon, 2008). In Peru, health posts were provided a ‘160W PV system along with a VHF transceiver, laptop, internet, lighting system and batteries for 5 days autonomy plus a central server was installed in a hospital in Lima’ (GVEP, 2013).

The impact evaluation had encouraging results:

‘The communication system was found to be successful and used for 100% of emergency

cases and in 64% of these reduced the time for referral by enabling the use of vehicles from other establishments (a 60% reduction). Health-care personnel reported that in 60 of the emergency cases (25.3%) the use of the system saved the life of the patient.’ ‘Obstetric emergencies, followed by cases of complicated malaria, were the two medical problems for which the communication system had the greatest benefit. In fact, the time to detection of cases of malaria was reduced by half, which over the long term, will affect the morbidity and mortality associated with this disease’ (GVEP, 2013).

In Uganda, communication through VHF radio alongside transport and improved service quality contributed to a 50% reduction in the maternal

mortality rate (after three years) due in part to the ‘increased referrals to health units made possible from the communication and transport facilities’ (GVEP, 2013). However, due to the relative rarity of maternal deaths, figures may not be robust (GVEP, 2013). Yet communication is one part of the whole that enables such impact, alongside transportation and increased quality of service (GVEP, 2013).

Communication on its own is not necessarily enough; it is part of the suite of healthcare benefits that electricity can enable which can then impact health outcomes. The solution required is integrated—to reap all the benefits we need to consider all aspects simultaneously.

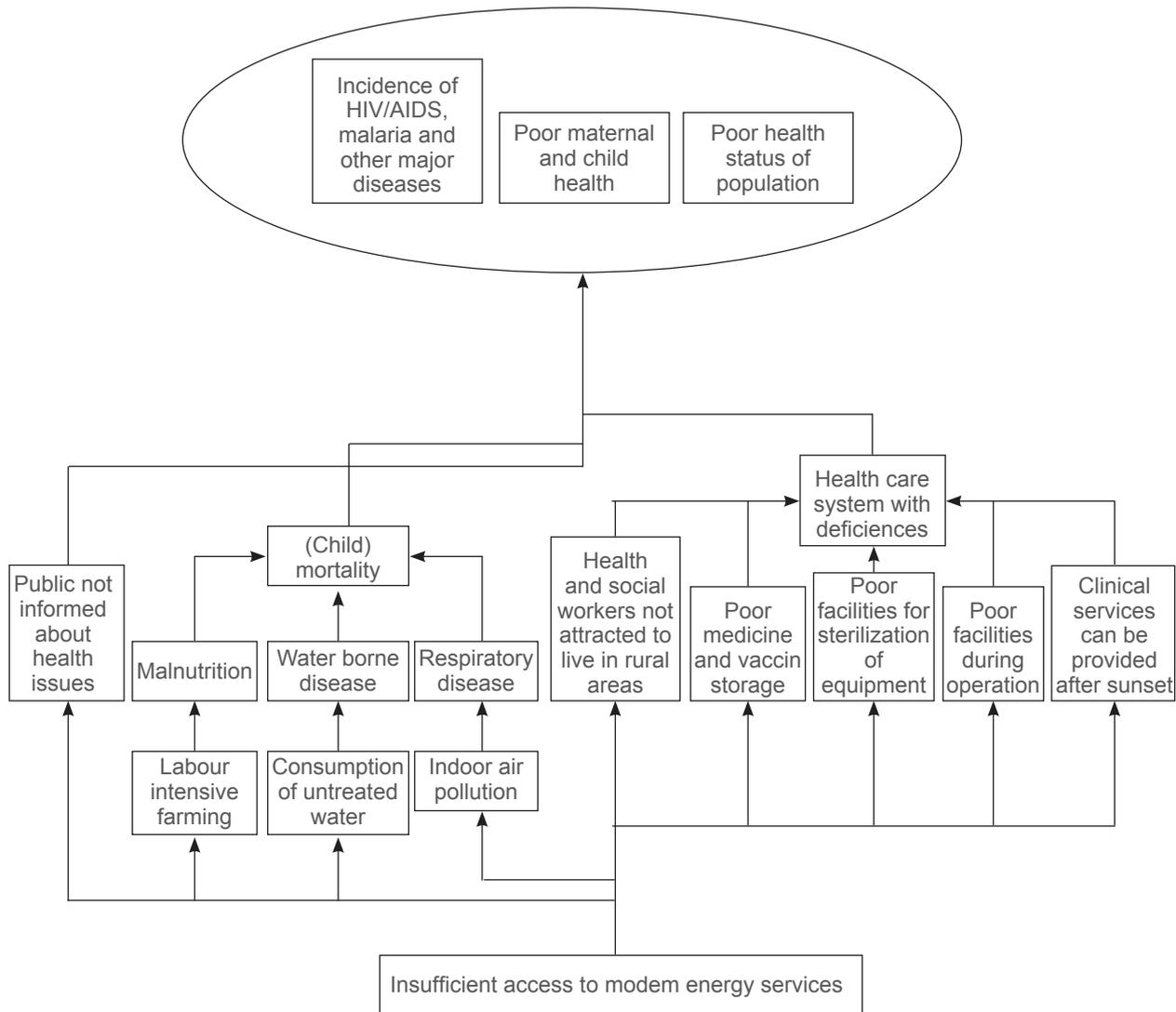
1.4 Other related issues

Section 1.4 key points:

- *If we go beyond health facility electrification and electrify the village as a whole, the benefits to health can be expanded. Health is interconnected with numerous sectors, including education, water, and agriculture. Improvements in any one of these sectors can have positive implications for another.*
- *What these interconnections show is the need for an integrated and whole-system approach if we want to maximise impacts on health outcomes, rather than viewing energy supply in isolation.*

The provision of health facilities alone does not span the full impact of energy provision on health. Whilst the purpose of this report is not to examine these extended benefits in detail, the figure below by the European Commission (2006), shows the

potential health benefits of community-wide electrification, considering the linkage between the health, education, water, and agriculture sectors (European Commission, 2006).



The diagram demonstrates at a high level the interconnection of other sectors meaning that, ‘improvements in one sector’ can have ‘positive implications on other sectors’ (European Commission, 2006). We have seen such connections in the productive enterprise benefits section.

In addition, integrating health electrification with clean water initiatives can also enhance and complement the benefits (USAID, no date). Access to clean water through energy-enabled water treatment and pumping also can help stem the spread of water-borne diseases, impacting health (European Commission, 2006). In the same case study, clean drinking water was provided

through a solar array, which gave not only the clinic but the community access to clean water, reducing likelihood of water-borne illness, improving cleanliness and hygiene in the clinic and contributing to better overall health for the community (USAID, no date).

Benefits of such electrification can in this way be maximised by extending the benefits to the whole community, which in turn can impact the challenges faced by health clinics in a positive way.

It is also worth noting that, in terms of gender, there has in some cases been a lack of gender disaggregation when it comes to identifying the impact of electrification with regard to health

(GVEP, 2013). A study in Uganda, however, did suggest that ‘women were impacted more by the provision of electricity but that is partly because they are the majority users of the health centres’ (GVEP, 2013).

What these interconnections show is the need for an integrated and whole-system approach if we want to maximise impacts on health outcomes—

rather than viewing energy supply in isolation. Actions in areas such as clean water, cookstoves, and agriculture have an impact and an important role to play. The Smart Villages’ integrated multifaceted approach is made all the more relevant and important by such interconnections. It is appropriate to start from the outcomes it is hoped to influence, and to work back to identify all the interconnections and areas of intervention.

1.5 The Challenges of Electrifying Health Facilities and the successes and failures

Section 1.5 key points:

- *Problems for health service delivery are not confined to energy access but reflect the multiple challenges faced in the sector. As such, to maximise the benefits of electricity access for providing quality care, potential solutions need to be integrated with other initiatives that are working to deal with the wider problems.*
- *Technical issues can present a key barrier and maintenance needs to be built into project plans. Where this doesn’t happen equipment may be left wasted and disused.*
- *Theft of system components can present a major problem.*
- *Reliability of supply is key, particularly for the running of sensitive medical equipment. Appropriate back-up needs to be factored in where supply may vary.*
- *Local ownership of the energy system has been identified as critical for system sustainability.*
- *Operating costs, not only capital costs, need to be taken into account when planning the financing of electrification projects. The sale of excess electricity back to the grid and the creation of micro-enterprises can present innovative ways of financing maintenance in the long term. Switching to renewables can also present cost benefits.*
- *Capacity building and training needs to be built in to enable the appropriate expertise for system maintenance. Such training should be ongoing to deal with potential staff turnover. Awareness raising is also needed for staff regarding the limits of the energy system.*
- *Extending access to households and the community can help maximise health benefits through health education and clean cooking practices.*

There are a number of projects that provide energy to health facilities at all levels (as per descriptions given in the requirements section), which are funded by Government ministries, international/bilateral agencies and NGOs (GVEP, 2013). Whilst many projects report ‘positive health outcomes’ the evidence, as indicated above, is not clear (GVEP, 2013). One particularly notable programme is ‘Powering Health’, a USAID initiative which helps promote health facility electrification in developing countries, ‘offering access to interactive tools, best practices and information on technology’ (Powering Health, no date). To do this it draws on international best practice as well as USAID’s work in the field.

In terms of PV system projects for rural health facilities, most have been implemented by international development organisations in close partnership with local authorities (IEA, 2014). Key successes/failures have varied depending on the project. For example, in Haiti, accurate design of the systems, professional installation and regular maintenance were central to success (IEA, 2014). In The GTZ PV programme in Uganda, it was reported that ‘use of services did not increase but this was due to factors other than power in the centres such as HR deficit, lack of medication or supervision and lack of motivation’ (GVEP, 2013).

Barriers for the effective uptake of PV solar energy include: security issues, inadequate budgets to replace batteries and parts (particularly for small clinics), and lack of technical capacity to troubleshoot/maintain equipment (WHO, 2015). These issues, along with ownership, capacity building and financing, and a lack of household access, will now be explored in more detail in seven sub-sections as follows:

1. Technical
2. Theft
3. Reliability

4. Ownership
5. Financing
6. Capacity Building and Awareness Raising
7. Lack of Community-wide Access

However, it is important to bear in mind that the challenges faced by rural health clinics are multi-fold, and whilst energy can contribute to some it cannot resolve all. In Uganda in one site that had received solar electrification, it was noted that the impact (improved services, safe environment, and faster record keeping) had been somewhat ‘overshadowed by the many other challenges that health facilities face such as a lack of adequate and qualified staff, a lack of adequate drugs, lack of space/beds and other equipment and a lack of sufficient funds for capital and operational expenditure’ (GVEP, 2013). Other issues may include a ‘lack of accommodation for health staff, lack of clean water, and security problems due to absence of fences surrounding health facilities’ (IEA, 2014). Again, an integrated approach is required to maximise the benefits to health outcomes, rather than dealing with energy in isolation.

1.5.1 Technical

Maintenance of electrification equipment is essential. A lack of this will ultimately ‘have a negative impact on reliability of the power supply’ (Energypedia, 2014). This includes routine maintenance, the checking of back-up generators, etc., and needs to be budgeted and planned for in advance (Energypedia, 2014). Powering Health notes that many ‘health centres describe experiences with PV systems with inoperative batteries, resulting in, for example, phones that only operate when the sun is shining’ (USAID, no date). In terms of technical issues, the appropriate finance for system maintenance and sustainability, as well as battery replacement, needs to be budgeted for, and the availability of

component replacements needs to be considered in the initial procurement (USAID, no date).

For example, in Guyana, whilst PV systems for health facilities were widespread, in the long run sustainability was not fully considered, either by funders or end-users (IEA, 2014). The result was that many systems were not working properly or had technical problems (IEA, 2014). One evaluation study in the country in relation to cold chain assessment found that 13 of 21 systems that were installed between 1982 and 2004 ‘were not functioning well’ (IEA, 2014). This was down to poor design (under-sizing of system components), improper installations (untrained technicians), lack of maintenance, and ‘lack of capacity building programs in parallel to the system installation’ (IEA 2014). In Rwanda where PV/diesel hybrid systems were installed in remote health centres, despite a reduction in fuel consumption and the enablement of the use of new medical equipment, maintenance remained a challenge for the beneficiaries (IEA, 2013). In Haiti the issues identified by USAID when it came to electrical installations were: poor/dangerous wiring, lack of maintenance (lack of distilled water and corroded battery terminals), ‘bad habits’, ‘unskilled technicians’ and ‘ad hoc solutions’ (USAID, 2012).

The recommendation from experts cited by Powering Health is to train ‘local personnel in the servicing of these systems or obtain a long-term maintenance contract’ (USAID, no date).

Another issue worth considering is the importance of robust quality measures in the initial phase, to minimise maintenance and repair requirements in the longer term. Powering Health has noted that national standards for ‘placement, design procurement, installation, and servicing of photovoltaic systems can help improve sustainability’ (USAID, no date). The Philippines Department of Health collaborated with Sentrong Sigla to ‘improve the quality of public health services’, and outlined specific

quality standards for rural health units and health centres, for certification and recognition at a particular level (Sentrong Sigla, 2000). There were numerous standards at level one that are related to or dependent on energy provision, such as ‘regular electricity/power source’, ‘adequate lighting and ventilation’ and access to refrigeration and cold chain storage for immunisations (Sentrong Sigla, 2000).

1.5.2 Theft

Theft is also a key concern. From the Uganda experience of solar PV electrification of rural health centres, theft of system components could be a major problem in some areas; the security situation needs to be analysed appropriately when installing and designing components (Energypedia, 2015). In the case of solar PV, PV panels are the most expensive part and are as such a target for theft. Vandalism also presents an issue (USAID, no date).

Tamper-free mounting systems have been used in some projects in Haiti to help prevent theft (IEA, 2014). In addition, in Haiti, ‘The procurement of PV systems equipped with anti-theft screws was highly recommended to establish a sense of ownership and a feeling of responsibility among the community itself’ (IEA, 2014).

1.5.3 Reliability of electricity supply

Even for grid-connected hospitals, reliability of the electricity supply is a problem. Only 34% of hospitals and 26% of other health facilities in sub-Saharan Africa (on average) have reliable electricity access (Adair-Rohani et al, 2013). The reliability and quality of the power supply can have numerous negative impacts and concerns. In Kamili, in Uganda, unreliability means hospitals are forced to rely on ‘expensive thermal generators’ for consistent flow of power (Ezor, 2009). Under such conditions, healthcare facilities may become ‘unable to perform simple surgical operations or treat patients properly’ (Ezor, 2009). In Haiti

USAID found various power quality issues such as variability, low voltages, voltage spikes, and equipment sensitivity (USAID, 2012). Certainly, in expanding laboratory infrastructure in health facilities in Haiti, it has been noted that ‘the success of this effort is highly dependent on the provision of stable and reliable electricity to these labs to support increasingly sensitive laboratory equipment’ (Ratterman, 2008).

Critical loads for health facilities can be identified as: equipment that is crucial to the operation of the facility, e.g. lighting, lab equipment, emergency and operating rooms, and computer (USAID, no date b). Such critical loads can be further categorised into contact and no-contact to reflect the importance of reliability. ‘Contact critical loads are those which can endure minor fluctuations in voltage and brief loss of power’; this can include lighting or refrigeration (USAID, no date b). Contact loads can be connected to a back-up battery/inverter system that is ‘automatically connected when the primary power goes out’ (TetraTech, 2010).

‘No-contact critical loads are loads for which any interruption in power will result in damage to the equipment or loss of data’ (USAID, no date b). ‘Sensitive laboratory instruments, medical equipment such as x-rays, and data acquisition systems are all no-contact critical loads’ (USAID, no date b). For example, no-contact equipment includes blood chemical analysers, microscopes, computers, spectrophotometers, and X-rays (USAID, no date b). No-contact loads need uninterrupted transfer between primary and back-up sources; ‘these loads must be permanently connected to a battery/inverter system which provides continuous high quality power... even when the primary power is cut’ (TetraTech, 2010).

The extent to which the equipment is affected by electricity quality will depend on the technology used as well as the back-up generation available. For example, in the case of USAID in Haiti ‘sensitive instruments may be limited to voltage

variations of no more than 5%’, there may be ‘no planning or consistency in power outages’ and any available generators might need a manual start (USAID, 2012). In one assessment of laboratories in Mozambique it was found that ‘most equipment and instruments will withstand variations of up to 10% (voltage variation in this case went as high as 6.5%)’ (TetraTech, 2010). Attention needs to be paid to voltage variations when assessing energy needs and equipment of health facilities. Identifying the portion of a facilities load that is contact/no-contact is also essential for the estimation of a back-up system (USAID, no date b). Uninterruptible power supply (UPS) devices need to be sized to cover all no-contact loads (USAID, no date b).

Such requirements make off-grid energy sources, even if as a back-up/alternative to the grid, all the more important, particularly if they can guarantee a certain degree of reliability.

Whilst there are concerns around the limited capacity of PV, it appears to offer greater reliability: ‘more solar equipped clinics reported having electricity available on the survey day compared with those using diesel generators’ (WHO, 2015). The Icelandic International Development Agency has sponsored all health centres in the Kalangala district in Uganda to run exclusively on solar power (Ezor, 2009). In Liberia, a study by Adair-Rohani et al (2013) found that: ‘The data suggest a higher level of reliable electricity service for primary health clinics using solar-powered systems as their primary source than for those relying on generators’. Although there are numerous ‘confounding factors’ this would support the claim that solar power may present a more reliable energy source than generators for rural health facilities (Adair-Rohani et al, 2013).

In order to aid reliability for clinics, ‘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’ (WHO, 2015).

1.5.4 Ownership

Local ownership of the energy supply system (which could be established via an initial cost contribution) is cited by Powering Health as critical for ‘system sustainability’ (USAID, no date). Management structures need to be in place so that an entity exists that has a real stake in the ‘continued successful operation of the system’: this is essential to cultivate ownership (USAID, no date). One possible way of encouraging a stake is through a mini-grid system with the clinic as the anchor—this is discussed later in the report. Ownership also has a potential role in discouraging theft, as noted earlier.

Ownership is particularly important when it comes to financing. Financing systems need to be effectively managed by the organisation or individuals who ‘use and pay for the power’ (EnergyPedia, 2014). The structure of management may include village cooperatives, the existing clinic management, and nearby villages or facilities (EnergyPedia, 2014). If the cooperative has ownership they may have an agreement in place with the clinic to ‘manage any of the financing arrangements’ (EnergyPedia, 2014). The level of responsibility of the cooperative ‘can range from total operation and management of the system to simply keeping track of usage and payments’ (USAID, no date).

1.5.5 Financing

Capital costs and operating costs need to be financed effectively. Not only the cost of the system but expenses such as transportation of modules and custom fees need to be included (USAID, no date). Renewable/hybrid systems still need more capital investments by health facilities when compared to conventional generators (WHO, 2015). In terms of financing these investments,

WHO (2015) argues that ‘public-private partnerships are needed that combine support from national and international health and energy budgets with private-sector investment. The ultimate goal is to catalyse interventions that strengthen health services’ access to energy to ensure effective delivery of health services to all’.

By leveraging partnerships between the health and energy sectors, ‘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’ (WHO, 2015). Such ‘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’ (WHO, 2015). An enabling policy environment, with such appropriate fiscal incentives, is key (WHO, 2015).

Financing for maintenance can sometimes be a key stumbling block. In particular donor-funded PV systems often ‘fail for lack of operating funds and local service infrastructure’ (USAID, no date). In Haiti, experience with PV installation in health facilities found that while getting access to capital for installation was not the central challenge, ensuring there were ‘sufficient funds to cover the maintenance and replacement cost of system components’ was a key contributor to success (IEA, 2014).

There are financial models that have been used to good effect in resource-constrained settings in order to improve sustainability. The sale of excess electricity, however, can be key in allowing clinics to pay for the maintenance and operation of their systems (USAID, no date). By installing a system with excess capacity, the income from the sale of power (either in bulk or at the point of use) can ‘offset a portion, if not all, of the system’s operating

costs' (USAID, no date). In many cases if there is a grid connection this may involve sales of excess electricity back to the grid.

In off-grid settings NGOs have supported health clinics in the creation of micro-enterprises that can 'mimic such arrangements' on a smaller scale (WHO, 2015). In these cases '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' (WHO, 2015). This also gives back to the community, and extends some of the benefits of electrification. Health facilities can also extend community benefits by making use of unused available energy from back-up sources (WHO, 2015). Available energy can be 'shifted to other community users, generating resource efficiencies and revenues' (WHO, 2015). However, who is responsible for running such a business needs to be carefully clarified, so as not to overburden health practitioners.

In another scenario, user fees pass the cost to the patient—although, of course, this may not be possible in remote locations where users lack the resources (USAID, no date). In addition, there is a challenge presented by 'managing the collection and disbursement of funds' (USAID, no date).

WHO stresses that 'Innovative business and policy models need to be explored to catalyse increased investment in modern energy systems, support wider access to electricity as well as good practices for sustainable delivery and use' (WHO, 2015). Also highlighted is the inclusion of 'financial packages for piloting of different on-site, mini-grid and grid systems. These should be built and tested for their efficacy in sustaining access to energy. Such models should also consider revenue-generating mechanisms from on-site energy production that can help ensure operational sustainability' (WHO, 2015). One

possible scenario of a health clinic as an energy provider within a mini-grid is explored after this 'challenges' section.

It is also worth noting that potentially there are certain cost benefits for health facilities in switching to renewables. In the absence of renewable/hybrid energy sources there may be high costs for fuel, and where energy fluctuates and is unreliable, possible damage to expensive instruments or medicine spoilage (USAID, 2012). Solar PV systems, whilst they have higher capital costs, have 'lower operating costs when compared to other energy generation options' (USAID, no date). For example, an information note for the installation of a 5 kW PV system at Deh Sabz District clinic in Afghanistan states that the operating costs are now negligible compared to the previous diesel costs of US\$30,000 a year. Previously nearly all the clinic's money was spent on diesel (GVEP, 2013). In addition, 'Mini-systems such as the "solar suitcase" have filled a niche for low-cost solutions with a capacity of 100–200 W that target the most immediate energy needs of front-line health clinics currently lacking any energy at all' (WHO, 2015).

1.5.6 Capacity building and awareness raising

In Haiti, it was found that capacity building of local staff (along with fund availability) was crucial for keeping projects going and making them sustainable (IEA, 2014). In Guyana, a lack of capacity building in parallel to system integration has been cited as a key reason for the failure of some of the PV systems in the country (IEA, 2014).

One such aspect of capacity building is maintenance. In Haiti one training programme involved training administrators on the importance of maintenance, training technicians in charge of installations, and training hospital staff on system operation (USAID, 2012). The nature of the training required and who is targeted will depend on the size and location of

the healthcare centre; for example, for smaller, more remote centres there may not be an on-site technician and appropriate local personnel may need to be identified for training. When designing the training programme and planning for sustainability, the existing workloads of health facility staff need to be taken into account. A small health post with a wide catchment and only a few staff may be hard pressed to conduct maintenance themselves.

Raising awareness of the limits and maintenance of the chosen energy system among staff is also important. Experiences in Uganda showed that some systems are overused, in particular in staff quarters. 'An in-depth user training with appropriate material that can stay with the health centre can help in raising awareness about the system's potential and limits' (Energypedia, 2015). Expectations also need to be managed; throughout the experience of the Powering Health Initiative it was found that 'End-user expectations of solar systems are often unrealistic' (USAID, no date). Work needs to be done to educate staff on practical applications of the system as well as design/installation (USAID, no date).

There is also the issue of potentially high staff turnover; a system needs to be put in place that ensures new staff members are trained appropriately by outgoing employees (Energypedia, 2015). Powering Health notes that with solar PV detailed user manuals are essential, particularly in areas where staff turnover is high (USAID, no date).

1.5.7 Lack of community-wide access

Some research has suggested a link between 'electricity access in a household with greater use of health facilities and/or with impact on health outcomes' (GVEP, 2013). The full benefits for health may not be realised by confining electrification projects to health facilities. These further benefits relate to the use of cleaner cooking technologies and health education. In one study

in six countries in central and west sub-Saharan Africa, 'differences in infant mortality rates between rural and urban areas were found to mainly derive from the disadvantage in rural household characteristics' (GVEP, 2013). Such characteristics include electricity, amongst others such as access to drinking water and quality of housing materials (GVEP, 2013). It could be that infrastructure services including electricity are a proxy for wealth. However, another study looking at determinants of infant and under-five mortality rates found that the electricity effect was largely independent of the income effect (GVEP, 2013).

An IEG evaluation in Bangladesh found a significant impact of 'household electrification on mortality' (IEG, 2008). A possible channel cited for this effect was that access to media can improve health education (IEG, 2008).

In Asia Pacific, educational awareness-raising programmes on epidemics/hygiene were 'enhanced through the modern tools of mass media, such as radios and televisions' (UNDESA, 2014). A further global review on health and electrification found that increased access to ICT increased awareness of health issues, leading to behavioural change 'which improved health outcomes and reduced fertility' (UNDESA, 2014).

It has been found previously that TV can increase women's health knowledge, and thus have a 'fertility-reducing impact' (IEG, 2008). Multivariate analysis of the 'determinants of women's knowledge of health and family planning provides very strong evidence that access to television significantly increases this knowledge; this variable is significant in all but one of the 11 cases examined' (IEG, 2008). In Uganda the 'Energy for Rural Transformation Project has promoted gender-specific TV and radio communications to raise health awareness' (IEG, 2008). In addition, increased access to the internet is expanding access to vital information/advice and 'through it, governments are finding new avenues, including official websites and

social media, to provide more information to their populations at large, and to promote women's and children's health programmes' (WHO, 2014).

In terms of the provision of clean cookstoves, these can help to alleviate the potentially 'devastating health impacts' of traditional fuels (Practical Action, 2014). This in turn has implications for a 'family member's ability to earn a living due to

illness and early death, as well as draining family finances on costly medical treatment' (Practical Action, 2014). It is by taking an integrated approach to community-wide energy provision that we can maximise health benefits, potentially reducing the burden on health services from energy-related illness, while improving the quality of the service.

1.6 Health facilities and mini-grids

Section 1.6 key points:

- *When establishing health facilities as potential anchor loads for mini-grids we need to bear in mind the work burdens of health professionals, financial sustainability, community engagement, and the dominance of the anchor load.*

As rural communities and health facilities gain better access to new technologies/financial models—improving system sustainability—they can become 'anchors for distributed energy generation in their communities, stimulating even wider development co-benefits' (WHO, 2015). Partnerships of health facilities with local communities to develop mini-grids using PV solar or hydroelectric power present an interesting opportunity (WHO, 2015).

Mini-grids need 'up-front investments in infrastructure with a long service life'; therefore it is preferable to have an anchor 'who is likely to be at the location for many years into the future' (Bourgeois et al, 2013). A health clinic can act as a potential stable anchor, yet there are still financial challenges. Within an anchor load model, the 'anchor load is predictable and offers a guaranteed source of revenue for the project developer, whereas business group and community members are usual customers for the project' (GNESD, 2014). Therefore, in order for the clinic to be able to support the community

as an anchor load for the mini-grid, it needs to be financially sustainable.

As we have seen, health facilities still face numerous financing challenges, one possible solution being leveraging private investment. However, to attract business investment as part of a partnership or otherwise, it is more likely to be successful if it can demonstrate economic sustainability and productivity. The dependence on the health facility as an anchor load 'enhances business risks, as the threat of exit of such a buyer can have devastating effects on the business' (Bhattacharyya and Palit, 2014). There has to be a clear plan for sustainability.

Solutions listed above, such as having a micro-enterprise situated at the facility, are possible solutions for providing sustainability. Practical Action, from their experience, noted that 'unless mini-grids are anchored to productive end use, financial viability is a challenge' (Practical Action, no date). However, for this to succeed there needs to be clear ownership and someone in place

with business acumen to manage proceeds and productive use effectively. There also needs to be an ownership structure for such proceeds, and the priority for profits to be channelled towards maintenance first before being opened to wider community priorities.

In one project in Malawi, engaging communities at all stages and giving communities ‘clear responsibility for managing and maintaining the systems’ was highlighted (Tembo and Mafuta, 2015). Indeed, in the Malawi project in question, they adopted the concept of an ‘Energy Committee’ as a ‘vehicle for community ownership and participation’ (Tembo and Mafuta, 2015). In this example there was conflict amongst committee members when it came to generated funds and a lack of understanding that some profit needed to be kept for maintenance (Tembo and Mafuta, 2015).

The danger is that health workers will become overburdened with responsibilities for maintenance and productive use if the health centre becomes the anchor load. For example, in smaller healthcare clinics, personnel often have to ‘manage building infrastructure alongside their

healthcare tasks, and lack funding for even fuel and spare parts’ (WHO, 2015). Sustainability of energy systems is a key concern, and ‘attempts to leverage the power generation potential of health facilities for broader community needs must be carefully planned, and supported by capacity-building and budgets for system maintenance’, as well as considering health worker burdens (WHO, 2015).

However, we need to bear in mind that by following the anchor load model there may be interdependence when it comes to electricity use, with the anchor often taking up the majority of the available electricity. In one case in a mini-grid in Northern Kenya, ‘the whole community had to be shut off whenever there was a critical medical procedure at the dispensary, such as surgery or a woman delivering, in order to ensure 100% reliable electricity supply during that critical time’ (Gollwitzer et al, 2015). Interdependence such as this is a concern, particularly when it may put at risk those who are using the energy for productive economic purposes which help the financial sustainability of the grid (Gollwitzer et al, 2015).



A.U.-UN Mission Conducts Medical Checkups in Darfur
Maruf Ayodegu Jimoh (right), a Nigerian doctor with the African Union-UN Hybrid Operation in Darfur (UNAMID), assists a woman with an eye problem in El Daein, East Darfur State. The UNAMID clinic sees about fifty people at a time from the local community, mostly women and children, every Tuesday and Thursday. Photo ID 531964. 09/10/2012. El Daein, Sudan. UN Photo/Albert González Farran. [www.unmultimedia.org/photo/CC BY-NC-ND 2.0](http://www.unmultimedia.org/photo/CC-BY-NC-ND-2.0)

CHAPTER 2: TELEMEDICINE AND TECHNOLOGY FOR HEALTHCARE

Innovation is at the centre of what is happening now and is beginning to take into account areas with limited infrastructure and access to clean running water. Sustainable energy access opens the door to the application of a range of innovations in rural health clinics: the focus of this chapter.

By way of an initial example, one inspiring innovation in medical technology for low-income settings is Vincent Garvet's affordable dialysis machine. Garvet, an engineer by training, was awarded the Affordable Dialysis prize by the George Institute for Global Health, the International Society of Nephrology and the Asian Pacific Society of Nephrology for his compact design, which fits into a small suitcase and 'uses a standard solar panel to power a highly efficient, miniature distiller capable of producing pure water from any source' (George Institute,

2016). The scope of energy-dependent medical technology innovation is huge and can benefit a wide range of medical specialities.

This chapter of the report starts by briefly examining the key technologies of refrigeration, sterilisation, and microscopes (Section 2.1). It then goes on in Section 2.2 to consider more advanced interventions within telemedicine and eHealth which aim to improve access to health information, ease of diagnosis, and health worker training for remote communities' health facilities. Sections 2.3 and 2.4 summarise the benefits and challenges of telemedicine, and finally Section 2.5 lists a number of specific examples. The technologies and innovations that are highlighted have been selected on the basis of their immediate relevance to rural frontline healthcare.

2.1 Key technologies and innovation

Section 2.1 key points:

- *Solar autoclaves are a key innovation in enabling the sterilisation of medical equipment in rural, off-grid settings.*
- *Refrigeration is essential to maintain stores of vaccines. Direct drive solar refrigerators and cold boxes can present solutions for remote off-grid contexts.*
- *Solar-powered microscopes may help enable early detection of key diseases in rural areas.*

Essential health technologies as defined by WHO 'include technologies and medical devices to support emergency and surgical care, blood transfusion, vaccines and injections (e.g. refrigeration), diagnostics and laboratory technology and e-health' (GVEP, 2013). This Section reviews three of them: sterilisation, refrigerators, and microscopes.

Crucially, there are certain health services that cannot be operated without energy, including 'medical refrigerators, sterilizers, lamps, cookers, suction machines for deliveries, incubators, microscopes, centrifuges, mixers, X-ray viewers, etc.' (European Commission, 2006). 'Many rural health facilities in Eastern Africa are limited in their ability to deliver quality health services,

partly due to a lack of appropriate, affordable and accessible energy services' (European Commission, 2006). More and more innovation is happening within the space of energy-efficient medical devices that makes them suited to low-income settings. Such devices can operate from 'low-power battery and solar panel sources' (WHO, 2015, MAIN).

2.1.1 Sterilisation

For sterilisation of medical instruments as well as pasteurisation, solar energy can be a possible option (Energypedia, 2014).

'The lack of readily available sterilization processes for medicine and dentistry practices in the developing world is a major risk factor for the propagation of disease' (Neumann et al, 2013). Modern medical facilities often use 'autoclave systems to sterilize medical instruments and equipment and process waste that could contain harmful contagions' (Neumann et al, 2013). Conventional solar autoclaves act to concentrate solar radiation, for example, using a 'parabolic solar concentrator and a small boiler to collect solar energy to generate steam that is transferred to an insulated pressure vessel and an electronic sterilization indicator' (WHO, no date b).

In terms of innovation in this area, Neumann et al (2013) note the use of 'broadband light-absorbing nanoparticles as solar photothermal heaters which generate high-temperature steam for a standalone, efficient solar autoclave'; this can be useful for the 'sanitation of instruments or materials in resource-limited, remote locations'. One such example is Solar Steam, an efficient technology that can be used for the sterilisation of human waste—and can be used in one set-up for sterilising medical and dental equipment (Gizmag, 2013). "The "solar steam" sterilization system uses nanomaterials to convert as much as 80 percent of the energy in sunlight into germ-killing heat' (Rice University, 2013).

2.1.2 Refrigerators

Refrigerators are required to maintain a store of vaccines (IEG, 2008). One of the more commonly claimed benefits for 'health clinics of electrification is that it helps preserve the cold chain' (IEG, 2008). In an IEG evaluation of data for six countries it was found that the 'cold chain was significantly stronger in electrified clinics than in those without electricity', although the proportion 'of clinics offering immunization services did not differ between the two groups' (IEG, 2008). Energy supply can also help to bring down the costs for immunisation services, as such technology is 'most easily and cheaply operated by electricity' (IEG, 2008). UNICEF is currently making solar refrigerators a major procurement item for vaccine refrigeration (WHO, 2015). In Zambia, 'the lack of energy to power refrigerators...was a major hindrance to the delivery of quality health services' in the Lundazi district (Mfuno and Boon, 2008). The use of solar refrigerators has facilitated the storage of vaccines for distribution to more rural health centres (Mfuno and Boon, 2008).

'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' (WHO, 2015).

In addition, a 'cold box can keep vaccines at the required temperature for between two and seven days'. This is required in case of interrupted supplies of power or maintenance requirements (IEG, 2008). Basic health centres can also use a cold box where refrigeration is absent if vaccines are to be used immediately, e.g. National Immunization day (IEG, 2008). However, for successful deployment of a vaccine programme, refrigeration alone is, of course, not enough and some reviews of the literature have emphasised the importance of 'training and education for health care workers and social mobilisation' (GVEP, 2013).

2.1.3 Microscopes

Solar power-enabled microscopes can also enable key services in rural areas. In Zambia, the lack of energy to power microscopes for tuberculosis (TB) detection has proved a major hindrance to quality healthcare (Mfunne and Boon, 2008), while ‘solar-powered microscopes in the district have ensured an increase in detection of TB’, allowing centres to run sputum tests (Mfunne and Boon, 2008). Previously, people had avoided TB testing

as ‘the centre was at the district hospital which is quite far from remote areas.’ The solar microscopes saw a 25-30% increase in people tested at solar-powered health centres.

Of course, with all new technologies it is worth highlighting the need for continuous review, adjustments, and updates as we learn more about the real experiences of using these tools in remote communities, at the front line. The same can be said of telemedicine and eHealth.

2.2 Telemedicine and eHealth

Section 2.2 key points:

- *Telemedicine ‘signifies the use of ICT to improve patient outcomes by increasing access to care and medical information’.*
- *The opportunity for telemedicine is heightened as availability of network signals and bandwidth increases. Smartphones, tablets and other technologies are already being used to facilitate rural healthcare.*
- *Telemedicine can help to improve the quality and accessibility of healthcare.*

The term telemedicine ‘signifies the use of ICT to improve patient outcomes by increasing access to care and medical information’ (WHO, 2010a). The World Health Organisation (2010 a) has adopted the following broad description:

“The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities”

While other terms such as ‘telehealth’ and ‘e-health’ are also used, these all fall under the broad umbrella of the definition given above.

Smartphones, tablets and other services are currently being used to aid the increase in healthcare access for remote locations (Eurekaalert, 2013). As availability of network signals and bandwidth increases and spreads across the globe there will be a substantial platform for mobile medicine to reach remote areas (Eurekaalert, 2013). ‘The use of low-cost, dedicated remote-presence devices will increase access to medical expertise for anybody living in a geographical area with a cellphone signal’ (Eurekaalert, 2013). Telemedicine is constantly evolving as it responds

to, and incorporates, advancements in science and technology, and the needs and contexts of local communities (WHO, 2010a).

Telemedicine may have an immediate effect and response through videoconferencing, or data may be emailed (or otherwise transmitted) to an expert to reply at a later date (WHO, 2010a). Activities may include videoconferencing, remote monitoring, mobile health and store-and-forward data, images, and videos (Rural Health Info Hub, no date).

Telemedicine or e-health has the ‘potential to address several of the health challenges facing developing countries by providing cost-effective solutions’ (Novartis, no date b). Telemedicine can overcome time and distance barriers and provide ‘access to scarce specialist care, improve the quality of care in rural areas and reduce the need for rural patients to travel to seek medical attention’ (WHO, 2010a) (Mars, 2013). The expansion of telemedicine for developing countries is promising, with falling costs of ICT and digital storage; the growing development of Internet-based conferencing; and the minimal investment of basic store-and-forward email-based telemedicine amongst other elements (WHO, 2010a). Certainly in India, ‘Telemedicine has and continues to benefit the Indian health-care system in terms of preventive care and disease treatment’, yet challenges (such as connectivity) are still faced in

expanding access and establishing programmes that can scale (Pal et al, (2005).

In the case of Ghana, the limited health facilities and health workers in the Bonsaaso cluster are required to deal with conditions such as ‘malaria, anaemia, malnutrition, tuberculosis (TB) and HIV/AIDS, which affect many members of the community’ (Novartis, no date b). The actual delivery of care in this region is difficult and community members ‘regularly travel up to 40km to access medical advice or attention’. There are also particular risks for women during pregnancy and delivery. In the district in Ghana described above, there is also increasing demand for ‘point-of-care support for health workers’ to limit unnecessary referrals. ICT and telemedicine can help facilitate these kinds of problematic care situations by leveraging a number of beneficial services and impacts.

Telemedicine applications ‘have successfully improved the quality and accessibility of medical care by allowing distant providers to evaluate, diagnose, test, and provide follow-up care to patients in less-economically developed countries’ (WHO, 2010a). In addition, by ‘increasing accessibility of medical care, telemedicine can enable patients to seek treatment earlier and adhere better to their prescribed treatments (WHO, 2010a). The reasons for this can be seen in the benefits and services detailed subsequently.

2.3 Benefits of telemedicine:

Section 2.3 key points:

- *The enablement of telemedicine can help to reduce transportation and enable remote consultation through key communication links with medical expertise located elsewhere.*
- *It can help the management of major epidemics as well as encourage staff retention by providing them with professional support and training.*

- *Disease management, data collection, and home monitoring can also be facilitated and can be carried out in new, more efficient ways.*
- *Point-of-care diagnostics can reduce referral needs and the burden of reliance on larger medical facilities.*
- *Mobile technologies can be harnessed in a number of ways, including for education on key health issues and facilitating medical reminders for appointments and family planning milestones, as well as facilitating diagnostics.*

2.3.1 Reduce transportation

Telemedicine can act to reduce transportation, which is not only a burden on people but could ‘reduce the travel-related carbon footprint of health care’ as well as time and stress, through remote diagnosis (WHO, no date) (WHO, 2010a).

2.3.2 Remote consultation

Where there is a lack of medical expertise in rural areas, ‘remote-presence medical devices can help fill this void by connecting people in remote locations with experienced health care professionals for real-time assessment’ (Eurekalert, 2013). Certainly in the case of medical personnel in sub-Saharan Africa, staff shortages present a major problem (along with shortages of facilities themselves) (Meso et al, 2009). In sub-Saharan Africa, ‘the doctor-to-population ratios range from 1:5000 to as few as 1:30000’; ‘owing to reasons such as poor salaries, “brain drain,” and limited training capacity, the situation may get worse’ (Meso et al, 2009). While telemedicine through remote consultation cannot entirely solve the deficit in medical expertise, it can aid remote and rural areas to be able to connect more readily to what expertise does exist.

Connecting remote sites via telemedicine may also be cost-effective in providing care ‘when compared with the alternative of constructing facilities and hiring clinicians’ (WHO, 2010a).

Access to expert insight is enabled without them having to physically be present. Telemedicine can facilitate remote consultations irrespective of location, helping to reduce ‘congestions commonly experienced in hospitals since only serious cases will be there to attend to’ (Imouokhome and Osubor, 2012). Telemedicine can also assist with any follow-ups and assessing how patients respond to medication (Imouokhome and Osubor, 2012). However, we need to bear in mind that direct contact for patients and providers is still important (WHO, no date).

In Kenya, Mashavu is an initiative that utilises kiosks ‘to offer rural citizens ‘e-visits’ to the doctor; kiosks, manned by trained professional volunteers, offer the chance for remote-dwelling individuals to undergo basic diagnostic tests. The results of the test are then electronically sent to a doctor who can say if a consultation at a healthcare facility is necessary’ (KPMG Africa, no date). Access to expert advice through teleconsultation can be crucial for effective diagnosis and treatment. For example, in one case in Cambodia, teleconsultation with paediatric specialists in the US enabled the correct diagnosis and appropriate treatment of a child whose condition was otherwise not improving (Froelich et al, 2009).

2.3.3 Fighting epidemics

Technology and telemedicine have the ability to aid the fight against epidemics such as Ebola in

a number of ways. Messaging on mobile phones can help to educate populations on the hazards of the disease and how to avoid contracting the virus (WEF, 2016). A project in Sierra Leone did just this, sending one million text messages to inform the population about ways of preventing the spread of Ebola (WEF, 2016). This can keep even remote populations up to date, particularly with the spread of the use of mobile phones in these areas. Connectivity for telemedicine solutions and communication links that can function even when the power is out is critical to ensure the spread of viruses is spotted early and to enable attempts to contain it by educating the population (WEF, 2016). Other uses for telemedicine in epidemics include the training of medical professionals as well as real-time monitoring (WEF, 2016).

Efficient and remote training, allowing local health personnel to be guided by experts and given key advice, could 'prove an invaluable tool to optimize the treatment of patients and the development and deployment of strategies to fight this potentially lethal disease' (Rafael Grossmann, no date). Innovative solutions have also been trialled to assist with monitoring outbreaks that have included examining data from mobile phone towers in order to track users 'who have been close to a known case of the virus' as well as electronic storage of patient data (WEF, 2016). Furthermore, wearable technologies for remote and mobile vital signs monitoring could play a role (Rafael Grossmann, no date).

VSee telemedicine technology was deployed to aid the Ebola outbreak, allowing doctors to monitor patients thousands of miles away. It has also been used to allow for situational awareness updates in real time (through video conferencing), and engaging new medical recruits (VSee, 2016). Using technology such as 'digital stethoscopes, X-rays with wireless transfer, and real-time video allows it to keep Ebola treatment safe yet personal' (VSee, 2014).

2.3.4 Staff retention

As we noted when discussing remote consulting, shortage of medical personnel presents a significant problem. Telemedicine programmes (like electrification) also have the potential to 'motivate rural practitioners to remain in rural practice through augmentation of professional support and opportunities for continuing professional development' via provision and dissemination of general information (WHO, 2010a).

One of the most central benefits of telemedicine is connectivity, not only in terms of connecting patients to medical specialists but also for remote or isolated health workers who need to consult with their peers (Novartis, no date b). In Ghana, the Novartis foundation used mobile phones to connect healthcare personnel and enable them to communicate 'within their peer group for coordination and informal telecounselling' (Novartis, no date b). Tele-education can help to reduce the 'sense of isolation experienced by rural doctors' (Mars, 2013). However, in the case of Africa, such practices have been largely restricted to urban areas due to poor infrastructure (Mars, 2013).

2.3.5 Tele-education

Accompanying a lack of medical expertise in remote locations is a lack of doctors to help train healthcare professionals (Mars, 2013). Tele-education presents a solution to this, not only removing some of the isolation but possibly improving the quality of healthcare offered in primary facilities by allowing staff to access training and expertise relatively easily (Mars, 2013). Providers are 'able to receive health education through lectures and computer-based training programs. This includes teleconferencing with other healthcare professionals to share knowledge and experiences' (Rural Health Info Hub, no date). For example, the University of KwaZulu-Natal has provided medical education

via videoconferencing since 2001 with ‘over 40h of interactive sessions broadcast per week by 2010’ (Mars, 2013).

For patients, mobiles and technology can also allow expanded access to health education (as we saw in the electrification of health facilities section). Some examples of such programmes will be elaborated on in the case studies section.

2.3.6 Disease management and data collection

Telemedicine can provide the ability to ‘organize and collect patient data’, tracking health issues and illustrating trends (WHO, 2010a). This allows for the ‘monitoring of disease evolution and can support communication to plan and mobilize vaccination teams’ (WHO, 2010a). Other systems can include electronic record-keeping and data management through network databases (WHO, 2010a). The Novartis Foundation, together with WHO, has developed an e-learning tool for the ‘integrated management of Childhood Illness’, in addition, they are working with other partners to develop a similar e-learning tool ‘to improve and scale up training in maternal and new-born health’ (Novartis, 2013).

Another knock-on consequence of improved data management is that the ability to ‘transfer seamlessly medical laboratory results and patient data to hospitals and clinics for diagnostics and advice’ can enable a decrease in the costs of healthcare, whilst increasing quality, access, and capacity (Kilfe et al, 2006).

2.3.7 Home monitoring

There is great potential for telemedicine services such as home monitoring for conditions such as cardiac failure or hypertension in regions like Africa. However, such potential benefits of telemedicine are limited by infrastructure: ‘fewer than 2% of homes have fixed telephone lines and few have Internet access, simple low cost mobile phone based solutions are required’ (Mars, 2013).

Services involving such home monitoring, which would enable early identification of issues for people in remote areas, also need to be cheap enough to use—perhaps through government, mobile service providers, or universal services funds subsidies (Mars, 2013).

Systematic ‘review of telehealth, telecare and home monitoring schemes has found evidence of effective management of the frail and elderly for diabetes as well as effective management of mental health conditions, cardiac disease and high-risk pregnancy monitoring’ (WHO, no date). Some meta-analysis has also found ‘evidence of health benefits for patients with lung diseases, diabetes and chronic wounds’ (WHO, no date). When it comes to maternal and child health, monitoring is a key element, and can also be facilitated by eHealth. A 2013 survey (in which 64 out of 75 countries responded) found that 48% of countries had adopted ‘at least one type of eHealth initiative for the monitoring and surveillance of maternal, neonatal and paediatric patients’, telemedicine/teleconsultation being the approach most frequently adopted (WHO, 2014).

2.3.8 Registration

In addition, access to ICT can also enable the registration of births, deaths, and causes of death, aiding with the provision of a ‘continuum of care’ (WHO, 2014). Registration can provide a ‘passport to protection’, ‘extending from basic services in health, social security and education, to safeguards against other threats to their wellbeing and safety’ (WHO, 2014). Indeed, a 2013 survey (64 of 75 countries responded), found that 69% of countries ‘have implemented, at least partially, an electronic information system to register births, deaths, and causes of death’ (WHO, 2014).

2.3.9 Diagnostics

Point-of-care diagnostics, via telemedicine, can act to increase medical efficiency and reduce reliance on large medical facilities that

present time and distance barriers for rural communities (Eurekalert, 2013). There have been numerous telemedicine kits developed which may incorporate a computer and medical ‘peripheral devices’ to enable analysis of diagnostic information (Imouokhome and Osubor, 2012).

In Nigeria, one such toolkit uses custom software to capture diagnostics through the ‘Quantum Magnetic Resonance Analyser’ connected to the computer (Imouokhome and Osubor, 2012). The patient ‘grips the sensor in his hand’ and his medical information is captured by the sensor, then analysed (Imouokhome and Osubor, 2012). The information received can indicate the health status of vital organs such as the brain, nerves, lungs, kidneys etc. to the doctor/medical professional (Imouokhome and Osubor, 2012). Other devices that may be used with the software include an electronic stethoscope, ECG recorder, blood pressure monitor, medical image system and digital thermometer (Imouokhome and Osubor, 2012). Some examples of prominent diagnostic kits are examined later in the report.

2.3.10 Leveraging mobile devices

The use of mobile devices can be harnessed effectively for telemedicine (Imouokhome and Osubor, 2012). ‘Already, well over 100 countries are using mobile phones to achieve better health, or exploring how they can do so (WHO, 2014). Mobile technology has been used in a variety of ways to improve the efficacy of and access to healthcare in remote settings. For example ‘Text message reminders sent to patients have improved appointment adherence in Malawi and follow-up in Nigeria and Cameroon’ (Mars, 2013). Furthermore, there have been ‘clinical services using mobile phones including cervical cancer screening, teledermatology in Egypt, Botswana, and Uganda, assessing trachoma in Niger, obstetrics in Ghana, and telemedicine in Cameroon and Malawi’ (Mars, 2013). Mobile phones are also leveraged for family planning in Malawi and medication adherence programmes/education in Botswana and Kenya, amongst many other health-related uses (Mars, 2013). In addition, mobile phones now have the ability to take photographs with enough resolution to allow for digital images of ‘skin lesions, burns, skin discolouration etc.’ to be taken, shared with and analysed by dermatologists/GPs in remote locations (Imouokhome and Osubor, 2012).

2.4 Barriers facing telemedicine

Section 2.4 key points:

- *A key barrier for telemedicine is costs, and the need for these to become lower to make it more accessible for resource-poor settings where funding is limited.*
- *Capacity building and awareness raising are needed for the successful deployment of telemedicine. Practitioners and patients need to understand the benefits over traditional approaches. Acceptance is key to success.*
- *Solutions and deployment need to take into account the local context.*

The legal environment and institutional frameworks need to adapt to the changing healthcare approach and to enable and support medicine from a distance.

Technical issues can present problems and design needs to be suited to the rural context. There also needs to be appropriate infrastructure to facilitate the use of the many telemedicine technologies.

For these barriers to be overcome partnership is needed at all levels and with a diverse range of stakeholders.

A 2010 global survey on eHealth indicated that developing countries are ‘more likely to consider resource issues such as high costs, underdeveloped infrastructure, and lack of technical expertise to be barriers to telemedicine’ (WHO, 2010a). On the other hand, for developed countries, legal issues such as patient privacy and lack of demand are more likely to be of concern (WHO, 2010a).

Furthermore, as with energy, we need to bear in mind that the barriers to health provision in general go beyond energy and telemedicine provision. For example, progress in areas such as women’s and child health is still hampered by ‘lack of government commitment in some cases, lack of skilled health professionals and expertise in others, and lack of financial and other resources almost everywhere’ (WHO, 2014).

2.4.1 Cost

‘The most frequently cited barrier to the implementation of telemedicine solutions globally is the perception that the cost of telemedicine is too high’ (WHO, 2010a). The Global Observatory for eHealth survey (2010) indicated that almost ‘70% of countries indicated the need for more information on the costs and cost-effectiveness of telemedicine solutions, and over 50% wanted more information on the infrastructure necessary to implement telemedicine solutions’ (WHO, 2010a). Infrastructure is something we will deal with later in this report.

Good telemedicine can be expensive, and rural facilities—whilst they may understand the benefits—have to wait it out until technology becomes ‘cheaper, less technical and independent of public utilities that are erratic in their respective countries’ (Nuviun, 2015). Access to telemedicine is therefore limited by financial constraints.

In South Africa, corporate investment was key to successful deployment (Nuviun, 2015). On the other hand, in Uganda the activities are ‘largely non-commercial and provided by the government’ (occasionally partnered with international institutions) and telemedicine activities are still very much in their initial phase (Nuviun, 2015). Attracting private sector buy-in to telemedicine efforts in developing countries may be key to battling the financial constraints (Nuviun, 2015). However, low-cost applications have proven to be feasible, clinically useful, as well as sustainable and scalable for low-income settings with limited infrastructure (WHO, 2010a). Unfortunately, the application cost is not the only barrier faced in scaling up these initiatives.

It is not just the technology that needs to be funded: ‘Equipment, transport, maintenance, and training costs of local staff can be daunting for countries with little income or limited funding for the implementation and maintenance of telemedicine initiatives’ (WHO, 2010a). However, it is worth bearing in mind that in the longer term telemedicine can even work to reduce costs by

reducing admissions and unnecessary emergency department visits (Rural Health Info Hub, no date).

2.4.2 Traditional approaches

Suspicion of new practices perceived to be in conflict with traditional approaches, lack of ICT literacy, and linguistic and cultural differences between patients all present challenging cultural factors for the deployment of telemedicine (WHO, 2010a). The adoption of telemedicine requires acceptance by both the patient and the doctor, particularly as both sides may be accustomed to face-to-face encounters (WHO, 2010a). ‘There are two reports from South Africa of resistance by health workers to using mobile technology’ (Mars, 2013). In these cases ‘Nurses would not use a mobile point-of-care eHealth solution to record stock used for patients in a large private hospital. Community healthcare workers given mobile phones to report on patients on treatment for drug resistant tuberculosis completed fewer than a third of reports’ (Mars, 2013).

2.4.3 Awareness and capacity building

As with any technology initiative, there needs to be ample capacity building to enable deployment of telemedicine solutions. An effort also needs to be made to raise awareness of the benefits of telemedicine in rural areas. This is particularly important as it may be the case (as found in Ghana) that staff in urban hospitals are more likely to be familiar with ‘telemedicine and more likely to have access to information technology’ than those in a rural area (Darkwa, 2000). Certainly in Africa a lack of awareness amongst health workers and the patient community presents a barrier to deployment (Mars, 2013). A lack of buy-in from practitioners contributed to previous telemedicine programme failures in South Africa and Ethiopia (Mars, 2013).

A lack of computer-literate workers and local skills and knowledge can act as constraints,

with medical personnel needing to be trained appropriately (WHO, 2010a). Using simple ‘user-friendly interfaces and systems that people with little to no technical expertise and limited English-language knowledge can operate are important means of overcoming barriers to implementation’ (WHO, 2010a). ‘For instance, the Sub-Saharan African region is notable for its incredible language diversity. For example, Cameroon, a country with only a population of 14 million has 279 distinct languages, Nigeria has 515, and Ghana has 79’ (Meso et al, 2009). However, this does not negate the need for effective capacity building and training; cultural and social awareness are also key to effective deployment.

‘Collaboration, participation, and capacity building are fundamental to the success and sustainability of telemedicine initiatives’ (WHO, 2010a). In addition to the community, a wider range of stakeholders also needs to be engaged (WHO, 2010a). For example, the quality of initiatives is dependent on the experts involved—these then have to be carefully selected and show commitment to local capacity building such as through train-the-trainer models, etc. (WHO, 2010a).

2.4.4 Knowledge of the local context

Experiences in previous failed implementations of telemedicine (such as in South Africa and Ethiopia) were relatively similar. Reasons for failure included ‘lack of a change management plan, no business model, limited buy-in from practitioners, high staff turnover, limited eReadiness, problems with connectivity and transmission of large files, inappropriate software and devolution of project management to health authorities which had not budgeted for ongoing telemedicine services and their management’ (Mars, 2013). As well as including many of the factors we have already touched on, a key takeaway in this case was the need to understand and take into account the local human, management and cultural context in order for there to be ‘successful change management

and technology adoption' (Mars, 2013). Similar lessons would apply in a developed world context.

As with any energy/technology provision initiative, the technology alone is not enough. 'Organizations and individuals engaging in telemedicine initiatives in developing countries need to be aware of the local context in which they work, i.e. available resources, needs, strengths, and weaknesses' (WHO, 2010a). For example, for an application to be technically feasible it needs to be developed with the local context, infrastructure, and connectivity in mind (WHO, 2010a).

2.4.5 Legal issues and institutional framework

Legal considerations include the 'absence of an international legal framework to allow health professionals to deliver services in different jurisdictions and countries' (WHO, 2010a). There are limitations on many applications due to processing capacity, privacy issues, signal problems, perceived high costs, 'medical liability, patient confidentiality, physician payment', authentication, continuity of care, quality, jurisdiction and consent, amongst other policy issues (Eurekalert, 2013) (Mars, 2013).

A government institutional framework is also needed: national ICT policies need to take into account the applications of telemedicine. However, reforms at the institutional level can be hampered by a lack of regulatory authorities, lack of experience, and by poor institutional linkages, amongst other barriers (Meso et al, 2009).

2.4.6 Technical

As we have seen with energy systems, technical issues are an important concern. Technology challenges also include the danger that due to the complexity of the systems and the potential for malfunction—potentially causing software/hardware failure—the mortality of patients as well as the liability of providers could increase (WHO, 2010a). In addition, the design needs to

be appropriate to the rural context, where energy supply may be unreliable, e.g. requiring longer battery life, and the ability to function offline.

2.4.7 Infrastructure

In order for telemedicine to function, the appropriate infrastructure is needed as well as the hardware—this includes energy access to charge and operate devices as well as network signal and bandwidth. In the case of Africa, 'In rural areas, where telemedicine is needed the most by the poorest of the poor, it is least likely to be provided because of inadequate infrastructure and high connectivity costs' (Mars, 2013). For instance, developing countries are only predicted 'to account for a small share of the market in mobile health, in Africa's case 5% by 2017, according to PwC' (Guardian, 2014).

Although smartphone penetration rates are expected to climb, unreliable signal strength still presents a serious challenge for telemedicine technologies (Guardian, 2014). In addition, despite the growth of the internet, there is a growing digital divide between rich and poor (Guardian, 2016). 'Adoption gaps between the bottom 40 percent and the top 60 percent and between rural and urban populations are falling for mobile phones but increasing for the internet' (World Bank, 2016).

It has been suggested that the 'success of telemedicine in South Africa' is 'largely connected to the high-speed broadband penetration rate and the country's highly impressive internet speed' (Nuviun, 2015). In Uganda, where broadband infrastructure is lacking, telemedicine is still 'in the initial stage' (Nuviun, 2015). Affordable broadband can facilitate more efficient use of telemedicine by providing faster connection speeds for the effective transmission of data for these services (Rural Health Info Hub, no date).

What we can identify from all the challenges listed here is that their resolution requires

partnership, involving all stakeholders so that the contextual challenges are taken into account, from planning, to implementation, to monitoring. Stakeholders should include: ‘Community leaders, health professionals, academic institutions and educators, health administrators, and policy-makers’ (WHO, 2010a).

2.5 Examples of telemedicine initiatives:

This section provides a selection of case studies and examples of telemedicine or tele-education initiatives. It specifically focuses on mobile health and point-of-care diagnostics to demonstrate the interesting work being done in the field.

2.5.1 Leveraging mobile devices for education and communication

mDiabetes: mDiabetes uses text messages to increase awareness and help prevention of diabetes in India (Engineering for Change, 2016). ‘Sixty-plus million Indians live with diabetes and one million die from it each year. Indians get the disease an average of 10 years earlier than counterparts in the West, often in their 30s and 40s’ (Argoia World, no date). One million people opted in to receive the relevant text messages and 56 messages were developed in collaboration with Emory University (Argoia World, no date). The study carried out to assess the results of the initiative found that: ‘Consumers’ awareness of diabetes and its complications increased and promising trends in behavior change were noted: an 11% increase in daily exercise, a 15% increase in the intake of 2-3 servings of fruits a day, and an 8% increase in 2-3 servings of vegetables a day.’ (Argoia World, no date). Argoia World is expanding the programme to cover other areas of concern relating to diabetes, such as kidney disease and reducing fat and cholesterol.

Project Masiluleke: Project Masiluleke in South Africa also uses text messages to raise awareness around HIV/AIDS (connecting recipients to

existing HIV/TB call centres for information, counselling and referrals), remind individuals of scheduled clinic visits for treatments and support self-testing with counselling via mobiles (Poptech, no date).

Smart Health India: ‘SMART Health India’ (developed by George Institute researchers) is a ‘unique low-cost, high-quality healthcare delivery system that...utilises advanced mobile health technologies that provide the healthcare worker with personalised clinical decision support to guide the Systematic Medical Appraisal Referral and Treatment (SMART) of individual members of the community’ (George Institute, no date). As wireless networks now reach more than 80 per cent of the population in India, ‘SMART’ health technologies are more and more relevant (George Institute, no date). For each village in India there is an ‘Accredited Social Health Activist’ (ASHA); the ASHA will use a low-cost tablet with custom software that allows patient information to be ‘entered and recommendations received for personalised, evidence-based healthcare’ (George Institute, no date). The tablets can determine whether the patient is at risk of heart disease and calculate a prevention plan. The tablet can then transmit patient information to a ‘secure server for storage in an electronic medical record accessible to local doctors and hospitals’. Patients can also access their information through their phone and receive reminders and prompts.

Novartis Foundation: The Novartis Foundation aims to pioneer innovative healthcare models ‘that have a transformational impact on the health of the poorest populations’ (Novartis, no date a). In one project in Ghana they used ‘mobile technology to centralize expertise and coach community healthcare workers in their patient care through telemedicine’ (Novartis, no date a). The telemedicine project was piloted/validated from 2012 to 2014 and collaborators included the Earth Institute at Columbia University (Novartis, no date a). The project covered six millennium villages and thirty communities within the ‘Bonsaaso cluster,

home to 32,000 people, with only seven healthcare centres (Novartis, no date b). The programme is currently being scaled to the whole district, and a national roadmap for telemedicine in Ghana is being established—the ultimate aim is to ‘cover the entire nation with telemedicine services by 2017’ (Novartis, no date a). Results from the pilot stage were as follows:

‘The teleconsultation centre (TCC) at the District Hospital in Agroyesum served 30 communities, and covered about 7,500 households (32,000 people). During the pilot, the TCC received an average of about 380 calls a year with cases ranging from complicated labor and pregnancy, malaria, fever, diarrhea, hypertension and diabetes. Of all teleconsultation cases in 2013, 54% were resolved by phone through the TCC and included 31% avoided referrals.’ (Novartis, no date a)

The results of the pilot support many of the time, efficiency, and expertise benefits of telemedicine discussed in this report, helping to reduce ‘the need for perilous distances to be traversed when patients and community health extension workers (CHEWs) need medical advice from a specialist, or in emergencies’ (Novartis, no date b).

2.5.2 Point-of-care diagnostics

VSee: The VSee kit was designed with isolated communities in mind and is a prime example of designing for the local context. ‘The VSee kit comprises of an iPad, diagnostic tools and medical devices such as ultrasound, dermoscopes, otoscopes, stethoscopes, EKG monitors, allowing real-time medical images and readings to be sent across to doctors at hospitals anywhere in the world via BGAN.’ (Inmarsat and Vsee, 2014). BGAN can be used in remote health facilities because it utilises Inmarsat’s global 3G satellite network, ‘which is completely independent of cellular or fixed connectivity’ (Inmarsat and Vsee, 2014). There are multiple case studies available that set out the effective use of the VSee kit and VSee technology across a broad range of areas and locations.

One such example is a 2013 trial with a hospital in Gabon in West Africa, which aimed to demonstrate how ‘invaluable telemedicine is in helping hard to reach communities (Inmarsat and Vsee, 2014). The hospital caters to around 60 isolated villages ‘many of which are only accessible by boat rides taking up to an hour’; most villages lack basic amenities such as electricity or water, and the hospital is their only point of call if they are sick. VSee trialled remote ultrasound checks using the ‘battery-powered VSee Telemedicine Field Kit and BGAN terminal’. IP connectivity and streaming were used to allow doctors to review ultrasound images in real time—this is enabled through their collaboration with Inmarsat, which offers ‘the broadest portfolio of global broadband, machine-to-machine and voice satellite services’ (Inmarsat and Vsee, 2014).

Swasthya Slate: Swasthya Slate is a device that allows ‘Android Tablets and Phones to conduct 33 diagnostic tests on the mobile device’ (Swasthya Slate, no date). These tests included ‘electrocardiogram measures, blood pressure, blood sugar, urine protein, and several other biometrics. The data is reported to be within 99% of the accuracy of far more complex machines’ (Forbes, 2014). Furthermore, ‘the Slate collects data input by users and communicates this to a central server, both creating a reliable record of patients’ health and enabling download of recommended therapies’ (Forbes, 2014). In addition, it is relatively low cost. ‘With all of its sensors included, the Slate is being manufactured for \$800, a cost that its creators expect to drop to perhaps \$150 with volume’; however, it is currently only available in India (Forbes, 2014). Results have been positive, for example ‘screening for pre-eclampsia (the cause of 15% of maternal deaths during childbirth in India) quadrupled, and because the condition was detected earlier than using previous methods, deaths were eliminated in the study group’ (Forbes, 2014). The use of the Slate can also improve the efficiency of antenatal care:

In the case of antenatal testing, mothers often had to go from clinic to clinic for tests over a 14 day period. This was impractical and costly. With the Slate, the tests are done in a single location in 45 minutes. For the individuals administering the tests, the time spent recording data and completing forms shrunk from 54% of the day to 8%. Given the shortage of healthcare workers in most emerging markets, this is a major achievement' (Forbes, 2014).

Medic Mobile: Medic Mobile is a software toolkit that combines smart messaging with decision support, data gathering, and management and health system analysis (Medic Mobile, no date). It can be used for disease surveillance, childhood immunisations, drug stock monitoring, and antenatal care. An Oxfam study found that only nine per cent of health facilities 'had a

full complement of essential drugs, including antibiotics and vaccines'. Medic Mobile allows health workers to report stock levels, manage stock, and monitor any dashboards, as well as guiding distribution.

Peek Vision: Peek Vision has created a tool that turns a smartphone into a 'comprehensive eye exam tool' which has been tested in remote locations (Peek, no date). Eighty per cent of blindness is avoidable, but for those in remote locations access to eye care tools will be difficult as they will often be too expensive to hold in primary healthcare facilities—and larger facilities may be too far off (Peek). The Peek tool has been found to 'reliably identify and photograph not just cataracts but severe diabetes and macular degeneration as well. All three are leading causes of blindness' (Guardian, 2014).



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CONCLUDING REMARKS

Concluding remarks and key points:

- *Isolating the impact of electricity may be tricky, but it is clear from the evidence we have examined that electricity is a key enabler of health services and outcomes.*
- *An integrated approach is needed to take into account the local context and to maximise benefits for the wider community. The starting point for this integration is to address interconnected issues such as water and sanitation, and extend electrification to households as well as health facilities.*
- *In addition, the other problems facing rural healthcare need to be dealt with in parallel to energy access to maximise benefits.*
- *Data connectivity and energy access is needed to make full use of the potential of medical technology innovations and telemedicine.*

One of the central issues we have in terms of how the evidence for electricity impacts on health outcomes is the difficulty in isolating the impact of electricity alone (GVEP, 2013). However, what is clear is that electricity is a ‘key enabler for improvements in health services and outcomes and in the case of tertiary care is essential to provide the required care during surgical procedures or in intensive care units’ (GVEP, 2013). The potential benefits of electrification are huge in enhancing quality of care, not only by extending hours of service, but also by facilitating the use of potentially life-saving technologies. However, the problems facing health facilities are multi-fold and not restricted to energy access. When approaching the electrification of health facilities with a view to improving health outcomes and quality of care it is important to not only be aware of these issues but also integrate solutions in these areas into project planning.

Planning for supplying health centres needs to be integrated and take into account the kind of technologies (whether telemedicine or ICT) required in that setting and the demands of each

health centre, as well as the wider local context. Interestingly, Philips has developed Community Life Centres in Africa, which actually bundle technology with solar power to create community hubs. The package includes solar power, LED lighting, healthcare equipment for monitoring, diagnosis and triage, lab equipment (antenatal care tests), refrigeration, IT solutions (data management) and water supply/purification (Philips, no date). Furthermore, community members are involved in the assessment and design, creating ownership and tailoring the hub to the needs of the facility and the community, as well as training staff appropriately. It is this kind of approach, that looks at the whole set-up and the local context and needs, that can help ensure some of the risks of electrification and technology deployment—such as ownership and capacity building—are mitigated. An integrated solution, considering the people involved and their priorities, is key, although to achieve this sustainable financial planning is required.

Rural health facility electrification can act to benefit the wider community by facilitating

wider community access to water/sanitation or electricity itself, and the electrification of the wider community can in turn benefit the health and health education of the community and contribute positively to the work of rural health facilities. Furthermore, in order for telemedicine to work effectively for rural communities, the approach needs to be integrated, with the local context taken into account, and potentially planned alongside electrification efforts. The most appropriate solution for the context needs to be identified rather than trying to make a particular technology fit the problem. To make full use of the huge potential benefits of telemedicine and

health technology, good data connectivity and energy access are needed in rural areas.

Furthermore, we cannot view electrification in isolation, with multiple areas such as water and sanitation contributing to health outcomes as stated in previous sections. Although this report is focused on the electrification of health facilities and telemedicine, if we want to maximise impacts on health outcomes we need to look at the environment and context as a whole. There are multiple interrelated factors such as water and sanitation, agriculture, and cookstoves that need to be addressed in tandem with electrification initiatives.

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Cover:

Mothers wait to vaccinate their babies

Foune Kouyate waits to vaccinate her baby, Kadidia Goulibaly at the Centre De Sante Communautaire De Banconi (ASACOBA) a health clinic in Bamako, Mali on November 4, 2013. Photo © Dominic Chavez/World Bank/CC BY-NC-ND 2.0



SMART VILLAGES

New thinking for off-grid communities worldwide

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