GVEP International

ARIES PO number: 40062121

Low Carbon Studies

Powering the Health Sector -

Final Report

Powering the Health Sector

UKaid from the Department for International Development

March 2013

Contents

1. Introduction

Key to improving the health of the poorest rural communities and to achieving the health related Millennium Development Goals are improvements in the quality of health services provided and increases in the utilization of current services. Challenges to provision of quality services are compounded with difficulties for the recruitment and retention of more qualified staff in rural areas and stock outs of medicine and equipments. Changing this situation and ensuring primary health care services to rural remote communities' requires not only better support and payment of staff but also an improvement in infrastructure. The lack of reliable energy provision to health centres and staff accommodation makes health care more challenging and deployment in rural areas less attractive. Energy provision is one factor to consider if the situation for the poorest and rural inhabitants is to change for the best.

This study has been commissioned by DFID to use evidence relating to renewable energy use in the health sector to answer the following questions:

- What are the net health benefits of renewable energy sources at health facilities?
- What are the cost elements of renewable sources of energy that should be included in cost-benefit analyses of projects that provide renewable energy for health facilities? What are the main criteria that determine which type of source would be best VfM in each context?
- In order to test assumptions about the health benefits of renewable energy sources at health facilities and measure achieved outcomes, what are the logframe indicators that might be included in projects that provide renewable energy for health facilities?

The theory of change that access to electricity at health centres and clinics leads to better health outcomes in the population is based on the fact that the quality of health services provided can be improved with access to electricity.

Basic lighting, cold chain equipment, equipment sterilisation as well as power for medical equipment mean that medicines, vaccines and blood can be stored; and patients can be monitored, treated and operated on more effectively. Improved lighting allows patients to be treated and emergency operations to be held after dark; medications requiring cold chain will be properly stored and their use increased and proper reanimation equipment will save maternal and neonatal lives; well-equipped maternity facilities and upgraded water hygiene improve maternal and infant healthcare; and additional lighting around clinics and hospitals leads to increased public safety and acceptability of services. Greater uptake in health services means an increased number of patients treated leading to improved maternal and newborn health and better patient recovery.

Electricity also allows for improved Information and Communication Technologies (ICTs) including access to databases for information and reporting purposes and internet, which can have a positive impact on healthcare in many ways: through immediate reporting of routine data and epidemiological information, remote consultation, access to up-to-date information and medical training, improved public health information and increased sharing of knowledge and skills. In addition, the provision of electricity for doctors' and nurses' accommodation helps to make their lives easier and retain skilled staff.

There is consensus that electricity can improve health services, and of the impact that a lack of power has on health outcomes. In response to the study questions the assumptions behind the causal link between access to energy and health outcomes were tested. A literature review was carried out searching for evidence of health outcomes from energy provision at health facilities. However there is little if any empirical evidence of changes in health outcomes due to reliable electricity provision alone, although it is clear 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.

A key recommendation from this study is that if DFID wants robust evidence of impact from the provision of reliable energy at health clinics then there is a need for a specific quasi-experimental study to take place in the form of an intervention-control study. Such a study would assess the impact of energy on health and obtain the outcome measurement to complete a cost benefit or a cost effectiveness analysis. Currently this analysis can only assess costs rather than attributable benefits. GVEP and LSTM have provided an approach and methodology for conducting such an intervention study in two comparable areas before and after the provision of reliable energy.

The criteria that determine which type of energy source would be best value for money have been summarised along with design criteria for selecting services that require energy and their potential health service impact. At the same time an assessment of costs related to renewable sources at health facilities has been compiled to provide a benchmark for cost analysis for such projects.

Finally a number of (preliminary) monitoring and evaluation indicators have been proposed relating to potential health outputs that might be included in projects that provide renewable energy for health facilities. Once an intervention study has been completed it would be possible to update the indicators based on evidence of potential health outcomes.

This report includes the following sections:

- Overview of the literature review
- Description of potential benefits
- Design criteria for energy for health projects
- Renewable energy cost elements to be included in a cost-benefit analysis
- Proposed (interim) health service and output indicators, and .
- Recommendations for an approach and methodology for an intervention-control study

2. Literature review

GVEP reviewed secondary data from academic and development reports and project and programme evaluations to try to establish the evidence base on the health impacts of reliable sources of electricity.

The search which has included medical and health databases as well as grey literature, focused initially on the identification of outputs of service provision in health facilities where electricity was provided. The assumption behind this choice was that the provision of power to health care centres should increase uptake for, and availability of services with extension of its hours of operation. The indicators of service uptake (before and after provision of energy) that the team looked for in the literature included among others:

- Utilization rate (all patients)
- Utilization rate (Under five)
- Coverage of antenatal Care 1st and 4th visits
- Percentage of deliveries in the health facility
- Number or proportion of births by C-sections in the health facility
- Availability and number of blood transfusions, or existence of blood bank, in the health facility
- Proportion of children fully immunized or vaccinations conducted in the health facility
- Availability and number of surgical procedures in the health facility

It became apparent early on in the search that there was no reliable information relating energy access in health centres to either measures of services provided, or to improvements in the health status of the community served by the centres, or both. To widen the scope of the search, researchers added additional indicators of service availability and quality, including:

- Description of extra services or service time expansion provided after installation of power in the health facility.
- Recruitment of new staff or reduction of attrition rate of staff as a result of infrastructure (energy) improvement.

The study does not include other non-electricity energy requirements at health facilities such as energy for heating, hot water and cooking nor the potential for reduction in demands from energy efficient demand. In addition since the study focused on the *health* impacts of providing electricity, the technical aspects, the operation and maintenance of any system and the cost benefits due to technology choice were not reviewed in the literature review.

A full copy of the literature review is included in Annex A.

Conclusions of the literature review

Results of the literature search showed that beyond anecdotal evidence, there are few available studies that provide some evidence of links between electricity access at health facilities and changes in health outputs or outcomes. Considering the number of projects providing energy to health facilities which have been funded by Government Health ministries, international and bilateral agencies and NGOs it is surprising that many of these projects report positive health outcomes, but the evidence behind this statement is not provided.

There is a general consensus that electricity can improve health services provision and it is assumed that a lack of power is likely to have an impact on health service provision. Anecdotal evidence suggests that, where there is a lack, or inadequate supply of electricity, then workaround solutions are found by the health care workers. This leads to complications in attributing health outcomes to the provision of a more stable source of energy alone. While a lack of energy may hinder health services or reduce health staff satisfaction, provision of health services, or the quality of services is dependent on many other critical factors, such as availability of trained staff, medicine and equipment. In addition the reasons for using or not using a health facility are linked to the presence of staff, medicines and supplies as well as being culturally mediated and not necessarily linked to energy availability in a clinic.

Studies on the effects of electrification of health clinics (all other factors being equal) are needed if clear evidence is needed of the links between electricity access and changes in health outputs or outcomes. However it is clear from reviewing the literature 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.

3. Quantifying and Valuation of Benefits

The following table outlines the potential impacts on health service provision from a variety of energy applications which were found during the research as well as identifying some of the frequently quoted health outcomes and outlining the non-quantifiable benefits. The final column shows what evidence was found in the literature review relating to these impacts or outcomes.

Table 1*: The Potential Health Service Benefits and Impacts, Health Outputs and Health Outcomes of Energy Services.*
Adapted from IT Power 2007i, USAID Powering Health, and WHO's Service Readiness Indicators.

	Energy Services/ Appliances	Potential Health Service Impact / Benefit from Energy Provision	Potential health outputs of service provision	Potential Health Outcomes	Evidence found in literature review relating to energy provision/health services and outcomes[1]
Medical services	• Internal and external lighting • Mobile phone charging • Air circulation • Air conditioning • Space heating • Ultrasound • Incubator • Suction apparatus • Anesthesia machine • Oxygen concentrator • Blood refrigeration	• Prolonged opening hours with general lighting and security lights provided; • Wider range of services will be implemented, because more qualified staff are motivated and attracted to stay; • Improved emergency surgical services including blood transfusions; • Better obstetric emergency care; • Improved management of childhood illnesses; • Better management of chronic conditions;	• Increased utilization rate (all patients) • Increased utilization rate (Under five) • Increased ANC 1st and 4th visits • Increased no. of deliveries in the health facility • Increased no. of C-sections in the health facility • Increased no. of blood transfusions in the health facility	• Reduced mortality and morbidity • Reduced maternal mortality • Reduced child mortality • Fewer complications • Reduced DALY	• 1-4 hours extended opening hours • Mixed evidence of increase in service use – none to an increase • 61% reduction of likelihood of dying in centres with electricity[2] • 25% of emergency patients saved with PV and tele[3] • Papers/Case studies show

[1] References included in the Literature review in Annex A
[2] Note study was observational and may have included tertiary centres/confounders
[3] ibid

	Energy Services/ Appliances	Potential Health Service Impact / Benefit from Energy Provision	Potential health outputs of service provision	Potential Health Outcomes	Evidence found in literature review relating to energy provision/health services and outcomes[1]
		• Improved referral system (communication system between peripheral and referral units); • Improving planning and quality assurance • Increased medication services	• Increased number of surgical procedures in the health facility		increasing assisted delivery • Anecdotal/case studies stating reduced maternal mortality and reduced mortality from surgical and emergency services (various)
	• Autoclave • Sterlization oven • Boiler or steamer	• Better sterilisation procedures; • Better waste management		• Reduced infection	• Better sterilization
Disease preventi on,labor atory,dia gnostics and treatmen t	• Vaccine refrigerator • Centrifuge • Haematology mixer • Microscope • ECG machine • Blood chemical analyser • Water bath • Haematology analyzer • CD4 machine • X-ray • HIV/TB testing equipment	• Improved cold chain will make vaccination easier and diminish waste of vaccines due to cold chain failures. • Facilitate diagnosis for infectious diseases including HIV and TB. • Evening awareness sessions with general lighting and a TV/VCR. • Improved diagnosis of certain diseases (lab techniques).	• Increased number of children immunized in the health facility	• Reduced mortality and morbidity • Reduced child morbidity and mortality (polio, measles, meningitis, HiB) • Reduced neonatal mortality due to Tetanus vaccination	Better cold chain but no evidence of clear impact on immunization levels Case study of reported neonatal mortality due to lack of tetanus toxoid availability due to unavailability of cold chain

	Energy Services/ Appliances	Potential Health Service Impact / Benefit from Energy Provision	Potential health outputs of service provision	Potential Health Outcomes	Evidence found in literature review relating to energy provision/health services and outcomes[1]
	• Nebulizer				
Health and Safety	• Water pumping • Water purification • External lighting	• General cleanliness improves with general lighting and water available; • In-patients would feel more comfortable and secure; • Staff feel more secure; • Security lights provided during evening open hours.		• Reduced infection • Reduced maternal mortality due to increased attended births at health centres	Patients feel more secure. Staff feel safer.
Staff recruitment and retention	• Lighting (internal and external) • Communication (internet/mobile) • Computing • Radio/TV/VCR/Projectors • Fans/air conditioning • Appliances	• Better job satisfaction and motivation for staff because of better living and working conditions; • Continuity of care provided due to impoved staff retention as a result of better living and working conditions; • Electricity in staff houses means continued medical education is possible; • Easier recruitment and retention of staff to locations with electricity and water; • Easier to train staff because of improved lighting, equipment and TV/VCR.	• Wider range of services will be implemented	• Reduced mortality and morbidity	Better job satisfaction and retention (anecdotal)
Administ	• Computing and	• Better administration and record	• Better health records	• Reduced disease	Reduction in costs

	Energy Services/ Appliances	Potential Health Service Impact / Benefit from Energy Provision	Potential health outputs of service provision	Potential Health Outcomes	Evidence found in literature review relating to energy provision/health services and outcomes[1]
ration and logistics	internet • Printing • VHF radio • Lighting	keeping; • Better communication between health facilities and better planning of transport logistics	and epidemiological surveys	from early awareness of outbreaks	and time Detection and reporting of outbreaks of communicable diseases

Since the literature review did not provide clear empirical evidence of health impacts or outcomes as a result of electricity provision it has not been possible to quantify the benefits. As mentioned in the literature review, to be able to quantify the impact of the electricity, in terms of health benefit, it is necessary to assess changes in mortality and morbidity. These are measured by changes in health seeking behaviour and in coverage of key service indicators (outcomes) whose positive change points to a reduction of suffering and deaths. The recommended study is a case control study using an intervention and counterfactual study group of children under one year of age, potential users of health services in areas similar in health services endorsement other than provision of energy. This recommendation is included in more detail in Section 7 of this report and in Annex B.

In the absence of this data the team has reviewed the possibility of using proxies for valuing the benefits. For example it would be possible to use the energy provision related to availability of surgery over 24h (which would include c-sections) as a proxy to calculate cost per life saved because a C-section is a clear life saving procedure. In contrast energy for lighting only, or laboratory testing is likely to help but is not necessarily life saving. Other services provision, such as blood transfusions made available as a result of energy for refrigeration, are also life saving, but the effect is difficult to quantify since it depends on the probability of dying, which is not only related to the availability of blood, but also to the level of Haemoglobin and how fast blood loss happened. For immunization it is necessary to reach a level at which transmission is not possible, for example at least 65% immunization levels for Measles but this means 80% of children vaccinated. Again this is difficult to assess particularly when the literature review showed that with workaround solutions (for example vaccination days) the level of immunization was not significantly different with and without reliable cold chain equipment.

Cost effectiveness of the energy provision can be measured by analyzing all possible costs and benefits. Without an outcome of interest cost effectiveness or cost benefit can be measured by considering the marginal costs and marginal benefits over the baseline and as the difference between the intervention and the control groups, all other things being equal. The calculation of the marginal cost in this way is straight forward. The calculation of the marginal benefit will again require the definition of the benefit for each unit change in the particular context where the intervention takes place as follows:

- Cost per additional patient seen (Utilization rate (all patients, under 5s) or marginal cost for seeing an extra patient. This indicator is useful to measure productivity and to corroborate survey data as well as progress towards targets rather than for cost benefit analysis.
- Cost per monitored pregnancy (Antenatal Care 1st and 4th visits) – marginal cost for an extra pregnancy monitored – benefit is limited to attention in the Ante natal care clinic..However benefits increase if the clinic provides state of art prevention of tetanus, malaria and testing and treatment of Syphilis and HIV .An additional benefit is the possible detection of pregnancy complications or the strengthening of the relation between midwife and pregnant women.
- Cost per additional delivery in the health facility – Marginal cost for extra skilled birth attended can be transformed into marginal cost per extra life saved using the Life Saved Tool or LiST.
- Marginal cost per additional child immunized in the health facility – Every fully immunized child has a relative risk of mortality reduction of 20%; absolute reduction of mortality in less developed country with a mortality of 10% is 2 lives for every 100 children immunized.

Energy provision can also result in cost savings due to the maintenance of a reliable cold chain and the decrease in wastage of medication requiring constant low temperatures and vaccines. Having medication and vaccines at hand means they can be used in emergencies or at hours which are more convenient to the community rather than fixed immunization days, though this will depend on the availability of staff and the organization of the district. .

Finally where the use of renewable energy is used to eliminate (or to reduce) the use of diesel generating sets and kerosene lighting then the benefits can include:

- operating cost reductions (thereby freeing up resources to spend on the direct supply of healthcare),

- reduced risk of service discontinuity, whether through mechanical failure of the equipment or irregular supply of diesel,
- reduced local emissions from kerosene and diesel (particulates and GHG), and
- greater planning certainty on costs due to less exposure to volatile diesel prices.

Example: Hypothetical health benefits of providing 24 h emergency care

Assumptions: C-sections are made possible by the provision of energy (light in the theatre; staff trained and confident) A minimum of 5% of pregnancies require a C-section (WHO). Meaning that for every 100 pregnancies; ten to fifteen will have complicated deliveries and 5 will require life saving C-section.

Benefits: The provision of energy and retention of staff to allow a 24 hour surgical department available for C-sections, and will save 5 lives of women and likely 5 lives of babies per year due to obstructed labour for every 100 pregnancies in the area. For a catchment area population of 10,000 this investment can save a minimum of 20 lives per year.

As an example if the net present value for providing energy for 24 hour emergency care is $ 130,000 for the 20 year lifetime. Although the marginal cost of provision of energy is a hefty $130,000; the cost per life saved (not considering costs associated with training and staff dedicated to this function) is $325 as a result of the the accrued benefits . In addition the provision of life saving interventions closer to home has added benefits to the community in terms of transportation and associated costs of travelling and living far from home until recovery. . Using local health facilities facilitates return to homes and care of family as well as productive activities. However as the initial investment is considerable, this initiative should be considered in light of population numbers and distance to other secondary health facilities to obtain the maximum returns from the investment. These criteria have been taken into account to recommend energy packages adapted to the services provision which are the object of the next section of this document.

4. Development of design criteria

A set of criteria has been developed to assist project designers in determining the energy source that provides the best value for money for health facilities. Since there are different types of health facilities, different health targets, different available renewable energy sources and energy sectors in any country or region most clinics will need to be looked at on an individual basis unless their characteristics are very similar. An expert should be involved in the final design, installation, training and maintenance.

Review of existing tools and data

As an initial step GVEP has reviewed the existing data and tools included in the USAID's Powering Heath Programme, as well as in projects funded by the World Bank and European Commission to determine what additional information is required to help project designers.

General web-based tools for sizing and configuring renewable energy systems and comparing life-cycle costs, grid extensions, diesel generator sets, diesel hybrids, and other options are publicly available free of charge. These include RETScreen (www.retscreen.net) and HOMER (www.homerenergy.com). These tools include links to solar resource data as well as cost data. They can be useful as a cross-check of both technical design and costs.

There are several tools and guidelines for electrification options specifically targeted at rural health centres. These include cost data, although none of them include the health impacts of energy access. Guidelines on technology selection and at what cost have been developed by IT Power under the ENABLE Project funded by the European Commission, the World Bank "Photovoltaics for Community Service Facilities" and made available by USAID through the National Renewable Energy Lab (NREL).

Rapid Electrification Screening Tool (REST) – ENABLE, EU

The Rapid Electrification Screening Tool (REST) was developed under the EU funded ENABLE Project with a focus on Uganda, Tanzania and Kenya. It aims to help the rural electrification agencies or local government to make decisions on electrification options for educational facilities, health centres and water supply.

A Microsoft Excel sheet helps in calculating the costs of the different options, including solar PV, wind and diesel, but no hybrid options. While the use of pre defined criteria on consumption patterns and basic country data on costs makes the tool easy to use, it is too general to calculate the costs of installation for a particular health clinic. A more detailed energy audit and forecast would be necessary before a procurement process, for example for a solar PV installation, could be started.

Includes:

- Parameters defined for Kenya/Uganda/TZ
- Detailed grid access costs per km, with or without transformer
- Setting for PV and wind costs can be adjusted in detail including import costs
- O&M assumptions that can be modified
- Predefined energy usage packages for dispensaries and medium and large health facilities. Some adjustments possible

Does not include:

- Detailed demand calculation
- Choice of individual appliances
- Adjustable consumption or hours of use
- Diesel/PV Hybrid costs
- Medical equipment costs
- Benefits/impacts

Outputs:

- Total capital and lifetime costs, also graphic
- Costs per kWh, also graphic

USAID Powering Health tool

The USAID Powering Health website includes an easy to use version of the HOMER model. The Hybrid Optimisation Model for Electric Renewables (HOMER) was originally developed by the National Renewable Energy Lab (NREL) and is now commercialised by Homer Energy LLC. The software includes an assessment of solar PV against grid and diesel generation, or a combination of them. It automatically retrieves NASA information on solar radiation, if the location is given as an input.

The tool also calculates the energy needs. It includes good tools and estimates for devices plus guidelines for office and lighting use. While the consumption patterns of devices and their hours of operation can be easily adjusted, the prices for the installation and operation and maintenance are fixed.

Includes:

- Global scale
- Adjustable grid electricity price
- Adjustable cost for PV or diesel generation
- Adjustable interest rate
- Medical and office equipment can be adjusted by consumption and hours of use
- Solar radiation and efficiency of the panel

Does not include:

- Grid connection costs
- PV costs fixed, no choice on number of back-up days required
- Other energy technologies (eg. wind)
- Insight into the calculation; only results are shown
- O&M costs not adjustable
- Medical equipment costs
- Benefits/impacts

Outputs:

- Total capital cost and net present costs
- Costs per KWh
- Load profile

The selection of technology for the USAID model seems sensible (PV and diesel) since if based on good radiation data, a solar PV installation can be modeled reasonably accurately, however wind data is very local and would need to be measured locally in any case before proceeding with the installation. Feasibility and costs will vary drastically due to local conditions Therefore the value added of that option might be questionable.

Unfortunately, the operation and maintenance costs are integral in the HOMER model and cannot be changed in the simple version made accessible on the website. On the other hand, the model allows for adjustments to the electric load inputs in detail. The REST model allows only minor changes to the given load consumption patterns of the health facilities and the variation of consumption during the day cannot be modeled.

Both models however make suggestions on the preferable technology choice, the required size, and give the net present value for these options. The decision which technology to chose is highly influenced by the discount factor or interest rate applied to the investment.

Whereas a potential health impact could be allocated to the energy services, it will still not be possible to quantify them. This would need to be done in a separate impact study after the installation has occurred.

Furthermore, the economic model could be refined by including the costs of the health care equipment, rather than the mere provision of electricity, which in itself might have only indirect health benefits through lighting for example. Once equipment costs are specified they would be easy to incorporate into a refined HOMER model, as this already lists a range of appliances and their consumption. Such a model would be able to estimate the costs for an electrification of a health centre including the additional equipment purchased to make use of the available power but would still not quantify health benefits to the patients.

Another improvement to the current models could be an enhanced compatibility with the SARA questionnaire by WHO[ii]. Although answers can be translated into the necessary inputs of the model, they might be tuned to correspond with standard service packages.

Design Criteria

The design criteria have been based primarily on the USAID's excellent Powering Health tool which includes useful questions to enable decisions to be made on types of energy sources for health facilities. GVEP and LSTM have reviewed these against their experience and provide an edited version of the criteria below. One of the conclusions from reviewing the criteria and options for energy for health is that energy should not be seen in isolation but should be provided as part of a wider programme aiming at particular health targets or to increase the quality of care. The key difference to the existing tools is that the potential energy demand will be based on the appliances/technologies required to meet a particular health target or outcome, rather than only being based solely on the size/type of the facility. The questions, and related criteria, include the following[iii]:

- Classification of health facility
- **Determine appliances/technologies required for health targets/outcomes***
- Establish target energy demand (eg. kWh/day), and diurnal or seasonal variations.
- Identification of any near-future changes/health policies and associated energy demands
- Selecting appropriate energy source and technology
- Procurement and project management
- Long-term operation and maintenance

** - The additional step relating to health targets/outcomes*

For each of the criteria/questions there is some more detail in the following sections.

Classification of health facility

Health facility energy demand varies between a couple of kWh per day to over a MWh per day --- depending on the number of staff and beds, the amount of equipment, whether or not they are connected to the grid, etc. The classification of the health facility or facilities takes into account the size of the facility as well as the type of health services it is able to offer. It is useful for the project designer to classify the facility since not all health services and the related equipment are available at all facilities. For example a small health post may not be in a position to provide emergency surgery if the trained staff are not available. The following table shows some common classifications although each country may have its own classification system.

Table 2: Health facility classification

	WHO	USAID Powering Health	EC ENABLE project
	Health post	Health post	Health Centres
		Treatment of minor illnesses, tending of minor injuries and, where possible, the provision of basic immunization services	<20 beds, lighting, cold chain, basic lab
	Health centre	Category I Health Clinic (plus blood banks, stand-alone labs and pharmacies)	Sub district/ Cottage hospitals
		0-60 beds, Full time staff. Lighting, limited surgical procedures, cold chain, basic lab (centrifuge, heamatology mixer, microscope, incubator and hand powered aspirator), communication	<100 beds, cold chain, lab equipment, sterilization, X-ray
	District hospitals	Category II Health Clinic (plus blood banks, stand-alone labs and pharmacies)	District hospitals
		60-120 beds, As above but more frequent use. More sophisticated diagnostic equipment and more complex surgery	<250 beds, as above but more frequent
	Regional/Provincial hospitals	Category III Health Clinic (Plus ARV clinics)	Provincial/ General Hospitals
		>120 beds, As above plus x-ray, CD4 counters, blood typing equipment, office equipment and internet	>250 beds

Determine appliances/technologies required for health targets/outcomes

A project designer must be clear on the objectives for providing energy at a health facility. Energy projects can be designed to supply the minimum of lighting and refrigeration at a facility, or it can aim to provide sufficient power for all the existing or planned equipment in the facility. Each of these options is likely to improve the general health service provision. Alternatively the objective for providing energy can be associated with specific improvements in health services, or with a targeted health programme such as the USAID PEPFAR programme which is related to preventing "transmission of AIDS as well as providing treatment and care for those affected with the disease".

Once the objective for energy provision is clear then the type of electrification depends on the daily demands to meet the objective. A proper energy demand assessment is needed. One of the first steps is to select the services that are needed and the equipment needed to provide those services or to carry out an inventory of the equipment used in the facility and the power needed to operate it. Understanding the daily energy needs will not only help in the selection of technology but also help in estimating a realistic budget for the purchase and maintenance of the new system. It is important to bear in mind that energy related equipment, such as lights or refrigerators, can differ widely in their energy efficiency and choosing the right equipment can reduce demand significantly and result in a smaller system.

The USAID Health Clinic Power System Design Tool (Electric Load Inputs) and/or the Energy Audit Spreadsheet(Future Electric Applications) can help in identifying the overall energy demands of health facilities. The amount of expected energy consumption in kWh/day will assist in the selection of appropriate electrification technology.

These tools allow users to pick and choose the equipment to power. There is also space available to add further equipment if it is not included in the list. The USAID tool also includes a typical energy package for three categories of health facility. This is useful as a first approximation for providing basic care and is based on a logical extension of services related to the health care facilities. However the energy packages are not tied to health outputs which may be used to adapt the packages to the actual needs rather than to assumed consumption. This assignment has looked at options to provide power to achieve specific health outputs by the provision of energy for a 'package' of services. The idea behind the 'packages' is that it aims to concentrate scarce resources on energy to provide the best 'value for money' rather than flat provision of energy which may or may not be adequate to the needs of the health facility or the population served. The Excel workpage provides illustrative examples of energy supply options and these 'packages' can also be used within the USAID tool to identify and size a suitable energy system for health facility categories and population needs.

Specific services have been identified in the Service Readiness Indicators from the Service Availability and Readiness Assessment (SARA) methodology, which WHO has produced as a health facility assessment methodology for monitoring health systems and their capacity to provide health services. The framework includes indicators for "General Service readiness" and "Service specific readiness" with an overall readiness based on training staff and guidelines, availability of equipment, medicines and commodities, diagnostics and infection control.. A table is included in Annex C which identifies where energy is required for these services. Areas included are family planning, antenatal care, obstetric care, neonatal care and child health (curative, immunization), HIV, PMTCT, TB, malaria and chronic diseases. In designing the packages these were taken into account.

The proposed 'packages' are outlined in Table 3 below and are included in a separate excel sheet. Alternative 'energy packages' could be designed based on a country's Essential Health Packages[4]. The energy provided to the health facilities is expected to combine the provision of lighting, which will mainly extend hours of service and make surgical procedures easier, and the provision of power to allow for the use of energy dependent equipment. Energy dependent equipment includes basic refrigerators to maintain the cold chain, but also more sophisticated equipment such as ultrasounds, incubators, monitors, oxygen concentrators and ventilators.

In constructing the packages the principle assumptions with regards to energy provision were as follows:

1. Because the intervention is to benefit rural health care facilities providing primary or essential health care, most benefits will come as a result of lighting with increased hours of operation and facilitation of care provided including surgical procedures after darkness.
2. These expanded hours of service provision may result in increased acceptance by the community and by prospective staff and increase service utilization particularly by the main users of services (mothers and children).
3. Increased service utilization (preventive and curative) will save lives and increase health status of the population.
4. Energy dependent equipment such as cold chain will facilitate the use medication which needs to be maintained at low temperatures (for instance Oxytocin) and facilitate vaccination.
5. Higher levels of energy provision will allow for use of monitors, ultrasounds, incubators and ventilators whose effect will be at primary level the identification and referral (or treatment) of pregnancy related complications; the diagnosis of foetal distress during labour and delivery (and treatment or referral); the treatment of hypothermia of the newborn and better reanimation procedures; the facilitation of blood transfusions (for ABO and Rhesus tests) and the treatment of kernicterus.

[4] An Essential Health Package (EHP) in a low-income country consists of a limited list of public health and clinical interventions which will be provided at primary and/or secondary level care. EHPs are intended to be a guaranteed minimum. (WHO 2008) They differ from country to country.

6. The use of lighting and ventilators in the operating theatre, will allow for more complex surgery to take place in the clinics. This may only be possible in larger/secondary facilities with the required mix of medical specialists. .

Table 3: Outline of Health Service Packages and Heath Service Impacts

	Health Services / Package	Potential health service impact *(blue text denotes a measureable indicator)*
A	**Extend primary care by 4-6 hours**	Increased opening hours
	Internal and external lighting Cell phone charging/VHF radio	Increased utilisation
		Emergency services –prompt diagnosis and treatment of common diseases and attention to labour and delivery
B	**Extend primary services to include lab and cold chain**	As A + wider range of services offered
	A + Basic lab and diagnostics Vaccine refrigeration Lighting/ICT for staff accommodation Energy for mobile phones	Increased utilisation
		Better staff retention
		Lower cold chain failure rates
		Vaccination can be provided daily to facilitate completion of immunization schedule
		Improved lab operations and tests for infectious diseases.
		Better management of chronic conditions/contact with health workers from districts and vice-versa.
C	**Extend services to include daytime emergency services including maternity, sterilization, surgical dept, lab**	As B + Wider range of services offered
	B + Obstetric and new-born care services Hygiene and sanitation Emergency and lifesaving equipment Surgical services Extended office services	Improved testing for HIV and TB
		Better staff retention
		Increased medication availability
		Improved emergency surgical services
		Increased number of surgical procedures at facility
		Reduced infection due to better sterilization and waste management
		Improvements in general cleanliness
		Better obstetric care
		Increased skilled birth attendance Deliveries in health facility and detection of complications for treatment or referral C-sections at health facility for obstructed labour Improved reanimation of newborn babies
		Better emergency care for children
		Better trained staff Easier reporting of outbreaks and of routine reporting if internet is provided. Easier contacts with the district office and vice-versa for reports, support and advice. Better coordination of health and district officers and easier management and supervision.

D	**Extend primary and emergency services by 24 hours**	As C above plus:
	C + 24 hour availability	Greater availability for each service
E	**Primary services and comprehensive obstetric care, surgery and blood transfusions**	As D above plus:
	D+ Extended lab and diagnostics Oxygen concentrators Blood storage	Blood transfusions possible at facility Incubators available for premature or low weight newborns. Oxygen concentrator available to treat respiratory insufficiency.

A schematic has been designed to help the project designer in selecting equipment or services (or package) that will enable specific health service outputs, shown in

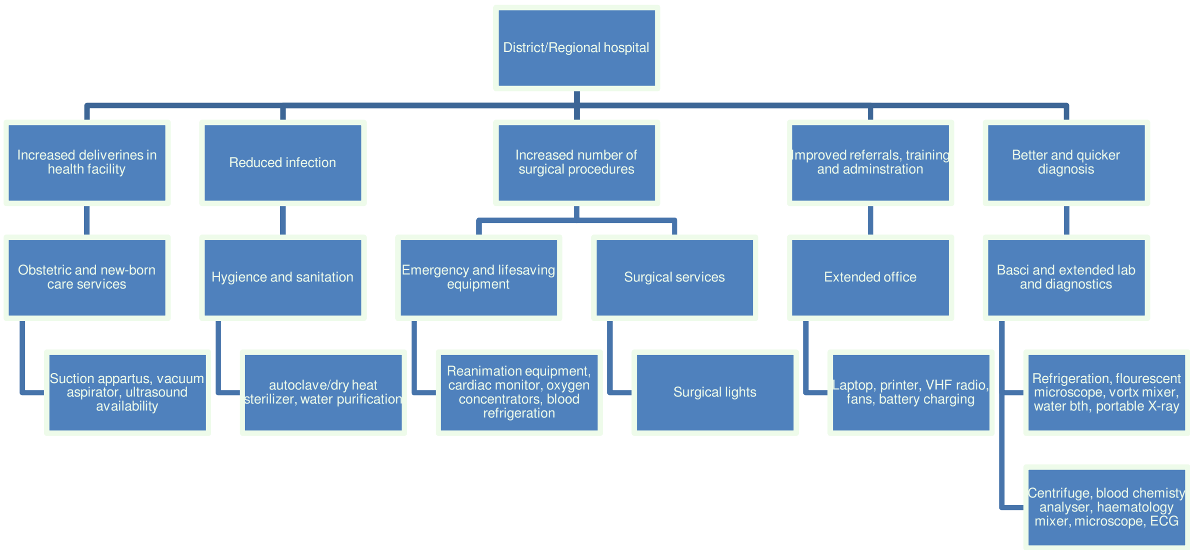
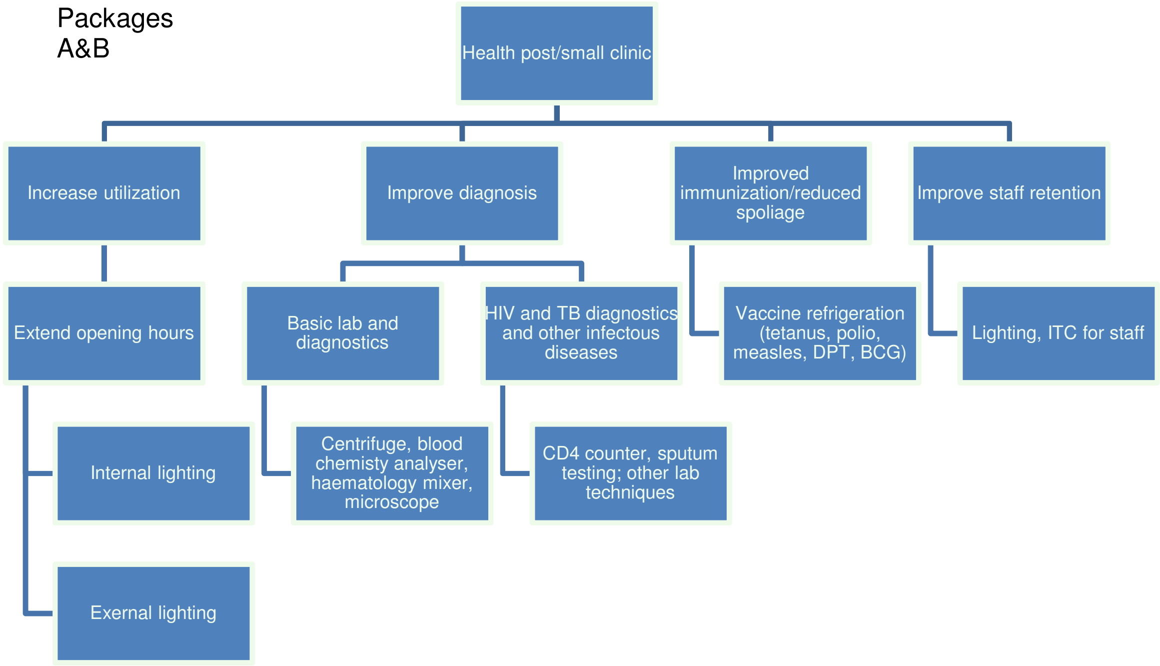
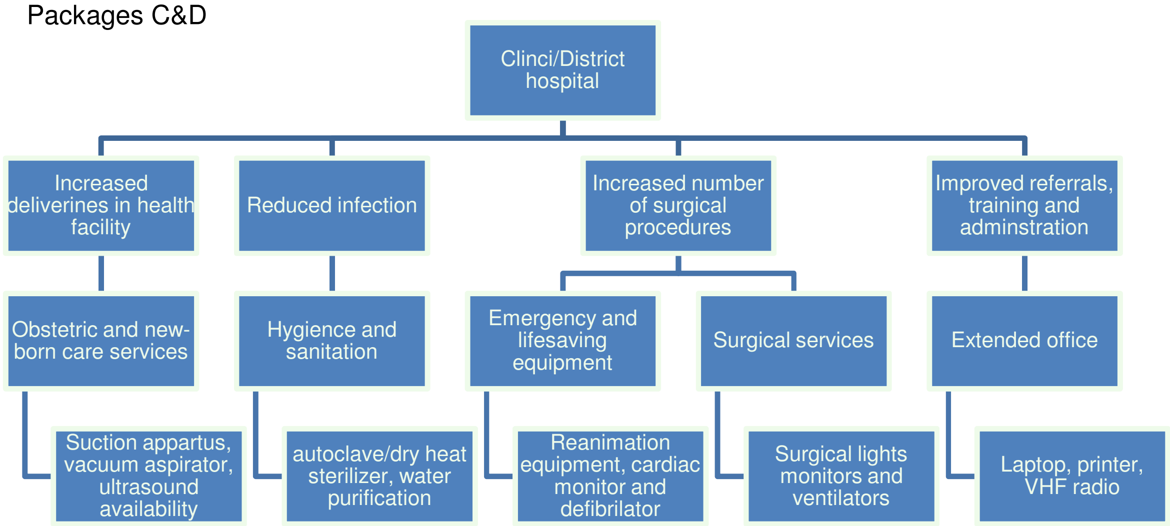


Figure 1 below. The project designer will also need access to the USAID on-line Powering Health tool and the attached Excel file.

Packages
A&B



In addition to A&B -
Packages C&D



In addition to A&B –
Package E

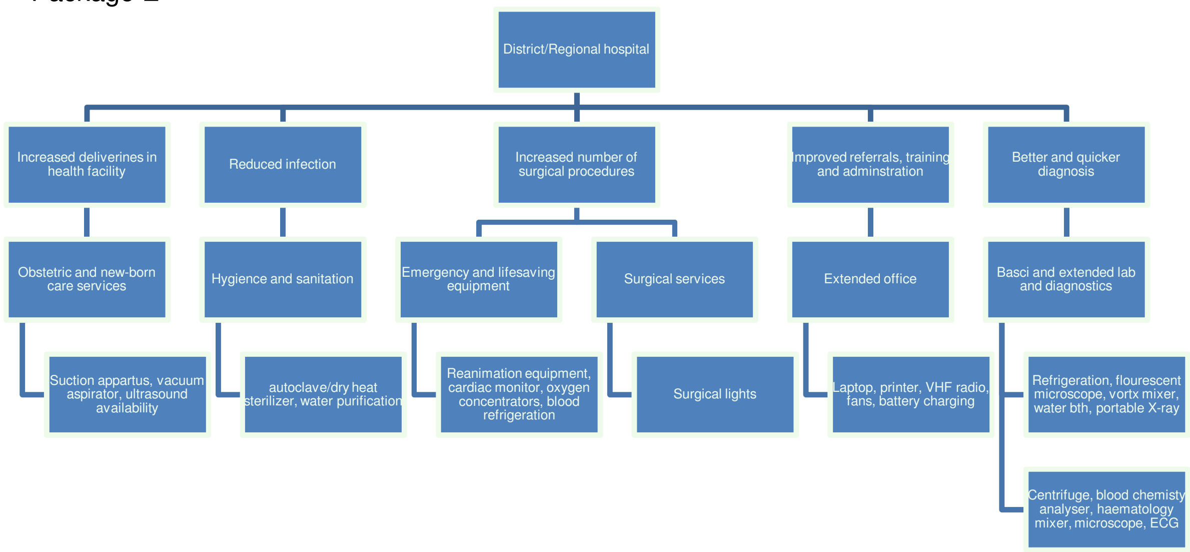


Figure 1: Schematic for selecting enabling energy services

The user, based on the category of the health facility, will review the possible health benefits available in each of the health packages (A-E) and select the target package for them. Based on the selected package the Excel tool will provide an estimate of the appliances and services that will need powering and the daily energy requirement (in Wh). As well as providing illustrative examples of net present costs the Excel sheet also provides the following information which can then be used directly in the USAID Powering Health tool (for a daily load up to 30kWh) to estimate the life cycle costs for PV/diesel generation/hybrids for this option.

- Appliance type
- Number of each appliance/technology
- Power of each appliance
- Expected hours of usage of each appliance

Linked to this approach are also the examples where energy is provided as part of a wider health programme targeting specific health services. In these cases a specific package of energy needs should be designed. For example in the USAID funded PEPFAR program the equipment *most relevant* to the program includes laboratory equipment for testing blood for the presence and levels of the HIV virus. It also requires refrigeration for certain cold chain dependent ARV drugs and HIV rapid test kits. Audio-visual equipment for outreach and counseling is also critical to the program, as well as lighting and ICT equipment for health care staff[iv]. The USAID tool also provides specific energy packages for different laboratory needs.

Once the project designer has an estimate of the energy needs to meet the required health outputs it is important to bear in mind any possible future changes which may impact on the energy requirements. For example future staff additions or extra beds, or an increase in opening hours and available services will increase the utilization of the facility and may increase the associated energy demand.

In addition it is important to remember, that if funds are limited and so energy supply is limited and targeted at a specific health target or programme, it is difficult to ensure the use of the energy for the specified equipment. Of course some of the equipment will be used for a wider range of services than the programme but at the same time the energy may be used for other 'non-programme' equipment resulting in less energy available for the programme/target equipment.

5. Cost elements for health facility energy systems

GVEP has collated information on costs for renewable and diesel energy systems that can be used as benchmarks for projects looking to provide renewable energy in health facilities. These costs include a breakdown of components for the project plus include for the on-going costs associated with operation and maintenance.

GVEP has focused on solar PV systems as well as diesel generators as alternatives to provide that energy. Wind resources are very local and usually very intermittent. Additionally, local wind data is not available for most of Africa so its applicability will need to be determined locally. Diesel is available in most places (and in many places subsidized) whilst the availability of biogas, gasoline or petrol generators is very limited.

We will first describe the different components and then analyse the costs for different components and countries.

Selecting appropriate energy source and technology

A number of technologies are possible to provide energy at a health clinic and the selection of one or more depends on the energy needs of the facility plus on a number of factors including the following[5]:

- Reliability of local grid, including an assessment of prospects for improvement in reliability and/or reach in the project area
- Local renewable energy resources (wind, solar, biomass)
- Local cost and availability of conventional energy resources (diesel, propane, gasoline)
- Local availability of systems, parts, service companies, and technicians
- System reliability requirements
- Clear value for money
- Government policies and incentives
- Technical capacity and funds for system maintenance and replacement
- Special considerations or desired operational characteristics – i.e., noise, emissions, etc.

To ensure value for money it is important that the proposed system is the least cost option over its lifetime – or has the lowest life cycle cost. The cost of the system must take into account not only the capital cost of the equipment and its installation but also the costs of its operation and maintenance over its lifetime.

The capital costs relate to the initial purchase and installation of the equipment. Indicative costs for the various components of an energy supply system are provided in the attached Excel file, as Annex C. These can be used when estimating costs and be input into the USAID tool to calculate the lifetime costs. Any system will include the generators (PV panels, wind turbines or diesel generators) plus inverters, charge controllers, batteries, wiring and controls. Higher quality components generally last longer with better reliability so despite being more expensive offer better value for money. Additional expenses relating to import taxes and permits must also be taken into account

The operating costs include the cost of fuel, cost of replacement parts and repairs, cost of maintenance and security. If maintenance is to be carried out by staff specifically trained for the task their additional time must also be factored in. Operating costs can vary significantly from place to place due to differences in labour costs, fuel costs and subsidies, remoteness of clinic, and depending on the use of the system (eg. hours of use, type of equipment etc).

Choosing the least cost technology depends on a number of factors including the availability of the local grid, the local renewable energy resource, diesel prices, access and logistics and availability of funding. The reliability of the local grid or plans for its extension is a major consideration. Rural electrification plans and decisions are often under political pressure and subject to change. If the grid is due to arrive in the next few years the economics of an off-grid system look less favourable. The available renewable energy resources greatly influence both the configuration and the cost of a

[5] *Adapted from the USAID Powering Health*

system. A wind resource will favour the use of wind turbines, whilst high solar radiation will favour the use of PV. Not only is the resource important but so too is its variability both daily and seasonally since this has an impact on the overall design, the use of batteries and also of back-up generators.

In general renewable energy options have lower lifetime costs although they have higher capital costs than diesel (or other fuel) generating sets. The highest operation cost for diesel gen-sets is the fuel whilst the operating costs for renewable systems are lower and include battery maintenance, cleaning and theft prevention. The highest costs for renewable systems are for the periodic component replacements, in particular for the battery. Battery replacements require relatively large payments every three to five years (depending on usage and management) and can be difficult to manage when the ordinary month on month costs are small or negligible. Hybrid systems (renewable energy plus diesel back-up) offer greater flexibility to power equipment with high demand (e.g. X-ray machines) that cannot be operated from a solar PV system and can be the least cost option for a reliable supply, particularly for larger health facilities.

The key aim for any system should be sustainability, which at the minimum is the reliable, cost-effective operation of a system over its design lifetime. To realistically meet the promise of the lowest life cycle cost means that not only must the proposed system be reliable, but also it is paramount that it operates for its whole design lifetime. An unreliable or inadequate supply has the potential to damage equipment, stop operations and to spoil storage. Systems can generally achieve greater reliability by adding backup components, although this generally increases cost and complexity.

The following table, edited from USAID, gives an overview of the advantages and disadvantages to the different technology options.

Table 4: Energy Technology Characteristics[v]

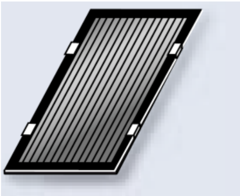
Energy Technologies	Capital Cost	O&M Cost	Reliability	Lifetime	Special Considerations	Emissions	Optimal Use
Solar PV System with Batteries	Very high	Low	High (if maintained properly) or low (if not)	20-30 years (PV), 4 years (batteries)	Theft (batteries or panels); Vandalism (panels); Low availability of trained technicians	None	Remote locations where fuel is costly or difficult to obtain
Wind Turbine with Batteries	High	Low-moderate	High (if maintained properly) or low (if not)	20 years (turbine), 10 years (blades), 4 years (batteries)	Theft (batteries); large battery back up necessary; likely to require diesel back-up; Lack of data on wind resources	None	Many moderate loads where resource is sufficient
Diesel Generator	Low	High	High	25,000 operating hours	High demand applications; Fuel spills; emissions	Very High	Larger loads; Emergency Generator; Component in hybrid system or stand-alone
Gasoline Generator	Moderate	High	Moderate	1,000 - 2,000 operating hours	High demand applications; Limited availability of equipment, fuel spills; emissions; flammability	High	Larger loads; Emergency Generator; Component in hybrid system or stand-alone
Gas Generator	Moderate-High	High	Moderate	3,000 operating hours	High demand applications; Propane is of limited availability, but can use biogas	Low	Larger loads; Emergency Generator; Component in hybrid system or stand-alone
Hybrid System	Very high	Moderate	Very High	Varies; optimization greatly extends battery life	High demand applications; Complexity for servicing;	Low	Medium and large loads
Grid extension	Varies	Limited	Varies	High	extending grid allows connection of nearby homes to grid	Not local	Where grid is reliable and not too distant

Other considerations which may also need to be taken into account include any hazards associated with the equipment; environmental factors from fossil fuelled generation including the particulates and greenhouse gas emissions; and the possibility of designing a larger system to deliver other benefits to the community by considering the clinic as part of a wider community electrification initiative.

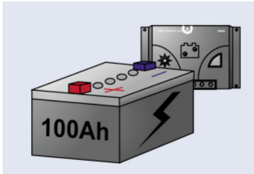
Components of solar systems

Most solar systems consist of four elements, although these elements may also sometimes be integrated. The critical elements are the solar photovoltaic panel, the batteries to store the power and make it available at night, 'balance of system' elements that include the charge controller that prevents the battery from under or overcharging and where AC appliances are used, an inverter is necessary.

Figure 2: Components of solar systems



A solar panel



A battery

A controller

The solar panel

A solar panel consists of a collection of inter-connected solar cells - semiconductors that transform sunlight radiation into direct current. The solar cells are typically made of crystalline silicon although increasingly thin-film silicon is being used. Solar panels are available in various sizes and output ranges from 1 watt to several hundred watts. The output of a solar panel depends on its size, the amount of sunlight, the panel's orientation and its cleanliness. As a rule of thumb, the output is calculated by multiplying the panel's capacity (e.g. 50 Wp) by the daily hours of sunlight (4 – 5 hours) although the actual output will depend on the solar insolation levels. A solar system can be expanded in a modular way: several solar panels can be connected to several batteries to increase capacity. As the most expensive component of a system consideration must be made with regard to the risk of theft or vandalism. The expected lifespan of a solar panel is about 20 years, without substantial loss in output.

Battery

The electricity generated by the solar panel is stored in the battery, to which electrical appliances (lamps, fridge, heater, etc.) are connected. Most often the batteries produce 12 Volt DC output but 24 V is also common for larger PV systems. This means that for AC appliances, an inverter is required (see below). There are various types of batteries available, deep-cycle lead-acid battery have been most commonly used and are standard for larger systems. In cheaper systems car batteries are used but these are not designed for deep discharge and their performance (especially durability) is often low. The lifespan of a deep-cycle lead-acid battery is variable and depends on the number of charge-discharge cycles, a good charge controller and maintenance, as well as other factors such as outside temperature. However, generally it must be able to last for three to five years. The battery is often the weak spot of a solar system as wrong use or lack of maintenance may negatively affect its performance substantially. Several solar PV installations that have been made for health centres and hospitals in Rwanda are not operational anymore since the quality of the installation was poor so that batteries have failed. Lack of maintenance and knowledge has led to the abandonment of the systems. Another consideration for batteries is their environmental impact since they can contaminate groundwater supplies if improperly disposed. Safe disposal or recycling of the batteries must be carried out at the end of their lifetime.

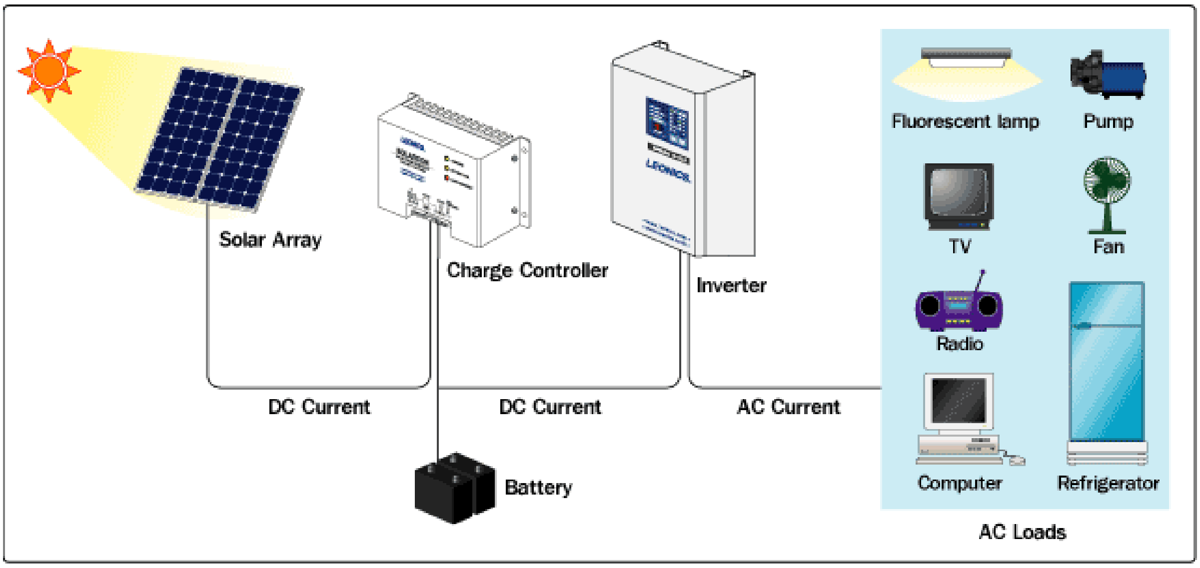
Charge controller & inverter

The charge controller protects the battery from overcharging and over discharging, both of which have a negative effect on the battery's life. An inverter converts DC (direct current) to AC (alternating current). As the battery's output is DC, it can only directly power appliances that work on DC. However, most household or medical appliances only run on AC. Therefore, unless the system is very basic and only includes lighting along with radio and phone and battery charging, an inverter is necessary. However, this conversion occurs at a cost as the inverter itself also consumes electricity from the battery. Depending on its efficiency, an inverter can consume between 15% - 50% of the power. Also, high power appliances such as an X-ray will require a large inverter that is able to draw the required peak power. The balance of the system needs to be carefully calibrated to cope with the quick withdrawal of power.

Appliances

Since the cost for solar equipment is high, the appliances should be as energy saving as possible. Although energy efficient appliances often cost more up-front this is more than compensated for by the reduction in the cost of the supply system and the running costs. Several medical appliances such as a normal X-ray machine require too much power to be made available with a standard solar system at reasonable costs. Therefore, portable appliances with their own battery, which can be charged over time, and energy efficient equipment should be used.

Figure 3: The solar panel, battery, controller and inverter at work to power domestic appliances



Diesel generators are on the other hand very simple and usually all electro-mechanical equipment is packaged and ready to use. Diesel gensets typically supply 220V AC current and normal appliances can be used. However, diesel generators require a supply of fuel, which is not only expensive over time, but its availabiliy, can be a real challenge in places. In addition diesel ties the user into a dependency on volatile future fossil fuel prices and is associated with greenhouse gas emissions.

In many places a hybrid system will be the most cost effective since the diesel generator can reduce the quantity of batteries needed and allow larger loads to be met whilst increasing the reliability. The genset is not designed for high use so its lifetime is extended as its annual hourly operation is lower.

Operation and maintenance considerations

Sustaining energy systems requires proper repair and maintenance. This can be problematic for health centres with limited budgets and a lack of energy skills. To ensure sustainability the health facility must be able to operate and maintain the system and be able to pay for it. The ability of the health facility to cover long-term costs of energy should be assessed and no site should be provided with equipment that is beyond its capacity to maintain in the long term. If the institutional arrangements are not in place to ensure funding for proper repair, spares replacement and maintenance, the system may fail and not contribute to any expected health benefits.

In some locations it is possible to outsource the maintenance of the system. A service contract is possible to provide routine service and maintenance of the system ideally including regular service visits as well as emergency visits over a period of years. Reliable suppliers will also provide warranties for their installation and the equipment, often 1 year on the batteries and the installation and 10 or more years for the PV panels. Larger and more complex systems need regular maintenance and servicing. However service contracts are not possible in all locations particularly in remote areas or where the service provider capacity is limited. Local skills must therefore be developed.

Not only must the energy system be maintained it must also be managed. For example the most common failure in solar-powered health facilities is due to battery failure. This is generally as a result of either poor sizing or installation, or due to poor system management rather than due to battery maintenance per se. It is therefore critical that there is local capacity at the health facility to manage the use of the installed system. This means training of local staff must be integral to any energy project. Staff need to be aware of energy and load management practices and aware of 'critical loads' (those that are vital) and 'non-critical loads' (those that can be switched off when less power is available). Unfortunately there is always a risk that the trained person (in maintenance and/or management) does not stay at the health centre. A system of on-going training should be put in place to minimize this risk.

In some cases, consideration should also be given to installing a larger system than required for the health facility which can also serve the staff accommodation, the wider community and/or other commercial or institutional facilities. Small additional services can provide a possible income for the facility to help in paying for the operation and maintenance. There are examples where the health clinic receives additional income from battery charging services and the use of video theatres[6]. Other options include retail selling (for time or metered energy) at a site adjacent to the clinic where workshops/stores or other income generation activities, and battery or mobile phone charging, could be established using the local power. Alternatively, where legally possible, a small grid could be extended from the clinic to nearby users through a distribution network. This would involve either the clinic establishing itself as an enterprise to sell power directly, or selling wholesale at the clinic boundary to an organization who manages the sales to the users. Although these options may help to recover some of the operation and maintenance costs it requires additional capacity for the health clinic and is likely to only be cost effective for very close users and is also likely to increase maintenance requirements.

Cost comparison and model

Based on the appliances in Table 1 and the impacts that can be achieved in the above section and table 3, GVEP has developed Microsoft Excel tables with demand data for various equipment types and developed a model to estimate the costs of an energy system that will meet these needs. This can help in the planning of achieving health benefits through inclusion of the required energy system and for a cost-benefit analysis of such interventions.

Costs will vary over time, and between geographies (reflecting for example different logistics costs, as well as varying import tariff and VAT regimes), these tables should be used as a guideline or benchmark, and not as a substitute for project specific due diligence.

The cost analysis for any energy 'package' can be assessed in terms of its cost only, and against expected outputs using marginal costs rather than total costs. Assuming the expected health service outputs are the same from providing energy from a number of different technologies the value for money of each option can compared based on the life cycle cost (or net present value) of the energy solution (as mentioned above).

Work on this model has been strongly influenced by the appliances power rating [WHO source] and the USAID HOMER tool that was described above. It combines the possibility of a detailed demand input as in the USAID tool, in which appliances and their hours of use can be adjusted, with the more detailed calculation of costs, which can be adjusted once local data are obtained but for a rough estimate can be used with standard input data for several countries.

The model is based on the following steps, in line with the layout of this report:

1. Select the health facility category (health post; health clinic/centre; district hospital; regional hospital), which you are interested in to expand services. Electricity requirements vary with the size and category of the health facility including whether it has in-patient facilities. Smaller

[6] Four communities in Colombia have done this (NREL 1998)

heath posts and clinics are only able to offer basic health services and have basic medical equipment whereas a district hospital will have a greater number of staff, offer more services and may have more sophisticated equipment.

2. The different energy packages as provided in Table 3 above are provided. Each package includes a detailed list of appliances and their potential impact on health services. The user can adjust the standard settings on hours of usage and number of appliances according to requirements. Also, the number or rooms or wards for lighting can be easily adjusted.

3. Given the demand data, the model will calculate a solar PV system with its individual components as well as a diesel generator alternative. For both the investment costs and the Net Present Costs over 15 years will be given. Greenhouse gas emissions are also calculated.

   The user can choose the country of the installation to call upon standardised cost data that reflect the different costs of solar equipment as well as diesel prices.

The costs for PV panels, inverters, batteries, charge controllers and gensets, have been retrieved from various suppliers and other sources, such as Africa Solar Design and Sollatek in Kenya, TaTeDo in Tanzania, MTS Sarl. in Rwanda, and were estimated where data was missing given the margins on products (smaller markets have typically larger margins); tax and import regimes that add to the costs of systems (however, for public health purposes, equipment is likely to be tax exempted in most countries, although VAT may still apply). Also landlocked and remote places will have different prices. Since prices can change considerably within a country the list should be updated given local supplier data in order to achieve a higher confidence in the estimated costs.

Table 5: Example standard system settings for the packages A-E in Kenya*

Solar PV system						
Power demand	kWh per day	1.7	4.8	10.6	23.8	77.9
Required PV Panel size	Wp	500	1,400	3,100	6,900	22,300
Required Battery size	Ah	300	800	1,700	3,800	12,200
Required number of batteries		3	8	17	38	122
Required inverter	kW	0	0.8	3.5	6.8	13.4
PV panel costs	USD	1,500	4,200	9,300	20,700	66,900
Battery costs	USD	450	1,200	2,550	5,700	18,300
Inverter costs	USD	-	420	1,767	3,387	6,677
Charge controller	USD	104	292	646	1,438	4,646
Transportation to the clinic	USD	100	200	300	400	500
Installation and wiring	USD	400	1,120	2,480	5,520	17,840
Investment costs per system	USD	**2,554**	**7,431**	**17,043**	**37,145**	**114,863**
Lifetime replacement costs discounted	USD	661	2,088	5,116	10,998	32,052
Yearly Operation and Maintenance	USD	100	200	200	500	1,000
Operation and Maintenance discounted	USD	761	1,521	1,521	3,803	7,606
Net Present Cost	**USD**	**3,975**	**11,040**	**23,680**	**51,946**	**154,521**
Diesel generator						
Generator size	W	400	1,100	3,800	7,200	14,300
Transportation to the clinic	USD	50	100	200	200	300
Wiring	USD	100	200	200	300	300
Generator costs	USD	**390**	**960**	**2,680**	**4,820**	**9,180**
Hours of genset availability per day	h	5	10	10	12	24
Yearly operation costs	USD	556	3,059	10,569	24,030	95,454

Yearly maintainance/repair costs	USD	39	96	268	482	918
O&M costs discounted	USD	4,528	24,000	82,427	186,444	733,015
Lifetime replacement costs discounted	USD	344	848	2367	4257	8107
Net Present Cost	**USD**	**5,262**	**25,808**	**87,473**	**195,520**	**750,302**

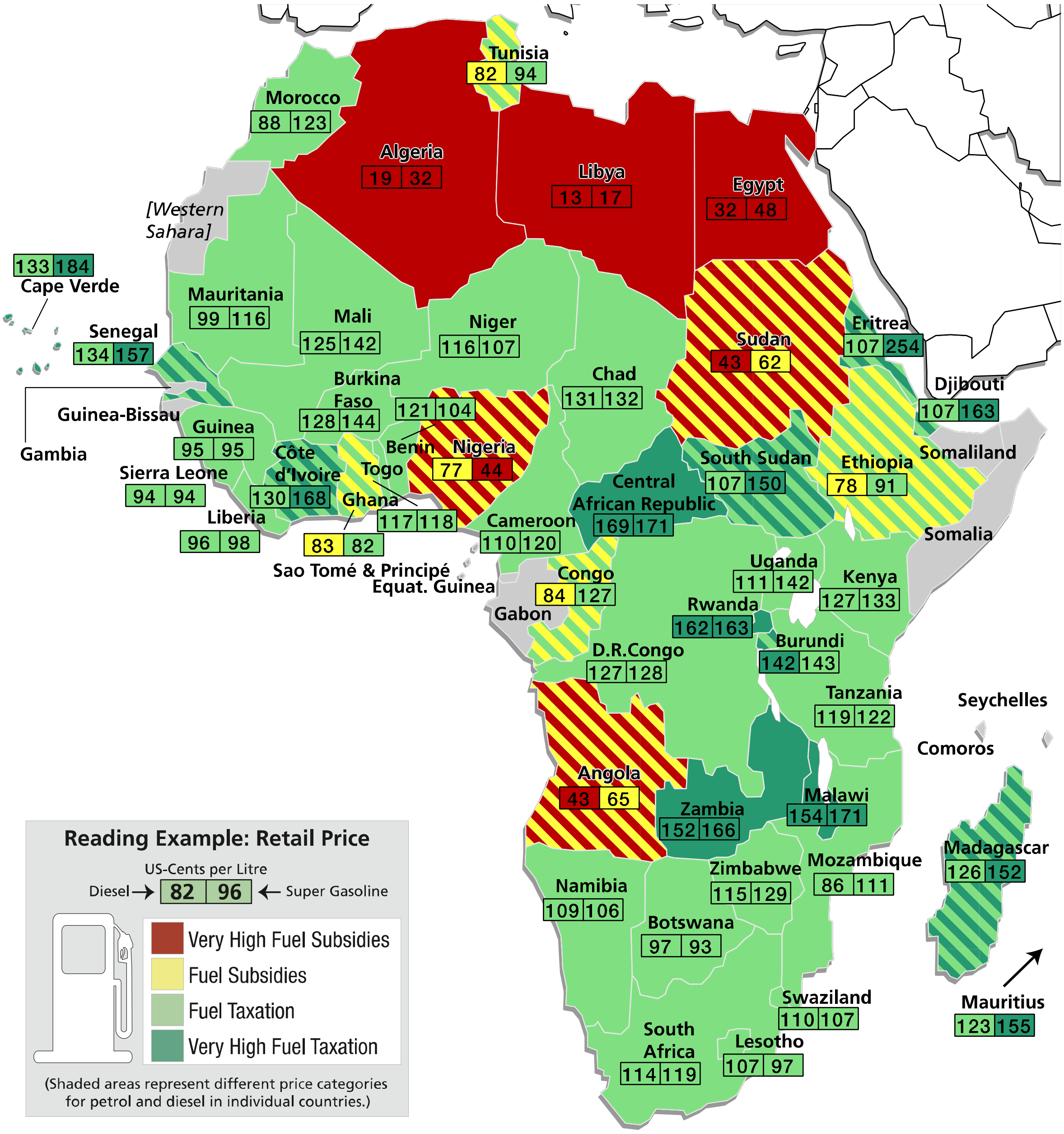
* Discount rate used in these figures is 10%.

In addition to these components adequate instrumentation should be included which will help the clinic staff in energy management. This can include load meters, battery voltage meters and state of charge meters.

It is also advisable to include basic tools (meters, controllers) and replacement parts (fuses, bulbs) with the initial procurement. In addition the supplier should provide a replacement schedule for components that are likely to fail over time (eg batteries, inverters).

In order to compare the economics of a solar PV system with a diesel generator, fuel prices are very important and make a large difference in the comparison of the options. While generators have much smaller investment costs, their operating costs are high. In the comparison and cost-benefit analysis therefore the applied discount rate will be important and can be adjusted in the model.

Figure 4: Overview of diesel and gasoline prices in Africa



Source: GIZ, International Fuel Prices 2010/2011, 7[th] Edition.

Table 6: Example of package B in several countries:

Cost for Package B in USD	Kenya	Uganda	Tanzania	Rwanda	DRC	Nigeria
1.4 kW Solar System						
Investment Cost	**7,539**	9,343	9,609	11,272	11,972	8,699
Net Present Cost	11,232	13,470	14,052	16,972	17,672	12,039
1.1kW Diesel Generator						
Investment Cost	960	960	1,070	1,180	1,180	520
Net Present Cost	25,808	22,877	24,633	32,803	26,390	15,483

It can be noted in the above table that the costs for solar systems can differ by up to 50%. Also, the example of Nigeria shows that low generator costs and subsidised diesel prices make the economics of solar systems less favourable. On the other hand, fuel prices in Rwanda are very high, favouring solar systems despite relatively high PV prices due to the small solar market and high transportation costs. .

6. Monitoring and Evaluation Indicators

Every health project has the possibility of selecting output and outcome indicators based on service provision and in use by national and supra-national organization such as UNICEF or the WHO. These indicators used as measures of health by organizations across the board should be included in the logframe and M&E framework for such projects and clearly defined following international consensus and modified as needed. In addition to the work undertaken within this project the team also reviewed other projects and documents for health related indicators used. The only ones found were those included in the EnDev programme and also those included in the Uganda Ministry of Health implementation plan. The measurement method for EnDev is included in Annex D. These indicators can be used as a basis for M&E frameworks that also have to adapt to assess progress towards objectives in agreement with precise targets and expected results. The suggested indicators for these programmes are included in the following table.

Table 7: Suggested indicators for EnDev and Uganda's Ministry of Health energy for health projects

EnDev Medical Infrastructure Indicators	Uganda MoH suggested Indicators
• Quality of service provision • Use of modern lighting devices • Use of sterilisation devices • Use of modern cooling devices • Penetration of information and communication facilities	• Expanded hours of service • Improved emergency service during dark hours • Improved and expanded laboratory service • Reliable refrigeration • Improved referral service • Improved staff conditions (facility and houses) • Retention of staff

Based on these and the results of the literature review, and the proposed potential 'energy packages' the following table outlines a number of project outcomes and outputs that can be selected for energy for health projects, although they may not necessarily be health related. In each case a set of indicators is proposed for the logframe and M&E framework along with their potential data collection requirements for their monitoring and valuation. Following the results of an intervention-control study it may be possible to add health outcome indicators to these indicators.

Table 8: Possible logframe indicators for Energy for Health Facility projects

	PROJECT OUTCOME	Outcome indicators	Source	Assumptions
1	Greater utilization of facility	Utilization rate (all patients)	Health facility routine reports	Record keeping at facility
		Utilization rate (under 5)	Health facility routine reports	As above
		Attendance to ANC 1st & 4th visits	Health facility routine reports	As above
2	Better staff retention	No. of staff leaving in year	Human resources for health records and quantified supervisory checklists	Systems for supportive supervision and HRH in place
3	Better service provision	Quality of Care score measured by surveys or quantified supervisory checklists	Health facility surveys Quantified supervisory checklists (QSC) or similar supervisory tools	Systems for measuring quality o care and supportive supervision in place Yearly or bi-yearly surveys for quality of care score
	HEALTH RELATED OUTPUTS	Output indicators	Source	Assumptions
1	Increased opening hours	Opening hours	Can be included in the QSC	
		No. of emergency procedures after dark	Health facility routine reports – can be included in the QSC	Routine reports/ HMIS in place
2	Increased deliveries in the health facility/skilled assistant	Number of deliveries in health facilities	Health facility routine reports	Routine reports/ HMIS in place
3	Improved emergency surgical services including blood transfusions	Number of blood transfusions in the health facility	Health facility routine reports	Routine reports/ HMIS in place
		Number of surgical procedures in the health facility	Health facility routine reports	Routine reports/ HMIS in place
		C-sections in the health facility	Health facility routine reports	Routine reports/ HMIS in place
4	Increased use of information and communication	Number of referrals	Health facility routine reports	Routine reports/ HMIS in place
5	Improved staff facilities	Availability of lighting	Can be included in the QSC	QSC is modified to assess new or expanded services

6	***Reliable refrigeration***	*Quantity of drugs and vaccines spoiled due to cold chain failure*	*Pharmaceutical and vaccine wastage reports*	*Routine reports/ HMIS in place*
		Number of children immunized in facility	*Routine report and Expanded Programme of Immunization reports*	*HMIS in place / Routine reports produced and sent*
7	***Expanded laboratory services***	*Lab tests completed*	*Laboratory reports or QSC*	--
	TECHCNICAL / ECONOMIC OUTPUTS	*Output indicators*	*Source*	*Assumptions*
1	***Savings in energy costs***	*Monthly cost of energy (kerosene, diesel, batteries)*	*Financial report from health facilities*	*Expenses records maintained in health facilities*
		Annual maintenance costs related to energy	*Calculated from aggregation of monthly reports and reconciliation with yearly budgets*	*As above (more likely at district level)*
2	***Reliable refrigeration***	*Cost of vaccine wastage*	*Calculation from vaccine costs to the country*	*Central level financial reports of EPI*
		Number of times cold chain temperature is inadequate	*Cold chain temperature records*	*This is SOP of immunization programmes*
3	***Reduced opportunity cost as a result of extended hours of service***	*Reduced opportunity costs for users of services*	*Economic analysis and records of out of hours attendance*	*Available estimates of opportunity cost based on daily income or daily household expenditure.*

7. Recommendations

The present study was not able to find clear empirical evidence of health benefits due to the provision of energy at health facilities. Evidence of impact from the provision of reliable energy at health clinics should be obtained by means of a well designed and implemented intervention-control study. Such a study would be valuable to assess the value for money of energy provision to health facilities and will facilitate understanding of the health impact of energy and help identify efficient ways to strengthen health services and achieve improved health outcomes.

GVEP and LSTM have provided an approach and methodology for conducting such an intervention study in two comparable areas before and after the provision of reliable energy. The health services strengthening project in the Democratic Republic of the Congo, implemented by DFID and Inter church Medical Assistance (IMA) World Health, is an opportunity to measure the impact of energy on health as it focuses on rural remote districts, where the provision of energy is likely to be unreliable or absent. However, the approach presented could be applicable to other rural districts in less developed countries where the provision of energy is unreliable for lighting and power dependent equipment.

The purpose of the proposed study is to measure the health impact of the provision of reliable energy to health facilities in less developed countries. The approach lays out three key objectives as:

- To provide definitive data on the impact of reliable energy on health of the population served by health facilities in less developed countries.
- To document the impact on health status from technology innovation.
- To establish the value for money of the provision of low cost renewable energy to health facilities.

The expected results will be:

1. Measure impact of the intervention in terms of:
   a. Mortality of children 0-11 months of age defined as the probability of dying before one year of age, using as indicators infant mortality rate or age-specific mortality rate.
   b. Lives saved calculated using coverage of health interventions (outcomes) relevant to mortality and morbidity of mothers and children younger than one year of age in less developed countries[7].
2. Obtain an estimate of variation of indicators attributable to the provision of reliable energy.
3. Provide relevant data to assess the value for money of the provision of reliable energy systems to health facilities in rural settings of less developed countries.

The full approach and methodology is provided in Annex B.

[7] *NB: The health outcomes of younger children, those under one year, are likely to be more sensitive to energy provision in health facilities than health outcomes of older children. This is due to the potential life-saving health interventions used for this age group that are reliant on energy sources such as, incubators; compressed oxygen for respiratory support and new-born resuscitation devices.*

Annex A – Literature review (separate file)

Annex B – Proposal for Generic Case-Control Study (separate file)

Annex C: Excel spreadsheet (separate file)

Annex D: EnDev proposed indicators for electricity in social infrastructure

Beneficiaries: Social Infrastructure (SI)

Observation field	MDG relevance	Indicator	What to measure	How to measure?
Medical Infrastructure				
Better service provision	**MDG 4 + 5 + 6**	Quality of service provision	▪ Perception of health staff regarding the quality of rural health facilities and changes related to electricity ▪ Effective health situation in the region and its relation to electricity	SI survey
Increased hygiene and safety	**MDG 4 + 5 + 6**	Use of modern lighting devices	▪ Number and percentage of clinics commonly using traditional lighting devices such as hurricane lanterns ▪ Number and percentage of clinics commonly using modern lighting devices	SI survey
		Use of sterilisation devices	▪ Number and percentage of clinics owning (electric) sterilisation devices	SI survey
Increased reliability of cold chain	**MDG 4 + 5 + 6**	Use of modern cooling devices	▪ Number and percentage of clinics using electric fridges, freezers ▪ Number and percentage of clinics using kerosene-run fridges, freezers ▪ Times per month, cold chain is interrupted for at least five minutes	SI survey
Improved information and commu-nication opportunities	**MDG 3 + 4 + 5 + 6**	Penetration of information and communication facilities	▪ Number and percentage of clinics using TV, video, DVD, radio, cell phone, landline phone ▪ Number and percentage of clinics having internet access	SI survey

Technical and economic indicators (education and medical)

Savings in energy expenses	**MDG 1**	Energy expenditures	▪ Average total expenditures on energy (liquid fuels, wood fuels, batteries, electricity, dung) per month	SI survey
			▪ Broken electric devices and respective expenditures per year	SI survey
Time savings	**MDG 1 +**	Time spent on	▪ Relation of firewood collected versus firewood	SI survey

	3	firewood collection	bought ▪ Frequency and time spent (daily/) weekly on firewood collection	
		Time spent on cooking	▪ Average total daily cooking time ▪ Cooking time for main meal	SI survey
Cleaner air in the kitchen	**MDG 3 + 4 + 5 + 6**	Emissions from burning of wood fuel	▪ Average monthly amount of wood fuels (firewood, charcoal, sawdust) used per SI	SI survey
		Emissions in the kitchen	▪ Number and percentage of SI which principally use an electric stove for cooking	SI survey
Biomass energy savings	**MDG 7**	Use of wood fuels	▪ *See "Emissions from burning of wood fuel"*	SI survey
Reductions in toxic waste	**MDG 7**	Use of dry cells	▪ Average monthly amount of dry cells used	SI survey

Annex E: WHO/SARA Service Readiness Indicators relating to energy provision

	Domain	Tracer indicator	Details
General			
1	Basic amenities	Power	Routinely has power during normal working hours
		Communication equipment (phone SW radio)	Does not include private mobile phones
		Access to computer with email/internet access	Functioning computer and internet access
2	Basic equipment	Light source	Torch is acceptable
3	Standard precautions for infection prevention	Sterilization	Dry heat sterilizer or autoclave (but could be wood)
4	Diagnostic capacity	Microscope	Microscope
		Blood chemistry analyser	Blood chemistry analyser
5	Essential medicines		
Service specific readiness indicators			
1	Family planning services		
2	Antenatal care services		
3	Basic obstetric care	Examination light	Torch acceptable
		Suction appartus	Manual or electric
4	Child Health services (immunization)	Refrigerator	
5	Child health services (preventative and curative care)	Diagnostics	Microscope Does haemoglobinometer required power
6	Adolescent health		
7	Malriia	Diagnostics	Microscope
8	TB	TB and HIV diagnostic	Microscope
9	HIV (counseling and testing)	HIV diagnostic	
10	HIV/AIDS care and support services	HIV diagnostic	
11	HIV/AIDS antiretroviral prescription and client management	Complete blood count	Haematological counter
			Centrefuge
			Vortex mixer
12	HIV/AIDS: Preventing mother-to-child transmission (PMTCT)	As above	
13	Sexually transmitted infections (STI)		
14	Diabetes		
15	Cardiovascular		
16	Chronic respiratory disease		
17	Basic Surgery	Suction apparatus	Manual or electric

		Oxygen	Cylinders or concentraors
18	Comprehensive obstetric care	Anaesthesia equipment	Anaesthesia machine to deliver anaesthetic gases and oxygen
		Incubator	
		Blood typing	
		Blood supply	
19	Blood transfusion	Blood refrigerator	
		Blood typing	
Maternal and child health priority medicines		**Medicines**	
Hospital level optional indicators			
1	Comprehensive surgery	Anaesthesia equipment	Anaesthesia machine to deliver anaesthetic gases and oxygen
		Suction apparatus	Manual or electric
		Oxygen	Cylinder or concentrator
2	Laboratory capacity (in addition to above)	Incubator	
		Blood chemistry analyser	
		CD4 counter	
3	High level diagnostic equipment	x-ray	
		ECG	
		Ultrasound	
		CT scan	

References and Bibliography

[i] IT Power: Use of Renewable Energy in the rural health, water and education sectors. European Commission, 2007EC 2007

[ii] WHO 2012: Service Availability Readiness Assessment. Geneva, World Health Organization. 2012. http://www.who.int/healthinfo/systems/sara_introduction/en/index.html

iii USAID: Powering Health Electrification Options for Rural Health Centers - Step-by-step guide on energy needs, power generation options, and sustainability issues for rural health centers. Case studies from Botswana and Uganda.

[iv] USAID - Energy Use in PEPFAR Rural Health Facilities: Assessment Report, Mark Hankins 2007

[v] Powering Health: Electrification Options for Developing Country Health Facilities - USAID website covering all major issues on electricity supply for rural health centers. Several country case studies available. Offers tools for energy audits and load calculation.

https://energypedia.info/wiki/Energy_for_Rural_Health_Centers

ESMAP 2010: Photovoltaics for Community Service Facilities - Guidance for Sustainability. Covers the most crucial issues regarding sustainability of community-based PV systems. Internet:http://www.lightingafrica.org/files/PV_Toolkit_FINAL_12-14-10.pdf

GIZ 2009: M Harsdorff & P Bamanyaki, Impact Assessment Of The Solar Electrification Of Health Centres, FRIENDS' Consult Limited, GTZ, September 2009

GIZ 2011: International Fuel Prices 2010/2011, 7th Edition

NREL1998: C: Jimenez, Antonio & Olson, Ken. "Renewable Energy for Rural Health Clinics." Golden, CO: National Renewable Energy Laboratory, Sep. 1998. http://www.rsvp.nrel.gov/vpconference/vp2000/handbooks/health_clinic_handbook.pdf) Publication on energy issues of rural health clinics: energy applications, electrical system components, system selection and economics, institutional considerations. Also provides case studies and lessons learned

UBS 2012:' Light up a Life' Research Factsheet." In: Factsheets Global Health Research. Zurich, UBS Optimus Foundation website. http://www.ubs.com/global/en/wealth_management/optimusfoundation/commitment/global_research/factsheets.html

USAID 2011: Evaluation of the USAID Powering Health Project in Haiti. Prepared by Seema Jayachandran (Northwestern University); Melissa Eccleston (Harvard University); Corrina Moucheraud (Harvard University)

World Bank 2011: Energy, gender and development : what are the linkages? Where is the evidence?, Working Paper 64410, World Bank, August 2011

WHO: Health in the green economy – co-benefits of climate change mitigation. Health Care Facilities. Preliminary findings – initial review. http://www.who.int/hia/hgebrief_health.pdf

WHO 2007: Everybody's Business. Strengthening Health Systems to Improve Health Outcomes. WHO's Framework for Action. Geneva, World Health Organization, 2007. http://www.who.int/healthsystems/round11_2.pdf

WHO2010: Increasing access to health workers in remote and rural areas through improved retention: global policy recommendations, WHO 2010