Solar for Powering Health and Education in India

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Executive Summary

Worldwide, there is a growing recognition of the role of energy access in the last mile delivery of community services. However, in India, energy access has had a strong household-level focus, while its role as an enabler of better health and education services has not gained enough attention. Even though 96.7 per cent villages in India are deemed electrified, electrification of Primary Health Centres (PHCs) and primary schools, two key institutions responsible for the last mile delivery of essential community services, is extremely poor. Besides the lack of a physical connection to the grid, the poor quality and erratic supply of electricity have been adversely affecting both health and learning outcomes. Globally and to some extent in India, solar-based decentralised solutions are being leveraged to address this energy access gap.

This study, based on the analysis of secondary data, assesses the current state of electricity access in PHCs and rural primary schools. Given the increasing policy support for solar energy in India, it also examines the experiences, benefits and potential of solar-based electrification. It offers insights on the opportunities for convergence between the objectives of education, health and solar policies in India and the barriers to the same.

Energy access in PHCs

In India, 4.4 per cent PHCs are un-electrified, implying that about 33 million rural Indians rely on health facilities having no electricity. Further, majority of such facilities are concentrated in the hilly and the tribal states of Eastern, North and North-Eastern India, with Jharkhand having the highest number of un-electrified PHCs at 42.5 per cent, followed by Uttarakhand, Arunachal Pradesh, Manipur and Jammu and Kashmir. The Indian Public Health Standards (2012) lay emphasis on electricity access in PHCs and prescribes facility level surveys to measure and monitor the energy gaps. However, there is a need to ensure that the energy demands of PHCs and the gaps in power supply are assessed in a systematic and periodic manner, and the related information is made public for independent evaluation and assessment.

Energy access in rural primary schools

Every second rural primary school in India is un-electrified. This implies that around 32 million children attend schools lacking any form of electricity. Un-electrified schools are highest in proportion in the Eastern, North and North-Eastern states of India, with Jharkhand having 92 per cent of its schools un-electrified, followed by Madhya Pradesh, Manipur, Assam and Jammu and Kashmir. The policy support for energy access in schools is rather missing. While the infrastructure guidelines for schools mandate electrification of premises, there is no emphasis on ensuring compliance, monitoring the progress, or assessing the impact of energy deficit on learning outcomes. Similar to PHCs, there is a need to assess the state of energy access in schools in order to bridge the energy deficit through evidence based policies and programmes.

Energy needs of PHCs and Schools

An understanding about the energy needs of PHCs and primary schools is the crucial first step for assessing the gaps in energy access. Even though facility level surveys are required to assess the actual energy demand, this study presents theoretical estimates based on the assumptions around the type and number of appliances and equipment used as well as their hours of operation. It is estimated that a typical PHC (as per IPHS norms) would have peak and daily mean power requirements of around 7.5 kWp and 45.8 kWh/day, respectively. Similarly, a rural primary school would have peak and daily mean power requirements of about 4 kWp and 25 kWh/day, respectively. In reality, the energy demand would vary with several factors, such as the actual infrastructure of the school or PHC, building design, and appliance parameters such as energy efficiency, time and hours of operation.

Solar power - An opportunity to improve energy access in health centres and schools

Solar PV systems, whether stand-alone with battery storage or grid-connected, can provide reliable power supply on most days of the year, for un-electrified establishments and also mitigate the poor state of supply in electrified PHCs and schools, at almost zero or marginal operating costs. Besides improved service delivery, these offer multiple co-benefits ranging from climate change mitigation to gender empowerment and greater likelihood of staff retention.

This study estimates that rooftop solar systems of 5 kWp and 3 kWp capacity could help meet 50 per cent and 70 per cent or more of the daily and peak power requirement of PHCs and primary schools, respectively (in accordance with the theoretical estimates for average energy requirements). If deployed across all the PHCs and rural primary schools in India, such rooftop solar systems would amount to an installed solar capacity of 154 MW and 2290 MW, respectively. Thus, collectively PHCs and rural primary schools could contribute towards 6 per cent of the 40 GW rooftop solar target of the country.

Locating health and education within India's solar priorities

Given the increasing policy support for solar energy in India, there is an unprecedented opportunity for leveraging solar power for improving energy access in schools and PHCs. However, multiple issues have hindered the uptake of such solutions.

First, electrification of PHCs and schools receive lower policy priority in presence of competing demands for human resource and other infrastructural services. Secondly, there is lack of adequate recognition about the potential opportunity for solar based electrification of PHCs and schools. Thirdly, the current solar policy is driven by the objective of achieving a fast paced increase in installed solar capacity and fails to emphasise upon maximizing the utility of such installations by targeting them in energy deficit areas. Fourthly, most policy incentives are dedicated towards grid-connected rooftop solar systems and not available for off-grid systems. Fifthly, the necessity of co-ordinating with multiple institutions involved in decision making, funding and implementation of electrification of PHCs and schools acts as a key barrier.

Recognition of the significance of energy access for last mile delivery of community services, adapting the solar policy to the institutional arrangement within which rural schools and PHCs exist, and cross-sectoral coordination between national and state level agencies could help bridge the energy deficit through solar power.

1. Introduction

Energy in the form of electricity has become essential to most services. Energy shortages can cause significant hindrances in the efficient and effective last-mile delivery of services. As the global discourse shifts focus to 'Energy for All', there is a need to ensure that we go beyond the basic energy needs of households. It remains imperative to provide quality energy supply to critical community services such as healthcare and education, which build the very fabric of the society and are at the core of human development.

The fact that health and education are fundamental to socio-economic development has been well established since the early 1990s (Anand & Ravallion, 1993; Chambers, 1995; GH, Brundtland, & World Commission on Environment and Development, 1987). Even the Sustainable Development Goals (SDGs) (and previously, the Millennium Development Goals) have enshrined quality education, good health and well-being, and affordable and clean energy as global development goals. However, it is important to understand that these goals are highly inter-linked. Energy access is one of the key drivers for achieving health and education outcomes. In the words of Fatih Birol, the Chief Economist at the International Energy Agency (IEA), "lacking access to electricity affects health, well-being and income" (IEA, 2011).

More often than not, the phrases 'Energy and Health' and 'Energy and Education' refer to the impacts of indoor air pollution (from biomass burning) and inability of children to study during post-sunset hours, respectively. Numerous studies have shown the positive impacts of electricity provision at the household level on health and education outcomes. Some of these impacts include improved perceptions of personal health and longer study hours for children, especially post-sunset (WHO, 2014a). The positive impacts are likely to be more pronounced when healthcare and educational institutions are electrified (GEA, 2012; UNDP, 2005; UN-Energy, 2005). However, these links are yet to be conclusively established. Urgent attention is needed to examine the synergy between energy and education as well as energy and healthcare services from an institutional perspective (WHO, 2014a).

Lack of data has been a major constraint in measuring access to energy for community services. Only recently, IEA has begun measuring the access to energy for public services, while efforts are underway to develop a comprehensive framework for measuring the state of access in healthcare facilities (World Bank, ESMAP, & IEA, 2013). It is estimated that across developing countries, around 1 billion people are served by health facilities without electricity and more than 291 million children go to primary schools without access to any electricity (Practical Action, 2013). While these studies indicate a significant gap in energy access for community services, including health and education, they also highlight the need for systematically measuring and monitoring the energy needs and unmet energy demands of such facilities, in order to facilitate informed policy action.

So far, access to energy in India has had a strong household-level focus and its role as an enabler of better health and education services, particularly in rural areas, has not gained enough attention. Under the Rural Electrification Policy (REP), 2006, the definition of electrified villages was revised to include within its purview the electrification of public institutions such as schools, health centres, and panchayat offices (Ministry of Power, 2006). However, a recent evaluation indicates that the electrification of public institutions is extremely poor and there is significant ground to be covered to meet the targets as per the revised definition of village electrification (Planning Commission, 2014). For instance, even though 96.7 per cent villages in India are deemed electrified, 40 per cent of schools in the country do not have an electricity connection (CEA, 2015; NUEPA, 2015).

Besides the lack of a physical connection to the electricity grid, the poor quality and erratic supply of electricity in most rural areas makes the challenge of energy access even greater. A recent study on household energy access, based on a survey of more than 8,600 rural households across six states in India, highlighted that an electricity connection does not guarantee energy access (Jain et al., 2015). As per the study, half of the electrified households remain in the bottom-most tier of electricity access. Similar to the state of electrification at the household level, many community-level institutions also receive poor quality and unreliable power supply, affecting the services these deliver.

In India, Primary Health Centres (PHCs) and primary schools are two key institutions responsible for the last mile delivery of community services viz. healthcare and education at the village level. In the absence of electricity, services catered by PHCs such as institutional deliveries, paediatric emergencies, and administering of vaccines get severely affected (WHO, 2014b). Electricity access in health centres is imperative to facilitate communication services, tele-health applications and for retention of skilled health workers (WHO, 2014a).

Similarly, the poor state of infrastructure including lack of access to electricity, is adversely affecting the learning outcomes in schools across the country, particularly primary education (Nanda, 2015). Electricity access in schools could facilitate better learning outcomes by improving enrolment and completion rates, allowing for classes to be taught early in the morning or late at night and enabling computer-aided learning in the classroom, apart from contributing towards better staff retention and other co-benefits, such as improved health and sanitation (Laszlo, 2013; UNDESA, 2014).

While the lack of access to electricity impedes service delivery, the same needs to be studied in light of the power sector situation in India. Although the power supply situation has improved in the country, the growth in electricity demand has also increased manifold, thus continuing to leave the power sector in deficit. The per capita electricity consumption in India stands at about 1,010 kWh for 2014-15 and is only expected to grow further (Central Electricity Authority, 2015). To add to these challenges, estimates indicate that about 300 million people are deprived of electricity access in India, and this statistic is probably worse when energy access deprivation is measured as a multi-dimensional phenomenon (Jain et al., 2015). This is further complicated by the poor financial condition of State Electricity Boards (SEBs) (Ganesan, Jain, Ray, Sharma, & Ghosh, 2014).

Given these complex challenges of the power sector, there is an increased interest in alternative solutions – particularly decentralised renewable energy. Of the decentralised renewable energy solutions being leveraged to bridge the energy divide, solar power systems are being used to provide energy access to schools and healthcare centres across the world. India has also witnessed similar initiatives, though at a very small scale. Solar power can contribute towards multiple objectives of reliable healthcare services and education through access to energy, local resource utilisation as well as climate change mitigation. As the Government of India has set the target of installing 100 GW of solar capacity by 2022, the overlaps between the objectives of the solar policy and the energy needs of schools and healthcare centres have become even more conspicuous. Yet, this opportunity needs to be assessed and prioritised.

Even though, the impact of electrification in enabling effective service delivery and more importantly, in enhancing capabilities of the community may not be conclusively established, its criticality is well recognised amongst researchers. The translation of energy access in primary schools and PHCs into a policy priority will require a sustained engagement with policymakers, on the basis of a concrete assessment of the existing energy gaps and the electricity needs of such institutions. In the context of healthcare and education, there is an urgent need to understand the state of electricity access across these sectors, and use evidence-based decision making for augmenting these institutions with reliable and quality power supply.

In this context, this background paper examines i) the current state of electricity access in PHCs and rural primary schools in India, ii) the energy needs of such institutions, iii) solar power as a potential solution to bridge the energy gaps and iv) potential overlaps between the National Solar Mission and the health and education priorities of the country.

2. Electricity access in PHCs and primary schools in India

2.1 Status of Primary Health Centres (PHCs)

As per the latest data, there were around 30,762 PHCs in India, of which 28,762 are functioning[1]. A PHC is considered as functioning if it has all the necessary services being delivered and does not suffer from the lack of human resource or key infrastructure. Even though the number of PHCs has been growing, many have been non-functional due to reasons, including absentee doctors, non-availability of drugs and equipment as well as lack of adequate power supply (Bhandari & Dutta, 2007). As regards the state of electricity in the functional PHCs, 4.4 per cent PHCs were completely un-electrified, as on September 2014 (MoHFW, 2015). Thus, almost 33 million rural Indians are dependent on PHCs having no electricity at all.[2] These numbers exclude the 2,000 non-functioning PHCs.

There is a vast variation in the share of electrified PHCs across different states in India (Figure 1). Of all the un-electrified PHCs, 60 per cent are concentrated in the hilly and the tribal states of Eastern, North and North-Eastern India. The state of Jharkhand has the highest number of un-electrified PHCs at 42.5 per cent, followed by Uttarakhand, Arunachal Pradesh, Manipur and Jammu and Kashmir. The three states of Jharkhand, Odisha (10.8 per cent un-electrified PHCs) and Chhattisgarh (8.8 per cent un-electrified PHCs), together account for every third PHC lacking an electricity connection. Besides, going beyond the physical connection to the grid, PHCs across India face the challenge of unreliable and poor quality power supply, which severely affects their capability to provide effective health care services (Energy Access Practitioner Network, 2014). Yet, these dimensions are often not captured in routine data collection.

The Indian Public Health Standards (IPHS) of 2012 are among the first government guidelines to acknowledge that electricity access is critical to the functioning of PHCs. As per the guidelines, every PHC should have an electricity connection and should be environment friendly and energy efficient, to the extent possible (MoHFW, 2012). The guidelines even suggest the use of solar energy and energy-efficient appliances/equipment. In addition, they also prescribe facility level surveys by external bodies such as Village Health, Sanitation and Nutrition Committee and the Rogi Kalyan Samiti to measure and monitor the gaps in facilities as compared to IPHS norms. The prescribed pro-forma for facility survey includes questions on the adequacy of electricity provision, reliability of power supply and the presence of a working standby facility (such as diesel generators). In line with the IPHS norms, a PHC qualifies as IPHS compliant only when it meets all the criteria, including those for electricity access. As per the Rural Health Statistics of 2015, only 21 per cent of the PHCs across India are IPHS compliant, and by extension with the norms on electricity access (MoHFW, 2015). Appendix 1 provides state-wise details on number of PHCs functioning, electrified and compliant with IPHS norms.

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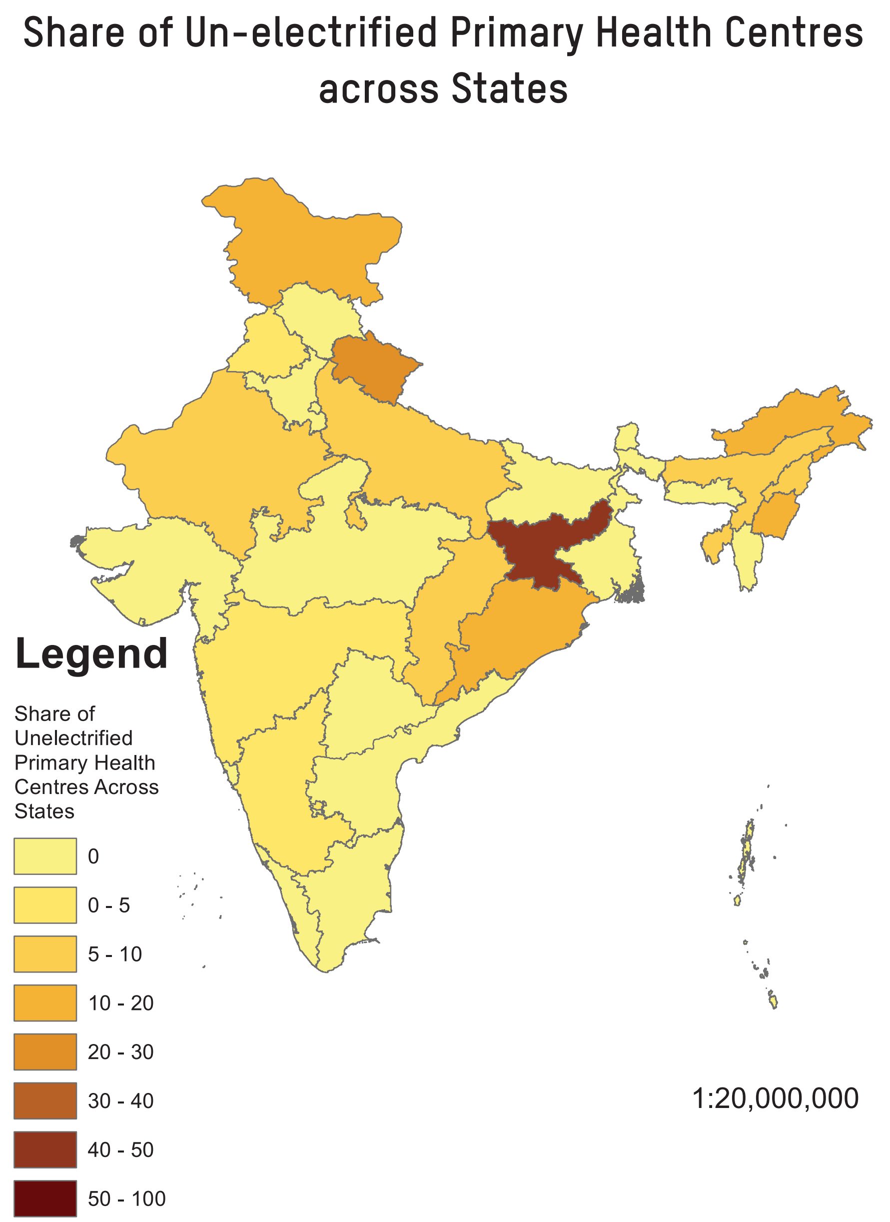
[1] Data sourced from the Ministry of Health and Family Welfare, Government of India.

[2] Every PHC on average caters to a population of about 30,000 in plain areas and a population of 20,000 in difficult, tribal and/or hilly areas (MoHFW, 2015).

Figure 1: Percentage of un-electrified PHCs across different states in India as on 31st March 2015



Source: CEEW Analysis based on India's Rural Health Statistics (MoHFW, 2015)

Even though the IPHS guidelines on facility level surveys lay emphasis on electricity access, information about the survey schedules, data and results regarding the unmet electricity needs of PHCs is currently unavailable in the public domain. There is a need to ensure that the state of electricity supply in PHCs is assessed in a systematic and periodic manner and the related information is made public for independent evaluation and assessment. While the facility level survey provided as part of the IPHS guidelines includes certain specific questions on electricity access, it fails to capture the multi-dimensionality of energy access. Efforts by WHO are underway to develop a comprehensive framework to assess energy access in healthcare facilities. It would be useful to adapt such ongoing efforts to the Indian context.

In case of health facilities, human resource, equipment and drugs are of prime focus, and access to energy is not given due priority (WHO, 2014b). However, access to reliable power supply is a key element for delivering effective healthcare services. In this regard, an understanding about the energy demands of PHCs and the gaps in power supply is crucial to devise and deploy alternative solutions in a timely manner.

2.2 Status of rural primary schools

India has a total of 1.45 million schools catering to primary, upper primary, secondary and higher secondary education, of which, 85.5 per cent are in rural areas. While only 60 per cent of schools in India are electrified, the share varies from 86.7 per cent in urban areas to 54.2 per cent in rural areas (NUEPA, 2015). This highlights both the poor state of electrification and a wide disparity between rural and urban schools.

The disparity related to electricity access grows further between the different categories of rural schools, as shown in Table 1. Primary schools, with the highest level being the 5th standard, are akin to the foundation or base of the pyramid in the education system in India. Even though primary schools[3] form the bulk of rural schools (62 percent), they seem to be given the lowest priority for school electrification. As per the statistics, every second rural primary school in India is un-electrified (see Table 1). This implies that around 32 million primary students in rural India attend schools lacking any form of electricity.[4]

Further, there is wide heterogeneity in the share of un-electrified rural primary schools across states (Figure 2). Lack of electricity access is most pronounced in the Eastern, North and North-Eastern states of India. In addition to having the highest share of un-electrified PHCs, Jharkhand also has the highest percentage of un-electrified

Table 1: State of electrification of different categories of rural schools in India)

Type of Schools	As a share of total rural schools (per cent)	Percentage of schools Electrified in each category
Primary Only	61.7	46.5
Upper Primary Only	11.0	46.0
Primary with Upper Primary	17.6	68.2
Primary with Upper Primary and Secondary	2.5	78.0
Upper Primary with secondary	3.2	86.8
Upper Primary with Sec. and Hr. sec.	2.4	93.7
Primary with Upper Primary, Secondary and Higher Secondary	1.6	92.6
All schools	100.0	54.2

Source: Adapted from NUEPA, 2015

rural primary schools (less than 8 per cent electrified). Appendix 2 provides the state-wise details on electrification of rural primary schools in India.

With regards to electricity access in primary schools, there appears to be a lack of policy focus. The discourse on school infrastructure in India is mostly limited to the number of classrooms, toilets and provision of drinking

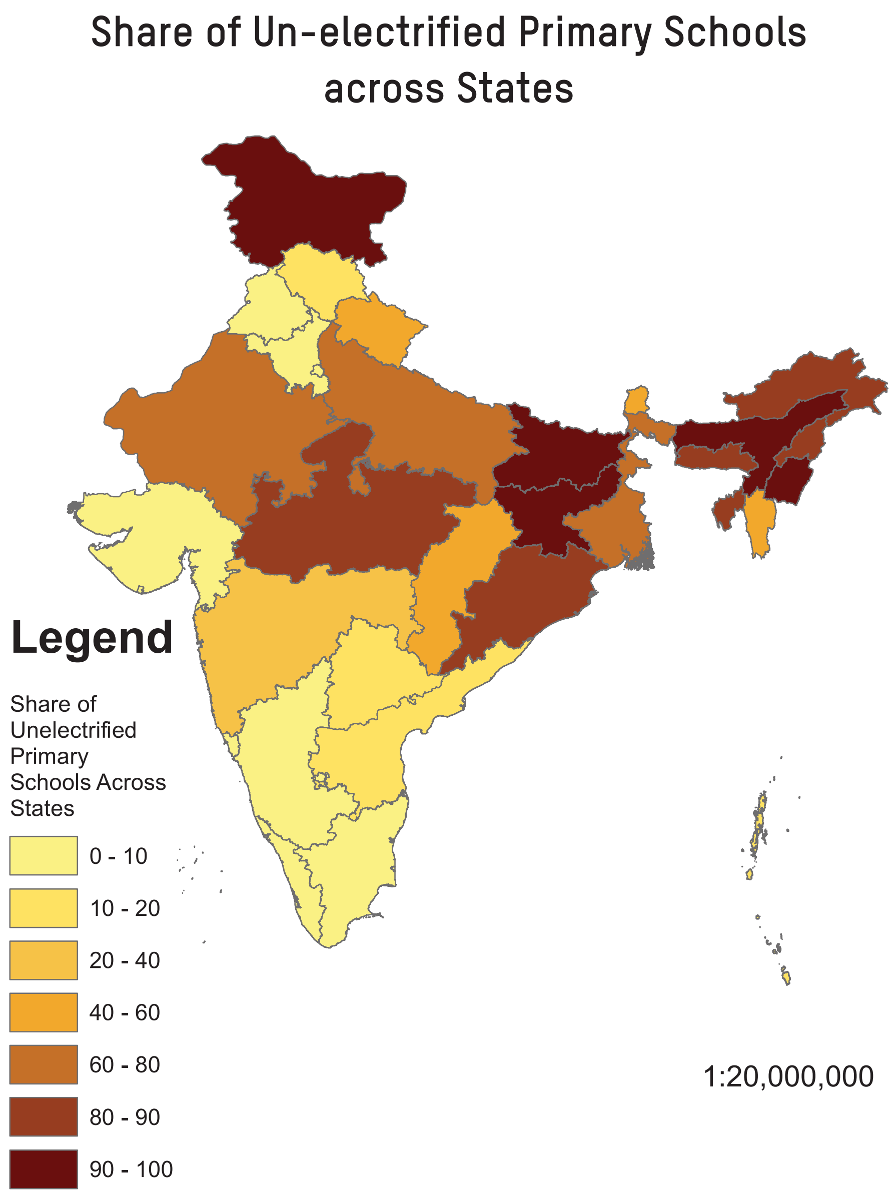
[3] Primary-only schools in case of this study

[4] Average number of classroom and student-classroom ratio in rural India in 2014-15 was 3.4 and 23, respectively (NUEPA, 2015)

water facility. Access to electricity, which is a critical aspect of school infrastructure (through lighting, ICT and water pumping services) has not been given the necessary policy alternatives. For instance, even though the infrastructure guidelines for primary, secondary and higher secondary schools mandate electrification of the premises, there is no provision to ensure compliance with the same or even monitor the progress of interventions being made (MHRD, 2014). The only information that is collected and made available in public domain is on the number of schools electrified.

Even for the electrified schools, the provision of a physical electricity connection does not guarantee access to meaningful power supply. In India, no efforts till date have been undertaken to understand the energy needs of schools or to assess the quality of power supply. In view of the importance of reliable and quality power supply in creating a conducive learning environment, there is a need to measure and bridge the existing energy deficit across rural primary schools in India.

Figure 2: Percentage un-electrified schools across different states in India as of September 2014



Source: CEEW Analysis based on NUEPA, 2015

3. Energy needs of PHCs and primary schools

As highlighted above, there is a lack of understanding about the energy needs of PHCs and primary schools in India, which is the crucial first step for assessing the gaps in energy access. As part of this study, the energy needs of both the PHCs and primary schools were estimated.

The energy needs of any health or education facility are directly related to the actual services consumed. This includes understanding indicative power requirements for (i) infrastructure, (ii) types of equipment required, their hours and number of days of operation, and, (iii) any support equipment, such as vaccine storage and computers (WHO, 2014a).

In order to estimate the actual energy requirements, facility level surveys would be required to gather information about i) the number of hours and days of operation of each equipment (electrical load), and, ii) the time of their use. In the absence of any detailed information on these parameters for PHCs and schools in the Indian context, reasonable assumptions for these on the basis of secondary literature and the mean hours for which these facilities operate were made (refer to Table 2 and Table 3). For the purpose of estimating daily power demand, it was further assumed that most devices are used simultaneously.

As a first step, reference building diagrams of a typical PHC and primary school facility in India were developed. These reference diagrams were used for estimating power requirements for lighting and space-cooling related to infrastructure needs. The reference diagrams for the PHC were those that have been provided in the Indian Public Health Standards (2012) document. For primary schools, reference diagrams based on the Guidelines of School Infrastructure and Strengthening (Civil Works) document were developed (MHRD, 2014). The lighting requirements were estimated using rules consistent with standard practice used by architects (Neufert, 2012). The reference diagrams for health and education facilities have been provided in Appendix 3 and Appendix 4, respectively.

For each of the facilities, a list of equipments along with their indicative power requirements to meet the prescribed service levels was developed, on the basis of secondary literature as well as expert interviews (refer to Appendix 5). Indicative power requirements were taken from the (WHO, 2014a) infrastructure survey.

3.1 Energy needs of a typical PHC

In terms of infrastructure, a PHC in India has a medical officers' room, nurses' room, laboratory, office, waiting room, immunization room, labour room, general store, gents ward, ladies ward as well as separate toilets for gents and ladies. We estimated that for a primary health centre, compliant with the IPHS norms, the peak power requirement (assuming that all the equipments and appliances are used simultaneously) would be about 7.5 kWp and the mean daily power requirement would be about 45.8 kWh/day (refer to Table 2 for details). Further, about three-fourths of the daily power requirement is concentrated during the daytime. In reality, many of the equipment and appliances are used in an intermittent manner, spread over the day and night time, which would imply a lower peak power requirement per PHC.

Table 2: Average load calculation for a Primary Health Centre										
Appliance	Total No.	Unit Power Consump-tion (W)	Total Power Consump-tion (W)	Hours of use (daily)	Days used Per week	Energy (Wh/day)	Day	Night	Day (Wh)	Night (Wh)
Tube lights	6	35	210	8	6	1680	0.8	0.2	1344	336
LED Lights	130	6	780	8	6	6240	0.8	0.2	4992	1248
Fans	14	75	1050	8	6	8400	0.8	0.2	6720	1680
Exhaust Fans	8	30	240	8	6	1920	0.8	0.2	1536	384
Halogen Lights	1	300	300	8	6	2400	0.8	0.2	1920	480
Mobile phone battery charging	5	5	25	8	6	200	0.8	0.2	160	40
Computer	3	160	480	4	6	1920	1	0	1920	0
Printer	1	100	100	4	6	400	1	0	400	0
Refrigerator (165 L)	2	200	400	24	7	9600	0.5	0.5	4800	4800
Autoclave (19 L)	2	1200	2400	2	6	4800	1	0	4800	0
Small water pump	1	100	100	4	6	400	0.8	0.2	320	80
Vaccine refrigerator	1	250	250	24	7	6000	0.5	0.5	3000	3000
Neonatal infant warmer	1	120	120	0.5	5	60	1	0	60	0
Centrifuge	1	350	350	1	6	350	1	0	350	0
Light Microscope	1	30	30	0.5	6	15	1	0	15	0
Portable Electro-cardiograph	1	30	30	6	6	180	1	0	180	0
Blood Glucose Monitor	1	1	1	4	6	4	1	0	4	0
Suction apparatus	2	100	200	1	6	200	1	0	200	0
Elisa Test Reader	1	500	500	2	6	1000	1	0	1000	0
Peak Power			7566							
Mean daily power consumption (Wh/day)					45769					
Mean daytime power consumption									33721	
Mean night-time power consumption									12048	

Source: CEEW Analysis
Note: Actual requirements in each PHC may differ from the analysis used here.
This is a representative calculation.

3.2 Energy needs of a typical rural primary school

A typical rural primary school has about three classrooms, a teacher's room, one activity room and separate toilets for boys and girls[5]. Each classroom is 66 square metre in size (MHRD, 2014) where the teacher to pupil ratio cannot exceed 1:40. It was estimated that for rural primary schools, the typical daily power consumption could be up to 25 kWh/day and peak power consumption up to 4.1 kWp (Table 3).

Table 3. Average load calculation for a rural primary school

Energy Requirement	No	Unit Power Consump-tion (W)	Total Power Consump-tion (W)	Hours of use (Daily)	Days used per (Week)	Energy (Wh/day)	Share of total daily (Consumption) per day
Tube lights	53	35	1855	6	5	11130	45
LED Lights	14	6	84	6	5	504	2
Fans	25	75	1875	6	5	11250	45
Computers	2	160	320	6	5	1920	8
UV Water Purifier	1	30	30	6	5	180	1
Peak Power			4164				
Mean daily power consumption (Wh/day)					24984		

Source: CEEW Analysis
Note: Actual requirements in each school may differ from the analysis used here.
This is a representative calculation.

The above calculations present a theoretical estimate for the typical energy requirements of a PHC or education facility. In reality, the energy demand would vary with several factors, such as the actual infrastructure of the school or PHC and the energy efficiency, time and hours of operation of the appliances. With improvements in technology, as more energy efficient appliances become available, power requirements may be significantly reduced. Another key factor is building design. Efficient building design could significantly reduce the demand for lighting as well as space heating and cooling. However, both appliance energy efficiency and building design were not factored into the current analysis.

In order to assess the actual and unmet energy needs, there is a need for precise information related to the infrastructure, appliances and consumption practices. This calls for institutionalising the facility level surveys and periodic assessment of the state of energy access across the PHCs and primary schools in India, as emphasised earlier in this study. The load estimation presented in the current chapter provides a segue into how the load requirements for both primary health centres and primary schools could be estimated. It also gives a preliminary understanding about the energy needs of these facilities, based on which alternative solutions such as decentralised solar power systems could be leveraged to fulfill the unmet energy demand.

[5] As of September 2014, rural primary schools in India reportedly have 3.4 classrooms on an average, and the share of such schools having boy's and girl's toilet is 94% and 83%, respectively (NUEPA, 2015)

4. Solar power - An opportunity to improve energy access in health centres and primary schools

In response to the general lack of energy access in many parts of the world, several innovative and decentralised solutions based on renewable energy (RE) technologies, particularly solar, have emerged. Many solar-based solutions such as solar suitcase, solar lanterns and rooftop solar systems are being deployed globally, to improve energy access in educational and health facilities. Developments such as fall in solar prices, availability of energy efficient appliances and market penetration of solar PV technology have made such solutions economically viable and accessible, even in remote areas. While there has not been a focused policy push towards electrifying PHCs and rural schools, the multiple associated co-benefits have been the major driver behind the adoption of solar solutions in the limited interventions that have been taken up.

4.1 Benefits of solar based electrification

Solar PV systems (grid connected or stand alone) with battery storage can provide reliable power supply on most days of the year, for un-electrified establishments and also mitigate the poor state of electricity supply in electrified PHCs and schools, at almost zero or marginal operating costs.

In the case of PHCs, solar systems range from small solar kits serving minimal electricity needs, such as lighting and communication devices, to large systems catering to almost all aspects of hospitals' electricity needs, from lighting and refrigeration to water pumping, equipment sterilization and use of advanced medical devices, are being used (WHO, 2014a). These varied solutions have been successful in facilitating timely and appropriate emergency care, night time deliveries, and availability of vaccines in remote areas by facilitating reliable power supply (TERI, 2015). Moreover, to a large extent, such solutions have benefited women and have contributed towards reduced maternal and infant morbidity and mortality (Harsdorff & Bamanyaki, 2009). Solar power has also benefitted medical staff by easing their work and improving their living conditions, and is likely to contribute towards attracting and possible retention of medical staff in rural health centres (Harsdorff & Bamanyaki, 2009).

Diesel generators, which have traditionally been used as a back-up or even as a primary source of power supply in PHCs, have become increasingly expensive to use. The high fuel costs and difficulties in securing fuel supplies have made solar solutions comparatively cost effective and attractive. Besides, solar power is a cleaner energy source, reducing the risks of air pollution for patients and medical staff as it does not emit local air pollutants, which have been associated with cardiovascular and respiratory diseases (World Health Organization, 2009).

Similarly, solar-based electrification of schools could create a conducive learning environment by facilitating lighting, improved ventilation and water for drinking and toilet uses, for students as well as teachers (Mahmud, 2010; UNDESA, 2014). Further, by ensuring access to reliable energy, solar power could contribute towards improved attendance of both students and teachers in the school, though it is not found to be a decisive factor (Laszlo, 2013). With battery back-up, solar power could also facilitate multiple shifts in schools, such as evening classes as well as computer aided learning (Magrath, 2015).

Until now, schools and health facilities have been dependant on the centralised grid for both their power connection as well as for quality and reliable supply. Solar power solutions bring with them an opportunity to decouple the state of education and health services from the state of electricity at the local level. Besides, solar power helps abate carbon emissions and pollutants associated with the use of fossil fuel based electricity and is, thus, benign for the health of both the environment and the people. Thus, deployment of solar power at primary schools and PHCs could help ensure access to reliable power for essential services in a timely as well as sustainable manner.

4.2 Experiences of solar-based electrification of PHCs and schools

On the back of growing evidence around multiple benefits of solar based electrification, decentralised solar power is increasingly being leveraged for bridging the energy gaps in the health care and education sector.

According to a recent study, 36 per cent of all health facilities in Sierra Leone, 15 per cent of all hospitals in Uganda and close to 50 per cent of all the public primary health clinics in Liberia rely on solar energy in combination with other electricity sources (Adair-Rohani et al., 2013; WHO, 2014a). Through its 'Solar Sector Programme', Bangladesh has planned to improve the state of electricity access in about 18,000 of its rural community health centres, by installing 50 MW worth of solar capacity. The country has also rolled out a programme on 'Solar Electrification in Remote Educational Institutes' for financing 40 MW capacity solar systems over remote schools. (SREDA, 2015). Similarly, Malaysia facilitates solar hybrid solutions in remotely located schools, under its 'Rural Solar Hybrid Electricity Project for Villages and Schools in the Interior' (Mahmud, 2010). Several other initiatives for electrification of schools through solar, such as Beijing's 'Sunshine Schools' Programme for installing 100 MW of rooftop solar systems, are aimed at tapping renewable energy, while simultaneously ensuring improved awareness about sustainable energy among students.

In India, the Tripura Renewable Energy Development Agency (TREDA) recently facilitated the electrification of 80 PHCs, 13 sub-divisional hospitals and many district hospitals through off-grid solar systems (Su-Kam, 2015). Thus, close to 90 per cent of PHCs in the North-eastern state of Tripura are currently powered by solar energy. Chhattisgarh Renewable Energy Development Agency (CREDA) has electrified around 542 primary and community health centres through solar PV systems, in the insurgency prone areas of the state (Shukla, 2013). In West Bengal, the state Environment Department, Renewable Energy Development Agency and Pollution Control Board have been implementing a project to install rooftop solar panels in more than 100 schools and primary health-care centres across the state (Chakraborti, 2015). In Andhra Pradesh, the Integrated Tribal Development Agency (ITDA) has been implementing a centrally funded scheme for installing 1 kWp capacity solar power packs in schools and PHCs in the state's remote tribal areas, as a back-up against erratic power supply (The Hindu, 2014b). Similarly, the Kerala government, under its Sustainable Urban Development Project, has planned to support deployment of 1 kW solar panels on its urban schools (Paul, 2014). Besides such state-led initiatives, municipalities (see Box 1), civil society organisations and multilateral institutions (see Box 2) have also led or supported deployment of solar for improving energy access in educational and health institutes, though at a smaller scale (Energy Access Practitioner Network, 2014; Fischer, 2014; MetroPolis, 2013; TERI, 2015; The Hindu, 2014a).

Box 1: Local government supports solar power for schools

The municipality of a remote town in Tamil Nadu, India, got 3kWp capacity rooftop solar power systems installed across 14 schools in the town. These systems produce enough energy during school hours to run fans and lights, and also help to operate motors to store water in overhead tanks for drinking and toilet use. The excess power generated is sent back to the grid and the schools benefit through the net metering system.

Source: (Fischer, 2014)

Box 2: Government of India and UNICEF supported solar power systems over 407 PHCs in Maharashtra

The government of Maharashtra, in support from the Ministry of Health and Family Welfare (MoHFW), Government of India and technical support from the United Nations Children's Fund (UNICEF), has deployed hybrid solar PV systems across 407 rural PHCs in the state. Hybrid solar PV systems have been deployed to provide uninterrupted power for existing cold chain equipment, critical electrical medical equipment and lighting load of PHC. These solar systems have allowed the doctors to respond to medical emergencies and use life-saving medical equipment such as resuscitation cap and phototherapy machine even during power cuts from the grid. Reliable solar power has improved the quality and availability of basic health services for the local community in these areas.

Source: (Energy Access Practitioner Network, 2014)

As is evident from the initiatives highlighted above, solar-based solutions extend an opportunity to provide reliable power supply and ensure effective delivery of community services. Such solutions have been deployed at scale across different countries and several impact assessment exercises have clearly established the utility of deploying decentralised solar power systems over schools and health centres.

However, in India, such initiatives have been mostly led by proactive action on part of some state agencies, backed by philanthropy or taken up as a pilot with no clear strategy for scale up. Of the deployments that have taken place, for instance in Chhattisgarh and Andhra Pradesh, few have been monitored and there is lack of information about their sustained use, quality of maintenance and servicing, and impact on intended outcomes. Even though in Odisha and Uttar Pradesh, the respective state governments have been planning to deploy solar PV systems on all the hospitals and health centres in order to ensure uninterrupted power supply, such plans have not moved forward (Khyati, 2010; The New Indian Express, 2012).

Given the increasing policy support for solar energy in India, there is an unprecedented opportunity for leveraging solar power for improving energy access in schools and PHCs.

4.3 Potential for deploying solar over PHCs and schools in India

Solar power solutions for PHCs and primary schools could improve the availability, reliability and quality of power supply, besides contributing towards a cleaner energy mix in the country. This section estimates the potential for deploying rooftop solar power systems for bridging the energy gaps in PHCs and rural primary schools.

As per our analysis in section 3.1, a typical PHC in India would have peak and daily mean power requirement of around 7.5 kW and 45.8 kWh/day, respectively (refer to Table 3 for details). If solar energy were to meet half of the PHC's daily power requirement, a rooftop solar system of 5 kWp would be required, which would also be adequate to meet 70 per cent or more of the PHC's peak power requirement (depending upon the use of equipment). Rooftop solar systems of 5 kWp capacity, if deployed across all the PHCs (30,762 as of November 2015) in India, would collectively amount to an installed solar capacity of 154 MW.

Similarly, it is estimated that rural primary schools in India would have peak and daily mean power requirement of about 4 kW and 25 kWh/day, respectively (refer to Table 4 for details). A rooftop solar system of 3 kWp could meet half of the daily power requirement and 70 per cent or more of the peak power requirement (depending upon the actual use of the different appliances). Rooftop solar systems of 3 kWp capacity, if deployed across all the rural primary schools (0.762 million as of September 2014) in India, would lead to an installed solar capacity of around 2,290 MW.

As per the official estimates, the rooftop solar PV potential for central government buildings under the Ministry of Health and Family Welfare and the Ministry of Human Resource Development is 45 MW and 497 MW, respectively (MNRE, 2015b). These estimates do not include PHCs and schools, which together offer an additional opportunity to deploy 2,444 MW of rooftop solar systems. Thus, collectively PHCs and rural primary schools could contribute towards 6 per cent of the 40 GW rooftop solar target of the country. This is a significant share of the solar potential, which can be tapped, while extending the benefits of improved energy access for the last mile delivery of community services.

5. Locating health and education within India's solar priorities

As stated in the previous section, solar energy could help bridge the energy gaps in health and education in India. However, this would require an alignment between energy, health and education policies. This chapter looks at some of the policy gaps that need to be addressed, in order to leverage solar power for meeting the energy gaps in rural health and education facilities. Under the Jawaharlal Nehru National Solar Mission (JNNSM), India recently quintupled its target of installed solar power capacity to 100 GW by 2022. The revised mission has a strong emphasis on decentralised systems and envisions installation of 40 GW of rooftop solar power systems on residential, community, institutional, industrial and commercial establishments (MNRE, 2015a).

In order to promote installation of solar rooftop systems, the Ministry of New & Renewable Energy (MNRE) is implementing two national level programmes: (i) Grid-Connected Rooftop and Small Solar Power Plants Programme, and, (ii) Off-Grid and Decentralized Solar Applications (MNRE, 2015c). Under these, the Ministry provides a capital subsidy worth 30 per cent of the benchmark costs for general category states, and 70 per cent and 90 per cent for grid-connected and off-grid solar systems, respectively, for certain states[6]. Further, to facilitate the uptake of grid-connected rooftop solar systems, several other measures have been devised. These include loans at concessional terms from the Indian Renewable Energy Development Agency Limited (IREDA), inclusion of rooftop solar systems in the proposals for home loans, priority sector lending for renewable energy, tax-holidays, and concessions in customs duty on import of certain equipment (IREDA, 2015; Ministry of Finance, 2014; MNRE, 2015a; RBI, 2015).

While the target and measures to achieve it seem promising, these have been unable to stimulate the uptake of rooftop solar solutions by primary schools and PHCs at significant scale, for several reasons.

First, there is a lack of awareness around the importance of electricity access in schools. In case of PHCs, even though electrification is recognised as essential to service delivery, it is lower in priority amongst competing demands for human resource, medicines and equipment.

Secondly, there is a lack of recognition about the potential opportunity that solar power offers for meeting the electricity needs of PHCs and schools and the multiple co-benefits of such an approach. As a result, the incentives for promoting rooftop solar capacity are more suitable for households, commercial and industrial segments and are not tailored to the institutional arrangement within which rural schools and PHCs exist.

Thirdly, even though there is an ongoing scheme for off-grid solar applications, the current policy focus is tilted towards grid-connected rooftop solar systems, as is evident from the several support schemes such as home loans, concessional loans, and tax-holidays which are dedicated only for grid-connected systems. As a result, these supportive measures would not be available for off-grid systems and hence, by extension for a significant proportion of primary schools in India, which are un-electrified.

Fourthly, the current policy is driven by the objective of achieving a fast paced increase in cumulative installed solar capacity. For instance, the state governments of Haryana and Uttar Pradesh have made it mandatory for all

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[6] These include Islands of Andaman & Nicobar and Lakshadweep and special category states (Jammu &Kashmir, Himachal Pradesh, Uttarakhand).

buildings larger than 5000 square feet, to install rooftop solar power systems, with the objective of reducing the pressure of power demand on the grid, and thereby ease operations of power distribution companies. There is a lack of emphasis on maximizing the utility of solar power installations by targeting them in energy deficit areas and sectors. Further, due consideration has not been given to monitoring the performance of the rooftop solar systems that are being installed. This would be of particular concern in the case of community institutions, where the responsible entities have no incentive for repair and maintenance of the systems and the enforcement mechanisms are often weak.

Fifthly, the necessity of co-ordinating with multiple institutions involved in the decision making, funding and implementation of electrification of PHCs and schools has acted as a key barrier in adoption of solar power solutions. As per the division of powers and responsibilities between central and state governments in India, health and education are state subjects, while electricity is a concurrent subject. Thus, ensuring electrification of public schools and PHCs is the responsibility of the education and health departments of a state government, respectively. These in turn get a major share of their funds from the respective departments of the central government, under pre-decided subject heads for disbursement of funds. On the other hand, the incentives for solar powered systems are disbursed by the Renewable Energy Development Agencies (REDAs) at the state level and Ministry of New and Renewable Energy (MNRE) at the national level. Further, in the case of tribal areas, Tribal Area Development Agencies (TADAs) are responsible for implementation of schemes in each state. Thus, the involvement of multiple agencies, lack of coordination across line departments and absence of clear guidelines or a roadmap to be followed in order to leverage solar solutions for electrification of PHCs and schools, have limited the scale-up of such an approach.

As discussed in the last section, only few states in India have deployed solar-power solutions over schools and health facilities, and more often than not, these have been led by the respective REDAs of the states. It should be noted that the priorities and actions of REDAs are governed by the priorities of the JNNSM, which is to achieve the target of 100 GW of installed solar capacity. It is the state education and health agencies, which are best placed and have the capacity to understand the energy requirements of schools and PHCs, respectively. Therefore, their leadership and involvement in planning and implementation of any rooftop-solar programme would be imperative, to ensure that such systems further the health and education objectives effectively. It is also important to recognise the need to shift the policy focus towards off-grid solar systems for meeting the energy needs of un-electrified public facilities, particularly the schools and PHCs, which provide key developmental services for the community at large.

6. Conclusion

In India, the provision of public services such as health and education are impeded by the poor state of electrification. This is further hampered by poor reliability of grid based power. While several efforts to reform the power sector in India are currently underway, given the complexity of the challenges, the reforms are unlikely to have their full impact within a short time frame. Until then, there is a need to ensure that the unmet energy needs of health and educational institutions, especially those involved in last mile delivery, are addressed in a timely fashion.

In order to address the energy deficit for community services such as healthcare and education, the current policy debate around energy access in India needs to move beyond households' basic energy needs. This study estimates that a typical PHC (as per IPHS norms) and rural primary school in India have mean daily power requirement of around 45.8 kWh/day and 25 kWh/day, respectively. Accordingly, solar power systems of 3 kWp and 5 kWp could meet 50 per cent of mean daily and at least 70 percent of daily peak power requirement of rural primary schools and PHCs, respectively. If deployed across the country, such rooftop solar systems would collectively amount to an installed solar capacity of more than 2,400 MW and contribute towards 6 per cent of India's 40 GW rooftop solar target. In India, few states have witnessed solar-based electrification of PHCs and schools; however, a strategy for scale up is missing.

As India traces a path towards 100 GW of installed solar capacity, there is an opportunity to maximise the utility of solar power solutions by deploying these in energy deficit areas, for public services such as health and education. Recognition of such opportunities at the policy level, a clear roadmap for deployment, and cross-sectoral coordination between national and state level agencies could ensure that solar power can bridge the energy gaps in India's health and education facilities.

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Appendices

Appendix 1

State-wise details on electrification of PHCs in India				
State/UT	No of PHCs functioning	No of Un-electrified PHCs	Share of PHCs without electricity (percent)	Share of PHCs complaint with IPHS norms (percent)
Andhra Pradesh	1,069	0	0	100
Arunachal Pradesh	117	22	18.8	0
Assam	1,014	90	8.9	0
Bihar	1,883	0	0	0
Chhattisgarh	792	70	8.8	0
Goa	21	0	0	100
Gujarat	1,247	0	0	28.7
Haryana1	461	0	0	1.7
Himachal Pradesh	500	0	0	0
Jammu & Kashmir	637	81	12.7	0
Jharkhand	327	139	42.5	0
Karnataka	2,353	40	1.7	0
Kerala	827	0	0	0
Madhya Pradesh	1,171	0	0	0
Maharashtra	1,811	36	2	38.3
Manipur	85	13	15.3	0
Meghalaya	110	0	0	0
Mizoram	57	0	0	0
Nagaland	128	7	5.5	0
Odisha	1,305	141	10.8	0
Punjab	427	3	0.7	0
Rajasthan	2,083	130	6.2	26.6
Sikkim	24	0	0	95.8
Tamil Nadu	1,372	0	0	92.6
Telangana	668	0	0	100
Tripura	91	7	7.7	56
Uttarakhand	257	67	26.1	27.6
Uttar Pradesh	3,497	213	6.1	4.9
West Bengal	909	48	5.3	24.5
A& N Islands	22	0	0	95.5
Chandigarh	-	0	0	0
D & N Haveli	7	0	0	100
Daman & Diu	3	0	0	66.7
Delhi	5	0	0	100
Lakshadweep	4	0	0	100
Puducherry	24	0	0	100
All India	25,308	1,107	4.4	20.7

Source: MoHFW, 2015

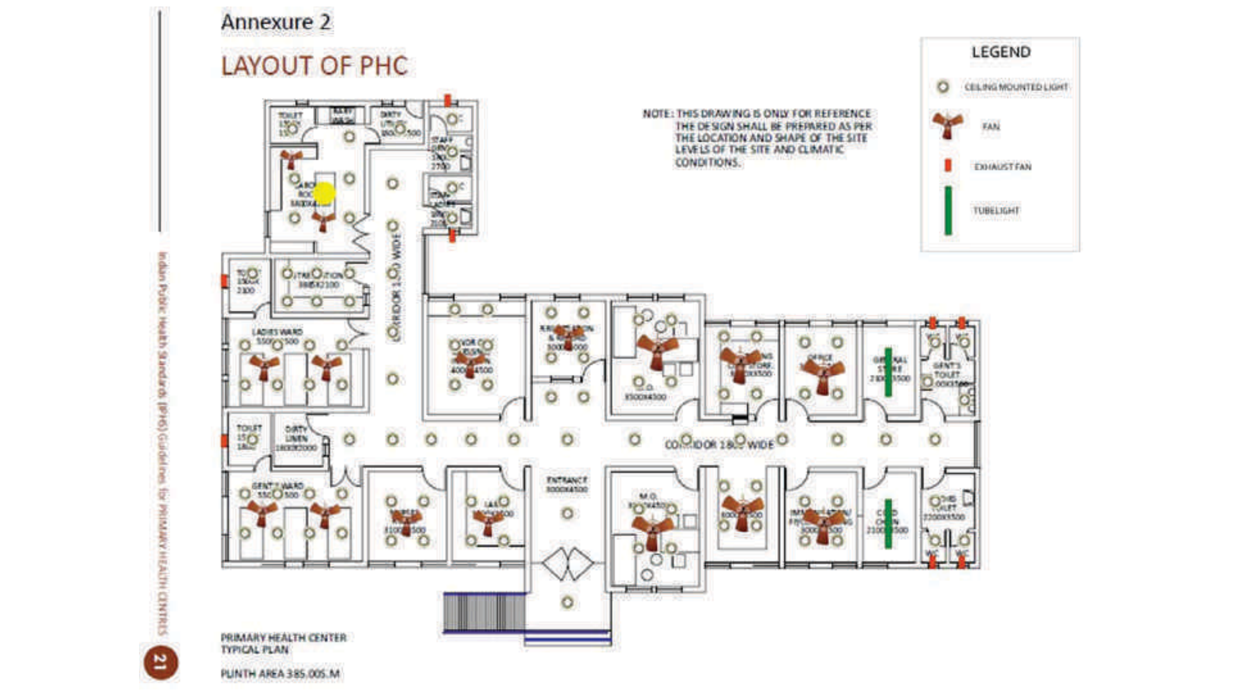
Appendix 2

State-wise details on electrification of rural primary schools in India		
State/UT	Total number	Percentage un-electrified
A & N Islands	213	20.19
Andhra Pradesh	35,132	9.26
Arunachal Pradesh	2,213	80.7
Assam	46,786	90.1
Bihar	40,424	86.99
Chandigarh	-	0
Chhattisgarh	32,813	41.07
Dadra & Nagar Haveli	163	3.07
Daman & Diu	43	0
Delhi	117	0
Goa	809	1.24
Gujarat	10,564	0.8
Haryana	8,595	1.45
Himachal Pradesh	11,064	6.07
Jammu And Kashmir	13,681	90.08
Jharkhand	26,515	92.66
Karnataka	23,237	2.67
Kerala	7,255	5.54
Lakshadweep	14	0
Madhya Pradesh	82,754	90.89
Maharashtra	46,648	10.06
Manipur	2,736	90.68
Meghalaya	8,893	86.83
Mizoram	1,162	43.46
Nagaland	1,327	83.65
Odisha	34,530	87.55
Pondicherry	159	0
Punjab	12,852	0.14
Rajasthan	38,135	85.84
Sikkim	675	42.52
Tamil Nadu	28,138	2.38
Telangana	19,949	13.53
Tripura	2,414	87.99
Uttar Pradesh	1,40,229	52.26
Uttarakhand	14,605	29.76
West Bengal	67,528	51.5
All States	7,62,372	53.46

Source: Adapted from NUEPA, 2015

Appendix 3

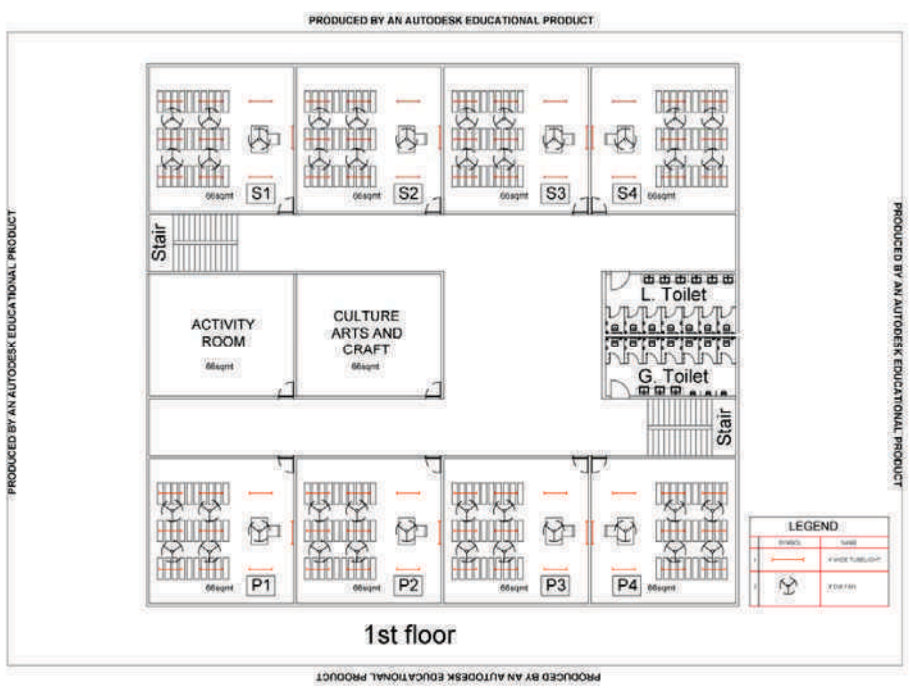
Reference diagram of Primary Health Center



Source: Adapted from design specifications as per MoHFW, 2012

Appendix 4

Reference diagram of a Secondary School



Source: Adapted from design specifications as per MHRD, 2014

Appendix 5

Table 2. List of Equipment	
Equipment	Indicative Power Rating (W)
Tubelights	30 - 50 W
LED Lights	~1.8 - 2.14 W/m2
Fans	50 - 100 W
Exhaust Fans	30 - 40 W
Halogen Lights	250 - 400 W
Mobile phone battery charging	5 - 20 W
Computer	50 - 200 W
Printer	65 - 100 W
Refrigerator (165 L)	150 - 200 W
Autoclave 19 L (sterlization)	1200 - 1400 W
Small water pump	50 - 200 W
Vaccine refrigerator	115 - 370 W
Neonatal infant warmer	125 - 550 W
Centrifuge	250 - 400 W
Light Microscope	20 - 30 W
Portable Electrocardiograph	1.2 W
Blood Glucose Monitor	1 W
Suction apparatus	90 - 200 W
Elisa Test Reader	500 - 650 W

Source: Adapted from (WHO, 2014a)

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