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Impact of Quality of Electricity Access on Health & Education Delivery

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About The authors

Dr. Jyoti Parikh
(jparikh@irade.org)

Dr. Jyoti Parikh is the Executive Director since the inception of IRADe in 2002. She was a member of the Prime Minister's Council on Climate Change –India and is a recipient of Nobel Peace Prize awarded To IPCC authors in 2007. She has more than 40 years of experience with expertise in gender and energy access, poverty alleviation, environment and climate change. She has made valuable contributions in this field. She holds a PhD from the University of Maryland, College Park.

Dr. Ashutosh Sharma
(asharma@irade.org)

Dr. Ashutosh Sharma is the Area Convenor at IRADe and had worked on projects related to energy access, climate change, macroeconomics, poverty and gender, health and education. He did his PhD from Mumbai School of Economics and Public Policy, University of Mumbai. He has more than 15 years of experience with expertise in gender and energy access, poverety alleviation, climate change, and agriculture.

Dr. Chandrashekher Singh
(chandrashekhar@irade.org)

Dr. Chandrashekhar Singh is a Senior Research Analyst at IRADe. His research focuses on energy access, fossil fuel subsidies reform, gender and related policy issues. He is also working in the area of agriculture and climate change. He did PhD in Macroeconomic Implications of Capital Flows in India and M.A.in Economics from the Gokhale institute of Politics and Economics, Pune in June 2006. He has more than 16 years of experience with expertise in gender and energy access, climate change, and agriculture.

Saumya Vaish
(svaish@irade.org)

Ms. SaumyaVaish is a Research Associate at IRADe. Currently she is associated with projects on the impact assessment of energy access, clean cooking research, energy and gender. She did Masters in Environment Management from Guru Gobind Singh Indraprastha University and is a Delhi University graduate in Botany Hons. She has more than 3 years of experience in gender and energy access.

Dr. Mohit Kumar Gupta
(mohitgupta@irade.org)

Dr. Mohit Kumar Gupta is a Project Analyst at IRADe.His did B.V. Sc. and M.Sc. in Environmental Sciences and PG Diploma in Rural Development. He is presently working on projects related to renewable energy, impact of energy access on health and education, electric cooking, environment and climate change& health . He has more than 10 years of experience with expertise in renewable energy projects, energy resource planning, renewable energy, gender and energy access environment and climate change urban development.

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1. Introduction

Health and education are the two important pillars of human resource development fundamental to the development process. Better education and better health are important goals in themselves. Each can improve an individual's quality of life and their impact on others. Access to quality education and healthcare services are of great importance and can have a transformative effect on socio-economic development.

The United Nations sustainable development accorded a very high priority to good health and well-being and quality education. Good health care and well-being (SDG 3) require expanded access to skilled care, essential medicines, and remedial technologies to treat diseases and health conditions. In addition to this, providing a quality electricity supply is crucial in powering all the medical services. It enables uninterrupted availability of modern healthcare service delivery; therefore, strengthening electricity supply at health centres is vital to achieving health-related SDG. SDG 4, quality education although has gained significant interest from government and development organizations, huge gaps exist in educational service delivery (Welland, 2018). Among the schools' multiple and diverse challenges, providing quality energy can successfully improve educational access to students and enhance teachers' overall experience at schools (*ibid.)*.

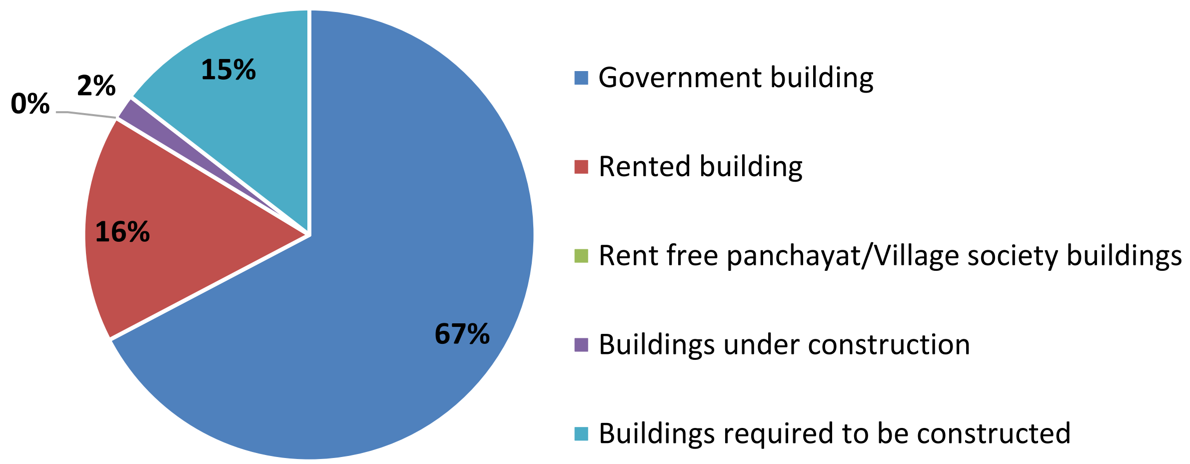


Figure 1: Status of the buildings of the health centres in Bihar

Source: Rural Health Statistics, 2018

India's outlook as an emerging economic superpower is being challenged, including failure to provide basic amenities such as education and health to the bulk of its population (Anand, 2014). Bihar is home to nearly 10 percent of India's population. Total fertility rate (TFR) for Bihar in 2018 was 3.2 in comparison to the India TFR of 2.2 and a low literacy rate 63.82 percent (GoI, 2018; Census, 2011). The state ranks poorly on education and health-related indicators. In the latest report on SDG India Index developed by NITI Aayog, Bihar occupies the bottom position in the state ranking for SDG 4 (Quality education) and remains in the bottom 10 states for SDG 3 (Good health and wellbeing) (NITI Aayog, 2021).

Rural Health Statistics report, 2018-19 highlights 100% electrification of the PHCs/CHCs in Bihar. However, available statistics on electricity access do not provide information regarding the quality of access. Energy is required to operate a spectrum of services at health centres ranging from basic lighting, cooling to advanced services, including vaccine storage and medical equipment. Even if the public centres have modern equipment and health staff, unreliable electricity can adversely impact the overall service performance.

Power cuts adversely affect health facilities' operations, like reduced deliveries, lower-skilled birth attendants, and increased home births (Koroglu et al., 2019). Thus, defining the essential energy demands that cover all the aspects of health service delivery needs to be undertaken with the utmost attention.

On the educational front, the literacy rate in Bihar is 63.82% (Census, 2011). The statistics reveal that out of the total schools in Bihar, 61.45% of the government-run schools are electrified (UDISE, 2018). Integrated science laboratories and functional libraries are accessible at 31.81% and 69.49% of the secondary schools in the state (*ibid.*). The efficient working and service delivery of such facilities gets affected in the absence of regular electricity.

With modern energy, the schools can much better serve the needs of students and teachers by providing educational facilities including ample lighting, computers, information and communication facilities, audio/visual equipment, clean water, hygienic toilets. Without access to electricity, modern quality education that can positively impact the children and quality of teaching cannot be delivered (Zhang *et al.*, 2019*)*. It might be argued that to reap the benefits of 'demographic dividend' by harnessing the potential of younger generations, access to quality electricity becomes quintessential for development. Existing literature indicates that rural electrification improves education, income, and household productivity. (World Bank, 2002).

The available literature states the linkages and importance of uninterrupted electricity in various sectors. Still, limited secondary data is available on different attributes that determine the power supply quality, such as reliability and affordability. This study aims to bring out the current status of energy access at the health and education community infrastructures in Bihar. In addition, the study seeks to tap into the problems arising from the lack of quality power supply at community centres and suggest measures to improve it.

1.1 Rationale of the study

It is critical to understand the status of electricity access in PHCs/CHCs and Schools, focusing on the quality and consistency of electricity supply. Reliable electricity services have roles to play in providing primary and community health and education services delivery.

The study brings out the status of electricity supply at PHCs/CHCs and schools in rural and peri-urban areas of Bihar regarding access, reliability, quality, convenience, and usage. Due to the COVID-19 pandemic and the reverse migration of workers to their native places, these public facilities had to bear an additional burden to serve these additional people. This all placed an additional higher demand on the community institutes like health centres and schools. We classify the quality of supply in terms of six tiers as per the multi-tier framework of the ESMAP and evaluate the availability of enabling infrastructure and equipment in PHCs/CHCs and schools using "tracer indicators. "These are used to measure patients, staff, and students' satisfaction with the health and school services. The electricity supply sources are also analysed to understand renewable energy's role in meeting these facilities' electricity requirements. The primary objectives of the study are as follows:

- To assess the quality of electricity supply at PHCs/CHCs and government schools using the multi-tier framework (MTF) of energy access.
- To study the reasons for inadequate electrification of PHCs/CHCs and schools, if any.
- To assess the service readiness of PHCs/CHCs and government schools regarding infrastructure and equipment availability.
- To assess the impact of electricity access in PHCs/CHCs on health care service delivery; patients, and staff satisfaction.
- To assess the impact of electricity access in schools on educational service delivery, students, and staff satisfaction.

2. Methodology

2.1 Study design

The study was carried out in three districts of Bihar and across 15 blocks. With the view that the capital district of the state may have better health and educational infrastructure, Patna was selected as one of the districts for this study. Being the state capital of Bihar, health centres and government schools in Patna may have more reliable electricity access. Apart from Patna, the remaining districts of Bihar were categorized into two groups (i) aspirational districts as per the NITI Aayog, Government of India, and (ii) other set of districts. We randomly selected one district from each of these two groups, namely Gaya, from the list of aspirational districts and Lakhisarai from other districts.

Further from each of the selected districts, we randomly selected five blocks each. In each chosen block, we visited the PHC/CHC; in a block, there is either a PHC or a CHC. Based on the available secondary data and knowledge gained during official visits, we selected one government-run senior secondary school from the rural/peri-urban area in each block to conduct the primary survey. The present study tried to adequately capture the geographical diversity and status of electricity access at health centres and schools in the selected districts of Bihar.

COVID- 19 pandemic delayed the field activity to collect the primary data for this study. The research team visited 15 PHCs/CHCs and 15 schools across the three selected districts starting from December 2020 onwards. Schools were opened from January 4, 2021, for the students of 9th to 12th classes. Structured questionnaires were prepared separately for (i) PHCs/CHCs, (ii) schools, (iii) patients/non-patients visiting surveyed PHCs/CHCs and (iv) students at the surveyed schools. PHC/CHC and school questionnaires' structure captured the availability of equipment, staff, and several attributes of energy access as per the multi-tier framework (MTF). The patient/non-patients and student questionnaires captured the quality-of-service delivery and the overall perception of patients and students at health centres and schools, respectively.

2.2 Primary survey and interviews

The survey team followed the COVID guidelines prescribed by the local administration, including social distancing, protective masks, and gloves, while surveying schools and PHCs/CHCs. The team was trained thoroughly to follow all precautionary measures while collecting data temperature of the surveyors was recorded daily before and after the survey. Due to COVID concerns, enumerators had to restrict physical verification of infrastructure and visited the safe areas to list equipment availability at health centres and schools. Since open discussion among interest groups increases the chance of obtaining credible and relevant information and challenges biased or incomplete answers by group dynamics. Focused group discussions were conducted at selected PHCs/CHCs and schools to gain perspectives about the issues and situations, including gaining insights from shared understandings.

At each selected PHC/CHC, we selected 5 patients and 5 non-patients (patient relatives) for the survey. The structured schedule collects preliminary information on the accessibility of health care services, comfort level during treatment, quality of routine services, and patient preference for treatment at PHCs vis-a-vis other private health centres. Therefore, we surveyed 75 (15*5) patients and 75 (15*5) non-patients in Bihar across 15 PHCs/CHCs. At each school, 10 students were randomly surveyed to gauge the overall student satisfaction level. The team interviewed a total of 150 (15*10) students. Through student surveys, we tried to understand teaching-learning resources, learning opportunities, assessment and feedback, academic support, water sanitation facility, and comfort in the classroom.

2.3 Data collection and analysis

The primary data was collected using the computer-assisted personal interviewing (CAPI) software, where the enumerators used an electronic device to capture the response. Before starting the field survey, multiple virtual training sessions followed by dummy data collection sessions were conducted for the surveyors to make familiar with the data collection techniques and platform to avoid any chances of error in data collection. The data collected on the field was securely uploaded and saved on the main server with the web interface. The incoming data was monitored regularly for quality checks and to streamline the seamless information flow between the frontline and backend teams. The primary surveys and group discussions generated quantitative and qualitative responses. Quantitative responses produce data in numbers while qualitative data provided a picture of the non-numerical aspects. The quantitative data generated were analysed using MTF measurement and tabular analysis, whereas qualitative data were analysed to interpret the pattern of respondent's perceptions. For this, we developed two different multi-tier frameworks based on the knowledge gathered from desktop research and field visits. The MTF analysis of PHCs/CHCs corresponded to Table 1 (see Appendix 1) with 24x7 energy requirements. Since the non-residential schools are operational only during the day timings for a maximum of 6- 8 hours each day, we linked the MTF analysis for such schools to Table 2 (refer to Appendix 1). The data analysis provided information to evaluate the existing power supply sources at the PHC/CHC and school and the role of electricity access in improving service delivery quality.

2.4 Data description

Delivery of health care in India comprises a three-tier structure of health services, including a Sub-centre (SC), a Primary Health Centre (PHC), and a Community Health Centre (CHC) as a referral centre. The present study collected data from 5 PHCs and 10 CHC/referral hospitals in three districts of Bihar. Tables 1, 2, and 3 summarise the infrastructure and service readiness of surveyed health facilities in terms of energy access, availability of essential equipment, and pathology services.

Table 1 Infrastructure and electricity access at health centres

District	Block	Service availability 24x7	Population covered (in '000')	No. of Beds	No. of Patient treated in previous calendar month#	Access to grid	Secondary source of electrical energy	Sufficient backup power from secondary source
Gaya	Konch**	Y	42	30	1703	Y	Generator	Y
	Tekari**	Y	311	76	4159	Y	Generator	Y
	Manpur**	Y	186	30	2856	Y	Generator	Y
	Wazirganj**	Y	271	30	3242	Y	Generator	Y
	Bodhgaya**	Y	168	35	3398	Y	Generator	Y
Patna	Fatuha**	Y	230	30	3303	Y	Generator	Y
	Khusrupur*	Y	124	8	878	Y	Generator	Y
	Bikram*	Y	176	6	1094	Y	Generator	Y
	Dhanarua**	Y	243	30	1868	Y	Generator	Y
	Athamalgola*	Y	98	6	799	Y	Generator	N
Lakhisarai	Pipariya*	Y	58	6	821	Y	Inverter	N
	Halsi**	Y	116	30	1449	Y	Generator	Y
	Ramgarh chowk*	Y	107	6	893	Y	Inverter	Y
	Surajgarha**	Y	349	30	3185	Y	Generator	N
	Barhiya**	Y	374	28	1944	Y	Generator	Y

Y= Yes, N=No
* PHC **CHC/Referral hospital
# Sum of patients treated in the past 30 days for emergency service, minor surgery, poisoning, fractures, wounds, ante-natal care, intra-natal care, post-natal care, new-borns, child-immunization and tubectomy/vasectomy.

Source: IRADe primary survey

Table 2 Availability and functioning of equipment at health centres

District	Block	Refrigerator		Ice-lined Refrigerator		Oxygen cylinder		Baby warmer		Phototherapy unit		Suction machine		Computer		X-Ray machine		Ultrasound machine		ECG	
		A	F	A	F	A	F	A	F	A	F	A	F	A	F	A	F	A	F	A	F
Gaya	Konch**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	*	N	*
	Tekari**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	*	N	*
	Manpur**	Y	Y	Y	Y	Y	Y	Y	Y	N	*	Y	Y	Y	Y	N	*	N	*	N	*
	Wazirganj**	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	*	N	*	N	*
	Bodhgaya**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*	N	*
Patna	Fatuha**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*	N	*
	Khusrupur*	Y	Y	Y	Y	Y	Y	Y	Y	N	*	Y	Y	Y	Y	Y	N	N	*	N	*
	Bikram*	Y	Y	Y	Y	Y	Y	Y	Y	N	*	Y	Y	Y	Y	Y	Y	N	*	N	*
	Dhanarua**	Y	Y	Y	Y	Y	Y	N	*	N	*	Y	Y	Y	Y	N	*	N	*	N	*
	Athamalgola*	Y	Y	Y	Y	Y	Y	Y	Y	N	*	Y	Y	Y	Y	N	*	N	*	N	*
Lakhisarai	Pipariya*	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	*	N	*	N	*
	Halsi**	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N
	Ramgarh chowk*	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	N	N	N
	Surajgarha**	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N
	Barhiya**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N

A=Available, F=Functioning, Y= Yes, N=No and * = Not applicable
* PHC **CHC/Referral hospital
Source: IRADe primary survey

Table 3 Availability and functioning of pathology services at health centres

District	Block	Pathology laboratory available	Adequate chemicals available	Blood test		Sputum test		Malaria test		Pregnancy test		HIV test		Dengue test	
				A	F	A	F	A	F	A	F	A	F	A	F
Gaya	**Konch****	Y	Y	N	*	Y	Y	Y	Y	Y	Y	Y	Y	N	*
	Tekari**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Manpur**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Wazirganj**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*
	Bodhgaya**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*
Patna	**Fatuha****	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Khusrupur*	Y	Y	N	*	N	*	N	*	Y	Y	Y	Y	Y	Y
	Bikram*	Y	Y	Y	Y	Y	Y	N	*	Y	Y	N	*	N	*
	Dhanarua**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	*
	Athamalgola*	Y	N	N	*	N	*	N	*	Y	Y	Y	Y	Y	Y
Lakhisarai	**Pipariya***	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*
	Halsi**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	*
	Ramgarh chowk*	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Surajgarha**	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Barhiya**	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

A=Available, F=Functioning, Y= Yes, N=No and * = Not applicable
* PHC **CHC/Referral hospital
Source: IRADe primary survey

The study covered a total of 15 higher secondary schools in 3 districts of Bihar. The survey focused on the availability of infrastructure, emphasizing electricity supply in school, which supports education and adds to students' convenience and comfort and other school staff. Table 4 below highlights the surveyed schools' primary attributes, such as student classroom ratio (SCR), pupil-teacher ratio (PTR), and status of energy access. Table 5 summarises the facilities available for students in these schools.

Table 4 Student-classroom ratio, Teacher-pupil ratio and energy access status in schools

District	Block	Enrolled students	Classrooms in use	Dilapidated classrooms not in use	Student Classroom Ratio (Only for used classroom)	No. of teachers	Pupil-Teacher Ratio (PTR)*	No. of Desks & benches	Access to grid	Secondary source of electrical energy	Sufficient backup power from secondary source
Gaya	**Konch**	320	12	0	27	8	40	60	Y	None	N
	Tekari	1131	9	4	126	13	87	135	Y	Generator	N
	Manpur	841	13	0	65	12	70	300	Y	Inverter	Y
	Wazirganj	460	12	2	38	9	51	60	Y	None	N
	Bodhgaya	110	9	3	12	2	55	50	Y	None	N
Patna	**Fatuha**	2128	25	0	85	22	97	350	Y	Inverter	N
	Khusrupur	3075	12	0	256	20	154	250	Y	Inverter	Y
	Bikram	2140	13	12	165	24	89	350	Y	Inverter	N
	Dhanarua	579	11	0	53	15	39	400	Y	Generator	Y
	Athamalgola	1468	12	0	122	18	82	165	Y	Inverter	Y
Lakhisarai	**Pipariya**	493	20	0	25	17	29	180	Y	Generator	Y
	Halsi	732	14	0	52	10	73	120	Y	None	N
	Ramgarh chowk	552	5	10	110	17	32	25	Y	None	N
	Surajgarha	750	7	0	107	11	68	150	Y	Inverter	N
	Barhiya	2282	37	3	62	18	127	500	Y	Inverter	Y

The Right of Children to Free and Compulsory Education (RTE) Act, 2009, prescribes that the Pupil-Teacher Ratio (PTR) should be maintained at the school level at 30:1 and 35:1 at primary and upper primary level, respectively. The highlighted ratios represent schools with higher STR and PTR than the standard ratio provided by the government.

Source: IRADe primary survey

Table 5 Facilities for students in the schools

	Block	Blackboards available in classrooms	Lights available in all classrooms	Fans available in all classrooms	Functional library for students	Lights in library	Fans in library	Computers available for students	Computers functional	Computers connected to internet	Television for students	Functional science laboratory	Lights available in science laboratory	Fans available in science laboratory	Toilets for students	Lights in toilet
Gaya	**Konch**	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N
	Tekari	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N
	Manpur	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
	Wazirganj	Y	Y	Y	N	N	N	N	N	N	Y	N	N	N	Y	N
	Bodhgaya	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N
Patna	**Fatuha**	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N	N
	Khusrupur	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y
	Bikram	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Dhanarua	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
	Athamalgola	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lakhisarai	**Pipariya**	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
	Halsi	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
	Ramgarh chowk	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N
	Surajgarha	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N
	Barhiya	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	N

Y= Yes, N=No

Source: IRADe primary survey

2.5 Limitations of the study

The COVID- 19 outbreak affected the research in many ways. Government actions have followed a common goal of reducing coronavirus spread by introducing measures limiting social contact. This delayed the primary survey in Bihar facilities by almost 8 to 9 months. It took some time to devise alternatives and shift to virtual meetings and training. It was equally challenging to acquire permission to visit the health centres and schools amidst COVID. Even with the planned efforts and prior intimation, there was a lack of administrative information and missing update at some community health centres and schools. The PHC/CHCs and schools' service readiness depends on three crucial factors- availability of energy, essential/desirable equipment and services, and sanctioned workforce at the facilities. Therefore, it is difficult to calculate the net impact of electricity access on service delivery at health centres and schools under this study. Furthermore, the data captured in students' service satisfaction surveys is based on the respondent's experience and perceptions before the school closure.

3. Multi-Tier Framework (MTF) assessment

We have used MTF framework to define energy access that is adequate, available in need, reliable, affordable, legal, good quality and safe. MTF evaluates energy access based on a set of attributes and attainment levels, which ranges from Tier 0 (no access) to Tier 5 (the highest level of access). The higher tiers in the framework correspond to better energy availability conditions in terms of the eleven attributes considered, suggesting improved service delivery with each progressive tier at the institution.

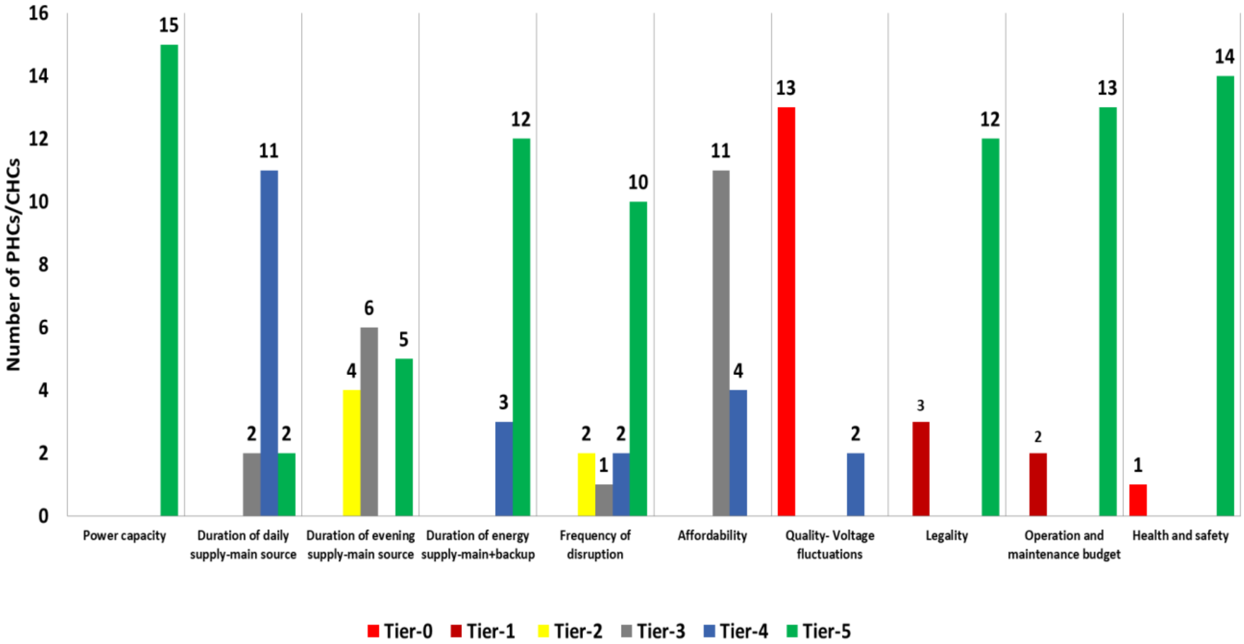
Using the MTF framework, we can propose a clear indicator for each aspect and provide one single indicator by combining all the aspects to track energy access throughout the surveyed facilities (World Bank, 2018). The detailed profile of energy access can identify the gaps and needs of the institution precisely. The multi-tier framework can support investment prioritization and policy formulation strategies for making progress towards energy access.

Every attribute is assessed separately to compile the electricity access tier at each health and education facility. All the functional primary and secondary sources of electricity at the facility were considered while calculating energy access tiers. The distribution of the facilities using the MTF approach has been shown in the charts below, providing more accurate and disaggregated data on the community institutions' level of energy access. The data collected under the MTF section provided information on certain key indicators of energy access and a fraction of facilities with - *minimum or limited access to energy supply, adequate daily supply including the evening service hours from the primary source of energy, improved daily supply using a durable back up source of electricity, reliable and unreliable energy supply, affordable energy supply, voltage fluctuations, illegal connections, operation, and maintenance budget and casualties due to electricity.*

3.1 Energy supply status at health centres

All the health facilities were connected to a grid; hence, they were grouped under tier 5 for electricity's power capacity. The duration of daily electricity supply during the working hours from the primary source of power supply reveals that only 2surveyed health centres fall under tier 5 (more than or equal to 23 hours of daily supply). Majority of the centres were placed under tier 4 with more than or equal to 16 hours of daily supply; the remaining fell under tier 3 particular attribute. In our survey, 33.3% of the health centres reported grid electricity supply during the evening as per tier 5 specifications; 40% gets evening electricity supply as per tier 3 specifications, and 26.7% as per tier 2. Access to a reliable secondary energy source at health centres significantly improves the duration of daily electricity (Fig.2).

Figure 2 Distribution of PHCs/CHCs according to MTF attributes (Refer appendix I)



Source: IRADe primary survey

Frequency of disruption gives the number of power interruptions from the primary and the secondary source of electricity during working hours. Repeated power interruptions result in reduced work efficiency. Under the MTF framework, a community facility with more than 14 disruptions falls under tier 2. Data for power disruptions showed that 10 (66.7%) health centres had less than 3 disruptions during the working hours (tier 5), while the remaining 2 (13.3%) centres faced 3-14 disruptions (tier 4), 1 (6.7%) centre 14 disruptions (tier 3), and 2 (13.3%) centres more than 14 disruptions (tier 2) respectively. Affordability accounts for the average cost of using secondary sources per kilowatt-hour as compared to grid electricity. For the affordability attribute, which is measured by the cost of running a secondary source of electricity at the centre, 73.3 % of the health facilities had to bear more than twice the cost of grid electricity. Voltage fluctuations capable of damaging the electrical equipment were recorded in 87% of surveyed health centres. 80% of health centres regularly paid the electricity bill (tier 5), and 86.7% of health centres reported having a maintenance budget to repair and replace electrical equipment. Majority of health centres (93%) reported no serious health accidents in the last 12 months.

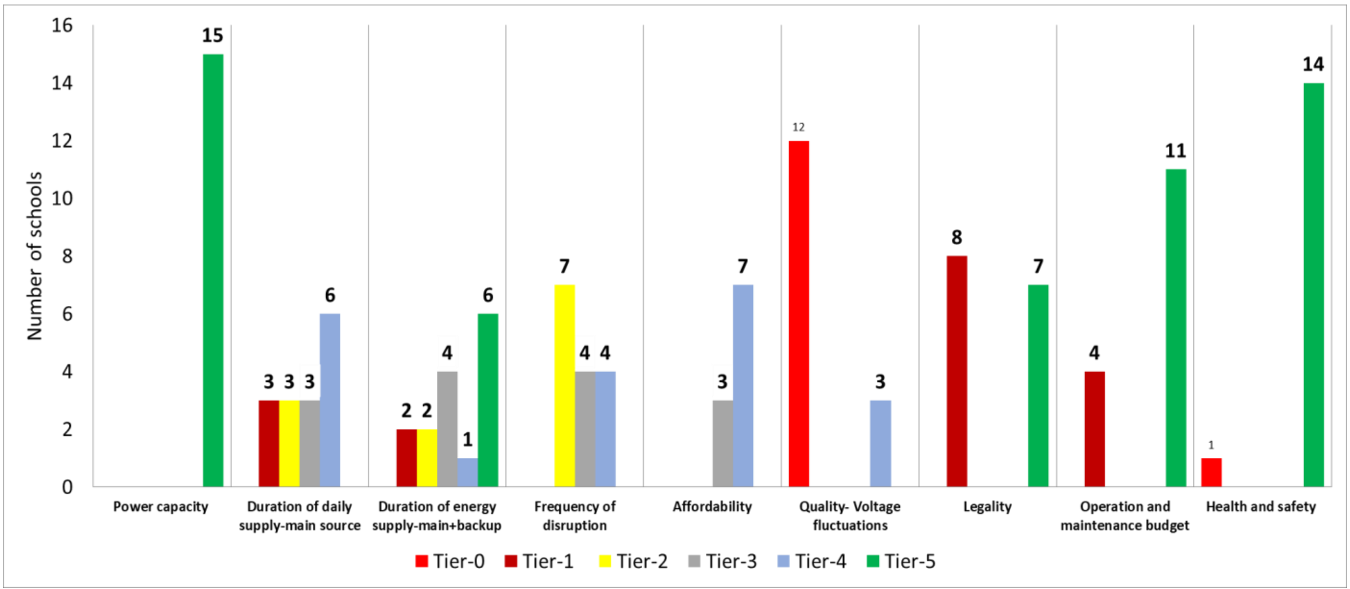
3.2 Energy supply status at schools

Figure 3 presents the tier-wise distribution of schools under the different attributes of the multi-tier framework. All the 15 surveyed schools were connected to the grid. The majority of the government schools in the selected blocks are non-residential, usually open from 9 a.m. to 3 p.m. (6 hours a day only), after which the students return to their homes. The analysis of daily power supply from the primary source showed that 6.7% schools had more than 6 hours of power supply (tier 5), 33.3% schools had almost 5 hours of power supply (tier 4), 20% schools each were under tier 3 (4 hours), tier 2 (3 hours) and tier 1 (2 hours) respectively.

The analysis suggests that 46.6% of schools witness high frequency of power interruptions (more than 14 disruptions) during working hours as per the facility head's data. The cost of using a secondary power supply source, i.e., affordability, for 20% of schools was more than 2 times the grid tariff (tier 3) and for 46.7% of the schools depending on the inverters was 2 times the grid tariff (tier 4). During the survey 80% of schools reported erratic voltage fluctuations, thus marked under tier 0 for quality of power supply; 53.3% of the schools were not paying regular power bills (tier 2), and 26.7% of schools reported the lack of adequate maintenance budget.

Majority of schools (93%) did not report any severe accidents due to electricity infrastructure breakdown; hence they were placed under tier 5.

Figure 3 Distribution of schools according to MTF attributes (Refer appendix I)

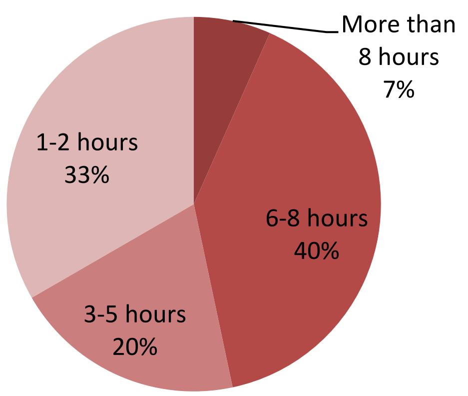


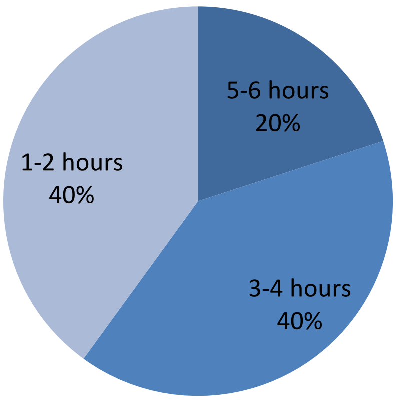
Source: IRADe primary data analysis

4. Understanding the need for reliable electricity access

Connection to mere grid power supply alone does not assure reliable power during working hours. All the surveyed health centres and schools reported interruptions in grid supply during working hours. However, the extent of power availability varies across the health centres and schools (Fig. 4). The surveyed data reveals that 7% of the health centres experienced a daily power-cut of more than 8 hours,40% in the range of 6-8 hours, 20% faces 3-5 hours power-cut, and the remaining 33% witness 1-2 hours. Power interruptions have been recorded in the schools, albeit the duration of working hours for non-residential schools is comparatively less than the health centres. 20% of schools reported daily power-cut of 5-6 hours, 40% reported 3-4 hours, and the remaining 40% experienced 1-2 hours (Fig. 4).

Figure 4 Percentage of a) PHCs/CHCs b) schools with power interruptions from the primary source during the working hours





a) Health centers **b) Schools**

Source: IRADe primary data analysis

The power supply status has been improving for last 2-3 years. However, due to poor voltage in the summer season, some health centres cannot run the basic machines like a printer at the patient registration desk. Voltage fluctuation hampers the delivery operations. Hospital staff has to alternate between devices to get their work done. During the FGD it was found that 40% of the work efficiency gets affected in case of an unreliable power supply. Powe cuts interrupts operating computers- needed for patient registration and online medicine procurements.

Participants of the focus group discussions at PHCs/CHCs expressed dissatisfaction over the quality of electricity – voltage fluctuations and the resultant damage to appliances. Examples of damaged appliances due to voltage fluctuations include baby warmer/radiant warmer, oxygen concentrator stabiliser, autoclave. This problem increases during summer when consumers place a higher emphasis on the quality of electricity. This means that facilities have to either incur a higher additional cost for installing voltage stabilisers, or decide not to use electrical appliances that can be prone to damage with voltage fluctuation.

A few surveyed schools' principals and teaching staff reported major power interruptions while repairing or faults during the monsoon season. Due to the lack of adequate infrastructure development funds, they reported delays in getting the faults repaired. During the student satisfaction surveys, some students described the lack of sufficient light intensity in the classrooms.

"Earlier, the status of energy access was such that it was difficult even to charge the inverters. Over the years, the daily duration of electricity supply has improved manifold. But 30-40% work efficiency reduces in summer, due to unreliable electricity", says a teacher at a school in Bikram.

Figure 5 Focus Group Discussion at Parvati High School, Bikram

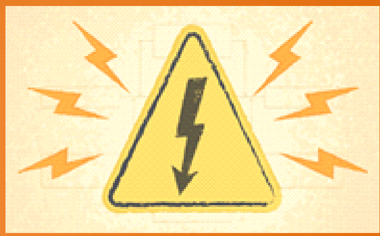
Source: IRADe primary survey

Besides the inconvenience, an unreliable power supply forces the community facilities centre to bear additional expenses on electricity power back-ups. Most facilities cite voltage fluctuation as a significant barrier. To deal with power outages and voltage fluctuations, most health centres use diesel-powered backup generators that are expensive to run. 66.7 % of the surveyed schools have to bear 2 or more than 2 times the cost than the grid electricity to run the backup sources. Some surveyed school authorities also reported worn-out batteries due to excess usage of inverters.

Figure 7 Battery inverter at government-run school in Patna district, Bihar

Improper voltage load calculation!!!!!

During FGDs, some facilities have described the inefficiency of grid power to operate all the appliances.



"To overcome voltage fluctuations, we need to run secondary power sources, i.e., generator sets even in the presence of grid power. Many life-saving devices and basic lighting need a power supply from backup sources without quality voltage. Unfortunately, we are not getting paid for this secondary power." exclaims a participant at CHC Konch.

Tekari substation releases the grid supply report highlighting a 22-23 hours grid supply to the feeder. But the voltage is low to run the equipment such as autoclave (for sterilization), deep freezers, X-ray machine, etc. Therefore, the facility sometimes requires running diesel generators, even during the availability of grid electricity. A critical problem arising from low voltage was noticed when the CHC

5. Service readiness of health and education facilities

One of this report's unique contributions is the insight on service-specific readiness of the health centres and schools of Bihar. Particularly for the health facilities, Service Availability and Readiness Assessment (SARA) mainly focuses on the infrastructure, essential equipment, diagnostic capacity, trained healthcare personnel, and aspects of service utilization (WHO, 2013). School readiness comprises children's academic and social skills and preparedness to serve all children as they enter school. Legislators, policy-makers, and educators are increasingly focused on school readiness as a key to improving school outcomes for all children (Early, 2004).

5.1 Modes of secondary energy at the facilities

The absence of functional lighting affects health facilities especially offering child and night-time care. Provision of power backup facilitates is extremely important at the time of power failure from the primary source. It enhances health-relevant service outputs (e.g., advanced diagnostics and treatment, safe medical equipment), to outcomes for patients (e.g., infection control), facilities (e.g., efficiency) and staff (e.g., working conditions) at facilities level, and population health outcomes (Suhlrie, 2018).

Likewise, a school could be left without lights, fans, computers, and if there are smart classes, they may not be accessible. This may impact the school's schedule, damage equipment, and delay education. An adequate backup power supply in schools will kick in automatically and supply the necessary power to keep things like electricity functional without interruption. Emergency power backup thus becomes an absolute necessity.

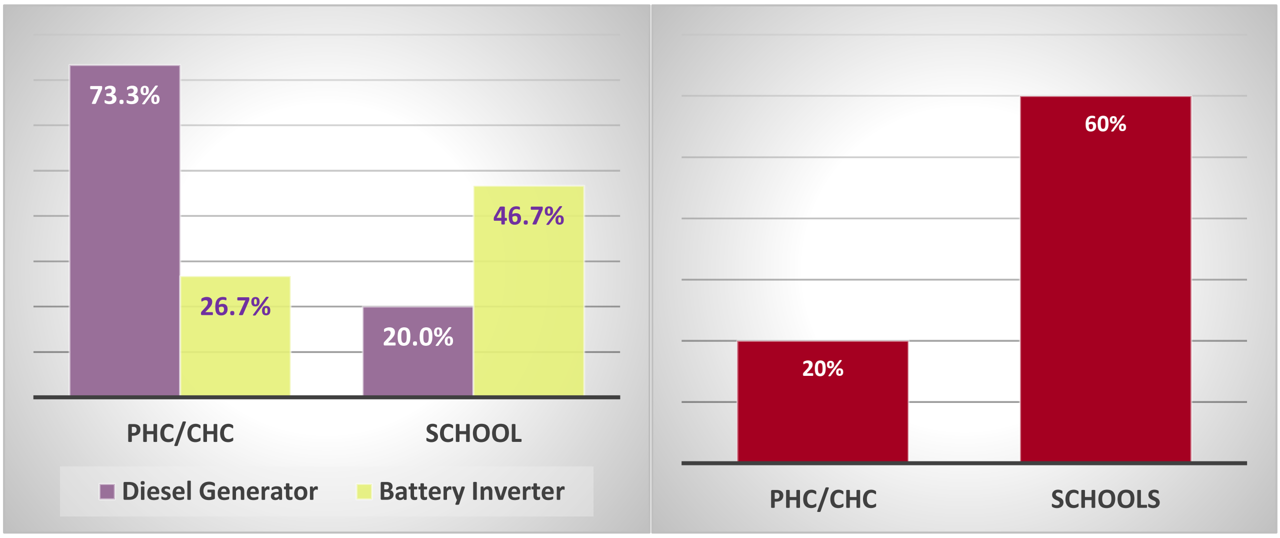
Source: IRADe primary survey

All the surveyed health facilities had access to secondary power options, out of which 73% have diesel-powered generator sets installed on the campus, and the remaining 27% rely on battery inverters. Even though all health facilities cited the availability of power backup, most facilities reported a lack of sufficient secondary energy. Lack of fuel or the additional costs of running the power backup accounts for this dissatisfaction.

Simultaneously 66% of the surveyed schools were equipped with power backup during the primary data collection. Only 20% had a dedicated gen-set, while the others have battery inverter as power supply backup. However, 60% of the surveyed schools were not satisfied with the available power backup options.

Bihar Renewable Development Agency (BREDA), under their solar roof-top program, has reached out to the health centres and has started installing rooftop solar power plants. This is a relatively new initiative taken by the state government to install solar power systems in some health centres. Based on the primary data and discussions with facility heads and staff at the health centres, generators run for 7-8 hours during the working duration in the absence of primary supply.

Figure 6 Left-Availability and types of power backup sources; Right- Percentage of facilities with no or insufficient power backup



Source: IRADe primary data analysis

Figure 7 Power backup a) Generator set b) Battery inverter

Source: IRADe primary survey

Solar rooftop net metering- an immediate backup source?

Under the solarising initiative, the state nodal agency BREDA has initiated installing roof-top solar systems in the health centres and schools of Bihar in the last six to eight months. However, due to the COVID situation, these installed solar systems were yet to become functional till the time of survey.

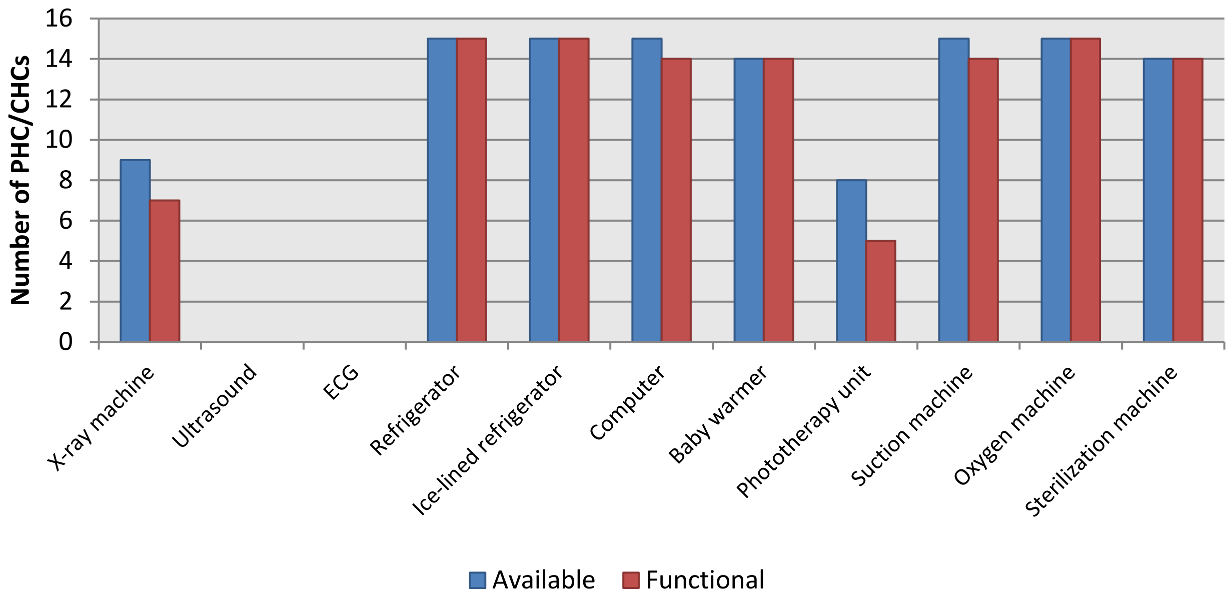
Maximum health centres and schools in Bihar face a daily power interruption from the main source, with durations affecting their quality of service. The installed solar systems require battery storage to ensure electricity access and fulfil the current need for a reliable backup. The stored solar power will make the facilities energy self-sufficient in case of power interruptions from the main source. Energy self-sufficiency gives a sense of security to the staff; this was perfectly reflected in the interviews with the facility heads of health centres in Jharkhand, where JREDA has provided solar batteries along with the rooftop solar panel.

5.2 Availability of essential/desirable equipment and services

Quality care at a health centre depends on the basic inputs and infrastructure such as drugs supplies, workforce, equipment, water, and electricity. The absence of basic essential inputs obstructs the provision and use of maternal health services. Under the WHO's quality standards, emphasis is given to equipment in health facilities for improved maternal and new-born healthcare (WHO, 2016). The use of electric equipment at any health facility largely depends on the availability of a quality energy supply.

The Indian Public Health Standards guidelines give a list of essential/ desirable facilities for PHC and CHCs. Every health centre must provide the services which have been indicated as essential and desirable. NRHM is continuously working towards bringing the PHCs and CHCs to the level of IPHS.

Figure 8 Number of PHCs/CHCs with functional essential electrical equipment



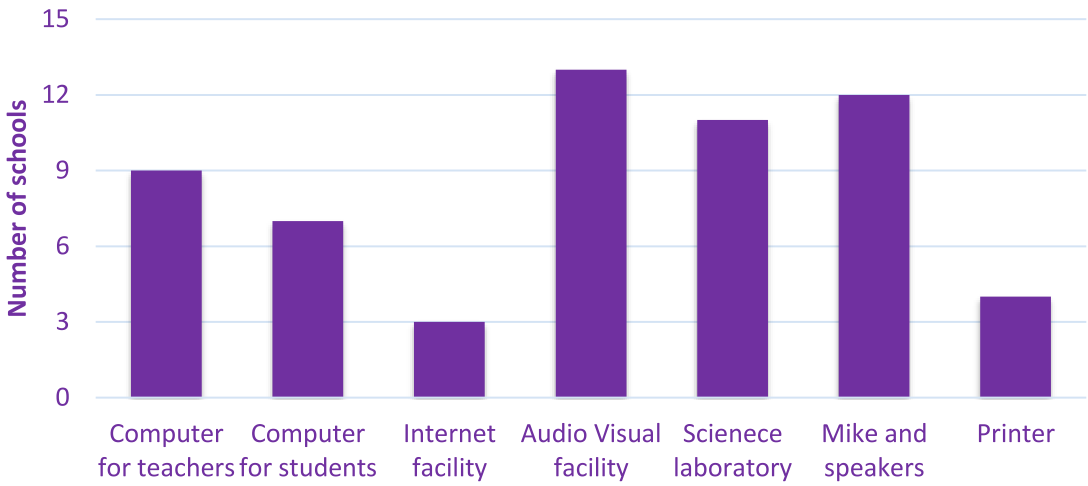
Source: IRADe primary data analysis

Figure 10 above gives a picture of the available and functioning equipment at the surveyed health centres. It was known from the primary survey and infrastructure verification that many essential devices were either missing or damaged. For example- A diagnostic X-ray unit (essential equipment for radiology) was available at 60% CHCs/PHCs, and functioning at less than 50% centres. 2 radiant warmers and 1 photo therapy unit are essential for neo- natal resuscitation (IPHS, 2012); only 33% CHCs/PHCs had a functional phototherapy unit. Furthermore, ultrasound and ECG machines were absent in all the health centres; the above-said machines are required to implement major national health programs such as the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases & Stroke (NPCDCS) (IPHS, 2012).

Figure 9 Essential and desirable equipment at CHC; Left- Radiant warmer Right- Oxygen concentrator

Schools in rural areas of Bihar continue to suffer from a scarcity of adequate infrastructures, such as classrooms, benches, and computer labs. Figure 11 below shows number of schools with computers for teachers (60%), computers for students (47%) and a supporting internet facility (20%). It has been argued that remote communities with a lack of learning resources like computers and the internet cannot access online education content. The percentage of surveyed schools having functional science laboratories is 73%, the audio-visual facility is 87%, printers 27%, and announcement devices is 80%.

Figure 10 Number of schools with functional electrical devices



Source: IRADe primary data analysis

Figure 11 Electricity-driven equipment at school

Source: IRADe primary survey

Encounters with shortages of equipment at health centres and schools

Health facilities and school staff showed feelings of demotivation and dissatisfaction due lack of functional equipment. A school teacher said: "*Service delivery is severely compromised without proper functional equipment; students feel uncomfortable during the hot summer hours in the absence of fans. I feel students get gloomy when we have to cancel the smart class period due to power cuts.*"

Similarly, a principal heading the school showed her resentment while saying, "*I feel guilty when we are unable to provide an adequate number of benches for the students or when one teacher has to look after many subjects due to the shortage of trained teachers willing to work in the rural areas.*"

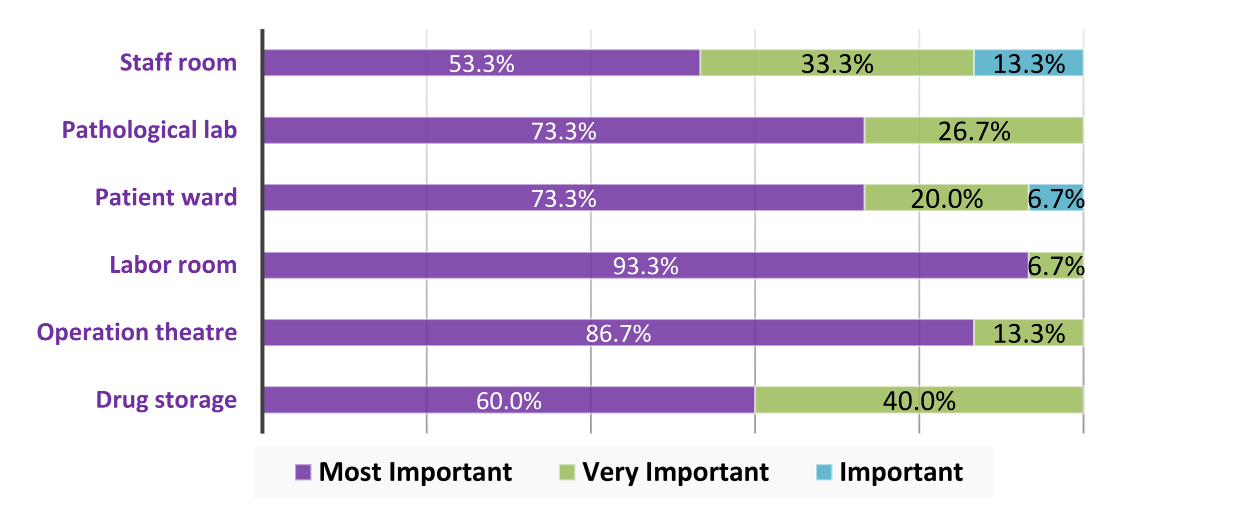
Health facility staff expressed challenges around the medical equipment which is not maintained, repaired, or replaced. A lab technician said, "*Instrument damage due to voltage fluctuation is very common. At times the equipment is not of good quality, which fails to last long. The budget with us is not sufficient to replace this damaged equipment now and then.*" Another health professional added, "*There is no service plan for the equipment. Here we use it for a longer time without service then it gives a problem in functioning because there is no service. Enough space is not available to accommodate major equipment like ECG, ultrasound.*"

5.3 Access to electricity for the functioning of essential equipment and services

Electricity is used for various purposes, including cooling/ heating equipment, lighting, fans, ventilation, sterilization, water pumps, refrigerators, autoclaves, computers, etc. Many health centres have been relying heavily on diesel-powered generators to keep the health centre's critical facilities running without a reliable grid power supply. From the group discussions, it is known that the installation of a dedicated transformer at a few of the surveyed health facilities has improved the quality of the power supply.

Figure 15 shows the health staff's perception of the importance of a reliable power supply for some essential facilities at the PHCs/CHCs. For all the services asked during the interview, like, drug storage, operation theatre, etc., more than 50% of the responses ranked electricity as the most important for the proper functioning of the service. 93.3% of the respondents ranked electricity as the most important for the labor room. The other responses also ranked from important to very important, implying that unreliable electricity can hamper service delivery.

Figure 12 Health staff perception of the requirement of electricity for different purposes

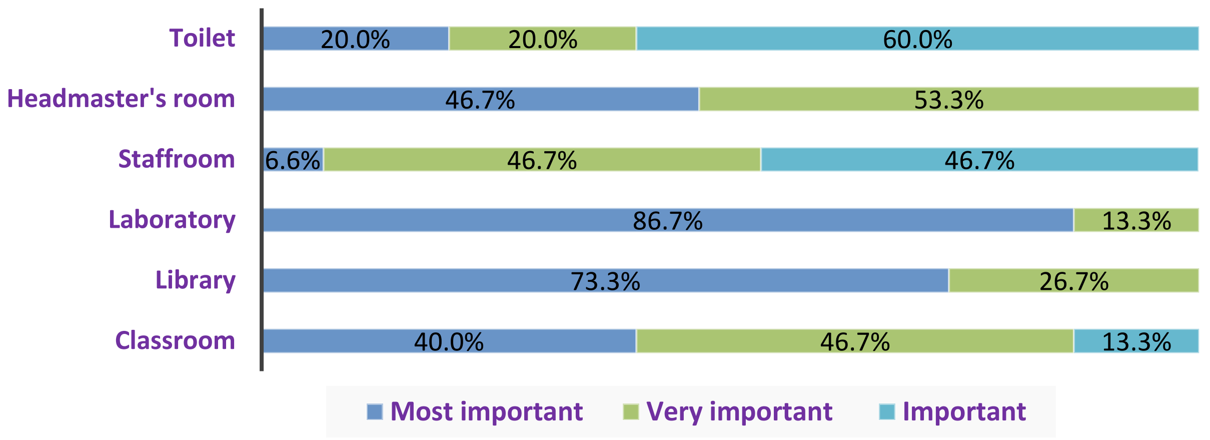


Source: IRADe primary data analysis

While discussing the requirement of electricity for running the equipment at the health centres, one participant from CHC Konch commented, "So, there are instances when we are unable to run the basic machines like a printer at the patient registration desk. Hospital staff has to alternate between machines to get their work done. Sometimes we cannot operate the computers- which are needed for patient registration, bills generation, online medicine procurements, etc."

The school staff reiterated the importance of electricity for basic comfort and services at school. As high as 87% of the respondents ranked electricity as the most important input for running science laboratories at the school, 73% for the library, and 40% for classrooms. The responses captured from other participants for the importance of electricity in staffrooms, headmaster's room, toilet, etc., were also very important/ important.

Figure 13 School staff perception about the requirement of electricity for different purposes



Source: IRADe primary data analysis

COVID-19 isolation centres-Reliable power infrastructure needed to fight the pandemic

With the onset of the first wave of the global pandemic in March 2019, the Bihar government declared the health centres as isolation centres with a dedicated section to treat people affected with this disease. Later due to the added pressure on the healthcare system with the increasing number of daily infected cases and reverse migration from cities, some government-run schools were also used as isolation units.

Along with adequate health workers and equipment, reliable power is critical for the effective treatment of COVID-19. Patients needing further diagnosis like pulse oximeter or requiring artificial ventilation through oxygen masks need health centres with better-equipped facilities, including reliable power.

Furthermore, autoclaves, air filtration like sanitization, and cleaning equipment also require electricity. This is necessary to prevent the spread of infection among the other patients and associated staff. Electricity also powers the water motors, which provide water to maintain hygiene among the affected.

5.4 Procurement of medical equipment/devices and supplies

The Government of Bihar established the Bihar Medical Services and Infrastructure Corporation (BMSICL) in 2010 to improve the performance of the state's health care system. BMSICL works as the sole procurement and distribution agency of drugs and equipment for all establishments under the Department of Health, Govt. of Bihar. Along with this, the corporation also looks after the construction of healthcare institutes and related areas.

A web-based application, E-Aushadi, which deals with the procurement process of the essential and local drug and surgical supplies, was developed to meet 'BMSICL's vision. Timely drug availability at the healthcare facilities can be ascertained through the use of this application. Some of the unique features of this application include:

- It creates and sends an alarm when the minimum stock level is reached;
- Management of the drug based on their expiry dates

The official website also hosts drug rate contracts, equipment rate contracts, tenders for suppliers/vendors. With a clear layout of the guidelines for the payment and delivery, the corporation tries to encourage maximum participation by qualified vendors. The use of technology ensures a fair and transparent procurement process and also brings uniformity.

6. Electricity access and community service delivery

6.1 Evidences of better service delivery with improved access to electricity

A majority of the poor people of Bihar usually depend on government healthcare facilities for their curative and preventative health needs. Energy plays a critical role in strengthening healthcare service delivery and improving health outcomes such as prolonged opening hours with improved emergency surgical services. With the availability of power from the primary and secondary sources, the surveyed CHCs and the PHCs are running 24x7. However, services at these 24x7 health centers gets affected by the quality of the power supply and the uninterrupted fuel sources required for running backup devices.

From the primary interviews and group discussions, most health facilities' major problems centred down to voltage fluctuations. The efficiency drawbacks arising due to voltage fluctuations such as equipment damage and the need to run power backup due to low voltage from primary source were largely solved with the installation of dedicated transformers for the facility. While many health centres still complain of the erratic voltage and the associated problems, many of the surveyed facilities gave positive feedback for the policies and programs under which they installed the transformers. Solar energy as an effective backup source for the public infrastructure is in dialogue across various states.

Figure 14 Online registration for COVID-19 vaccination

Source: IRADe primary survey

The status of the power supply at the schools has improved over the years. Almost all the surveyed schools were electrified 5 years back, but the duration and reliability during the working hours have been the focus for the past few years. Reliable electricity is related to improvement in the level of education, literacy, and school attendance. The integration of modern energy with schools and effective curricula is emerging as a fundamental approach to achieving improved education in rural areas of the state. During the interview, the principal of Mahadev School, Khusrupur, said, ***Educomp installed 20 computer systems at our school, and a generator set for the computer backup power supply was installed. Wifi for the school has been proposed to the government***

Gaya Guidance Program: Adapting to online teaching during COVID-19 lockdowns

As part of the consequences of the COVID-19 pandemic lockdowns, schools in Bihar closed in March 2020 and continued to remain shut even under the subsequent guidelines. Forced by this the teachers had to look for alternatives for face-to-face instructions. In most of the schools, teachers adopted online teaching to deliver knowledge and keep students involved in the learning process.

Information and communication technologies (ICT) tools, basic digital skills among students and teachers particularly digital teacher competence and access to required infrastructure are instrumental in adapting to online teaching during COVID-19 school closures. Electricity facilitates the use of these ICT technologies at schools as well as the individual households.

While there were concerns relating to the effectiveness of online learning, a group of teachers at Kanya Uchh Vidyalaya Konch leveraged the resources available at the school and compiled online video of their respective chapters for geometry, history etc. for their students of 10th standard appearing for the board examinations. The videos were also uploaded on social media platform you-tube for wider circulation. They also made these videos and pdfs available to students of other schools. This program was a local effort to minimize the student's loss due to the pandemic, it was coordinated by the nodal officers of different schools.

6.2 Health and education manpower and service satisfaction

During the interviews of health centre facility heads, the number of sanctioned and filled seats for various positions was discussed. The lack of the requisite number of doctors in the centres increases the patient load on the present doctors. The discussion revealed that even if the infrastructure was in place, it did not necessarily translate into service provision. Lack of doctors and medical staff attributed to this underutilization of resources. Due to the absence of lab technicians, some CHCs/PHCs could not provide adequate testing facilities to the people. In such cases, either the centres outsource the testing services or refer patients to other government or private testing centres.

Likewise, the surveyed school administration reported a shortage of teachers available in the school. The average student-teacher ratio calculated for the surveyed schools is 73:1. Right to education act mandates an optimal student-teacher ratio of 30:1. Due to the high student-teacher ratio, it becomes difficult for teachers to pay adequate attention to each student in the classroom. There is a need to recruit more teachers to impart quality education.

6.3 Patients' satisfaction towards healthcare services

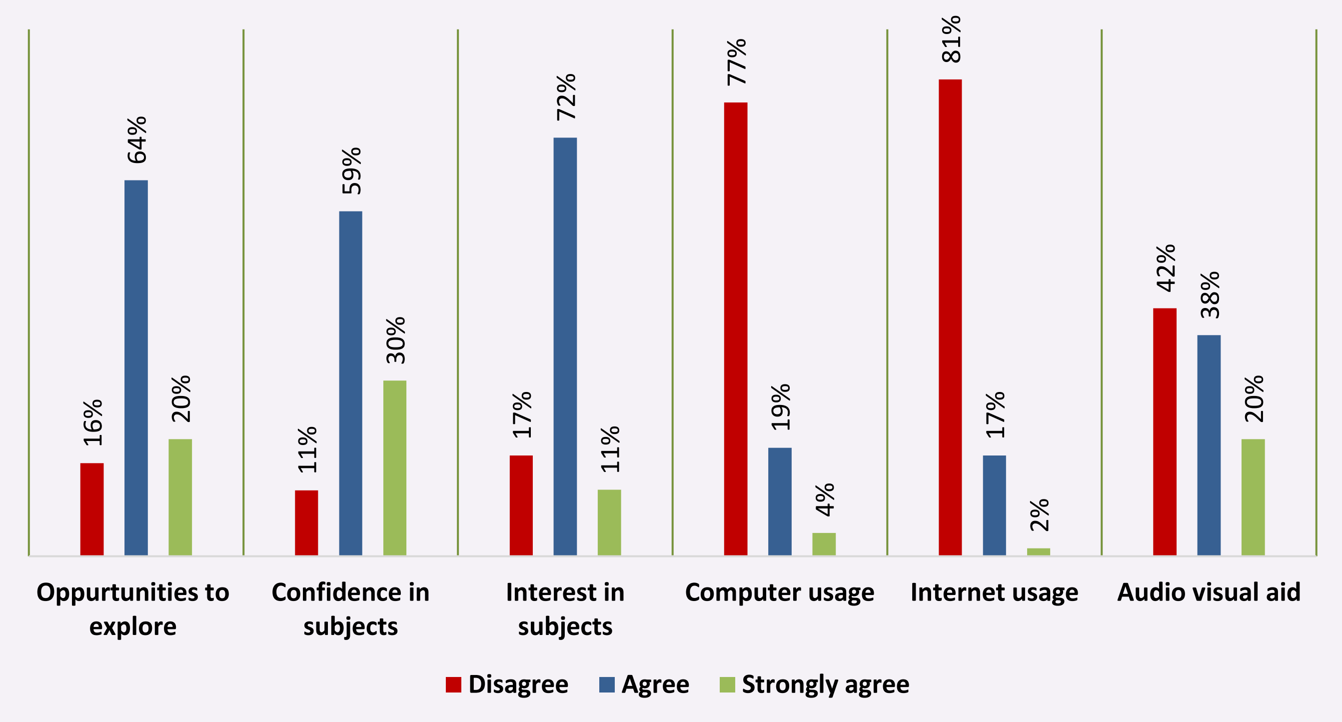
Bihar has improved some important family health indicators in the last few years, driven by the national and state governments' cumulative efforts to strengthen the state public health system's quality. Patient satisfaction that depends on the treatment and services provided at the health centres has improved over the years, even though ample room for improvement still exists. 38.7% of patients travelled more than 5km to reach their nearest PHC/CHC for treatment. 67% of the respondents agreed to the centre having a good waiting room, 43% of the patients also shared that the waiting time was less than 1 hour. 83% of respondents were satisfied with the drinking water supply at PHCs/CHCs, and 81% reported water availability in the toilets. Adequate vaccination facility is available at the surveyed health centres according to 92% of the respondents.

Cleanliness, lighting, and cooling facilities were ranked between good to poor. The analysis also revealed the proportion of respondents who were satisfied with the facilities for lighting (97%), wards (97%), labour room

(70%), operation theatre (52%), OPD (88%) and toilets (64%). On the other hand, a few respondents were not satisfied with the healthcare service delivery for the lack of lighting, doctors, staff, medical treatment, poor infrastructure at PHCs/CHCs. A fraction of respondents also complained about energy-related issues such as lack of safe drinking water.

6.4 Students' satisfaction towards educational services

Figure 15 Student satisfaction with classroom facilities



Source: IRADe primary data analysis

Student's opinion on various classroom facilities was noted during the student satisfaction survey. The above figure shows the percentage of students who agreed/strongly agreed or disagreed to the mentioned school facilities. For example, while a high percentage of students agreed to be given opportunities to explore different ways of learning in the classroom (64%), confidence in reading, writing, mathematics and science (59%), and the opportunity to develop an interest in subjects (72%), a high percentage disagreed to the use of a computer (77%), internet (81%), and audio-visual aid (42%), by the teachers.

Student's perception of cleanliness, lighting, and cooling facilities using a good to poor range was recorded. Students who responded positively to lighting facilities in the premises (88%), classroom (91%), library (53%), laboratory (54%), and toilets (40%). 94% of the surveyed students reported power cuts during the school hours, with an average duration of power cuts during the winter, summer, and monsoon season as 1 hour, 1.5 hours, and 1.5 hours, respectively. Reduced visibility, lack of concentration, hot and humid classrooms appeared to be the major problems arising from the power cuts. Due to the absence of proper bulbs and locks in the door, 25% of students do not feel safe using the toilets. The lack of running water supply in the toilets was informed by 28% of the students. 74% of the students believe that providing regular electricity would solve all the energy-related problems at their school.

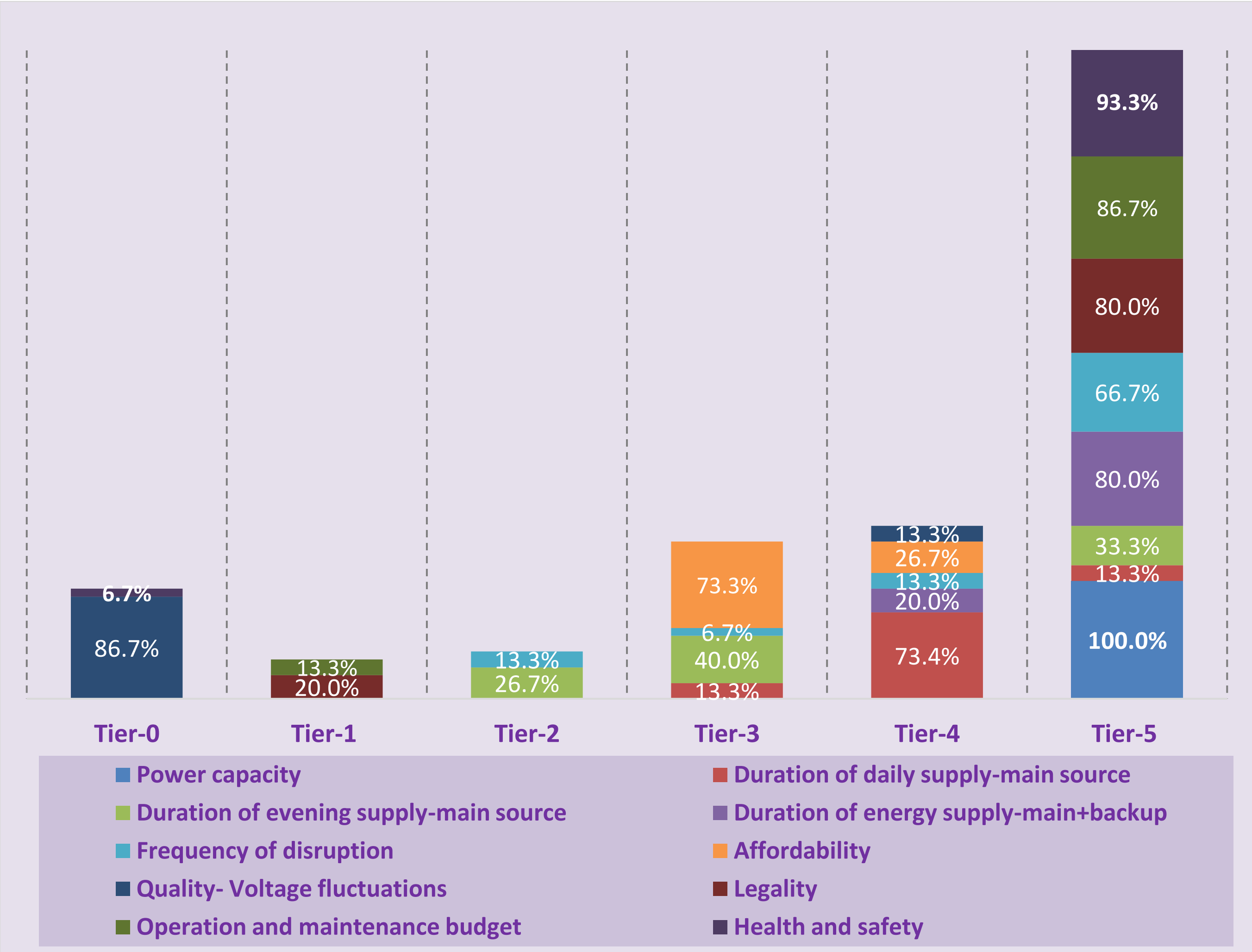
6.5 Targeting electricity access interventions in health centres and schools

The detailed information on various parameters from the disaggregated analysis allows the stakeholders to track the prevailing status of electricity access at the community infrastructure. It will inform and provide evidence to the policymakers to formulate strategies to ensure health centres and schools have electricity access at levels that satisfy the benchmarks of tier-5 for all the attributes of MTF measurement. In addition to that, the data collection approaches from the MTF framework help the government to set the baseline targets and identify the demand-side needs. It also sets department-wide aspirations for providing quality energy access to all, thus achieving SDG 7.

Figures 22 and 23 present the tier-wise disaggregated results of the current status of electricity access at health centres and schools for each attribute analysed under the MTF approach. Of the 15 surveyed PHC/CHCs, 100% fell under tier 5 for power capacity; more than 50% of the health facilities also had tier 5 specifications for reliability, health/safety, operation and maintenance budget, legality and power supply from main/backup sources. Result for the quality attribute (voltage fluctuations) presented 86.7% facilities under tier 0 and the remaining 13.3% under tier 4. 20% of the health centres fell under tier 1 as their electric connections was not registered for monthly electricity bills.

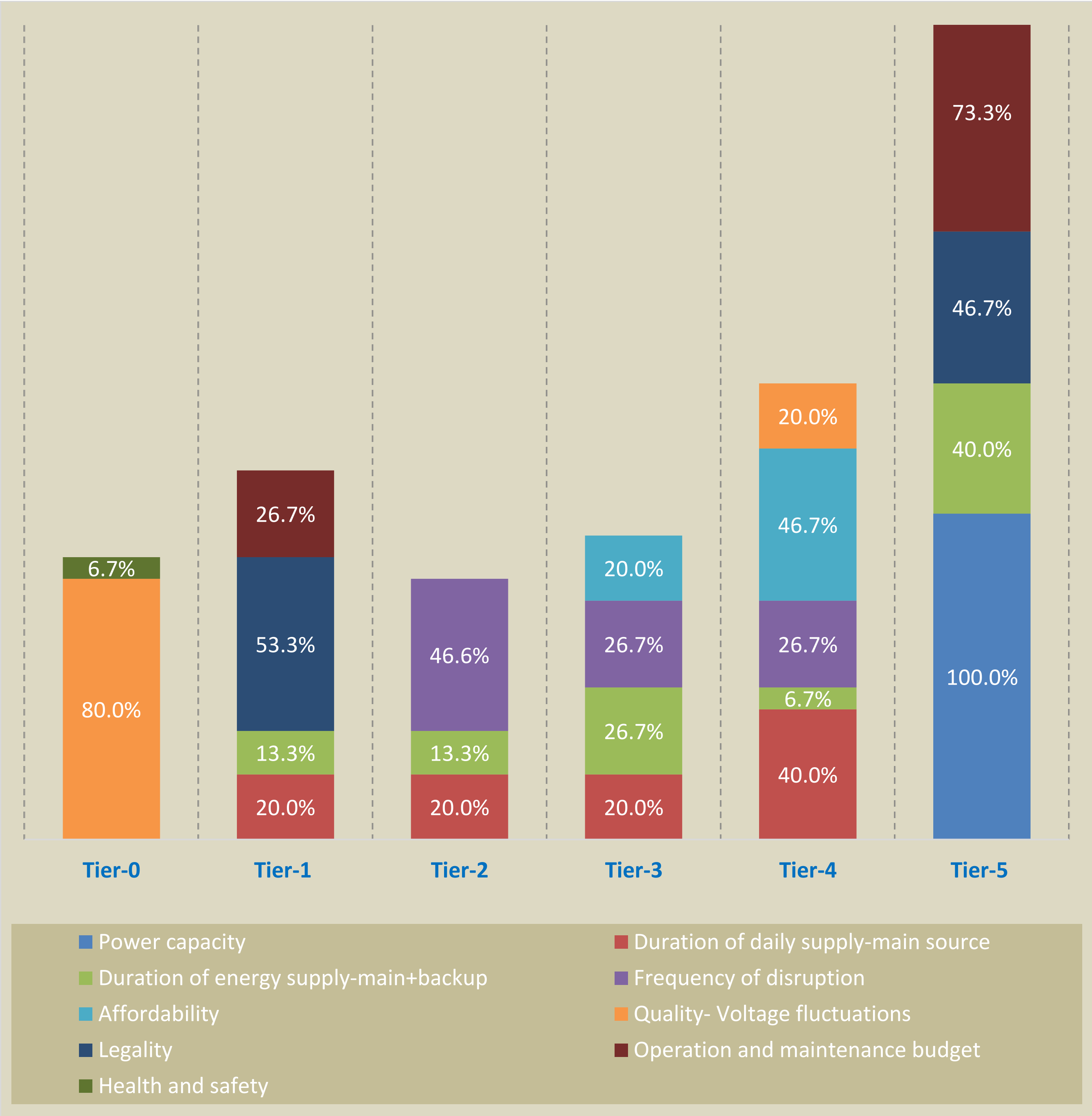
Power capacity attribute for all the selected schools fell under tier 5, 73.3% for operation and maintenance budget and 46.7% for legality. 46.7 % of the surveyed schools in Bihar met the tier 4 specification for affordability i.e., 2 times than the cost of using grid electricity, 26.7% for reliability, and 20% for power quality. Almost 25% of the schools reported tier 3 level services for power supply from primary/backup sources and reliability of the power supply.80% of schools fell under tier 0 for quality and attribute of energy access.

Figure 16 Tier-wise distribution of PHCs/CHCs based on MTF attributes



Source: IRADe primary data analysis

Figure 17 Tier-wise distribution of schools based on MTF attributes



Source: IRADe primary data analysis

7. Key Insights and Policy recommendations

The role of reliable electricity as a key for cost-effective and enhanced delivery of health and education services is being recognised throughout the globe. The understandings from this study encompass several areas – electricity access and health, the critical link between electricity and education services. The report highlights the role of electricity access in the primary/community health centres and government-operated schools in Bihar and its influence on the services and satisfaction of the patients and students. The analysis of the multi-tier framework approach provides key insights about the existing electricity supply, followed by the qualitative opinions gathered from the staff interviews, group discussions, and satisfaction surveys.

7.1 Interventions for the health sector

- **Prioritizing quality energy as a critical component for medical infrastructure**

United Nations SDG 3 and the Global Strategy for Women's, Children's and Adolescents Health (2016–2030) stress integrating health with other sectors such as basic infrastructure and electricity is pivotal in achieving health goals. The present study also provides evidence that electricity is a critical component of the health infrastructure, and many life-saving interventions cannot be undertaken without electricity. CHCs/PHCs with sufficient daily power supply from primary and secondary sources have better service delivery than one facing power deficits. This was reflected through various indicators such as the number of deliveries, surgeries conducted, vaccination, out-patient records.

Meeting power demand is necessary to support essential services such as vaccine storage, reduced surgery failures, sterilization, sanitation requirements, improved mother and child care. There is a need to track the electricity demand side of health services. We propose an electricity demand audit of the health care facilities in the state. It will help ascertain the energy thresholds for the health facilities according to the local needs and considerations.

- **Synergies of health and energy policy instruments**

Much of the policy emphasis for attaining better health outcomes have been on direct factors such as expanding the network of health institutions, training the health workforce, drugs and equipment. There is a need to pay attention to the energy demands of the health centres in the policy structure and develop cooperative strategies involving both the health and the energy department. Thus, public health success requires related policy strategies such as developments in the power infrastructure demanding quality around-the-clock electricity access.

The COVID-19 pandemic brought various challenges that require decisive policy interventions for resilience and energy security. An uninterrupted energy supply has been fundamental to ensure energy services to healthcare facilities, even in remote areas. Re-evaluation of the traditional frameworks and community-targeted programs would provide accessible, effective, and affordable healthcare to rural people.

- **Solar roof-top with battery back-up**

Health centers requires immediate power back-ups during grid power disruption. Therefore, provision of an immediate switch to an alternative power source is essential in the health centres when the grid electricity is not available. To ensure energy self- sufficiency, the installed solar systems must have an inverter and battery storage to provide an uninterrupted power supply in the event of power-cuts.

Rooftop solar panels have emerged as a viable and inexpensive secondary power source that provides instant lighting needed during an emergency. Customized solar rooftops, as per the health centre's energy need, are a must to deter hospitals from using expensive, polluting, GHG emitting diesel generator sets. The clean energy-based infrastructure will have a multiplier effect, enhancing energy security and creating jobs for the local people.

- **Equipment evaluation and energy efficiency**

With the high density of rural residents per PHC/CHC, maintaining essential devices and equipment becomes even more critical in providing high-quality health services without disruption. To achieve a standard set of necessary equipment, an evaluation of the existing equipment according to the guidelines prescribed in national health programme will have long-term implication. This will highlight the missing equipment that may be a barrier to providing adequate healthcare services. In addition to this, in consultation with the department of energy, the health department must prepare a guideline prescribing energy efficiency standards for future electricity-driven medical equipment and electric appliances purchases. Robust monitoring of the operations and maintenance of the equipment will ensure the smooth functioning of the devices and reduce the energy demand.

- **Digitization of the primary health centres to provide quality medical assistance**

The concept of telecommunication has been a success in diagnosing and treating diseases via video conferencing with doctors in the rural health centres of many states. Improvements in the quality of electricity access will open a new opportunity for digitization of the primary health centres to provide quality services. Off-grid solar panel installation in power deficit primary health centres can strengthen the power capacity of the health centres.

7.2 Interventions for the education sector

Access to electricity is often discussed as an enabler to improve education outcomes, and this domain has several potentials to tackle, especially in the rural areas. In the current study, we have discussed the total daily hours of power supply at the schools. The availability of improved lighting can extend the effective schooling hours. Reliable electricity also offers digital teaching aids and increased use of electrical devices in the academic curriculum. Availability of necessary amenities, important among which is a stable power supply attracts quality teaching staff and enhances students' enthusiasm in the classrooms. Below are some of the suggested interventions derived from our study:

- **Need for more evidences for policy influencing**

The level of awareness and sensitivity in the government about the importance and role of electricity in service delivery by the public facilities has been constantly improving. However, the number of impact evaluation studies linking the electricity and education is low compared to other impact evaluation studies. Due to the small number of such studies, there is a substantial gap in the evidence base and limited details on the types of electrification interventions, specifics, and costs. Additional qualitative and quantitative research can help fill this gap, especially for process evaluation and the social development impacts.

- **Assessment of quality power demand**

Evidence from the current study suggests low reliability of power supply across the surveyed schools. The increased demand to run specific equipment has also brought up the insufficient backup capacity. The reliability issues result in authorities relying on alternative fuel, which has implications on the total management budget and associated degradation of the environment. Thus, future interventions should target the multiple constraints such as reliability, affordability instead of only focusing on expanding the physical access to electricity. Studies should understand and seek to provide intervention for the combination of demand and supply side.

- **Technical support to introduce DRE solutions**

DRE solar solutions may be a better fit for providing uninterrupted day-time power to schools. This requires further in-depth analysis by taking into consideration the associated costs and benefits. However, some beneficiaries do not have the technical skill and knowledge to operate, maintain, or repair renewable equipment, impacting key outcomes. The lack of knowledge to solve technical problems can lead to non-usage. Capacity building and technical training for the staff would play an important role in influencing the uptake of such solutions in the future.

- **Policy synergy frameworks**

Interventions to improve access to electricity often involve more than one implementing department and seek to engage combined efforts of the department for maximum outputs. The energy department and education department of the state government should cooperate to bring policy synergy to understand the education sector's energy needs better and provide reliable electricity to schools. Such types of partnership activities and agreements can influence the effectiveness of electrification programs for society.

- **Logistic planning and preparation**

Detailed logistical preparation and planning affect the success of any infrastructure project. Remote schools with limited opportunities to effectively plan for implementation logistics or unexpected changes may cause delays to deployment and full implementation of electrification programs. Installation of energy-efficient appliances will cut the power consumption and, therefore, reduce electricity bills, leading to savings for the education department. We recommend a thorough stakeholder engagement during design to prevent equipment shortages, and issues with procuring and managing contractors.

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Appendix- I

Table 1 Multi-tier measurement approach of electricity supply in health facilities

Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power capacity (in Watts/kW)	<3 W	≥3 W	≥ 50 W	≥200 W	≥800 W	≥ 2 KW
Duration of daily supply (main source) Hours per day	<4 hours	≥4 hours	≥4 hours	≥8 hours	≥16 hours	≥23 hours
Duration of evening supply (main source) Hours per day	<1 hour	≥1 hour	≥2 hours	≥3 hours	≥4 hours	≥4 hours
Duration of energy supply(main+backup) hours per day	<4 hours	≥4 hours	≥4 hours	≥8 hours	≥16 hours	≥23 hours
Reliability- Frequency of disruption*	>14 disruptions			14 disruptions	>3-14 disruptions	≤3disruptions
Affordability#	-	≤ 5 times grid tariff	≤4 times grid tariff	≤3 times grid tariff	≤2 times grid tariff	Government funded
Quality- Voltage fluctuations	Fluctuations that damage appliances			No fluctuations		
Legality	Illegal connection		Legal connection-No bill payment for the energy use		Legal connection-Bill paid to the utility	
Operation and maintenance budget	No budget available			Adequate budget available		
Health and safety ##	Serious accidents due to electricity			No accidents due to electricity No accidents		

*Frequency of power disruption in the last 7 days (both from main and backup sources)

Average cost per kilowatt-hour as compared to grid electricity

Any incidents of accidents over the past year that required professional medical assistance

Source: Bhatia & Angelou, 2015.

https://mtfenergyaccess.esmap.org/methodology/electricity

Table 2 Multi-tier measurement approach of electricity supply in day schools

Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power capacity (in Watts/kW)	<3 W	≥3 W	≥ 50 W	≥200 W	≥800 W	≥ 2 KW
Duration of daily supply (main source) Hours per day	<1 hour	≥2 hours	≥3 hours	≥4 hours	≥5 hours	≥6 hours
Duration of energy supply (main+backup) hours per day	<2 hours	≥2-3 hours	≥3-4 hours	≥4-5 hours	≥5-6 hours	≥6hours
Reliability- Frequency of disruption*	>14 disruptions			14 disruptions	>3-14 disruptions	≤3 disruptions
Affordability#	-	≤ 5 times grid tariff	≤4 times grid tariff	≤3 times grid tariff	≤2 times grid tariff	Government funded
Quality- Voltage fluctuations	Fluctuations that damage appliances			No fluctuations		
Legality	Illegal connection		Legal connection-No bill payment for the energy use		Legal connection-Bill paid to the utility	
Operation and maintenance budget	No budget available			Adequate budget available		
Health and safety ##	Serious accidents due to electricity			No accidents due to electricity No accidents		

*Frequency of power disruption in the last 7 days (both from main and backup sources)

Average cost per kilowatt-hour as compared to grid electricity

Any incidents of accidents over the past year that required professional medical assistance