Role of DRE Technology in Promoting Quality School Education in Bihar

Integrated Research and Action for Development

PR Number: IRADe-PR-103(2023)

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Preface

We are pleased to present the report "**Role of DRE Technology in Promoting Quality School Education**, supported by the New Venture Fund. It was felt that Access to electricity is essential for quality school education. It allows schools to use ICT technologies, such as televisions, computers, and the internet, which can improve teaching and learning. It also creates a healthier and more positive learning environment.

In Bihar, many government schools do not have access to electricity. This is a major barrier to improving the quality of education in these schools. The report "Role of DRE Technology in Promoting Quality School Education" examines the potential of off-grid solar (DRE) to address this challenge.

The report is based on a study that involved a baseline survey of available infrastructures in selected 45 government schools and a perception survey of 135 teachers from these schools spread across three districts Patna, Gaya, and Samastipur. The study found that access to electricity can have a significant impact on the quality of school education. Schools with electricity have higher student enrollment, lower dropout rates, and better teaching and learning outcomes.

The report also discusses the role of policies and government action in promoting the adoption of DRE in schools. It concludes that there is a need for a systematic approach to engage the government with sector players to mainstream solar technology for community services.

The report is an important contribution to the debate on how to improve the quality of school education in Bihar. It provides evidence of the potential of DRE to address the challenge of lack of electricity in schools. A business model is developed to help in scaling up the adoption of DRE in primary, secondary, and senior secondary government-managed schools .

The report also makes recommendations for policies and government action to promote the adoption of DRE in schools.

We are grateful to New Venture Fund (NVF) for supporting this study. We hope that this study will give a new direction to the use of DRE Technology in Promoting Quality School Education in all Indian states.

Dr. Jyoti Parikh,
Executive Director,
Integrated Research and Action for Development (IRADe).

Acknowledgement

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Finally, the project team acknowledges Mr. **Aklavya Saran**, Director- Desi Power for supporting the field survey and organizing the workshop, and IRADe Administration and Finance team for their support during the entire project.

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1. Introduction

As the global discourse focus on "Sustainable Energy for All" it is imperative that the discussion goes beyond the basic household energy needs and provide for access to quality electricity supply for critical community services like schools. Schools could contribute to community development through a variety of ways. Education featured highly in the UN Sustainable Development Goals (SDG) enshrined quality education as 4th goal. Sustainable Development Goal 4 targets ensuring the completion of primary and secondary education by all boys and girls and guaranteeing equal access to opportunities for access to quality technical and vocational education for everyone. Access to quality education enables self-reliance, boosts economic growth by enhancing skills, and improves people's lives by opening up opportunities for better livelihoods. Education provides an opportunity for people to escape the poverty trap (Cabraal, Barnes, and Agarwal 2005; White 2002).

Bihar is amongst the poorest states in India, according to NITI Aayog Multidimensional Poverty Index (MPI)[1]. The state has the lowest literacy rate, only 63.8 percent, compared to 74.0 percent as national average (Census, 2011). There is a wide gender disparity in literary rates, with female literacy at 54.2 percent against male at 73.4 percent (*ibid*). Bihar has 93,459 schools by the level of school education, which includes 76,290 government and government-aided schools and 17,169 private unaided recognized and other schools in 2020-21. The percentage share of government schools in total schools in Bihar is 82 percent and government schools have lower functional electricity availability than schools managed by the private sector. The total enrolment of students in government schools is more than 21 Million, and they have a total of 406,602 teachers with male-female teacher ratios of 60:40 and pupil-teacher ratios (PTR) above 50 (UDISE, 2020-21).

School infrastructure influences students learning. Several researchers, (Ajayi, 2002; Hallack, 2000; Kuuskorpi and Gonzalez, 2011), have linked the availability of infrastructure facilities of the school and school efficiency in their studies. Infrastructure facilities in schools have a considerable impact on the school environment and children's learning outcomes. The government of India has also recognized that the "unattractive school environment, unsatisfactory condition of buildings and insufficiency of instructional material" are de-motivating factors for children and their parents have a significant implication for the quality of education imparted (NPE, 1986).

There is a general concern regarding improving the school learning environment, including school infrastructure and facilities. Access to adequate and reliable energy is a prerequisite for running school

[1] MPI measure uses a globally accepted robust methodology developed by the Oxford Poverty and Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP) to measure poverty.

infrastructure and facilities and thus improving school education. In Bihar, 84.7 percent of government and 96.6 percent of private schools have electricity connections (table 1).

Table 1: Status of electricity access in schools in Bihar

School by Management type	Electricity facility (%)	Functional electricity facility (%)
Government	84.7	83.5
Private	96.6	96.0

Data Source: UDISE- 2020-21

However, mere access to electricity is not sufficient. The availability of reliable electricity enables schools to deliver modern teaching methods and techniques that improve the teaching-learning environment and attract more students to the classroom. This study tries to understand the status of quality electricity access in the government schools in Bihar and role of DRE (Decentralized Renewable Energy-Solar PV) in government-run school's technology in promoting quality school education. The precise objective of the study are followings:

- To develop business models to help in scaling up the adoption of DRE in primary, secondary, and senior secondary government-managed schools;
- To develop a modular set of procurement specification;
- To outreach with key decision-makers to generate buy-in on the business model to activate on-ground implementation of DRE systems.

In this context, a baseline energy survey of schools was conducted to understand the existing energy demand and energy use patterns in schools. In order to understand the teacher's aspirations about the requirement of types of appliances and usage of electricity in schools, a teacher's perception survey was conducted. It adopted a descriptive survey research design.

The report is structured into seven sections. Section 1 set the need for the study by discussing the role of electricity in school education, challenge, and opportunities in proving electricity supply through solar in the context of Bihar. Section 2 lays out the design for primary data collection. Sections 3 and 4 present the empirical framework and discuss the results obtained from primary data analysis. Section 5 illustrates the procurement guide for critical appliance in the schools and section 6 presents the business model for government school solarisation. Section 7 discusses the benefits and limitation of school solarisation and section 8 is a conclusion.

1.1 Potential energy needs of a school

A need assessment is required for the different levels of schools to ascertain the real electricity requirements in line with local preferences, needs, and resources. There are numerous potential applications of electricity within schools. At the most basic level, lighting, ceiling fans, and educational equipment require electricity for their operation. Common school applications of energy are as follows:

- **Lighting:** good lighting gives pupils and teaching staff an agreeable environment to concentrate and enhance productivity. Sufficient illumination in the classroom provides visual comfort and does not cause eyestrain minimizing distractions.
- **Space cooling:** extremely warm conditions can also exacerbate illnesses such as dehydration, fatigue, and heat stroke. Space cooling is important to keep classrooms and offices comfortable for staff and students - electric fans can make a significant difference.
- **Communications:** communication aid the efficient running of the school. Schools send daily reports like students' and teachers' attendance sheets to the administrative offices. Basic communication, like mobile charging, requires very little energy.
- **Water delivery and treatment:** providing clean, potable water is essential for the operation of any school**.** Water treatment machines, water cooling, and hot water machine require electricity for operation.
- **Food Preparation:** government-run programs to provide meals in schools. Schools are mostly using traditional biomass stoves or LPG stoves for cooking.
- **Computers and ICT:** these technologies assist in imparting quality education and act as an enabler for distance education. With the need to provide digital literacy and an increase in digital educational content, this technology has become an integral part of teaching.

All these potential requirements will depend on priorities and the number of students and teachers in the school. This potential requirement would decide the overall energy requirement of the school.

1.2 Challenges and Opportunities for school electrification

Despite documented benefits of electrification to schools, the availability of quality electricity supply is still a concern in many schools of Bihar. Schools function during day time when we have good sunshine therefore, solar PV systems could be a good option to meet schools' electricity demand. Solar electricity can provide schools access to clean and green energy and reduce their carbon footprint. However, providing solar electricity, especially to government schools also has many challenges.

The most obvious challenge to the solar electrification of schools is capital cost and limited financing available for capital expenditure. Schools may need help to afford high initial capital costs. Schools with installed solar PV system may find it difficult to maintain as they need more technical knowledge to operate and maintain the system. Schools in far-flung rural areas are prone to theft and vandalism of solar PV systems.

Schools have significant unused areas on their rooftop, which makes them an attractive customer for solar energy developers. The surplus electricity generated would be sold to DISCOM at a predetermined rate. Installation of a solar plant at the school will make them energy independent and substantially save electricity costs (Dutta, 2020). A comprehensive state-level policy for school solarisation in Bihar will have long term implication for energy access to schools.

2. Design frame, method, and data description

The study utilizes a multi-stage sample design technique. Three districts were selected from Bihar for intensive study and data collection. State capital district Patna was selected to serve as the benchmark district. NITI Aayog has launched an aspirational district program to expeditiously improve the socio-economic status of 117 districts across 28 states. Gaya, an aspirational district, has made significant progress in the education sector as per the National Achievement Survey 2017 and is selected as the second district for the study. Samastipur is the third district selected from the non-aspirational district's list of Bihar. Each selected district of the state is further disaggregated by existing blocks, and five blocks were randomly selected for data collection.

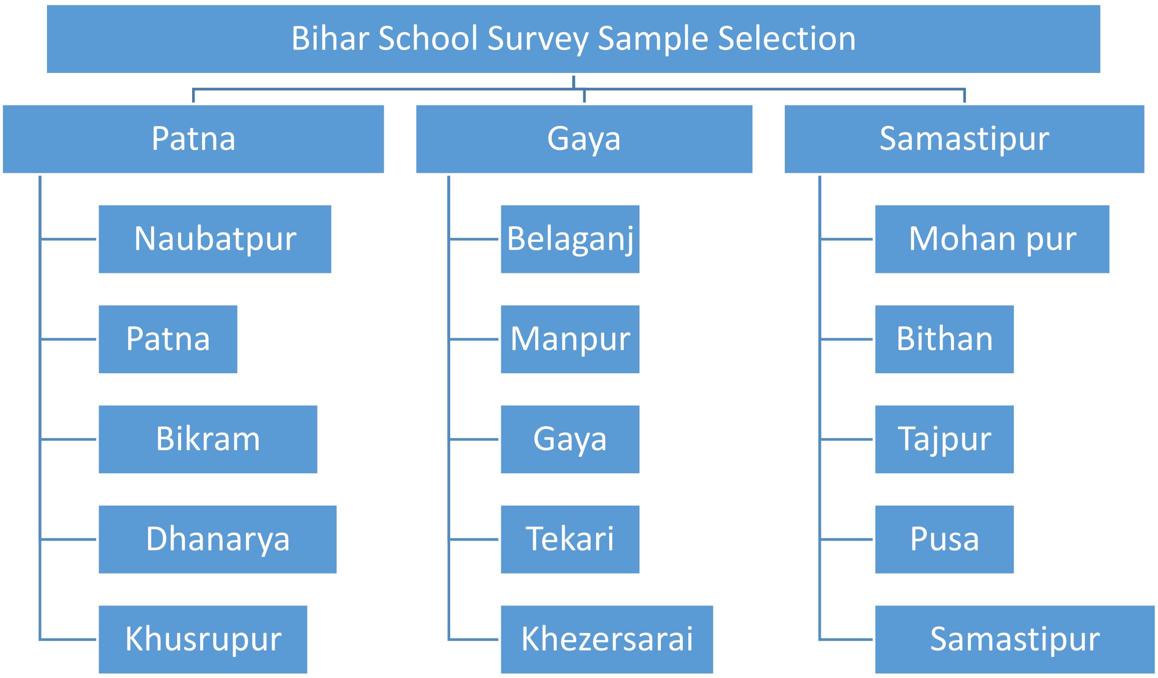

Figure 1: District and blocks selected for schools and teachers survey

In coordination with the Bihar Education Project Council, Government of Bihar, based on the available secondary data and meetings with the District Education Officer, a detailed block-wise school listing was prepared. After listing the schools in a particular block, one primary, one upper primary, and one higher secondary school were selected for the school facilities and teaching staff survey from each block. In total 45 schools (15 – Primary (Class 1-5), 15- Upper primary (Class 1-8) and 15- Higher secondary schools (Class 9-12)) and 135 teachers survey (3 from each 45 selected schools) were conducted.

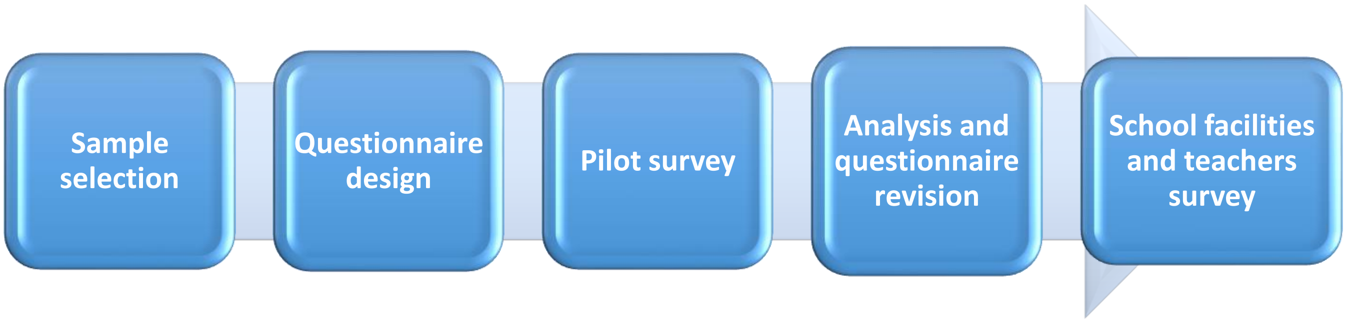

Figure 2: Steps involved in the school survey

The survey was conducted through a structured questionnaire for schools and teachers, in September 2022, in 15 blocks from three districts of Bihar (figure 1). The survey involved a five-step process starting with sample selection, questionnaire design, pilot survey, analysis of pilot survey data for both school facilities and teacher survey and finally survey was conducted to collect primary data (figure 2). Pilot survey was conducted to test survey questionnaire before using it to collect data. Pretesting and piloting help to identify questions that don't make sense to participants, or problems with the questionnaire that might lead to biased answers. The detailed school survey questionnaire collected quantitative and qualitative data about the school. The questionnaire is divided into sections and subsections for easy operability. Section A captured the basic identification information about the institute. The availability of infrastructure and student strength was collected in Section B. Power supply status, sources of supply, and attributes related to the quality of electricity supply were part of section C. Electricity demand and sources of demand (availability of electricity consuming appliances) were part of sections D and E respectively. The survey team captured the level of illumination in the classrooms, administrative rooms, and other areas like the library, laboratory, restrooms etc., using the LUX meter in section F. Awareness about energy efficiency and energy-efficient devices used by the schools is collected in section G. Section H collect information about Solar systems if it is there then repair and maintenance, accrued benefits, etc.

Unlike the school facility survey, the teacher survey questionnaire was designed to collect mostly qualitative information from the teachers. The identification data section followed teachers' perceptions of the existing school facilities. Questions on the linkage between energy and health were captured in a separate section. Familiarity with energy use efficiency and the availability of energy-efficient appliances in the local market was also collected. Descriptive statistical analysis, tabular analysis, and graphical representation of data are the techniques adopted for primary data analysis and drawing results from the data.

3. Summary statistics of the surveyed schools

A total of 45 government schools were surveyed, spread across 15 blocks from 3 districts of Bihar. Surveyed Primary schools have, on average, 150 students enrolled and managed by 3 to 4 teachers (table 2). The average number of student enrolments in surveyed upper primary schools is 524, 643, and 769 in Gaya, Patna, and Samastipur districts, respectively. Higher secondary schools in Gaya have on average 1192 students, in Patna 1642 and Samastipur 2030 students. Schools work between 6.30 AM to 11.30 AM in the summer season and 9.00 AM to 4.00 PM during the winter season.

Table 2: Basic statistics of surveyed schools

District	School Type	No. of Schools	Avg. No of teachers	Avg. No. boy students	Avg. No. girl students
Gaya	Primary	5	3	72	76
	Upper Primary	5	11	265	258
	Higher Secondary	5	20	724	468
Patna	Primary	5	4	68	84
	Upper Primary	5	11	306	308
	Higher Secondary	5	26	1273	878
Samastipur	Primary	5	4	78	78
	Upper Primary	5	15	346	422
	Higher Secondary	5	20	972	1057

Data Source: IRADe School Survey 2022

3.1. Basic infrastructure facilities in schools

Basic infrastructure is necessary for school operation. It also plays a role in student achievement, even though this relationship is not straightforward. A myriad of other variables goes into making good schools. Teachers and students together spend a good amount of their daily productive time on the school campus therefore, access to safe and healthy school place positively contribute to students and teachers attending and remaining healthy in schools. 44 out of 45 surveyed schools have concrete buildings, with roofs in good condition.

For schools to function properly, clean water is necessary for drinking, sanitary, cooking, and other kitchen requirements. Tube well/bore well and hand pumps are two sources of water supply to the schools. A small number of schools also reported having supply water connections provided under the Nal-Jal yojna of the state government. Even though water supply is available to schools in Bihar, only 62 percent of schools reported that the water supply is sufficient to meet requirements (figure 3).

A safe and hygienic toilet is another basic essential service. A separate toilet for girl students is available in 93 percent of surveyed schools and 64 percent of schools have separate toilets for staff members.

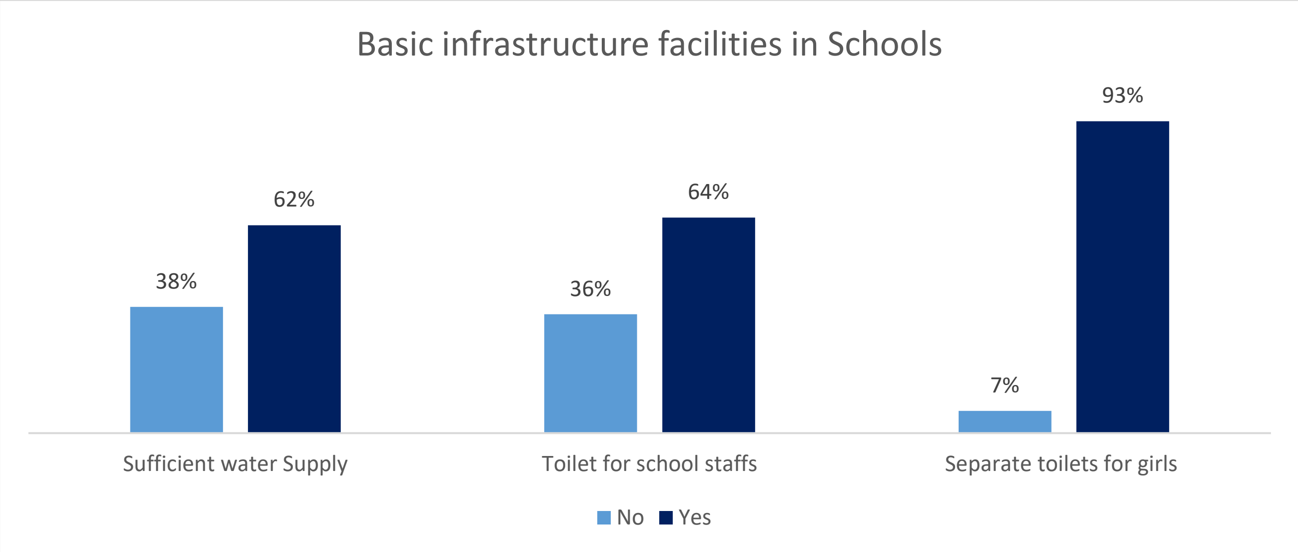

Figure 3: Basic infrastructure facilities in surveyed schools

Data Source: IRADe School Survey 2022

3.2. Electricity supply status in schools

Grid is the primary source of school electricity, even though some schools reported having a dedicated solar electricity supply for the smart class. Electricity supply to schools is constantly improving, as 16 percent of the surveyed schools reported getting connected to grid electricity supply in the last five years. However, load-shedding and abrupt power-cuts during school hours deprive schools from using electrical appliance. The quality associated with electricity supply could be assessed through multiple attributes, depending upon the context and end-use. For schools, we used voltage fluctuations (power surges or low voltages) and unavailability during school hours as the key indicators for quality.

The average duration of grid electricity supply during the school working hours is not only insufficient to meet the school requirement. Frequent power disruptions during working hours further add to the problem. Voltage fluctuations are an important barrier preventing the efficient use of appliances by schools. The number of high/low voltage days in a week causing appliance damage (table 3). 20 % of higher secondary schools reported using DG sets as power backup sources (table 3). A large problem with DG sets is its running fuel cost and school personnel require training for its operation, and maintenance. People associated with education in rural schools - teachers (custodians of school installed infrastructure) - do not have the training, or the experience, to operate it. Schools having power backup sources are hardly able to use them efficiently. Schools having solar PV systems (grid connected or appliance specific mainly for water pump) are mostly unaware about its maintenance. The panels are not cleaned for long, and teachers are not aware of the kW of electricity produced by the solar panel.

Table 3: Electricity supply status

Attributes	Details	Primary	Upper Primary	Higher Secondary
Electricity access	Average connected Load (kW)	1	2	6
	Duration of average daily electricity supply from the grid during school working hours (in hours)	5.3	6.0	5.7
Quality	Frequency of electricity supply disruptions in a week (Average No.)	9	8	9
	Voltage fluctuations during school hours (% of Schools)	46%	47%	60%
	Voltage affects the use of desired appliances (% of Schools)	31%	40%	53%
Secondary source	No secondary source (% of Schools)	93%	67%	7%
	DG Set (% of Schools)	0%	0%	20%
	Availability of any type of Solar PV system (% of Schools)	7%	33%	73%

Data Source: IRADe School Survey 2022

3.3. Illumination level in the schools

Lighting has a significant impact on students' learning performance. Lighting positively influences concentration, working speed, accuracy, task performance, etc. (Sleegers et al., 2013). In this study, room illumination intensity is measured to understand the availability and sufficiency of daylight and artificial lights in school rooms. Light illumination intensity for artificial lighting indoors is measured via “LUX.” A Lux meter was used to measure the illumination intensity of light in the school’s classrooms, library, administrative office rooms, and laboratory rooms. In the classrooms, illumination intensity was captured on the whiteboard, front rows, and last rows. Illumination data was collected with windows opened and all available bulbs and/or tubes switched on. An average of the illumination intensity was calculated for the analysis.

Typically, 150 LUX is the minimum illumination intensity required in the classroom and administrative office to create enough comfort for teachers and students to see, given the lack of natural light available in classrooms (Edwards, 2002). Figure 4 shows the average illuminance in the rooms, across the type schools, is much below the desired level. Optimal lighting in schools can create favourable viewing conditions for students to read and copy from the instruction board. Classroom environment plays an important role in the overall performance of the students, and hence they need to be planned and designed according to the standards and comfort needs of the students. Sufficient light should be ensured in the classrooms to improve students' productivity and performance.

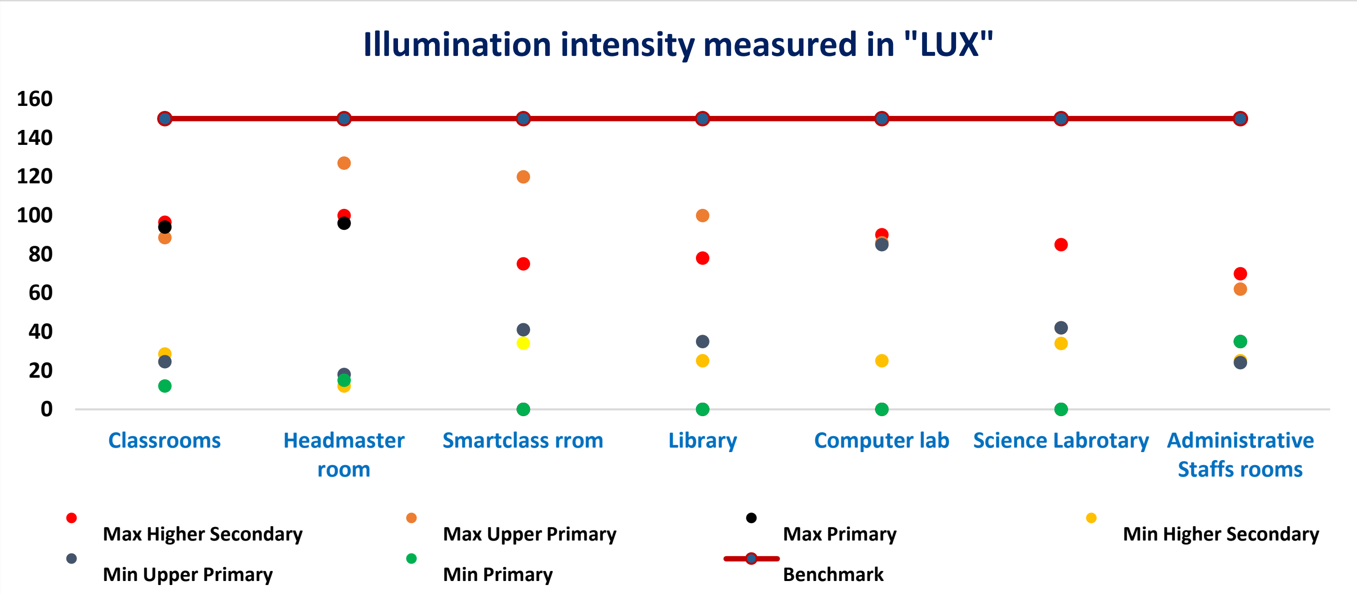

Figure 4: Illumination in the classrooms and other rooms of the school

Data Source: IRADe School Survey 2022

4. Energy consumption by school types

In a school, electricity is required for basic facilities like lighting, and space cooling and appliances are required to support teaching and administrative work. The requirement for electricity depends on several factors like the type of school, availability of appliances, school area, etc. Upper primary and higher secondary schools have provisions for smart classes equipped with audio-visual facilities, computer classes have several computers for teaching, and science laboratories require electricity to run types of equipment. Electricity is required for lighting common spaces, utilities (toilets), and maintaining water supply and purification systems. Table 4 below presents the available facilities in the surveyed schools (average).

Table 4: Available facilities in the surveyed schools (average)

Facilities	Primary	Upper Primary	Higher Secondary School
Number of Teachers (full-time)	3	12	22
Enrolled – Boys	72	306	946
Enrolled- Girls	79	329	801
Average area of school roof (in Sq. ft.)	1543	2717	5807
Functional classrooms	4	8	10
Library	n/a	1	1

Science Laboratory	n/a	1	2
Headmaster room	1	1	1
Office room	n/a	1	1
Teachers/ Staff room	1	1	1
Computer room	n/a	1	1
Audio-visual/ Smart classroom	n/a	1	1
Toilet for school staff	1	1	2
Separate toilets for girls	1	1	4
Separate toilets for boys	1	1	3
Number of Kitchens	1	1	n/a

Data Source: IRADe School Survey 2022

Peak time of energy consumption in schools is 10.00 AM to 3.00 PM and peak months of electricity consumption April to October (excluding summer vacation). Schools have almost stopped using incandescent bulbs. The school use mainly 75 watts' overhead fans for cooling and used Tube lights of 28-36 watts and LED/CFL bulbs of 9-18 watts for lighting. Table 5 presents the average monthly electricity and cooking energy cost by type of schools.

Table 5: Expenditure on electricity and cooking fuel

School types	Avg. school area (sq. ft.)	Avg. monthly electricity consumption (kWh)	Avg. monthly electricity bill (Rs.)	Avg. monthly expenditure on cooking fuel (Rs.)
Primary	3,979	70	319	5,327
Upper Primary	28,579	232	1,633	10,850
Higher Secondary	78,980	864	4,629	-

Data Source: IRADe School Survey 2022

4.1. Energy efficiency and usage

Schools are constrained by limited budgets to manage facilities and are in pursuit of saving money. Energy efficiency is often overlooked as schools purchase energy-inefficient appliances/devices that are relatively cheaper than energy-efficient devices. However, by following energy efficiency practices, schools can effectively reduce energy use and garner energy savings to reduce recurring operating costs. Rising energy costs associated with additional expenditure for replacing equipment attaining end-of-life adds strain to an already compact school's budget. Understanding the energy use status by appliance type is an important first step in identifying energy-saving opportunities. Schools can effectively reduce energy use, garner energy savings, and extend equipment lifetime by implementing an energy management program. An energy management program involves multiple steps in sequential order such as determining energy efficiency targets, conducting energy requirement assessment, identification of energy saving opportunities, calculating costs and paybacks, and finally, implementation followed by monitoring and evaluation.

A typical primary school in Bihar requires electricity for lighting or space cooling. Primary schools don't have any other electrical equipment except bulbs/tube lights for lighting and fans for space cooling. At present, in primary school's hand pumps for drinking water and LPG or biomass, or a combination of both is used for cooking. Upper primary and higher secondary schools use electronic equipment for smart classes, science laboratories, computer laboratories, or to run computers for administrative work

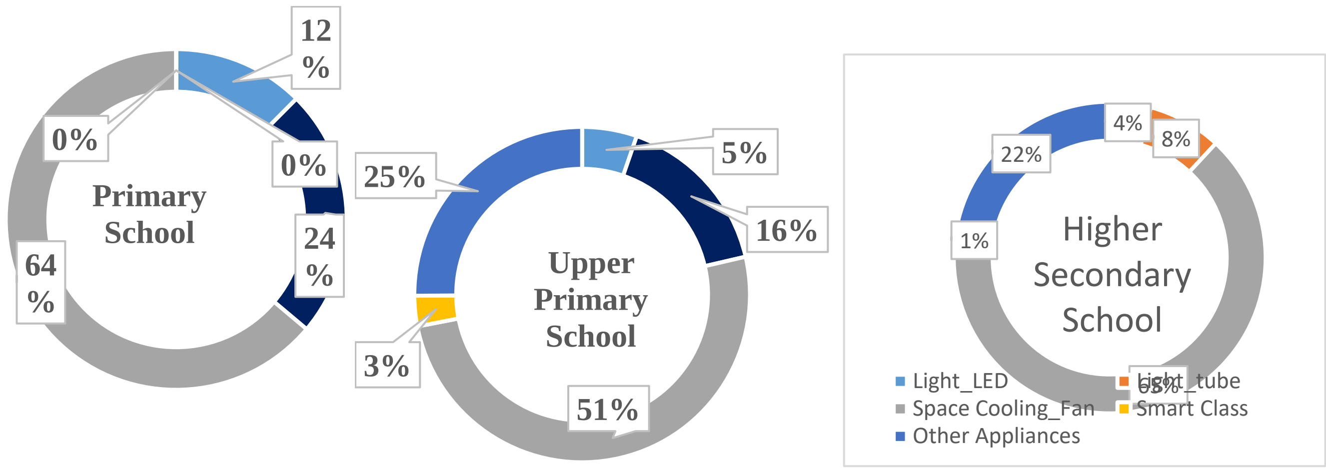

Figure 5: Energy consumption by end use in school types

Data Source: IRADe School Survey 2022

Figure 5, depicts the end energy use statistics for different types of appliances used by primary, upper primary and higher secondary schools. Most of the schools are using energy-efficient LED (light emitting Diode) based bulbs. However, the use of fluorescent tube lights of 28-36 watt is still prevalent in the schools, even though energy-efficient LED tube lights are available. Teachers need to be made aware that energy-efficient BLDC consumes less electricity for the same level of performance. Replacing ceiling fans with energy efficient 28 watts BLDC ceiling fans would reduce the school' total energy demand by more than 40 percent, 32 percent and 41 percent for primary, upper primary, and higher secondary schools, respectively.

4.2. Cooking energy needs

Primary and upper primary schools run a mid-day meal program that serves hot cooked mid-day meals to school children studying in primary and upper primary government, government-aided schools. Free nutritional lunches are provided to students on working days. These schools required cooking energy for food preparation. Schools were using LPG or biomass cooking foods. Liquefied Petroleum Gas (LPG) is considered safe, time-saving, and smoke-free fuel for cooking mid-day meals in school. However, with the increase in LPG cylinder refill prices, many schools have started using firewood for mid-day meal preparation. The use of firewood has become more prevalent in primary schools than in upper primary schools (figure 6).

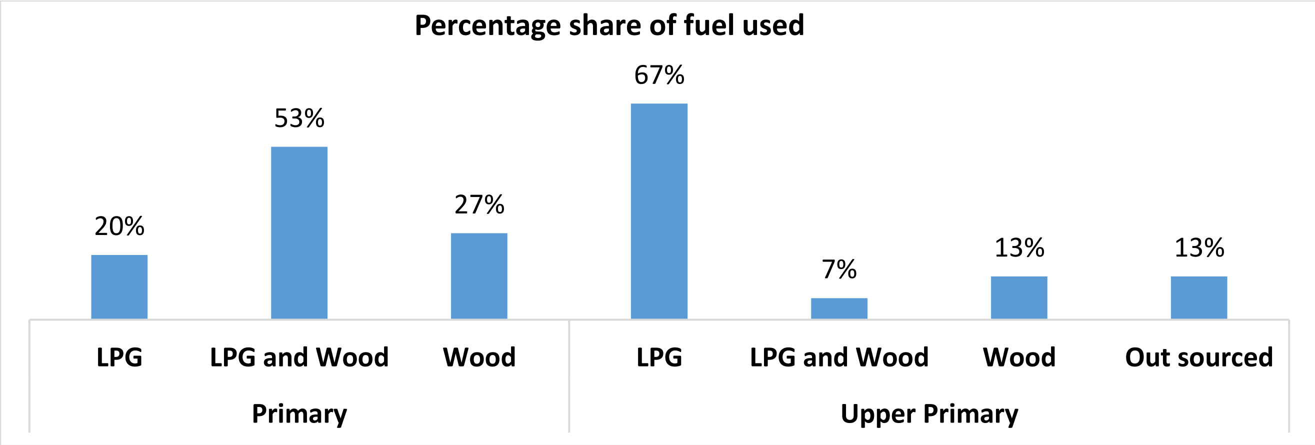

Figure 6 : Fuel used by schools for mid-day meal preparation

Data Source: IRADe School Survey 2022

Schools find it difficult to cope with increasing fuel costs and are forced to find other cheap alternatives. With the increasing use of firewood in mid-day meal preparation, schools are becoming large contributors to inefficient cooking as they often use outdated cook stoves. It generates air pollution on the school campus. The survey found that in the absence of kerosene, some schools resorted to using polyethylene bags to lit fires. A more efficient cooking technologies like e-cooking through induction hot plates or electric pressure cookers (EPCs) could also be explored. A pilot study by IRADe to test EPC adoption in the socio-economic and cultural context of Nepal suggests that a six-litre EPC was sufficient to cook boiled foods and vegetables for a family of 4-5 members (IRADe-PR-88, 2022). There are Electric Pressure Cookers (EPC) available of volumes up to 60 litres. With school kitchens as laboratories to showcase e-cooking cooking solutions, school cooking programmes can promote transformative change in the nearby area.

5. Procurement guide by school type

Based on our school survey and interaction with teachers we have prepared the following appliance requirements by school type (table 6). We estimated the appliance requirements for each school type by utilizing the appliance requirements in the facilities, based on our interactions with teachers and physical verifications of electricity points required on the premise.

Table 6 : Desired number of different appliances by type of schools

Facilities	Electric appliances	Primary	Upper Primary	High School
Functional classrooms	LED lights	3	4	6
	Tube lights	1	2	2
	Ceiling Fan	2	4	4
Library	LED lights		2	4
	Tube light		1	2

	Ceiling Fan		2	2
	Computer		1	1
Science Laboratory	LED lights		2	4
	Tube lights		2	2
	Ceiling Fan		2	2
	Refrigerator			1
	Other electrical equipment			1
Headmaster room	LED lights	1	1	1
	Tube lights	1	1	1
	Ceiling Fan	1	1	1
	Computer	1	1	1
	Printer	1	1	1
Office room	LED lights		1	1
	Tube lights		2	2
	Ceiling Fan		2	2
	Computer		1	1
	Printer		1	1
Teachers/ Staff room	LED lights		1	1
	Tube lights		2	2
	Ceiling Fan		2	2
	Computer		1	1
	Printer			1
Computer room	LED lights		1	2
	Tube lights		1	2
	Ceiling Fan		2	4
	Computer		2	12
	Printer			1
Audio-visual/Smart classroom	LED lights		4	6
	Tube lights		2	2
	Ceiling Fan		4	4
	Audio- Visual		1	1
Toilets	LED lights	1	1	1
	Exhaust fan	1	1	1
Kitchens	Tube lights	1	1	
	Exhaust fan	1	1	

Power usage of electrical appliances depends on several factors such as the kind of appliance, usage hours, size and age of the appliance, etc. The operating power electrical appliances to be used by schools are considered in this analysis are taken for energy-efficient appliances available in the market (table 7).

Table 7: Operating power for electrical appliances desired

Electrical appliances	Operating Power Wattage (Watts)
LED lights	12
Tube lights	20
Ceiling Fan	28
Computer	50
Printer	50
Audio- Visual system	160
Refrigerator	350
Exhaust fan	20
Other equipment required in the Science laboratory	100

5.1 Peak electricity load assessment of schools

The electricity needs are directly related to actual services consumed. In this study, a facility-level survey was conducted to gather information about electricity requirements by types of appliance and hours of operation etc. For each facility type, a list of equipment and their power requirement was used to estimate the peak electricity load. Using table 6 and 7, energy demand by school type has been presented in table 8.

Table 8: Average required energy demand by different types of facilities in schools

Types of facilities	**Type of schools**			**Energy (kW) by the facility types**		
	Primary	Upper Primary	Higher Secondary School	Primary	Upper Primary	Higher Secondary School
Functional classrooms	3	8	10	336	1600	2240
Library		1	1	0	150	194
Science Laboratory		1	2	0	120	1188
Headmaster room	1	1	1	160	160	160
Office room		1	1		208	208
Teachers/ Staff room		1	1		158	208
Computer room		1	1		188	826
Audio-visual/ Smart classroom		1	1		360	384
Toilet for school staff	1	1	2	32	32	64
Separate toilets for girls	1	2	4	32	64	128
Separate toilets for boys	1	2	3	38	64	96
Kitchen	1	1		40	40	

Source: IRADe calculation

Schools are connected to the grid electricity supply system. However, schools require a backup power supply when the power from grid is unavailable. Currently, BREDA is installing Grid Tied PV systems in schools, providing no back-up to schools during power cuts. Teachers during the interviews complained that they wish to have a solar PV system which provides electricity during the power cuts. Therefore, we suggest that to overcome this problem Grid Interactive PV systems are more suitable for schools. These are essentially grid tied systems with an additional battery bank which can store power. They can provide electricity for critical loads in case of a utility power failure thus providing a certain protection against short term power outs. The peak load for different school types is presented in figure 7.

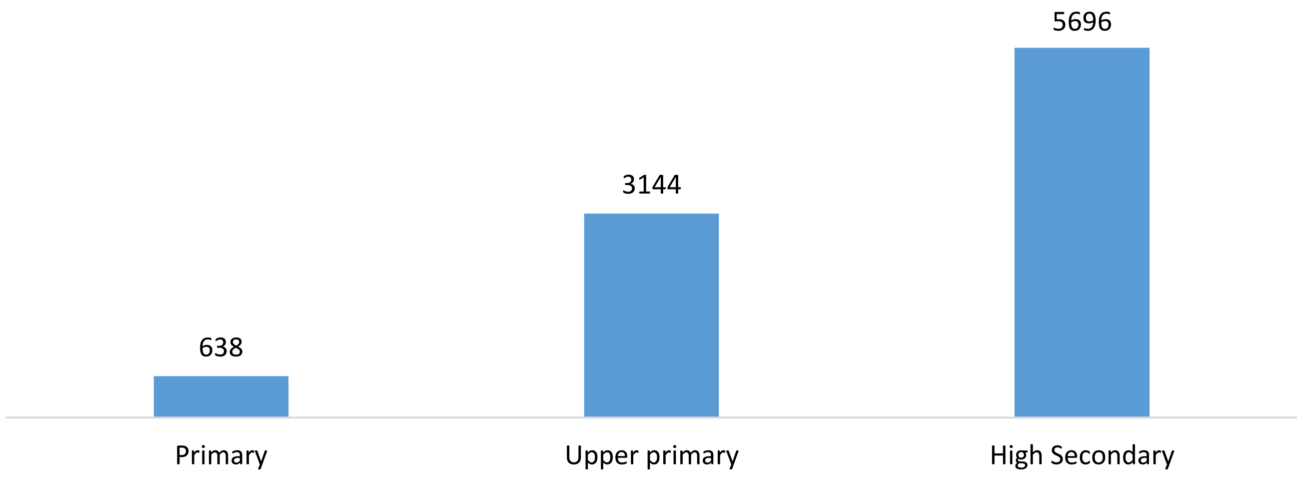

Figure 7:Peak energy demand (in kWh) by school types

Data Source: IRADe school survey 2022 and IRADe calculation

The estimated average solar PV system size by school types for meeting the critical energy demands are given in table 9. To estimate the size of solar panel required to completely meet the school electricity requirement at the time of power break down it is prescribed that the panel size should be 1.25 times the contracted load of the schools.

Table 9:Estimated average size of solar PV system by type of schools

School type	Primary	Upper Primary	Higher Secondary School
Solar panel size to meet electricity demand of school	1 kW	4kW	7kW

Data Source: IRADe calculation

6. Model for school electrification using a decentralized rooftop solar system

The electrical grid has reached schools. Diesel generators available in some of the schools could provide a backup source during power cuts but incurs high running costs. Solar PV is an environment-friendly energy that could simultaneously meet this electricity shortfall and contribute to meeting the national target of achieving 450 GW of renewable energy by 2030.

Rooftop solar rooftop school buildings would provide a saving potential and a revenue stream over the life cycle of the project for schools. Besides being financially beneficial for the schools it will save CO_2 by generating green energy. Table 10 presents the solar installation potential for primary (1-5 class), upper primary (1-8 class), and higher secondary (9-12 class) schools in Bihar. These three types of schools in Bihar have a combined solar RTPV installation potential of 180 MW (table 10). However, the installation of solar RTPV systems will depend upon a variety of factors including availability of the rooftop, condition of the rooftop, and shading situation which can be understood only after carrying out the feasibility survey of the schools. Therefore, the actual or feasible solar RTPV installation potential may be less than the reported in table 10.

Table 10: Solar installation potential by type of school

Solar installation potential by school type				
Sr. no.	Variables	Primary (1 to 5)	Upper primary (1 to 8)	Higher secondary (9-12)
1	Number of government schools	40523	25397	5410
2	Average estimated solar PV size (kWh)	1	4	7
3	Total solar PV installation potential (kWh) (=1*2)	40523	101588	37870

Source: UDISE+ (2021-22) and IRADe calculation

Solar PV projects are environmentally friendly and help in reducing GHG emissions that would have otherwise occurred due to fossil fuel-based power generation[2]. Solar PV systems are an eligible technology for carbon finance projects.

6.1 Evaluating feasibility of school solarization

The Financial analysis of business model uses following commonly used parameters for project appraisal.

[2] Carbon dioxide emissions mitigated per kWh of electricity generated by solar panel is 0.8 kg (Source: MNRE Benchmark)

Payback Period: The period between investment and to a point where the system's savings are enough to pay for the total investment made is termed as Payback period.

$$Payback\ Period = \frac{\text{Total system cost (Rs)}}{\text{Annual savings (price of electricity generated) per year (Rs)}}$$

Return on Investment (RoI): RoI is a ratio of net income and investment throughout the lifetime of project.

$$RoI = \frac{\text{Net profit over lifetime of project}}{\text{Investment}}\ X\ 100$$

Net Present Value (NPV): NPV is the present value of discounted future cash inflows and cash outflows calculated over the lifespan of a project.

$$NPV = \sum_{n=1}^{N} \frac{C_t}{(1 = r)^n} - C_0$$

Where n = 1…………..N

C_t is total cash flow at year t

C_0 is initial investment in project (in year zero)

N is lifespan of project in years

i is rate of interest rate considered for the project

IRR (internal rate of return)- IRR is the discount rate that makes the net present value (NPV) of a project zero. It is the expected compound annual rate of return that will be earned on a project.

It emerged from analysis that schools in Bihar wish to have solar energy which can provide backup during school hours. A grid-interactive solar PV system with an additional battery bank with 1 hour of storage that can store power and provide electricity for critical loads in case of a utility power failure would be suitable to meet the school requirement has been considered for the analysis. The average solar irradiation in Bihar is 1156.39 W / sq.m. Therefore, a 1kW solar rooftop plant will generate on average over the year 4.6 kWh of electricity per day (consider 5.5 sunshine hours). Figure 8 shows the month-on-month electricity generation from a 1kWp solar RTPV in Bihar. The month-on-month electricity generation varies depending on weather and climatic factors.

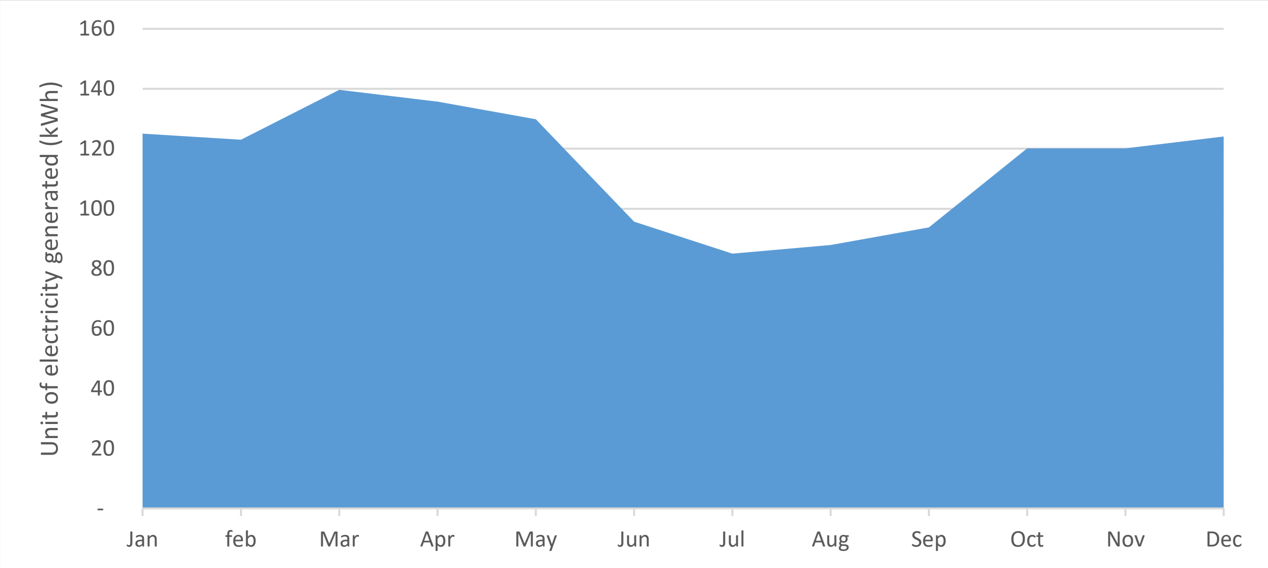

Figure 8: Electricity generation by 1kWp solar rooftop in Bihar

In this section, we have analyzed the financial viability of the deployment of solar PV on the school's rooftop. MNRE benchmark cost for solar rooftop system with a 1-hour battery backup system is considered for the analysis. As per the tariff order issued by Bihar Electricity Regulatory Commission (BERC) for North Bihar Power Distribution Company Limited (NBPDCL) and South Bihar Power Distribution Company Limited (SBPDCL) approved tariff for FY 2022-23 for Non-Domestic (Rural-demand based) consumers' energy charge is Rs.6.40/kWh upto 100 units and Rs.7.0/kWh for each additional units upto 200 units and then after Rs 7.55/ kWh for each units. For the calculation, we have considered Rs 6.40/ kWh for electricity generated by primary schools and Rs 7.0/ kWh for electricity generated by upper primary or higher secondary schools. The different tariffs are considered for different school types reflecting the monthly electricity consumption.

Table 11 : Solar PV system payback period

Particulars	Primary	Upper Primary	Higher Secondary
Size of Power Plant (Plant size as per estimated capacity requirement for school types)	1kW	4kW	7kW
Cost of the Plant (MNRE current Benchmark Cost)	62,000	248,000	434,000
Monthly average electricity generation	115	460	805
Value of electricity generated in a month at grid tariff rate	736	3220	5635
Payback Period (in years)	7.0	6.4	6.4

Solar project for schools has a payback period ranging from 6.4 years to 7 years (table 11). The project will generate a monthly saving on the electricity cost of the schools and over the lifetime (25 years) the project will generate approximately 3.5 times return for the schools (figure 9).

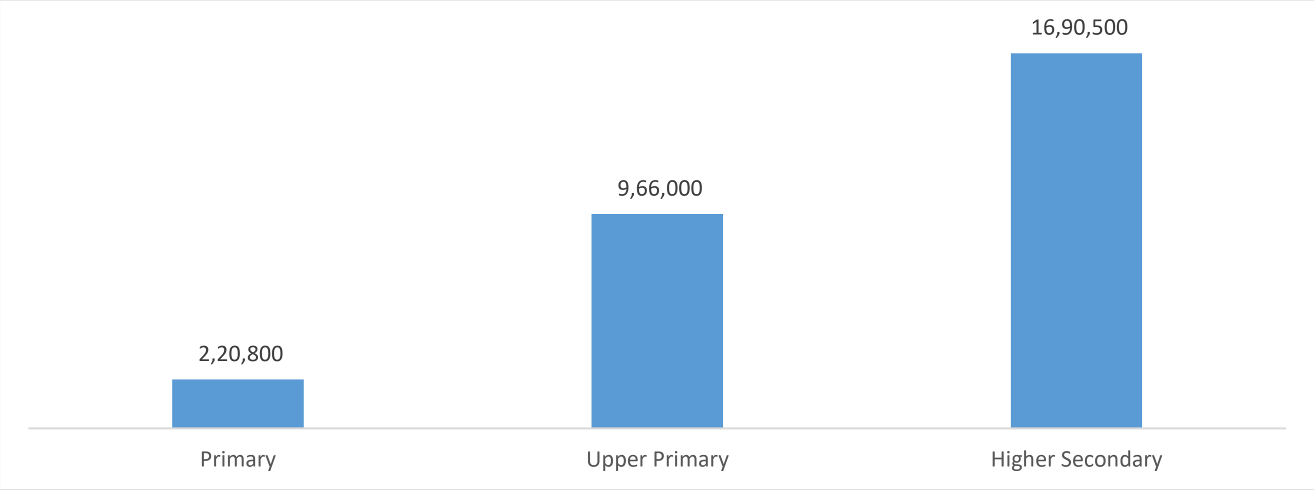

Figure 9: Value of generated electricity over the lifespan at ongoing grid tariff rate (in Rs.)

Data Source: IRADe, analysis

6.2 Business model for school solarization

The slow progress of solar RTPV systems installation in Bihar may be attributed to several barriers. On the demand side, it could be due to a lack of awareness and financial constraints. On the developer side difficulty in identifying consumer segments, limited access to finance, lack of innovative business models, etc. At the same time regulations for solar rooftop systems and their implementation are still evolving.

This study explores the business model to solarize government schools. The study has identified four business models based on ownership of systems to promote solarisation (figure 10). Model 1 is a CAPEX model where schools/government/designated government agencies will invest equity capital for the solar RTPV system. Model 2 and Model 3 are DISCOM-centric models. In Model 2 DISCOM will invest in setting up solar RTPV systems by leasing the school's rooftop. In Model 3 DISCOM will play the role of facilitator and the School Management Committee (SMC)[3] would hold equity capital in the solar RTPV system. Being a consumer-facing enterprise DISCOMs has an inherent advantage in setting up solar RTPV systems on school buildings. Model 4 is a third-party specialist organization (renewable energy service company - RESCO) that would set-up solar RTPV on school building and operate.

[3] School Management Committees (SMC) have been made mandatory for schools under the RTE Act of 2009. This is constituted in all elementary schools in the State to ensure the community and parents are involved in bringing schools quality education at an affordable price.

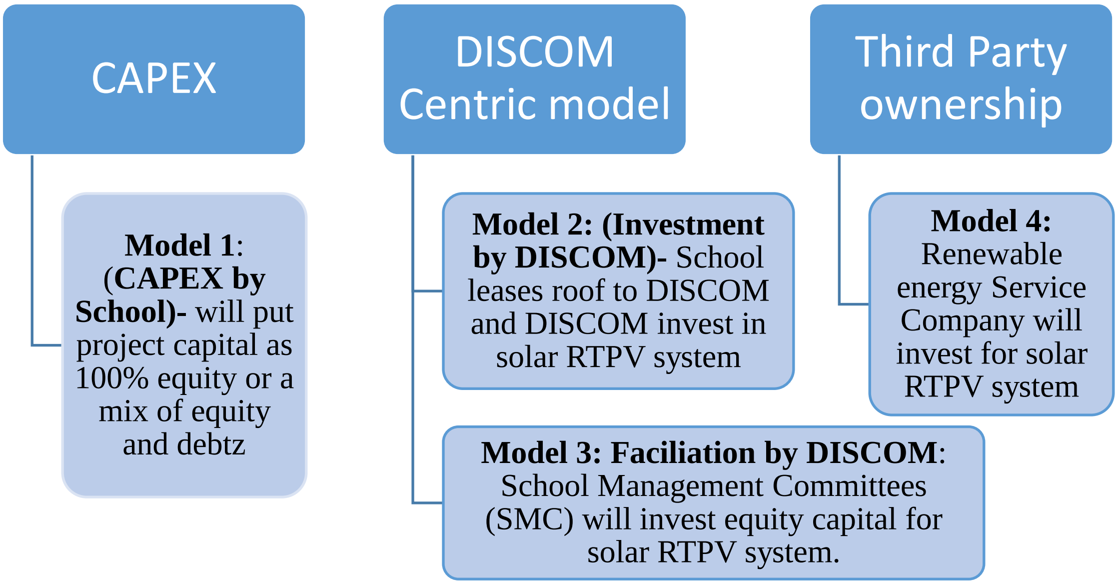

Figure 10: Business model for promotion of rooftop solar adoption by government schools in Bihar

Source: IRADe, analysis

For quantitative modelling we have built an Excel based cash flow model for a representative capital structure (100% equity for CAPEX and a mix of debt and equity for OPEX models) for a given price of solar system. The model is developed to evaluate the profitability of project. Other financial inputs like grid tariff rate, O&M expenses, interest rate on capital and escalations of these costs etc are kept in close range with industry standard. Table 12 lists the operational and financial variable and their associated values used for business models. Technical inputs models like solar irradiance, annual electricity production, plant life etc. are considered as per industry standard. Required system size for different school types are estimated based on the expected peak load in the previous section.

Table 12: List of operational and financial variables used in the model

Model inputs	Units	Primary	Upper Primary	Higher Secondary
Expected plant load factor	%	15.97%	15.97%	15.97%
PPA terms	Years	25	25	25
Debt	%	80%	80%	80%
Equity	%	20%	20%	20%
Capital subsidy	%	0	0	0
Rate of interest on the loan	%	8%	8%	8%
Loan repayment period	Years	10	10	10
Discounting factor for future earnings	%	8%	8%	8%
Annual escalation of grid tariff	%	1%	1%	1%
Annual escalation of PPA tariff	%	0%	0%	0%
Annual O&M expenses for the project as a % of capital cost	%	3%	3%	3%
An annual increase in O&M cost	%	1%	1%	1%

6.2.1 CAPEX model for schools

The study on the financial benefits of CAPEX model for schools suggests the model is financially viable and can be deployed in schools. Grid tariffs for the schools are much higher than the levelized cost of electricity (LCoE) from RTPV systems in CAPEX model (table 13). The results also show that higher self-consumption results in significant improvement in the payback period and rate of return. CAPEX model is best suited for those consumers that have the ability to spend upfront on the RTPV system.

Table 13: Financial returns for CAPEX model

Particulars	Primary	Upper Primary	Higher Secondary
O&M expense monthly	(155)	(620)	(1,085)
Return on Investment (ROI)	321%	359%	359%
NPV	19,759	117,873	206,278
IRR	11%	13%	13%
Levelized Cost of Energy (LCOE)	2.43	2.43	2.43

Source: IRADe Analysis; Note: Figures in bracket are negative expense balances

6.2.2 OPEX Models for schools

There are three OPEX models suggested, each model has its own advantage or disadvantage. Due to demand aggregation developers will enjoy economies of scale in both DISCOM-centric business models. DISCOM-led supervision would ensure better system performance. The availability of O&M services by DISCOM throughout the project life would be another advantage. For the community, it will provide a business opportunity and a recurring revenue at minimum collection costs and risks. DISCOM will enjoy a high control of assets. RESCO developers would find it difficult to serve schools as the small-size solar RTPV systems located in remote locations would increase O&M costs for the developer. Therefore, in the third-party ownership model (Model 4) if the RESCO developers are assigned to install solar RTPV systems on a cluster basis, consisting of several schools in one cluster, it will become economical for them to provide O&M services.

Table 14 has details of financial returns for both the school and the system developer. Schools would receive electricity supply with one-hour power back-up at a rate lower than the prevailing grid electricity rate. NPV for the project are positive and it enjoys an IRR of 10%.

Table 14: Financial returns for OPEX model

Particulars	Primary	Upper Primary	Higher Secondary
Loan Amount	49,600	198,400	347,200
Equity Amount	12,400	49,600	86,800
Interest for loan	(602)	(2,407)	(4,212)
O&M expense monthly	(155)	(620)	(1,085)
PPA tariff rate (Rs./kWh)	5.9	5.9	5.9

Return on Investment (ROI)	684%	684%	684%
NPV	6,203	24,811	43,418
IRR	10%	10%	10%
Saving to School (Rs)	48,388	288,030	504,053
Present Value of Savings to School	16,656	105,464	184,562

Note: Capital cost is spilt into a ratio of 80 % loan and 20% equity

6.2.3 Comparative analysis of different business models

From the analysis, it emerges that both CAPEX and OPEX models might be explored depending on whether the school would like to make an investment in the system or pay for the electricity (OPEX) every month. Schools need to sign a long term PPA (Power Purchase Agreement) with the RTPV developer to purchase generated electricity at a negotiated rate. In the event where the upfront investment is a constraint, OPEX model would ensure that the third-party investor or developer operates and maintains the systems in order to generate electricity and reap the corresponding financial benefits from the systems.

For cross model comparison table 15 lists the strength, weakness, opportunity and threat or each of the proposed four models.

Table 15: SWOT Analysis

Ownership	SWOT Analysis	
School (CAPEX Model)	Strengths	• Daytime load curve
	Weakness	• Investment cost barrier • Holidays will lead to excess generation
	Opportunities	• Green Campus • Reduce the recurring cost of electricity
	Threats	• Security concerns due to children or locations
DISCOM-centric business model (DISCOM will invest in projects, and schools would lend rooftops to DISCOM)	Strengths	• Large roof space, fairly spread out • The model can be easily scaled up • Same sector • Higher control of assets
	Weakness	• There is no incentive for DISCOM to promote rooftop solar other than RPO compliance
	Opportunities	• Easy to target due to working associations, as both are government entities • Gain access to additional revenues while promoting renewable energy
	Threats	• Poor financial health of DISCOM • Reluctance of utility
Community-centric business model (A group of community members would be	Strengths	• Low-security concerns due to the direct involvement of local people • DISCOM could supervise and supports O&M
	Weakness	• Lack of knowledge among community members about the business and sector

an investor and with support from DISCOM as the facilitator	Opportunities	• High visibility and could promote renewable to the community • Reduction in cost of system/services due to economies of scale due to demand aggregation by DISCOM
	Threats	• Irresponsibility and Unaccountability on the part of community members • Politicization and issue of inactive members • Lack of awareness
RESCO (OPEX Model)	Strengths	• Centralized electricity bill payment system
	Weakness	• Remote locations, dusty • Financial strength not so strong (not profit-making entity)
	Opportunities	• Tariffs moderately high • Accessible and easy to target
	Threats	• Shadowing from future developments • Security concerns

6.3 Implementation pathway

The development of rooftop solar PV systems faces several barriers however a confluence of factors, including a renewed push from the government, rising grid tariffs, and declining PV prices, are working in favour of rooftop solar. Schools that have concrete buildings with large terraces could be ideal locations for rooftop solar PV installations. Schools require electricity during the daytime, which matches solar PV electricity generation. Further, to understand the viability of solar rooftop PV installation, schools are evaluated and ranked for three criteria (Table 16). A rating concept of 1 to 2 has been adopted for each criterion. A lower score for any criterion suggests a greater opportunity for the rooftop solar PV system. A composite ranking would be created by arithmetically adding the score for schools under three different parameters means each parameter is assigned equal weight in the composite rank index. **This rating can also be used to prioritize schools – which means schools getting lower scores could be taken up first and likewise**.

Table 16: School raking parameters

Parameter	School type	Rank -1	Rank 2
Monthly Electricity Bill (rs)[4]	Primary	More than 320	Other wise
	Upper Primary	More than 1634	Other wise
	Higher Secondary	More than 4630	Other wise
Unshaded Roof availability (% total roof area)	Primary	More than 60 %	Other wise
	Upper Primary	More than 60 %	Other wise
	Higher Secondary	More than 60 %	Other wise
Support & Facilitation by DISCOM	Primary	Willing to support	Neutral
	Upper Primary	Willing to support	Neutral
	Higher Secondary	Willing to support	Neutral

[4] Average monthly electricity bills for different types of school are given in table 5.

Monthly Electricity bill: Monthly electricity bill determines the business case viability. The consumption captures the school's average daily load, peak load, and grid tariff categories. The idea behind this criterion is that if grid electricity prices are considerably higher than the cost of electricity from solar power generation, it shall be the suitable target for solar RTPV migration. This will motivate these consumers to augment a portion of their electricity (if not all) from RTPV systems. However, high tariffs alone would not justify the shift. There is a need for significant consumption – higher consumption means greater incentive.

Roof Availability: The availability of shadow-free rooftop space is a prerequisite for installing the rooftop solar PV system. However, it is one of the greatest challenges in urban landscapes in most major cities. Therefore, roof availability has been considered as a criterion for evaluation. It may be that buildings may not have adequate roof areas to install rooftop solar PV systems of considerable size even though the consumption is high.

Support & Facilitation: support from the local distribution company is an important criterion because DISCOM is responsible for according to the approvals. Government policies and support also impact the decision of DISCOM, and often the government prioritizes certain school types or geography. This rating captures the attitude and support of DISCOM and the government now and in the future.

Based on the above three criteria, each school is evaluated based on a rating index, which will determine the likelihood of rooftop solar PV system installation.

7 Benefits and limitations of rooftop solar systems for schools

The development of efficient decentralised renewable energy generation systems and fall in equipment prices, especially solar PV, has emerged as a viable technology for providing electricity access in schools where grid services have either not reached or are unreliable. The important factors for selecting the appropriate solar micro grids can be local conditions, peak power demand, timing of the electrical loads, capital cost and prices of alternative fuels.

- **Availability of space**: Most of the schools have adequate roofs, which is ideal for rooftop solar installation. Land is expensive in Bihar and most of the lands are cultivated land and hence use of roof will save land requirement for improving renewable share in the state
- **Energy savings**: Educational institutes operate mostly during sun shine hours and hence effective use of solar is ensured. Also, it will help in reduction on electricity bills.
- **Operational easiness**: Solar plants require less maintenance as compared to other technologies and it has life of more than 25 years.
- **Environmental benefits**: Solar can contribute a pollution-free and healthy environment and help reduce carbon emissions. Also, dependency on imported fossil fuel will reduce.
- **Awareness**: Demonstration and awareness creation to students as school can run courses for students. This will help to promote solar for different applications in society.
- **RPO (Renewable Purchase Obligation)**: More installation of renewable plants will help meeting DISCOMs renewable purchase obligation.

IRADe organised a workshop on March 1st, 2023 in Patna, Bihar to present the key findings of this study and to understand the views of academicians, researchers, NGOs, Developers and government officials. Participants highlighted that Climate Change is biggest threat to environment today and there is an urgency to adopt strategies to curb this through proper energy system planning. It is important to have balance between growth and emissions and DRE gives a balance to both, while working on the socio-economic aspect as well. Participants opined there concerns for the maintenance aspect of solar PV systems and suggested to have solar PV repair and maintenance agency assigned to each school before solarisation. From the discussion it emerged that DRE technology which delivers the cleanest energy will be very beneficial for the people, the economy, the society, and as well as the environment. A very high degree of energy correlation had been found between access to electricity and literacy rate, therefore, cheap and convenient sources of power are essential for good performance of our teachers and students. Government of Bihar schools very much needs the installation of solar panels to enable the smooth functioning of teaching-learning process. It is important to spread awareness on how to use the DRE technology and maintain the same, a proper training methodology should be imparted to educate teachers and students to make the benefits in the long run. It is important to identify the hurdles that hinder the installation of solar PV systems in schools.

8 Conclusion

The poor quality of electricity supply, especially in remote locations, coupled with intermittent load shedding hampers the quality of education delivery in the schools. Decentralized solar energy could be an option to address this challenge of the unmet electricity needs of schools. This study provides the status of electricity access in the government schools in Bihar and size of solar PV system required, based on desired appliance load, to overcome the problem of energy crisis at schools. Below we provide some of the suggested actions based on our study:

Solar mapping: Solar PV system relies on good access to the sun and schools with large amounts of shading or damaged roof is not suitable for deployment of this technology. Therefore, solar mapping analyses of government schools needs to be carried out to inform decision makers about the availability of appropriate roof areas.

Energy audit: This study has highlighted that existing appliances may not be sufficient to cater the lighting and cooling needs of students and teachers. Therefore, sizing of the solar PV system based on the existing power load of schools may not be adequate. Energy audit of schools will provide the information about the ideal appliance requirement and peak power load, which can be utilised to design the size of solar PV system for a particular school. This will also inform the decision makers, District education officer (DEO) and District planning officer (DPO) about the critical appliance needs at in a particular school of that district.

Type of PV Systems: The insights gained during the school surveys and interactions with teachers suggest for uninterrupted supply of electricity, they seek to have solar PV system with power back-up. Currently solar PV system in Bihar are getting installed only in higher secondary schools and that also without a battery back-up. Teachers finds Grid tied PV system of little use, except reducing facility electricity bill. Therefore, Grid interactive PV system, which has an additional battery bank to provide electricity for critical loads in case of a utility power failure, fits to the teacher's aspirations.

Business model: On March 7th 2023, Bihar state energy Minister said that solar power plants should be installed on the school buildings so that their electricity needs can be met from solar energy only. Government schools are run during day time. The solar units would be sufficient to meet electricity requirements of the schools[5]. This shows the Government of Bihar strong inclination for solarising schools. However, the large number of governments run schools in the state is both an opportunity and challenge. Putting solar PV rooftop system in such large number of schools will accelerate the pace of

[5] https://timesofindia.indiatimes.com/city/patna/plan-to-install-solar-plants-on-govt-school-buildings-soon/articleshow/98531335.cms

green energy generation in the state, but financing these solar PV systems will require huge capital expenditure. Going for a Capex model for solar PV system will put huge burden on government exchequer and it is likely that lack of funding may halt or slow down this program. This study has developed 4 business models for school solarisation. We suggest that while preparing the green strategy for solarising schools, Energy and Education department of Government of Bihar should opt for the best suited model presented in section 6.1. Selecting the right business models is key to ensuring the efficient functioning of model. The revenue and business models need to be carefully reviewed in the context of investments and expenses required to operate and manage. Schools may select the most suitable business model by breaking it down into three main steps: 1) level of engagement, 2) financing arrangement, and 3) operational ease.

Community engagement: In our discussion above theft of solar panels have been cited as an area of concern. Though RESCO model transfer this burden from Government to developers. However, still local community should be involved to avoid such theft instances. Local community should be sensitised and encouraged to be concerned and watch for vandalism and theft.

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