Role of DRE Technology in Promoting Quality School Education in Jharkhand

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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 Jharkhand, 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 involves 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 Ranchi, Hazaribagh, and Deoghar. 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 engaging 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 Jharkhand. 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.

Jyoti K. Parikh

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Finally, the project team acknowledges **Mr Ajay Jaiswal**, Director ASHA for supporting the field survey and organizing the workshop, and IRADe Administration and Finance team for their support during the entire project.

Contents

List of Table

List of Figures

1. Introduction

Energy for community facilities is fundamental for socio-economic development. Energy enables improvement in human capital by improving the quality of services delivered to the community (The World Bank, 2015). Considering the importance of energy for society, the overall energy access index considers three sub-locales as part of the broad indexes, 1) index of household access to energy, 2) index of access to energy for productive engagements, and 3) index of access to energy for community facilities - as the locales of energy access (*ibid*). Electricity is an integral part of delivering modern services. Lack of electricity or shortage can put a lot of limitations on efficient and effective service delivery. However, India's large-scale government-driven energy access programs have mostly focused on household-level electricity access. Electricity access in community facilities, including government schools, has gathered less policy attention. Unlike the household sector, there is no known large-scale nationwide electrification program or policy intervention for ensuring electricity access in community facilities. A study by IRADe measured electricity access for the community facilities (schools and hospitals) in Jharkhand using Multi-tier Energy Access Tracking Framework. The study found that even though electrification has improved in Jharkhand over the last five years, a significant gap exists in electricity access to facilities (IRADe, 2020). The study suggests that there is a need to move up energy profile of schools on the energy access ladder, which includes attributes of available energy supply such as reliability, power capacity, etc. (ibid).

Economic Survey (2019-20) shows that states with high school electrification rates also have higher literacy rates. It further says improving education infrastructure is always positive unlike other sectors there is no apparent diminishing return observed. Electrification of schools is important for illumination and cooking which makes teaching-learning enjoyable for both teachers and students. In addition to water, sanitation, and hygiene (WASH) facilities, access to electricity creates a comfortable environment for students and teachers. The lack of WASH facilities may lead to female students frequent absent from school or dropout altogether (UNICEF, 2018). Electricity also increases access to ICT (information and communication technology) and improves the quality of education. More recently, the dissemination and use of information and communications technologies (ICT) in schools have become a significant opportunity to improve student achievement, improve access to schooling, and enhance students' ability to learn. Digital education content is becoming widely popular in the modern school education system. Digital education is the way to seek education through technology and digital devices. Electricity provision contributes to strengthening all enabling components.

Electricity is necessary but not only factor to deliver quality education services. Electrification does not demonstrate a linear relationship with outcomes in the education sector, which are also influenced by several other structural and institutional factors and the contexts in which they are implemented (Polansky and Laldjebaev 2021).

Integrating electricity priorities into schools is interrelated with many SDGs (Sustainable Development Goals) besides SDG-4, which advocates quality education. SDG -7 supports access to affordable, reliable, sustainable, and modern energy for all (figure 1). Electricity is vital for school children's good health and well-being (SDG-3). SDG-6 is about clean water and sanitation for all. Clean water and sanitation facilities in schools can't be provided without access to electricity. Improved sanitation helps reduce girl child drop out from schools to improve gender equality (SDG-5). Solar electricity will be climate-friendly and help the country to meet NDC (Nationally Determined Contribution) goals and move a step towards the Net-Zero-2070 commitment by the government of India (SDG-13).

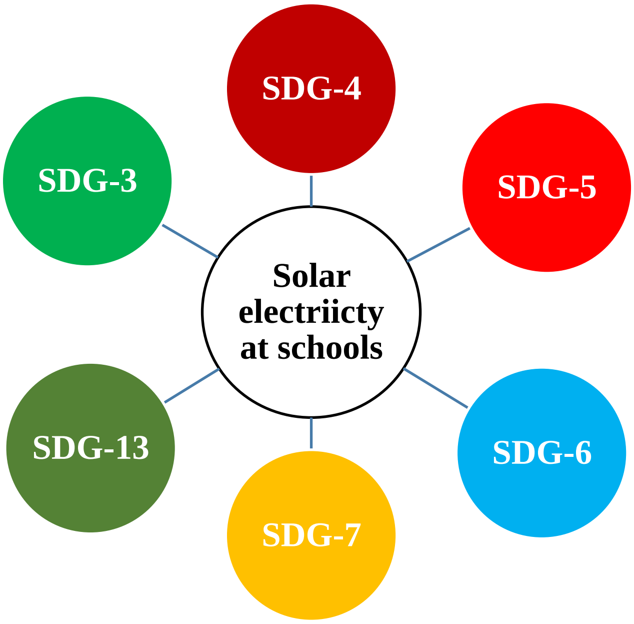

Figure 1: School Solarization and SDG

As per UDISE+ (Unified District Information System for Education Plus) -2021-22, Jharkhand schools (both Government + Government added – 82.5% and Private + Others -17.5%) have 7,970,750 students enrolled in 44,855 schools having 210,418 teachers. Approximately 92 percent of schools have functional electricity access, and 7 percent have installed solar RTPV system. Functional computers are used for pedagogical purposes in 5 percent of schools. Drinking water, hand wash facilities, functioning toilets for girls, and functioning toilets for boys are the essential components of WASH facilities in 91 percent, 96 percent, 97 percent, and 94 percent, respectively.

Table 1: Schools by management type

Schools	Primary (Class:1-5)	Upper Primary (Class:1-8)	Higher Secondary (Class:9-12)
All Schools (Government + Private)	23706	16140	478
Government Schools	21318	11613	646
Government Aided	496	497	39

Data Source: UDISE+, 2021.22

Electricity access is part of a broad indicator of the state of school infrastructure in the country. The percentage of schools with electricity connection has shown an increasing trend at the national level, from 76.7 % in 2018-19 to 89.3 % in the 2021-22 UDISE+ survey. In Jharkhand, 96.5 % of government schools have electricity connections, of which 93 % have functional connections in 2021-22. Given the level of electricity access in the schools and its importance to the education service in Jharkhand, this study attempts to identify the role of DRE (distributed renewable energy- solar photovoltaic electricity) in schools and measures for its uptake in government-run schools. The broad 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.

The precise objective of the study is to suggest policy intervention for the solarisation of schools in Jharkhand. The study estimates the electricity demand of different school types, to estimate the size of solar PV system by type of school (primary, upper primary and higher secondary schools).

The rest of the report is organized into seven sections. Section 2 explains the study methodology. A comprehensive analysis of the primary data collected from school and teacher surveys is presented in section 3. In section 4 a procurement guide for electrical appliances for the school types are developed. This section also estimated the electricity load of a school types and prescribe the required size of solar system to meet the school requirement. A business model is prepared and evaluated based on financial KPIs in section 5. Stakeholders' experiences in the state, efforts by different agencies for promoting solar electricity, and the challenges they face in this journey are captured in section 6. Section 7 presents a summary and recommendations for overcoming these barriers. Stable policy frameworks can counter financial and technical problems. In sum, the report shows that the schools can provide students with the comfortable school environment and quality teaching they deserve if planners, investors, and policymakers make a determined, coordinated effort to promote electricity for education.

1.1 Limitation

Education as a subject does not have a linear relationship with any single input and most often is influenced by a combination of multiple factors, such as the availability of skilled teachers, availability of appliances, buildings, accessibility of the school by road, etc. Hence, the study can only link the role of electricity access to the quality of education service delivery.

2. Methodology

The study utilizes a multi-stage sample design technique. Three districts were selected from Jharkhand for intensive research and data collection. Ranchi, the state capital district, was the benchmark district for the school's infrastructure availabilities. NITI Aayog has been running an aspirational district program to expeditiously improve the socio-economic status of 117 districts across 28 states of India. The program focuses on five main themes inter-alia education. Deoghar, 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. Hazaribagh is the third district selected from the non-aspirational district's list of Jharkhand. Each selected district of the state is further disaggregated by block, and five blocks are randomly selected for data collection. A detailed school landscape in each block was prepared based on the available secondary data and a face-to-face meeting with District Education Officer (figure 2). After listing the schools in a particular block, one primary, one secondary, and one senior secondary school were selected for the school facilities and teaching staff survey. Therefore, a total of 45 schools (15 – primary school class 1 to 5, 15- upper primary school 1 to 8, and 15 higher secondary school class 9 to 12) from 15 blocks of three districts were surveyed. From each school 3 teachers were selected for interview based on a questionnaire which had a set of both open ended and close ended questions[1].

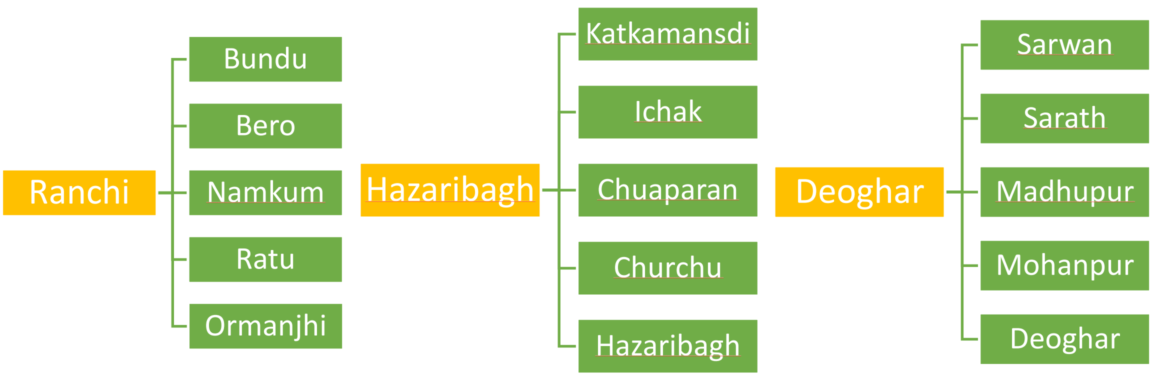

Figure 2: District and blocks selected for schools and teachers survey

The survey was conducted through a structured questionnaire for school facilities and personal interviews of teachers in November and December 2022. 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 3). 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.

[1] In several of the surveyed primary schools, only two teachers were present, so we interviewed only two teachers in those schools.

Section-A captures 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 were part of Sections D and E, respectively. Good lighting in classrooms and spaces affects us visually and impacts physical attributes; therefore, the level of illumination in classrooms and other places on the school campus is given its due share. 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.

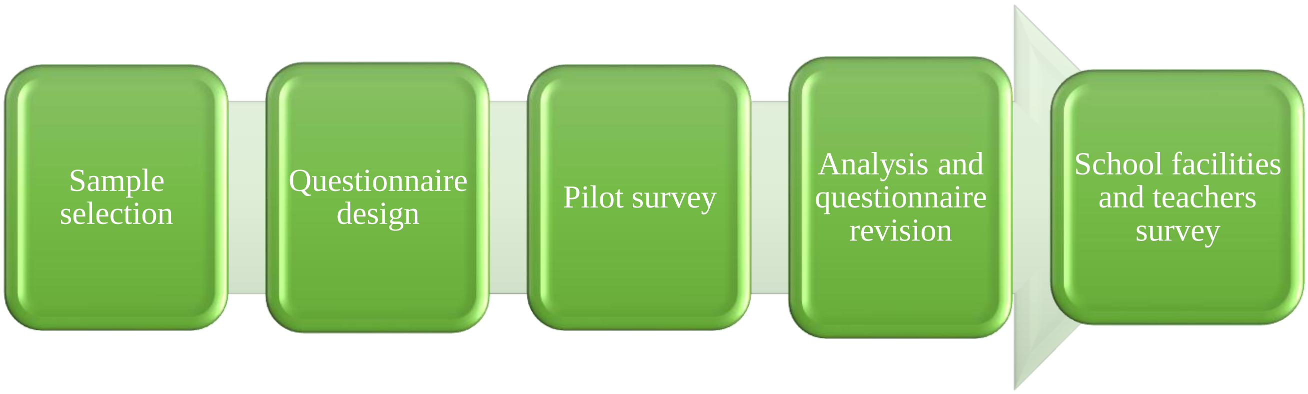

Figure 3: Steps involved in the school survey

Unlike the school facility survey, the teacher survey questionnaire was designed to collect primarily 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.

The study has been placed within the larger context of electricity access and its various dimensions, thus leading to a more holistic consideration of the existing sources of electricity in a school (grid and secondary source). The overall frame of analysis thus evaluates the current sources of electricity supply in a school, the availability of electric appliances, teachers' perception of differences in the quality of education services, if any, and the provision of solar RTPV systems.

2.1. Analysis techniques

The study collected primary qualitative and quantitative data from the schools and teachers. For analysing primary data, the study make uses descriptive statistical technique. Tabular analysis and graphical representation of data through bar, chart and other diagrams are used for better articulation and representation of data and analysis results. The Financial analysis of business model uses following commonly used parameters for project appraisal.

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_o 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.

3. Summary statistics of the surveyed school

While this evaluation aims to understand the role of electricity access on the quality of school education, it is important to set the context in terms of the state infrastructure available to schools. Access to electricity is important, but only as an enabler of many educational services and providing a conducive environment for imparting education. Without enabling school infrastructure and other supporting factors, it cannot have the desired impact. The following sections provide an overview of the state of education infrastructure (education-related and electricity) available based on the data from the sample survey of 45 schools across three districts in Jharkhand.

3.1 Basic infrastructure facilities in Schools

The teacher is perhaps the most important factor in the quality of education. There are two teachers on average in a primary school having a student strength of 74 students (table 2). Boys' and girls' enrolment ratios in primary and upper primary schools are the same, whereas the ratio changes in favour of boys in higher secondary schools. It may be inferred that the less average number of girl student enrolment than boys in higher secondary schools on account of many more girls than boys dropping out of school before completing higher secondary schools.

Table 2: Average number of different types of classrooms

Description	Primary	Upper Primary	High School
Number of Teachers (full-time)	2	6	15
Enrolled – Boys	35	136	884
Enrolled- Girls	39	143	680
The average area of the school roof (in sq. ft.)	1740	3667	5740
Functional classrooms	3	7	12
Library	1	1	1
Science Laboratory		1	1
Headmaster room	1	1	1
Office room			1
Teachers/ Staff room		1	1
Computer room		1	1
Audio-visual/ Smart classroom		1	1
Toilet for school staff	1	1	2
Separate toilets for girls	1	2	4
Separate toilets for boys	1	1	3
Number of Kitchens	1	1	

Data Source: IRADe School Survey 2022

An adequate number of classrooms is critical to education delivery which is also reflected in the student-classroom ratio. This ratio is calculated as 25, 40, and 130 in primary, upper, and higher secondary schools, respectively. Availability of library, science laboratory, headmaster room, room of the office and other staffs, toilets (separate for boys and girls) are other important required infrastructures necessary amenities to deliver quality education. Computer rooms and smart classrooms have become integral parts of modern education. In reply to a question about the source of water supply, all the schools said that they have a hand pump or bore well in the school. But in answer to a follow-up question, "Is the water supply sufficient to run the school?" Sixteen percent of schools answered that they don't have a sufficient water supply. Schools in the Jasidih blocks of the Deoghar district reported that they fall in a dry zone and hand pump or bore well hardly works; they need to purchase water to meet the demand. Primary and upper primary schools are also delivering mid-day meals to the students. Freshly cooked nutritious and hot meals are served to the students. To cook meals, these schools also have a kitchen attached. Table 3 shows schools in Jharkhand are faring goods on some basic infrastructure indicators, but much of this infrastructure is required to be improved across the school types.

Table 3: Facilities available in school types

Facilities	Primary	Upper Primary	Higher Secondary
Percentage			
Schools have a Library (%).		60%	93%
Schools have Science Laboratory (%).		40%	93%
Schools have Headmaster room (%)	93%	93%	100%
Schools have an Office room (%).			67%
Schools have a Staff room (%).		33%	93%
Schools have a computer room (%).		13%	80%
Schools have Smart class/Audio-visual rooms (%)		20%	73%
Schools have a Kitchen (%)	100%	100%	
Toilet for school staff (%)	20%	47%	80%
Average counts			
The average number of Separate toilets for girls	1	2	4
The average number of Separate toilets for boys	1	1	3
The average number of Functional classrooms	3	7	12

Data Source: IRADe School Survey 2022

3.2 Status of electricity supply in schools

The percentage of schools with electricity connection has shown an increasing trend over time, as 11% of surveyed schools (all types) reported getting an electricity connection in the last five years. Grid is the primary source of electricity reported by all the surveyed schools though some schools have solar or DG (diesel generators) as secondary source of energy. The average duration of daily electricity supply from primary source ranges from 4.3 to 4.6 hours during school working hours. Schools are observing, on an average, 10 to 12 hours of weekly power outages during school working hours. Voltage fluctuations or low voltage supply impact the efficient use of electric appliances. Solar power is available in schools but only as a limited secondary energy source. It is generally a task-specific (either for smart class or lighting for headmaster room etc.) power backup source. Electricity has a greater impact today. With the digitization of our educational methods, there is an increased dependence on modern electronic devices and the power supply needed to run these systems. In reply to whether power supplied by the secondary source is sufficient during power cuts, only 13 percent of schools responded affirmatively.

Table 4: Electricity supply status

Attributes	Details	Primary	Upper Primary	Higher Secondary
Electricity Access	Duration of average daily electricity supply from the grid during school working hours (school working hours depended on the days of week, location, season etc on normal working day a school is open for 6 hours a day)	4.6	4.6	4.3
Quality	Frequency of electricity supply disruptions in a week (Average No. of times irrespective of duration)	9.71	10.07	11.53
	Voltage fluctuations during school hours (% of Schools)	80%	60%	73%
	Voltage affects the use of desired appliances (% of Schools)	0.53	0.27	0.53
Secondary source	No secondary source (% of Schools)	67%	87%	20%
	DG Set (% of Schools)			60%
	Solar PV (% of Schools)	33%	13%	20%

Data Source: IRADe School Survey 2022

3.3 Illumination level in the school's facilities

The study investigates daylight illumination in classrooms and other rooms of a school. Illumination in the room depends on several factors, including the room's design. During the day time in the absence of sufficient daylight, the illumination of a room could be enhanced with artificial light bulbs run on electricity. Good quality lighting is very much required by teachers and students for learning without putting strain on their eyesight. The availability of good-quality lighting can considerably improve students' concentration, reduce health exposure, and, therefore, their learning ability.

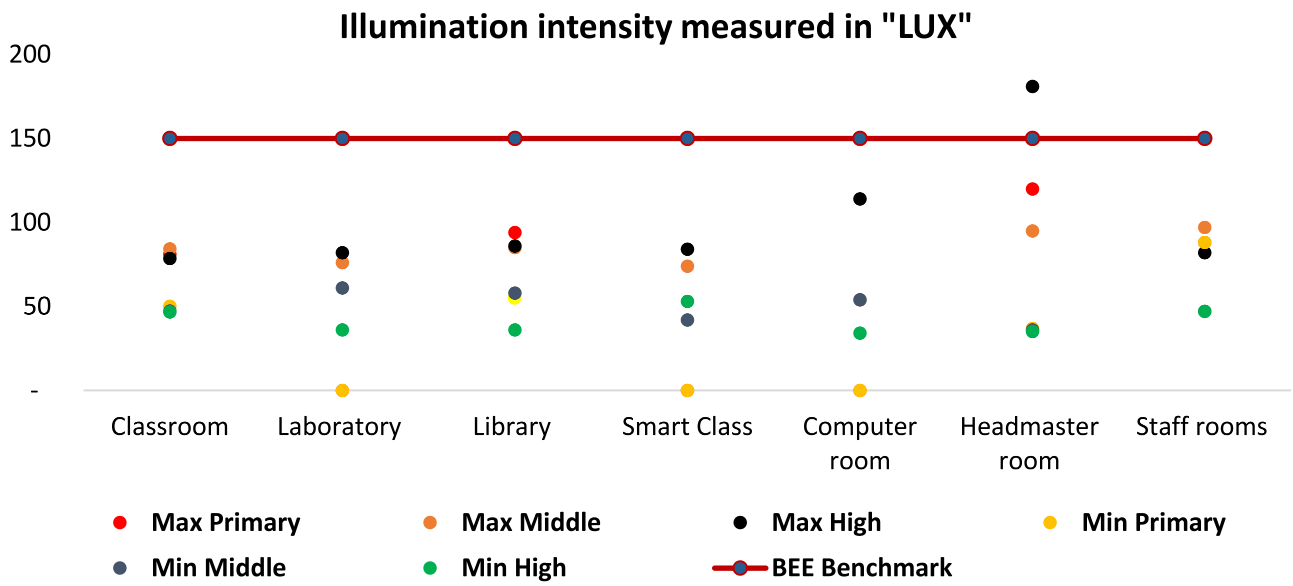

Figure 4: Illumination intensity in school facilities
Data Source: IRADe School Survey 2022

The assessment of illumination in the classrooms, laboratory, computer room, etc., using a "LUX" meter from the surveyed school, suggests that all these facilities have illumination levels below the minimum prescribed level in the daytime. It was observed that the facility either don't have sufficient bulb holder to place bulbs or, even though holders do exit but bulbs are not there in working condition. To improve indoor environment quality, adequate illumination should be ensured in the school rooms depending on the use purpose of the room in conformity with the prescribed standard.

3.4 Cooking energy

Under the National Programme of Nutritional Support in Government Primary and upper primary schools, primary and upper primary schools run a mid-day meal program for all children. The scope of this study is limited to the fuel used for cooking mid-day meals for the students.

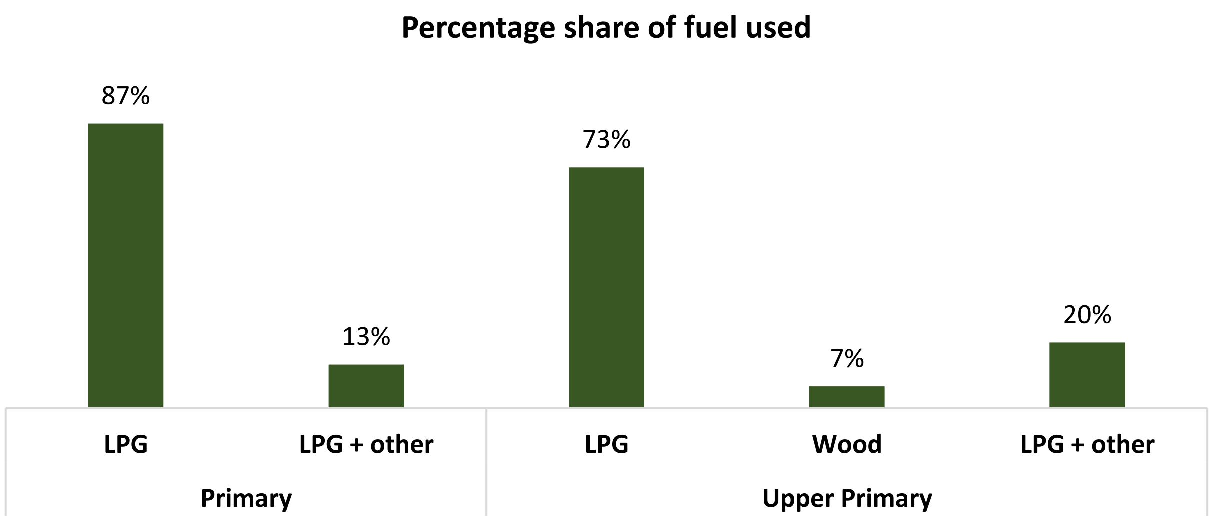

Figure 5: Energy used for mid-day meal preparation by schools
Data Source: IRADe School Survey 2022

Mid-Day Meal in the school is prepared by cook hired for this purpose. A kitchen is set up in the school for the same. Schools are provided with LPG stoves and cylinders to cook food. Cooking through LPG will ensure a pollution-free environment in and around the school campus. However, it was observed that meals were prepared with firewood and dung-cake, putting children exposed to harmful emissions with solid fuel burning in the school kitchen. Schools' cooking energy use profile suggests that despite having access to LPG, schools are using other fuels. LPG is the primary cooking fuel for more than 87 % of food preparation in primary and 73 % of upper primary schools (figure 5). Solarisation of schools may open an option for solar-based induction cooking solutions for the schools. EESL (Energy Efficiency Services Ltd), a subsidiary of the Ministry of Power, Government of India, is already exploring the possibility of providing Solar-based cooking solutions along with basic induction-based cookware. Alternatively, eCooking (Electric Cooking) is another energy efficient device for cooking.

3.5 Energy efficiency in schools

Energy efficiency is often overlooked in school buildings as the associated costs (impact on monthly electricity bills) are relatively lower than other expenses. By following energy efficiency, schools can reduce energy use, garner energy savings, and monthly outflow on electricity bills. While studying the factors affecting energy costs within school facilities, it is important to estimate where energy is utilized. Identifying areas of high and low energy use will help you target critical areas for improvement and areas that will provide maximum returns.

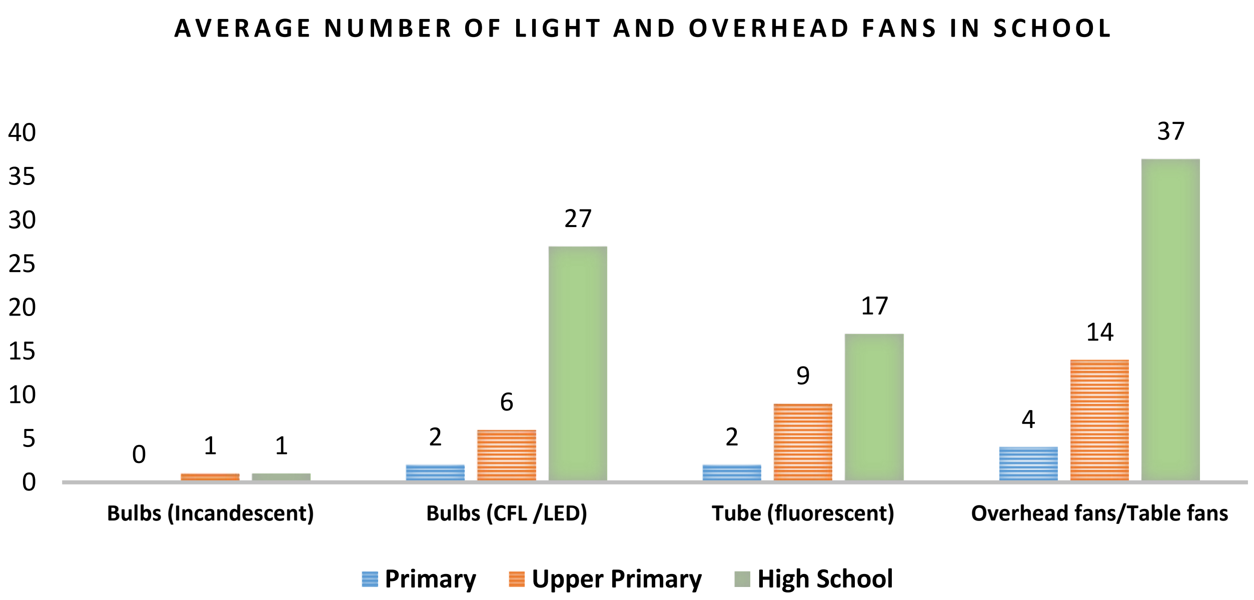

Figure 6: Average number of light and overhead fans in the school
Data Source: IRADe School Survey 2022

Lighting and overhead fans used for space cooling are a school's two major electric-consuming appliance. Figure 6 provides a snapshot of electrical appliances used by schools and energy-efficient alternatives available in the market, which also provides the same level of service but consume less electricity. For lighting, schools have partially adopted energy-efficient lighting systems as incandescent bulbs are replaced with energy-efficient LED bulbs. However, fluorescent tubes are still used in schools which could be replaced with energy-efficient LED tube lights. Overhead fans are another appliance that could replace energy-efficient BLDC motor fans. Other electrical appliances used by the schools are small. Therefore, our energy efficiency analysis assigns higher priorities to the appliance types which consumes a significant part of the total electricity consumed by the school.

Table 5: Power for various appliances used at schools

System types	In use at Schools (Watts)	Energy efficient available in market (Watts)
Lights		
Bulbs (Incandescent)	60-70	
Bulbs (CFL /LED)	9-18	9-18
Tube (fluorescent)	30-40	
Tube (LED)		16-20
Space cooling		
Overhead fans/Table fans	60-75	28-32
Other appliances		
Computer	100	
Printer	30-50	
Biometric attendance	5-10	
Audio Visual system	100-150	
Water dispenser	500	
Water pumps (depending on the number of students in the school)	1000-3000	

Data source: IRADe school survey 2021-22

The headmaster or someone authorized by the headmaster procures electrical appliances for the school using funds provided to the school for development expenditures. There is no instruction or guideline from the authority on the electrical appliances' product standard or energy efficiency. Schools could improve energy efficiency by:

- Installing energy-efficient lighting and space-cooling systems
- Purchase energy-efficient products like ENERGY STAR-qualified office equipment
- Educate students and staff about how their behaviours affect energy use. Schools may have student energy patrols to monitor and inform others when energy is wasted.

An instruction manual for the schools is required to decide about appliance procurement whenever it is replaced or upgraded. Schools can help prevent greenhouse gas emissions and reduce energy costs by being more energy efficient.

4. Procurement guide by school type

This procurement guide will help school planner as well as school administration to decide about the basic minimum electrical appliance requirement of a school type. This procurement guide is based on average requirement of the surveyed schools. Therefore, each school can adapt the advice best suits its own circumstances.

Table 6 presents the appliance requirements by school type. 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 in a facility in a school type

Facility type	Electric appliances (Watts)	Primary	Upper Primary	High School
Functional classrooms	LED lights (12 watts)	3	4	6
	Tube lights (20 watts)	1	2	2
	Ceiling Fan (28 watts)	2	4	4
Library	LED lights (12 watts)		2	4
	Tube light (20 watts)		1	2
	Ceiling Fan (28 watts)		2	2
	Computer (50 watts)		1	1
Science Laboratory	LED lights (12 watts)		2	4
	Tube lights (20 watts)		2	2
	Ceiling Fan (28 watts)		2	2
	Refrigerator (350 watts)			1
	Other electrical equipment (100 watts)			1
Headmaster room	LED lights (12 watts)	1	1	1
	Tube lights (20 watts)	1	1	1
	Ceiling Fan (28 watts)	1	1	1
	Computer (50 watts)	1	1	1
	Printer (50 watts)	1	1	1
Office room	LED lights (12 watts)		1	1
	Tube lights (20 watts)		2	2
	Ceiling Fan (28 watts)		2	2
	Computer (50 watts)		1	1
	Printer (50 watts)		1	1
Teachers/ Staff room	LED lights (12 watts)		1	1
	Tube lights (20 watts)		2	2
	Ceiling Fan (28 watts)		2	2
	Computer (50 watts)		1	1
	Printer (50 watts)			1
Computer room	LED lights (12 watts)		1	2
	Tube lights (20 watts)		1	2
	Ceiling Fan (28 watts)		2	4
	Computer (50 watts)		2	12
	Printer (50 watts)			1
	LED lights (12 watts)		4	6

Audio-visual/Smart classroom	Tube lights (20 watts)		2	2
	Ceiling Fan (28 watts)		4	4
	Audio- Visual (160 watts)		1	1
Toilets	LED lights (12 watts)	1	1	1
	Exhaust fan (20 watts)	1	1	1
Kitchens	Tube lights (20 watts)	1	1	
	Exhaust fan (20 watts)	1	1	

Data Source: IRADe Analysis

4.1 Electric Load (requirement) of the schools

The load is a significant driver of system design: peak load, the average load, the seasonal, and the quality of service needed. The potential load of a typical school is calculated based on the desired level of electric appliances required by the schools for the desired level of education service delivery captured through the survey of sample schools. Several considerations affect the amount and type of energy needed at a particular school. They include geographical location, operating hours in different seasons, design and construction of school buildings, etc., directly impacting the school's energy demand for various services. Quality of service desired is another important consideration for load, the system's capability to meet the load given the variability in solar electricity generation. The costs may be excessive if a very high quality of service is needed.

The number of facilities in a school would determine the electricity load of the school type. Further, to understand the desired level of services expected from the school's teacher surveys, a list of desired appliances and their numbers required in each facility type of the school is given above in table 6.

Based on the available facilities in different school types, desired types, and the number of appliances in these facilities, and the operating power required, we have calculated the maximum load of school types in Jharkhand (figure 7). The calculation is based on the average of the surveyed schools, and the peak load demand for an individual school may vary. Efficient building design could significantly reduce the need for light and fans.

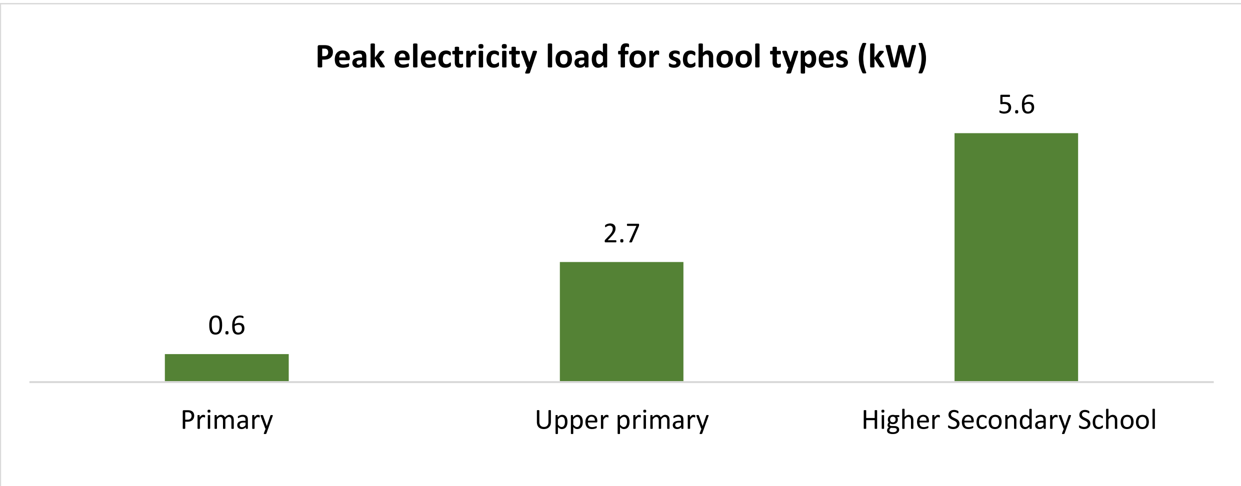

Figure 7: Estimated peak electricity load by school types:

Data Source: IRADe School Survey 2022

The primary consideration driving system selection are load, costs (component, fuel, and operating), and quality of service. The load is a major driver of system design peak load, and the quality of services needed dictates the size of the system required. The seasonal load distribution would vary. For example, an overhead fan is not necessary to be operated in winter. The operating hours of schools almost match the solar electricity generation as schools run during the day hours only. The analysis has not considered cooking energy requirement for the purpose of electricity peak load estimation.

The cost analysis of the system should be performed based on the system's life-cycle cost (LCC). The total cost of a project is the total of its initial cost and its future costs. Initial costs typically include expenditures for equipment purchase and installation. Future costs include operation and maintenance costs such as personal, fuel, and replacement equipment. Given the resource and time constraints, a standard design is prescribed based on the analysis; however, a detailed assessment could be carried out for the system design of an individual school.

4.2 Estimating Solar system size for school types

The goal of developing a solar electric system for a school is to offset a portion or all of the school's electric demand. Jharkhand state government has also adopted net metering to support the state's development of rooftop solar energy systems. Net metering is a billing arrangement where customers who produce their electricity can receive a credit on their electric utility bills for any extra electricity produced by the customer that flows back onto the electric utility's distribution system. The excess generated credits can accumulate until applied against future charges on the customer's electric bill.

However, for schools, the system should not be designed only to offset the electric demand of schools for ad. The system size which would meet the school's electricity demand should be 1.25 times the peak load of the school types. Therefore based on the peak load estimated in the section 4.1, the proposed system size for different school types is prescribed in Table 7.

Table 7: The estimated average size of solar PV systems by type of schools:

School type	Primary	Upper Primary	Higher School	Secondary
Solar panel size to meet the electricity demand	1 kW	3.5 kW	7kW	

Data Source: IRADe Analysis

5. Business model for school solarisation

Solar energy adoption has seen tremendous growth in the last few years owing to constant reductions in the price of solar power plants. However, adoption of solar electricity by schools are at its nascent stage only. The government schools (Primary, upper primary and higher secondary) in Jharkhand offer an opportunity to install 64 MW of solar RTPV system (figure 8). The estimated solar potential is the product of average plant size estimated for the school types (table 7) and number of schools (table 8).

Table 8: 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	21318	11613	333
2	Average estimated solar PV size (kWh)	1	3.5	7
3	Total solar PV installation potential (kWh) (=1*2)	21318	40645.5	2331

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

Solar RTPV in school will ease the burden on grids, allowing schools to lower their electricity bills and contribute to reducing carbon emissions. To decarbonise the electricity sector, solar PV will have to be installed everywhere possible. Hence, developing RTPV on schools building rooftops, will contribute decisively to decarbonise the electricity sector. However, not every school is an appropriate location for hosting solar RTPV. This technology relies on good access to the sun and locations with large amounts of shading, or north-facing orientations are not practical. Other school-specific considerations include the age of the roof, the size of the roof etc. A Solar potential mapping analyses can be conducted to inform decision makers about the precise availability of promising land or roof areas available with school for RTPV, quantify that available space, and calculate potential solar RTPV capacity and electrical production.

Solar produce energy when the sun is shining. There is an inherent intermittency of solar electricity due to diurnal and seasonal cycles. Figure 8 shows the monthly average production of solar electricity generated by a 1kWp solar panel system in Jharkhand. National Aeronautics and Space Administration provides average daily solar insolation at specified location (for given latitude and longitude) for each day of a year. This data can be used to calculate more precise daily solar electricity generation potential for a particular school.

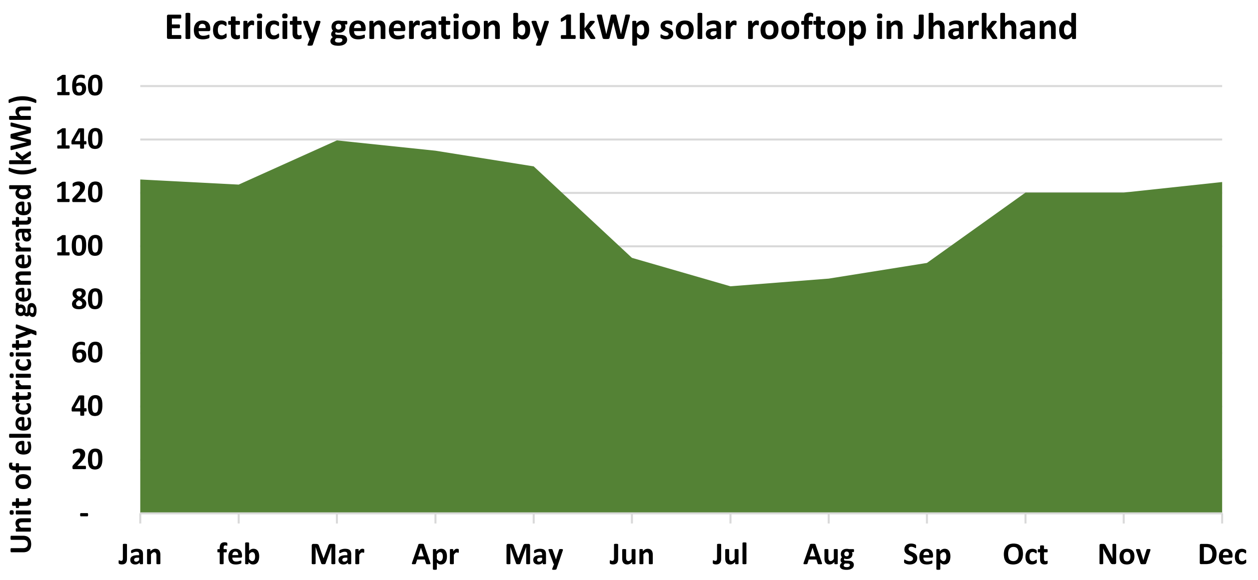

Figure 8: Month-on-month electricity generation from 1kWp solar rooftop in Jharkhand

Data Source: IRADe Analysis

The profitability and economic aspects of PV systems are dependent on several factors required investment capital, electricity tariff rate from alternative supply sources etc. The value of electricity generated by a system over the life time of 25 years installed in different types of school at the ongoing grid electricity tariff rate[2] in Jharkhand are shown in figure 9.

To calculate the value of electricity generated by a panel over the life span, we first calculated the value of electricity generated by the panel for a month and then multiplied it with 300 (life span of panel number in months). Value of monthly electricity generated is product of month electricity generated (kWh) and average grid tariff (Rs\kWh). Solar Panel Output (electricity produced by a solar panel) is power in watts multiplied by average hours of direct sunlight expressed in daily Watt-hours.

[2] The grid electricity tariff is considered as tariff proposed for FY 2020-21 for commercial consumer upto 5kW load in the Jharkhand State Electricity Regulatory Commission order on October 01, 2020 https://jbvnl.co.in/upload/0IOKV9.jbvnl%20tariff%20order%202020-2021.pdf

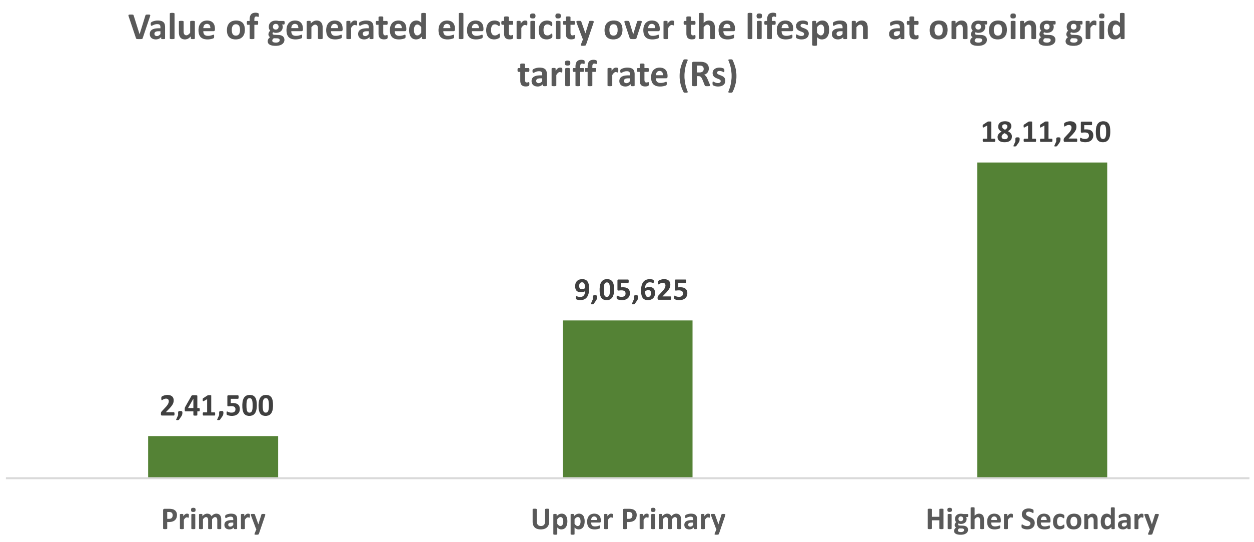

Figure 9: Value of solar electricity generated over life time

Data Source: IRADe Analysis

5.1 Proposed business model for School solarization in Jharkhand

From the interaction with schools, it was understood that schools would prefer to have a solar system that could provide electricity back-up support to meet critical loads (light in case classrooms are not well illuminated even during day time, the audio-visual device in smart class, computer in computer room etc) in case of short-term grid supply interruption. Therefore, we propose a grid-interactive solar system with a minimum 1-hour battery backup in the different school types.

Upfront costs remain a significant obstacle to the adoption of solar system by a wide range of consumers (schools). Financing also remains an issue due to several factors like higher perceived risks, inflation etc. The business models have not yet adapted to these challenges for many potential consumers. A solar RTPV investment plan in which a school can get desired quality of electricity supply either at a rate at least equivalent to ongoing grid electricity tariff rate would persuade the school to adopt to solar system.

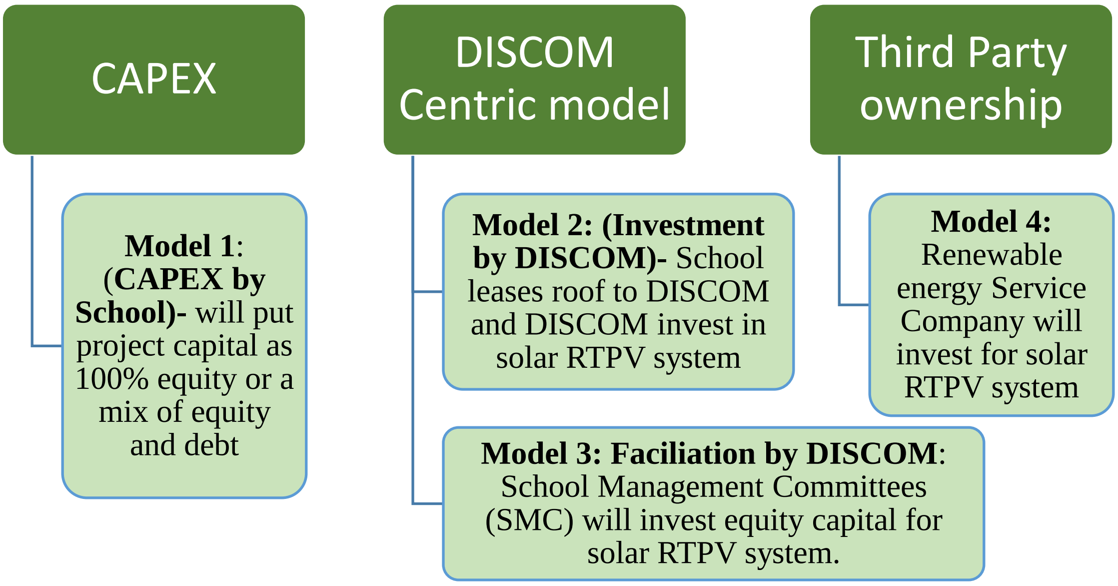

Figure 10: Business model for promotion of rooftop solar adoption by government schools in Jharkhand

Source: Developed by IRADe

The study evaluates 4 business models under which the solar RTPV plants can be deployed for schools (figure 10). These 4 business models are prepared based on the ownership of solar system. In the first model called a CAPEX model school would invest equity capital for the solar system. The other two models involve DISCOMs in one it plays the role of a facilitator and in another an active investor. Fourth is a third-party-owned solar system model.

A DISCOM-centric business model can be a possibility for promoting solar rooftops in Jharkhand. DISCOM can directly participate in deploying solar energy in schools either through facilitation or direct investment. Under the facilitation approach, DISCOM may encourage the community to be solar entrepreneurs and invest in capital required to setup a solar RTPV system in a school. DISCOM would act as a project aggregator to facilitate the procurement and instalment of solar systems. DISCOM may charge a token amount as a facilitation fee also. It will allow aggregation of decentralized electricity production capacity, which in turn allows procuring in large quantities leading to economies of scale. Direct involvement of DISCOM will ensure standardized components, services, and timely execution of the project. It will further help create a benchmark for consumers and developers for future rooftop solar project implementation in the state. The direct investment approach involves the aggregation of projects and investment in project development, or they can play a key role in system financing through linkage with financial institutions. It will reduce the risk for consumers and system developers. Government-owned DISCOM enjoys the confidence that financial institutions can get finance at low-interest rates to improve project economic viability.

In model 4, the developer (a specialized renewable energy service company- RESCO) would construct the power plant and sells the generated electricity to schools. Schools will pay for energy usage without worrying about the technical and financial aspects of the plant as per the tariff rate fixed for the PPA.

Table 9: Inputs included in Business models

Model inputs	Units	Primary	Upper Primary	Higher Secondary
Expected plant load factor	%	15.97%	15.97%	15.97%
PPA terms	Year	25	25	25
Debt	%	80%	80%	80%
Equity	%	20%	20%	20%
Capital subsidy	%	0	0	0
Rate of interest on loan	%	8%	8%	8%
Loan repayment period	Year	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%
The annual increase in O&M cost	%	1%	1%	1%

To evaluate the profitability of a solar RTPV project under different proposed business models a spreadsheet-based financial model was carried out. The model estimates the discounted cash flow to assess if the project represents an attractive investment opportunity. The model building assumes a set of financial and technical parameters listed in table 9. The key KPI (Key Performance Indicator) estimated to assess the financial performance of a RTPV project are payback period, NPV (Net Present Value), IRR (Internal Rate of Return), RoI (Return on Investment) on the invested capital and cost of electricity.

5.2 CAPEX model for schools

In this model school owns the solar system and buys from its own sources. School may own solar power with initial investment (between zero to full cost of system) if they finance it through solar loans. School will enjoy significant savings over the RTPV lifetime as it will keep generating solar electricity. In this model school takes the complete ownership and bears all the risks associated with the project. Generated electricity can either consumed or used to recharge battery and any residual electricity get injected into the grid. Table 10 presents the return from CAPEX model.

Table 10: Financial return from CAPEX model

Particulars	Primary	Upper Primary	Higher Secondary
Size of Power Plant (Plant size -estimated capacity requirement for school types)	1kW	3.5kW	7kW
Cost of the Plant (MNRE Benchmark Cost)	62000	217000	434000
Monthly average electricity generation (kWh)	115	402.5	805
Value of electricity generated in a month at ongoing grid tariff rate (Rs)	805	3018.75	6037.5
Payback Period	6.4	6.0	6.0
O&M expense monthly	(155)	(543)	(1,085)
Return on Investment (ROI)	359%	391%	391%
NPV	29,468	1,31,459	2,62,918
IRR	13%	14%	14%
Levelized Cost of Energy (LCOE)	2.43	2.43	2.43

Data Source: IRADe Analysis; Note: negative numbers are put into small bracket

School staff would get trained to maintain, and operate the project initially with support from solar developer and later their own. The calculated payback period for the project varies from 6 to 6.4 years for upper primary or higher secondary and primary schools. The projects are NPV positive for all school types and fetch an IRR of 13 to 14 percent varies for school types. The levelized cost of electricity for this model is Rs 2.43 per kWh (table 10).

5.3 OPEX Models for schools

Under these models' schools are required to enter into a long-term, legally binding agreement for the roof on which the solar system is installed with developer. They must also sign a long-term power purchase agreement (PPA) for the supply of power at a pre-determined tariff rate with or without escalation clause. Any excess electricity generated by the system would be injected into grid. Schools do not have to worry about investment capital. The developer will be the system's owner and must provide operation and maintenance services throughout the system lifetime. A major benefit of this model is going green (solar) without any large upfront investments.

DISCOM centric business models either facilitated by DISCOM or invested by DISCOM. In the facilitation model school management committee (SMC) would be persuaded to invest equity capital for the solar RTPV system. SMC being in the close vicinity of school would find it convenient to carry operation and maintenance of the system. SMC may have opportunity to setup system in several schools in the nearby cluster. DISCOM being a consumer centric company already having a relation with school and local staffs posted in the area would be better placed to invest in the solar RTPV system. It will also help DISCOM to meet RPO obligation and minimize transmission and distribution losses.

Developers may not be willing to undertake these scattered small size projects. Therefore, from a developer company perspective it becomes important that they are assigned cluster of schools for installing solar plants, thus enabling them to economize on operation and maintenance cost.

Table 11: Financial return from OPEX model

Particulars	Primary	Upper Primary	Higher Secondary
Loan Amount	49,600	173,600	347,200
Equity Amount	12,400	43,400	86,800
Interest for loan	(602)	(2,106)	(4,212)
O&M expense monthly	(155)	(543)	(1,085)
PPA tariff rate	5.9	5.9	5.9
Return on Investment (ROI)	684%	684%	684%
NPV	6,203	21,709	43,418
IRR	10%	10%	10%
Saving to School	72,008	320,916	641,832
Present Value of savings to School	26,366	120,601	241,202

Data Source: IRADe Analysis;
Note: 80% capital expenditure is met through loan and balance 20% equity

The value of input parameters for all the three business models are taken at same level to evaluate the return. However, in real world it may vary. For example, DISCOM being large company may raise capital at cheaper rate than other developer. DISCOMs could enjoy economy of scale which might reduce the cost of system for them. They can also leverage their presence in the area to optimise on the operation and maintenance cost. Table 11, provides KPI for the financial analysis of the business model. All the projects have good RoI and positive NPV. IRR for these projects are 10 percent. School will also make a saving on electricity cost over the life cycle of the project.

5.4 Comparative analysis of different business models

This section evaluates the business model to answer which option makes more sense for school looking to go green. The CAPEX model is generally preferred as it is relatively cheaper than the OPEX model. The effective cost of electricity per kWh under CAPEX is less than half the price under OPEX model (figure 11), but it requires 100% capital as initial investment. Large upfront investments required under the CAPEX model are difficult to arrange for already cash strapped schools.

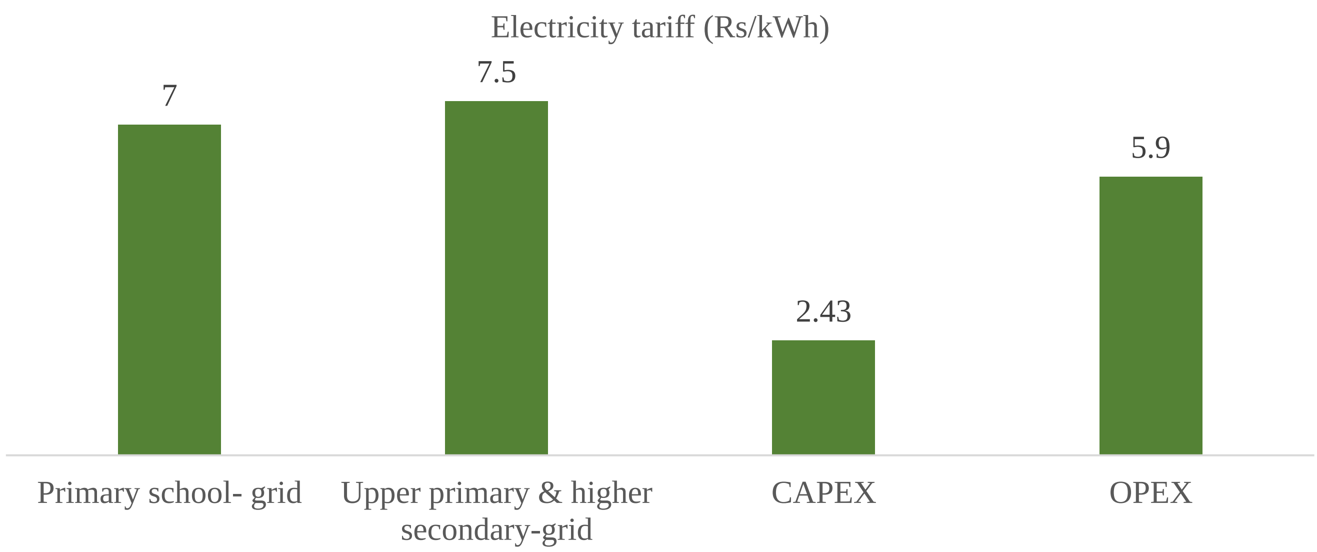

Figure 11: Electricity tariff for different supply models
Data Source: IRADe Analysis

The operational risks, knowledge about technology, among other things are difficult for a school to manage. Our field visit suggest school which already have solar RPTV installed are not able to manage operation effectively either due to lack of technical know-how or lack of interest in taking ownership of the system. With OPEX installation school will enjoy benefits over power bill without worrying about the operational issues involved in system maintenance. Long term PPA with developer will insulate schools from grid tariff rate escalation. A SWOT analysis is also conducted for the business models where each of the four models are evaluated on their respective strength, weakness, opportunity and threats (table 12).

Table 12: 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 and 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 an investor and with support from DISCOM as the facilitator	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
	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

Data Source: IRADe Analysis

5.5 Implementation Pathways

Given the large number of schools in the state, it is practically difficult to implement any program in all schools at the same time. Therefore, the selection of a school for implementation become important to start the program. The implementation pathways prioritize a set of schools for initial implementation and later outscaling at the state level. We assign a rating to the school for selection (Table 13). The implementation pathways index is based on three parameters 1) monthly electricity bill, 2) availability of unshaded rooftops for setting up solar RPTV systems, and 3) support from the concerned agencies. Average monthly electricity bills for selected primary, upper primary, and higher secondary schools are Rs 200, Rs 430, and Rs 2129 respectively. The availability of shadow-free rooftop space is a prerequisite for installing the rooftop solar PV system. Support from other stakeholders especially DISCOM is important for grid-interactive solar systems.

Table 13: School raking parameters

Parameter	School type	Rank -1	Rank 2
Monthly Electricity Bill (rs)	Primary	More than 200	Other wise
	Upper Primary	More than 430	Other wise
	Higher Secondary	More than 2129	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

Data Source: IRADe Analysis

Based on the above three criteria, each school could be evaluated which will determine the likelihood of rooftop solar RTPV system installation. In addition to identification of schools for implementation following initiatives would further accelerate the pace of implementation.

Campaign for school solarization: JREDA can target schools across Jharkhand through a 'Green School Campaign.' It can be spearheaded in coordination with the Jharkhand Education Project Council (JEPC), the nodal body that manages all schools in Jharkhand in association with the Department of Education and the Department of Energy.

Pilot before state-wide implementation: The model should be implemented at a pilot scale first in selected schools to show how roof space can be utilized for solar PV installation when the building owner cannot invest in the project. Schools are ideal locations for rooftop solar PV installations because of the available roof space. Later, based on the learnings from pilot implementation, it could be extended to all schools in the state.

Positive externalities: The schools provide large rooftops and demand matching with solar generation patterns. A green school will help the country reduce emissions to meet NDC goals. India has set a target to achieve Net Zero emissions by 2070.

6. Stakeholder perspectives

As part of the research project, a workshop was organized in Ranchi on March 28, 2023, to deliberate on the topic and understand the broad set of stakeholders' perspectives. The workshop was organized in three sessions - the first inaugural session had a high-level introductory lecture by government and academic experts on the topic's relevance. Government officials also provide a brief account of initiatives taken by the Jharkhand state government. The second session had a presentation by the research team followed by a moderated expert panel discussion on important findings from the study. Session three was a moderated panel discussion for practitioners. Finally, a concluding section summarizes some final observations and the way forward.

In the inaugural presentation of the state government's work, Director JREDA Mr. K.K Verma provided a detailed account of the renewable electrification experience in the state. He said electricity is a basic need for social and economic development, and delivering it economically and securely to rural consumers is challenging in Jharkhand. Many remote villages still do not have electricity connections. Getting an electricity connection to these villages is difficult, primarily due to their geographical location. Villages in the hilly terrain are very much scattered, and getting grid electricity to these villages through the grid is commercially non-viable for DISCOM. However, solar micro-grid could be a viable alternative to provide electricity to these hamlets.

Access to finance is a challenge for the development of solar systems in the state. It was suggested that solar should be put into the priority sector by the government to access low-cost infrastructure finance available from specialized financed institutions for solar electricity generation. The state government has installed 10-30 KW solar PV microgrids in 500 remote villages- not connected to grid electricity- for electrification. The government needs to come forward with school solarisation and prepare a state-wide policy to install 5-10 KW solar PV plants in each school, depending on the school's requirements.

Practitioners put forward their concerns and suggested ways forward for school solarization. The experience of solar PV systems in agriculture suggests that many solar water pumps are not functioning without local maintenance support. Even a minor fault in the solar PV system takes much time to rectify. In the case of school solarisation, we need to learn from these experiences and also integrate the development of local repair and maintenance capability as a part of the program. Developing a local repair and maintenance capability would be helpful in many ways and support renewable energy development in rural areas. Some practitioners also highlighted the issue with net-metering schemes for the state government. Some private schools that have already installed solar PV systems are not getting net metering benefits. Their bills are not reflecting the import and export of electricity. Awareness among the front desk employee of financial institutions about renewable energy financing is also low. It impacts the availability of finance to renewable energy developers. Private players would find it difficult to go for the RESCO model for school solarisation till government provides a guarantee to honour PPA. RESCO players raise funds from the financial institution model based on PPA. Banks are not forthcoming in providing funds to RESCO players based on the PPA with non-revenue institutions.

The workshop successfully highlighted the challenges faced by solar PV electricity projects and school solarisation. It underlined the need for a collaborative research approach in this ambitious project to ensure high-quality applied research that can be practically used. The workshop ended with a positive note that the participants would try to work together to achieve the project objectives.

7. Conclusion and Suggestion

Although energy access to school has gradually advanced over the years, we are still far behind the desired level of access. Quantitative and qualitative information is required to reflect the challenge's magnitude and drive evidence-based decision-making. This report is an attempt to fill this gap. Based on the analysis of data collected from selected schools and interaction with stakeholders, including government officials following suggestion has emerged for the solarisation of schools in Jharkhand. These are categorized under four broad groups (institutional, operational, system design, and business model).

7.1. Institutional

- A policy framework to integrate solar PV into school buildings, both for improving efficiency and educational purposes, must be supported with political will and commitment.
- Local people should be trained to provide routine maintenance and timely repair.
- Evaluation of system costs based only on initial high cost may discourages the choice of RE choice. Therefore, awareness about the long-term perspective becomes important.
- Energy supply (excess) to the grid can generate some income to support school operating expenses. However, meeting school energy requirements, especially during grid load shedding, should assume high priority while designing the Solar PV system.

7.2. Operational

- Lack of maintenance is common and leads to system failure. It defeats the whole purpose.
- Lack of installation standards of acceptance leads to system failure.
- Schools are often unaware of solar systems' proper operation, care, or limitations. Metering is often not understood or confusing.
- Training must be thorough and ongoing.
- There is often a lack of spare parts available in the local market. Supply should be strengthened.
- Systems should be supplied as simple and complete as possible.
- Pilot projects must be monitored and evaluated before implementation of full-scale projects. Pilot projects must be replicable and use proven technologies.

7.3. System Design

- Lack of procurement standards leads to confusion on the part of suppliers and often results in the least cost, least robust option.
- Although higher energy efficiency results in lower costs, simplicity in system maintenance should also be considered.
- Energy systems should be integrated with end-use applications.

- The energy system/application must be the least expensive, highest benefit option to meet the school system's needs.
- Systems should be designed and provided as complete and detailed as possible.
- Adequate technical and user manuals must accompany solar systems and equipment.
- One size does not fit all. Systems must be designed appropriately for site conditions.
- Sophisticated electronics may be vulnerable to damage and should be avoided as much as possible.

7.4. Business Model

- The fact that schools are often located in remote, poorly accessible areas dictates that the technical designs for RE systems should be simple, robust, and easy to maintain; this should constitute an overriding system selection criterion.
- The third party needs to provide support to set up a system in the school building.
- A DISCOM-centric and Third Party ownership model seems more plausible for school solarisation.

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