SOLAR DE-FLUORIDATION FOR WATER SUPPLY IN RAJASTHAN	
Climate impacts	Site visits were conducted in two districts: Jaisalmer and Sirohi. Jaisalmer district in Western Rajasthan is part of the Thar desert. The region is characterized by uncertain rain, prolonged droughts, extreme heat, and water contaminated with fluoride, which can increase due to drought conditions. Geological conditions do not allow groundwater recharge, and even a few showers of rain can flood the area. Groundwater in several pockets in the district is fluoride affected. Sirohi district in southern Rajasthan has a dry and hilly terrain with an average annual rainfall of 620 mm. It has been observed that the overall number of rainy days has reduced, and extreme rainfall events have increased. Groundwater in the region is fluoride affected in some pockets, and the water depth is currently at 120 to 250 ft. Climate information is the same as mentioned above for other case studies from Jaisalmer and Sirohi.
Developmental challenges	Hilly regions, as in Sirohi district, need deeper bores and have fewer aquifers to tap into. Here, the main source of livelihood is agriculture, which is rain-fed or irrigated by borewells, which stresses the groundwater aquifers and can affect drinking water supply too. Some places have check dams that support surface irrigation and groundwater recharge. Compared to Jaisalmer, villages in Sirohi are densely populated. As in Jaisalmer district, extreme heat conditions in summer months coincide with water scarcity. In Jaisalmer and Sirohi, there are operational challenges, such as leakages, higher maintenance costs, and high need for human resources, in supplying water to remote households through centralized pumping stations. The only water source was hand pumps (when water is available, at max. 30–35 ft) or tankers provided by the Public Health Engineering Department (PHED). Many such areas also face groundwater contamination by fluoride. With the groundwater table receding, electricity is required to pump groundwater.
Energy situation at site [before intervention]	Almost all households in Jaisalmer and Sirohi have a single-phase electricity connection, but most do not yet have piped water supply. Households use traditional water storage methods at the household level, unlike large tanks in urban areas. To avoid long-distance piped water supply and tanker supply challenges, the PHED developed off-grid units to filter and supply water near the habitations.
Energy intervention features	The intervention consists of off-grid solar-PV-powered pumps combined with an overhead tank to store water. The tank is connected to a bio-media gravity-based filtration system that dispenses water through faucets. The solution also provides raw untreated water through clearly marked taps. The pumping system is automated and functional during the daytime. It is remotely monitored and controlled by the implementing agencies. Locations in Jaisalmer also have water troughs for animals, whereas those in Sirohi do not have water troughs. As the water level dips below a level in the overhead tank, the pump automatically starts, and the tank is filled. Some locations have added small solar-powered lights at the unit.

Table A.3 | Education

SOLAR PV FOR RESIDENTIAL GIRLS SCHOOLS IN JHARKHAND	
Climate impacts	Jharkhand state faces intense thunderstorms, with heavy rains, strong winds, and lightning strikes. For climate projections, refer to other case studies from E. Singhbhum, Hazaribagh, and Gumla.
Developmental challenges	Kasturba Gandhi Balika Vidyalayas (KGBVs) are in areas with a large population of tribal and other marginalized communities, including minority communities that have low levels of female literacy and are in remote habitations with sparse populations that do not qualify for a regular school. They are residential schools offering girl students free education from the upper primary level to higher secondary levels.
Energy situation at site [before intervention]	All the KGBV schools under the program are connected to the electric grid but face erratic electricity supply. Power outages can last from a few hours to days at a time. These outages worsen during thunderstorms, as uprooted trees and winds can damage the electricity grid infrastructure. To help them cope with outages, KGBV schools have backup diesel generators. However, when the grid outages last a long time, running diesel generators is not economical, so they must often go without electricity. During this time, the students and staff find it difficult to maintain good living conditions, such as lighting, water supply, and thermal comfort. They also have to compromise on learning activities like computer classes.
Energy intervention features	To help address the unpredictable and unaffordable electricity situation, the Jharkhand Renewable Energy Development Agency (JREDA) facilitated the installation of 20 kW off-grid solar systems with battery backup in KGBV schools. The solar system is connected to 50–60 fans and lights, 10–12 computers, 1–2 water pumps, 1–2 reverse osmosis (RO) water purifiers, and 1 refrigerator in each school. During a power outage, a trained staff member turns on the solar system, which allows the school to continue its normal functions. With the coming of solar PV, the schools report several benefits: over 50% reduction in the use of diesel, with some schools eliminating diesel usage; the presence of constant running water supply and fans improving living conditions, especially during the evenings and in summers, respectively; lights improving the perception of safety and enabling students to study late into the evening; uninterrupted functioning of facilities such as computer labs, water purifiers, refrigerators, and recreational and educational devices like televisions.

SOLAR PV FOR DIGITAL-EDUCATION-CUM-FLOOD-RELIEF CENTRE IN NORTH LAKHIMPUR, ASSAM	
Climate impacts	Compared to the baseline (1981–2010), the annual rainfall by mid-century (2021–2050) in the district will increase by an average of 72 mm. The district will see an increase in pre-monsoon and monsoon rainfall with a rise in extreme precipitation events. The district's average temperature is also set to increase by 1.2°C, with extreme heat days increasing from 36 days in 2020 to 69 in 2050. An increase in overall rainfall and extreme precipitation events are set to exacerbate the existing flooding situation. The villages get intermittently flooded every year between July and September. The flood levels rise 2–4 ft above the ground level. However, with increasing rainfall, the level of inundation may increase. Various tributaries of the Brahmaputra cut across the district, making 67.5% of the area flood-prone.
Developmental challenges	The older houses constructed in the region get inundated with floodwaters almost every year. New homes have been built on stilts and are less affected. During floods, the electricity grid connections are shut off, and the relief shelters are the only places with electricity supply powered by solar panels. Due to the lack of electricity and public lighting, there are safety and security concerns, especially for women and children.
Energy situation at site [before intervention]	The relief shelter is connected to the grid and doubles up as a digital resource center for villagers, conducting computer classes for students when there are no floods. The shelter has five computers and one printer and is managed by the village committee for printing certificates, filing applications online, and booking train tickets. During floods, because the grid is disconnected, solar power and battery backup are used for lighting and mobile charging at the shelter.
Energy intervention features	The shelters have each have a 1.5 kW off-grid solar PV system with 12 V 200 Ah lead-acid battery backup to power DC lights and a mobile charger in addition to the grid connectivity.

Table A.3 | Education (Cont.)

SOLAR PV FOR RESIDENTIAL GIRLS SCHOOL IN DHUBRI, ASSAM	
Climate impacts	Compared to the baseline (1981–2010), the annual rainfall by mid-century (2021–2050) in Dhubri is set to increase by an average of 116 mm. The district will see an increase in pre-monsoon rainfall, but no monsoon rainfall change with a rise in extreme precipitation events. The district's average temperature is also set to increase by 0.9°C, with extreme heat days increasing from 36 days in 2020 to 67 in 2050. In addition, an increase in cumulative rainfall and extreme precipitation events is set to exacerbate the existing flooding situation, which may increase the school's risk of being inundated in the future. Moreover, river islands are also subject to land erosion, which can result in landmass loss. Increased incidence of floods can result in high levels of erosion; 24% of the district is at high risk of riverine flooding.
Developmental challenges	The school is located on a *char* island—the riverine islands in the Brahmaputra prone to heavy flooding—although the school itself is situated on elevated land. During flooding, classes get interrupted as many teachers find it challenging to reach the school. Only 3 out of 10 staff members stay on the school premises. These islands have limited access to basic education and health facilities. The communities must go to the mainland for most necessities. The literacy rate is very low, especially among girls. Dropouts and early marriages are common. Most of the students are from economically backward families.
Energy situation at site [before intervention]	The *char* regions are not connected to the grid. Before this intervention, the school did not have any electricity supply. The school was given a diesel generator in 2008, and it stopped functioning in two years. After that, the school started using kerosene lamps. The school had 22 lights, 9 fans, 1 TV, 1 electric sewing machine, and 1 water pump, although it had no electricity to power these. Classrooms were dark, hot, and humid, and students did not have any access to digital literacy resources. There were no lights and fans in the student hostels, posing comfort and safety issues. There was no running water in toilets, and water had to be carried from tanks.
Energy intervention features	The Assam Energy Development Agency (AEDA) has installed a 5 kW solar PV system with 48 2 V 500 Ah lead-acid batteries with a 5 kVA power conditioning unit (PCU). Solar PV provides electricity in the daytime, and the school uses kerosene lamps in the evening. Only lights and fans are connected to the solar panels, so essentials like computers and water pumps remain unused. They still have the same number of appliances, although many are not powered. Teaching and learning conditions have seen some improvement because fans operate during the afternoon. However, solar and battery backup do not function at all times, because of which kerosene lamps are used at night. Living conditions have not improved. Monthly expenses have reduced by approximately 50% because of the reduction in diesel use.

SOLAR PV AND HEATER FOR WASH AND MID-DAY MEALS IN SCHOOLS IN JORHAT, ASSAM	
Climate impacts	Compared to the baseline (1981–2010), the annual rainfall by mid-century (2021–2050) is set to increase by an average of 106 mm. The district will see an increase in pre-monsoon rainfall with a rise in extreme precipitation events. The district's average temperature is also set to increase by 1.1°C, with extreme heat days increasing from 36 days in 2020 to 70 in 2050. With increasing rainfall, dependence on groundwater can be reduced by managing surface water better. Furthermore, the Brahmaputra river cuts across the district, making it prone to floods and inundation; 42.5% of the district is flood-prone, with 10% under high risk.
Developmental challenges	Jorhat district has a high incidence of arsenic contamination in groundwater. According to the 2018 Ministry of Water Resources database, 79% of the district's habitations are affected by arsenic. According to WHO, drinking arsenic-contaminated water can induce several short-term effects like diarrhea, vomiting, abdominal pain, and long-term effects like skin problems, including cancer. Hence, the district encourages decontamination of groundwater before use or dependence on surface water sources. Until recently, the school administration and the communities nearby did not realize that their groundwater was contaminated with arsenic. The school used to draw water for drinking and sanitation from hand pumps. A few years ago, the school administration started getting more and more complaints of abdominal pain in children. Upon testing the water, they realized that it was contaminated with trace quantities of arsenic.
Energy situation at site [before intervention]	The school is connected to the electricity grid, but receives erratic supply, especially during the monsoon, when the grid is shut down to avoid electrocution in waterlogged areas. Accessing water requires electricity, either to pump groundwater or to pump surface water from nearby ponds into the overhead tanks of the school building. The school provides mid-day meals to its students. The cooking, done within the school premises, required energy sources like firewood or LPG. Firewood is difficult to procure during the rainy season as it becomes damp and unusable, and alternative sources of energy for cooking were required during this time.
Energy intervention features	The electricity solution is an off-grid 2 kW solar PV with a 650 VA inverter and two 75 Ah batteries. It is used for powering a water pump to supply water from a rainwater-harvesting structure and a pond nearby, to an overhead tank and a solar water heating system. The overhead tank supplies the water to a drinking water reverse osmosis (RO) plant (which is also powered through solar) and to the toilets. An additional solar water heater pre-heats the water for cooking, and from there, the water gets stored in an overhead tank for the kitchen. The solution provides reliable electricity all day for pumping and filtering water, and the electricity generated can also be used for powering lights, fans, and charging mobile phones.

APPENDIX B: INTERVIEW GUIDES

This section provides questionnaires developed for interviewing implementation agencies, funding agencies, vendors, and beneficiaries. Implementation agencies coordinated the installation of the solar systems and were responsible for their operation and maintenance in many cases. Beneficiaries are communities (and representatives of the beneficiary communities). Vendors here also include energy enterprises that designed and installed the decentralized solar system.

INTERVIEW GUIDE FOR IMPLEMENTING ORGANIZATION

Informed consent script:

I am ____ from the Energy Program/ Climate-Resilience Practice at WRI India. We are conducting a study on how energy access solutions address energy needs and contribute to health/education/livelihood outcomes in energy poor, climate vulnerable areas. We would like to ask you a few questions regarding the energy solution in this locality. This interview will take around 1 hour. The information we capture will be used for research purposes only. The information will be treated as confidential and any individual-identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project name:
2. Interviewed by:
3. Date:
4. Name of the interviewee(s), organization(s) and role(s)
5. Contact details
6. Location of implementation
7. Village:
8. Block:
9. District:
10. Geo-location:
11. Landmarks (if any)

FOR INTERVIEWER'S REFERENCE

Objective of these interviews

- To understand whether the *energy solutions are resilient* to any climate events/conditions in the region, *address the energy needs, and contribute to development outcomes* (such as health, education, livelihood)
- Capture communication stories

Stakeholder categories

1. Implementing organization: Responsible for coordinating various activities for implementation of the energy solution in/not in the climate vulnerable areas and bringing different stakeholders together. *Questionnaires may need to be administered at both the headquarters and the field level*.
2. Funding agency: Organization that partially or fully funds the implementation and/or bears the financial risk.
3. Vendor: Organization responsible for design, installation, and O&M, if applicable.
4. Beneficiary: Those who benefit from the facility.

Context

1. Tell us about your organization and the work that it does.
2. What are your geographies of interest?
3. Is the health/education/livelihood facility where the energy interventions have been installed owned and operated by you? If not, please mention who owns and operates the facility.
4. What natural calamities or conditions are faced by the **state in general and your facility in particular** *(Probe: like floods, droughts, extreme rainfall/temperature, soil or water contamination, land erosion): [TO BE ASKED AT LOCATION]*
    a. Which months in a year?
    b. What changes have you been experiencing in the past years in terms of frequency and/or severity of the climate events?
    c. How are the communities affected and how do they cope?
    d. How do your facilities get affected and how do they cope?
5. What is the electricity situation in regions where you work *(probe on grid connection, backup power, voltage situation)*?
6. Do the climate event/conditions affect the electricity situation? If yes, how?
7. Does the electricity situation affect service delivery in your facilities? If yes, how?

About the energy need and solution

8. What form of technology are you using in your facilities to solve the electricity issues?
9. Who conceptualized the idea of installing the energy access solutions and what were the reasons for doing so? *(Probe: accessibility, affordability, reliability, sustainability, other reasons)*
    a. Access to electricity
    b. Reduction in power cuts
    c. Reduction in voltage fluctuations
    d. Reduction in cost
    e. Others
10. Where is the solution installed? Who owns the space where it is installed?
11. On an average, what is the system specification for the energy solutions you have implemented in your facilities?

Capacity in kW (range, average)	
Space occupied	
Module cost	
Is there a battery? Battery type	
Battery capacity in Ah	
Battery cost	
Inverter specs	
Inverter cost	
Total system cost	

Sustainability in the climate context (impact of natural calamities during and after installation)

12. What precautions have you taken to ensure that your energy solutions are not affected by natural calamities or conditions? *(Probe: Is the system robust—ability to withstand events, resourceful—ability to manage stresses during the event, and recoverable-ability to restore operations after the event)*
13. What was the impact of climate vulnerabilities, natural calamities on design of the system?
14. What was the impact during the installation period?
15. How did you deal with the same and bring the project back on track after the disruptions (if any)?
16. Have you seen any impact of the climate vulnerabilities, natural calamities on O&M of the system?
17. How do you deal with the same and ensure the system performs as planned?

Financial sustainability of the system

18. What is the average cost of the installation and how was it funded? *(Probe: grant, loan, self-funded and their breakdown by source)*
19. What convinced you/funders to invest in this energy solution?
20. Who funds the O&M of the system?
21. Who will fund post completion of the AMC tenure?

Operational sustainability of the system

22. Which stakeholders came together to design the project (organization/individual/community/government)?
23. What role (if any) did you play during the installation process?
24. Who takes care of the O&M (human resource)?

25. Please answer the following questions regarding your experiences with maintenance of the systems:
    a. Have the systems been performing as expected?
    b. How prompt are the maintenance services?
    c. Has there been a situation where you had to halt operations as the system was not working? Elaborate on the experience.
    d. How do you track the efficiency of the system—performing as vendor had promised?
    e. What are the challenges you have faced to date?
26. Do you have an AMC in place for the systems?
27. What is the average duration of the AMC?
28. After the AMC ends, who will ensure operation of the systems?
29. Did you/do you do local capacity building for day to day troubleshooting?
30. Is there remote monitoring of the system—its performance and disruptions caused by climate vulnerabilities or natural calamities?
31. Do you have plans to scale up this model? *(Probe: in other geographies you work, increase system capacity in existing geographies, with other partners, etc.)* Why/Why not?
32. If similar projects come up in such locations, would you be willing to take them on? If not, why?

Impact of the energy intervention in the context of climate vulnerabilities and natural calamities

33. How has the electricity access situation improved after installation across your facilities?
    a. What improvements do you see in the electricity situation during the time when climatic events/conditions affect your facility?
34. How has the improved electricity access situation impacted service delivery/helped communities nearby?
    b. What improvements do you see in the service delivery during the time when climatic events/conditions affect your facility?
35. Did these implementations bring about the changes you expected to see when you began this project? Please explain how.
36. What were your broad experiences with the following when you think about your operation in exacerbated climate stress and more frequent/severe climatic events? *(Probe: what went well, what was difficult)*
    c. Space for installation:
    d. Approvals/ permissions from the Government:
    e. Funding:
    f. Civil work:
    g. Energy vendors, including O&M support:
    h. Logistics like transportation of system components:
    i. Natural calamities or conditions:
    j. Other:
37. Have you conducted an impact assessment of the energy solution installation? If so, can you share the findings/report?
    k. Do these assessments include the climate vulnerability angle—how electricity/ service delivery is affected during climate events/conditions?
38. Do you or other stakeholders involved have plans to scale up this model *(Probe: in other geographies you work, increase system capacity in existing geographies, with other partners, in areas with similar climate stress, etc.)*
39. If you have already scaled up—please share more about how you scaled this up and who are the partners

Learnings from the implementation

40. Are there any broad learnings for you and your organizations from this implementation?

INTERVIEW GUIDE FOR BENEFICIARY

Informed consent script:

I am ____ from the Energy Program/Climate-Resilience Practice at WRI India. We are conducting a study on how energy access solutions address energy needs and contribute to health/education/livelihood outcomes in energy poor, climate vulnerable areas. We would like to ask you a few questions regarding the energy solution in this locality. This interview will take around 1 hour. The information we capture will be used for research purposes only. The information will be treated as confidential and any individual-identifying details will be anonymized before publication. May we have your consent to proceed?

(Record verbal consent)

Interview details

1. Project name
2. Interviewed by
3. Date
4. Name of the interviewee(s)
5. Occupation(s)
6. Age(s)
7. Hold a SC/ST certificate?
8. Contact details
9. Gender(s)
10. BPL card?

FOR INTERVIEWER'S REFERENCE

Objective of these interviews

- To understand whether the *energy solutions are resilient* to any climate events/conditions in the region, *address the energy needs and contribute to development outcomes* (like health, education, livelihood)
- Capture communication stories

Stakeholder categories

1. Implementing organization: Responsible for coordinating various activities for implementation of the energy solution in/not in the climate vulnerable areas and bringing different stakeholders together. Questionnaires may need to be administered at both the headquarters and the field level.
2. Funding agency: Organization that partially or fully funds the implementation and/or bears the financial risk.
3. Vendor: Organization responsible for design, installation, and O&M, if applicable.
4. Beneficiary: Those who benefit from the facility.

Interview questions

About climate vulnerability

1. Name of the district, block, village
2. Climate vulnerabilities or natural calamities faced by this region and by beneficiary/communities being interviewed here *(Probe: like floods, droughts, extreme rainfall/temperature, soil or water contamination, land erosion, increasing temperatures)?*
   a. Which months in a year?
   b. How are you affected?
   c. How do you cope?

About electricity access situation

3. Is your village connected to the grid?
   a. Since when?
   b. How many households are connected?
   c. Do other buildings in the village like schools, hospitals, panchayat buildings, *anganwadi* have access to electricity?
      i. Do they have grid/alternate electricity connection?
      ii. If no electricity access, what challenges do they face?
      iii. If any of them recently got electricity access, have you noticed any changes in services?