Highlights

- In India, poor and marginalized communities face the dual challenges of low socioeconomic development and extreme vulnerability to climate change. Providing reliable access to electricity through decentralized renewable energy creates an opportunity to stimulate low-carbon socioeconomic development in climate vulnerable areas.
- India has made impressive progress in increasing the reach of its grid connectivity. Climate-related events can impact the supply of electricity, especially the distribution network of the centralized grid structure.
- Decentralized energy solutions play an essential role in supplementing grid connectivity to support basic services such as health, education, and livelihood generation during uncertain times.
- Development agencies are increasingly adopting decentralized energy solutions to provide affordable, reliable, and sustainable electricity access, which is key to building long-term adaptive capacity. Notably, these solutions can also be affected by climate-related events, thus requiring resilience planning.
- Developing climate resilient energy solutions requires working across conventional silos; incorporating climate considerations in technology, planning, and execution; and aligning organizational responsibilities and funding arrangements at each stage of the project cycle.

Many of India's most impoverished and underserved people live in the country's climate vulnerable regions. With limited access to healthcare, education, and livelihoods, the poor are among the least equipped to cope with the climate change threat despite being overrepresented in climate vulnerable areas (Diwakar et al. 2019).

Energy in Climate Vulnerable Areas

Although there have been significant improvements in India's rural household electrification, electricity availability for health centers, schools, and rural enterprises is still limited.

Electricity is one of the enablers of socioeconomic development. Access to reliable electricity can improve the working hours, staff availability, water availability, and medical and diagnostic services in hospitals; improve the learning environment, school attendance, and the quality of education delivery in schools; and enhance productivity, savings, and income for rural livelihoods (Chaudhury and Hammer 2003; World Bank IEG 2008; SEforAll 2018). In climate vulnerable areas, facilities for essential services, such as healthcare, education, and livelihoods, that are functional under all conditions can help the poor improve their socioeconomic situation and cope with the existing and new threats posed by climate change.

Decentralized solar energy solutions are increasingly considered for bringing reliable electricity to community facilities, especially in climate vulnerable areas. **Although decentralized solar solutions are not entirely immune to extreme events, they are relatively more resilient than centralized electricity systems** (IEA 2015; PGCIL 2015; WBCSD 2014; OECD 2018).

About This Report

In this report, we explore the impacts of climate-related events on electricity needs, whether decentralized solar solutions consider climate change in the lifecycle of the installation, and if not, then what factors need to be considered.

Since 2015, World Resources Institute (WRI) India's work on improving energy access in India has focused on the states of Assam, Jharkhand, and Rajasthan. We adopt a four-pronged approach encompassing technology, data, policy, and finance as a scaling-up strategy to ensure reliable electricity for social and production loads.

Our partners are development agencies such as public health departments, charitable hospitals, schools, local administrations, state government departments, and not-for-profit livelihood grassroots organizations. To further that work, through this report we explore the nexus between energy for development and climate change. We analyze 14 decentralized solar energy systems installed in community-level healthcare, education, and livelihood facilities in climate vulnerable regions across these three states. For this report's purposes, *decentralized solar energy solutions* refer to stand-alone or minigrid-sized installations that provide electricity supply to facilities such as schools, health centers, and communities.

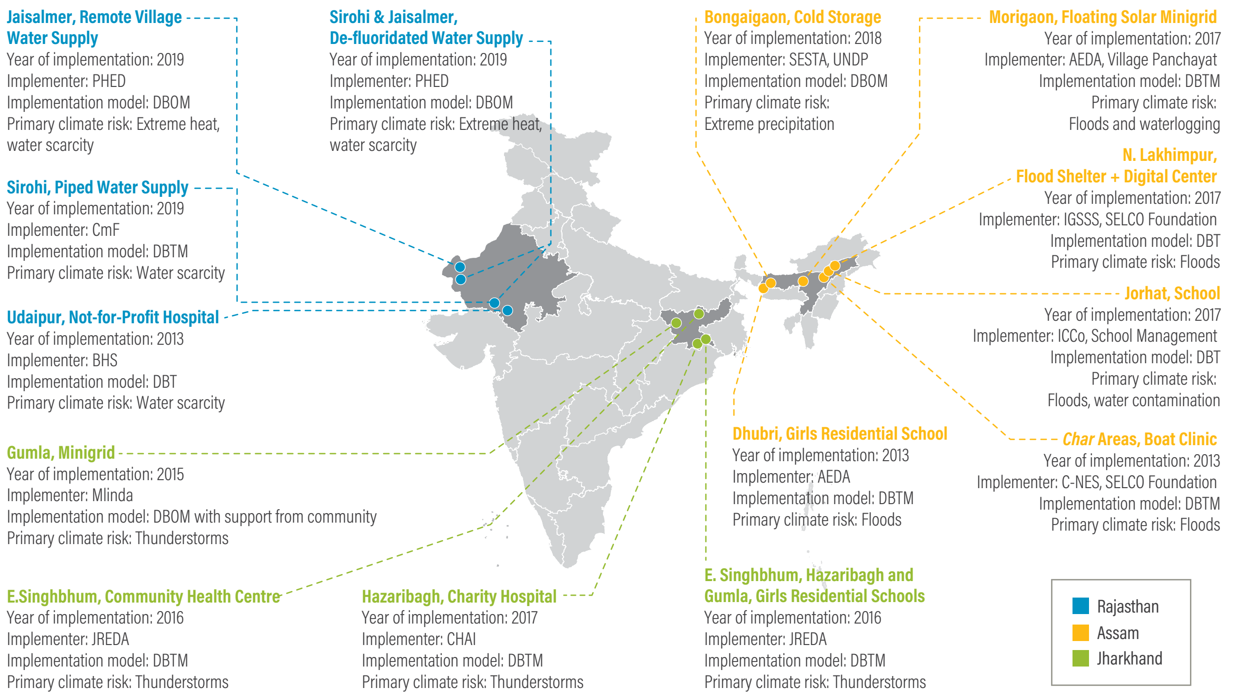
We explore whether electricity demand for healthcare, education, and livelihoods is affected by climate-related events and whether energy solutions take climate risks into account. A summary of the case studies is shown in Figure ES-1.

How to plan for energy for development in climate vulnerable areas?

Through this study we inquire about the impact of climate vulnerability on energy needs for development. By studying energy access installations, we explore how these solutions account for climate vulnerability in their design and implementation models, specifically in energy-poor states. These case studies of installations help us to arrive at the factors that should be considered for improving the sustainability of energy access solutions in climate vulnerable areas.

This study is the culmination of extensive background research, in-person interviews, state-level multi-stakeholder consultation workshops, and field visits. An initial list of decentralized renewable energy (DRE) projects was created with the help of this network. This list was then distilled to 14 case studies based on population served,

Figure ES-1 | Fourteen Case Studies of Decentralized Solar Energy Systems in India



Note: AEDA = Assam Energy Development Agency; BHS = Basic Health Care Services; CHAI = Catholic Health Association of India; CmF = Centre for Micro Finance; C-NES = Centre for North East Studies and Policy Research; DBOM = Design Build Operate Maintain; DBTM = Design Build Transfer Maintain; DBT = Design Build Transfer; ICCo = Innovative Change Collaborative; IGSSS = Indo-Global Social Service Society; JREDA = Jharkhand Renewable Energy Development Agency; PHED = Public Health Engineering Department; SeSTA = Seven Sisters Development Assistance; UNDP = United Nations Development Programme.

Source: WRI authors.

location, access to the site (permission to visit), and willingness to share information. The field visits conducted between June and November 2019 document various stakeholders' experiences at the sites. During the field visits, we interviewed implementers, donors, operators, and end users about the experience of installing and operating DRE solutions, the challenges faced, and benefits accrued. We expect our research to provide practical, usable information for government agencies, energy enterprises, financing agencies, and development organizations implementing decentralized solar energy solutions in climate vulnerable areas.

Findings

Our research indicates that electricity demand for the delivery of essential services is impacted by climate risk in three ways:

- Backup power: Electricity supply through the grid is often disconnected during thunderstorms and floods because of, or in anticipation of, damage to the grid infrastructure. As a result, the demand for backup sources of electricity, such as diesel generators, increases during these times.
- Demand surges: Electricity demand increases as people seek to cope with specific climate-change-induced events. For example, they need electricity for information and communication, medical diagnostics and treatment of diseases, or pumping and filtration of water due to contamination or scarcity.
- Service expectations: Electricity demand will increase for ongoing activities such as digital education, quality healthcare, and income and livelihood enhancements that build the long-term capacities of communities to cope with climate events.

Climate change impacts the technical, operational, and financial design of a project. Many renewable energy projects adapted their designs considering specific local conditions. For example, in Assam, to deal with waterlogging and flooding, installations are designed to withstand higher water levels, either through raised platforms or through technologies such as floating solar installations. Jharkhand is prone to thunderstorms and lightning, and a few pilot implantation projects in the state have installed lightning rods, surge protectors, and chemical earthing. In the desert state of Rajasthan, the installations are designed to withstand extreme temperatures and strong winds and include insurance of structures in project design.

However, none of the installations covered in the case studies specifically incorporate predictions of future climate change into their project design. Climate considerations are even less evident in the operational and financial design. Our research finds that only a