Distributed Energy Resources as an Equity Asset

Lessons Learned From Deployments in Disadvantaged Communities

FOR AN ENERGY SYSTEM TO BE truly equitable, it should provide affordable and reliable energy services to disadvantaged and underserved populations. Disadvantaged communities often face a combination of economic, social, health, and environmental burdens and may be geographically isolated (e.g., rural communities), which systematically limits their opportunity to fully participate in aspects of economic, social, and civic life.

Introduction

Access to energy resources and enabling technologies would allow all communities to derive benefits from the energy system. Distributed energy resources (DERs) offer a unique opportunity to maximize the accessibility and availability of energy resources to disadvantaged communities in rural, remote, urban, and suburban contexts. DERs are small-scale energy technologies and systems (i.e., energy generation and storage technologies) that provide energy at or near the point of consumption.

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More than before, DERs are used in ways that provide benefits to low-income households and historically marginalized communities. The adoptions of solar energy systems, electric vehicles, building electrification technologies (including heat pumps and water heaters), and energy storage all hold promise as equitable energy assets. DERs are designed in ways that allow for colocating electricity generation and consumption, thereby preventing any disproportionate allocation of costs that might result from the building of new centralized or large-scale infrastructure that does not directly benefit communities. In comparison to the socialized costs of centralized grid modernization, which is financially borne equally by all communities, the development of DERs can reduce energy insecurity in rural and remote areas and can lead to the development of equitable assets.

From a global perspective, DERs have been adopted as an equitable asset in various countries to advance sustainable development goals. This is particularly true of DERs in the form of stand-alone systems and minigrids, which have played an important role in bridging the energy access gap. They have emerged as a cost-competitive option to grid-based electrification in remote and/or rural areas that either are power deficient or lack grid-electricity connections. Through innovative delivery and financing models and with a more diverse set of stakeholders that includes communities, local entrepreneurs, technology providers, and development organizations, DER solutions are now increasingly supporting community basic needs (e.g., drinking water), social needs (e.g., health care) and productive needs (e.g., agriculture livelihoods).


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While configurations and application contexts might differ, DERs can be adopted and implemented in ways that allow communities to benefit from new technological advancements. For example, while solar both can provide on-site energy to users and often results in cost savings, building electrification technologies and storage can be implemented to control energy use or provide power back to the grid. Through the use of energy at preferred times, DERs can also reduce costs for customers and support the efficient and lower-cost operation of the grid. DERs and microgrids can also be designed to support community resilience by powering shelters in the face of disasters and power outages.

The range of benefits that DERs can provide to disadvantaged and underserved communities includes

- ✔ rural electrification and energy access
- ✔ bill savings and a reduction in energy burden
- ✔ energy bill stability and a hedge against fossil fuel prices
- ✔ improved air quality and associated health benefits
- ✔ greater energy independence
- ✔ new clean energy jobs
- ✔ community wealth building and local tax revenues
- ✔ educational benefits for youth and the community
- ✔ expertise in new and advanced clean energy technologies
- ✔ greater community resilience to disasters and power outages.

This article discusses the role of DERs in supporting equitable energy outcomes for disadvantaged communities. The benefits are organized across three categories: DERs for low-income communities, DERs for tribal communities, and DERs for the Global South. Under these categories, the article offers examples of projects that highlight the practical applications of DERs as an equitable asset to enhance positive community outcomes and share lessons learned to support broader implementation.

DERs for Low-Income Communities: Energy Resilience and Affordability

To date, rooftop solar and community solar systems have been the most commonly adopted DERs as equitable energy assets, but the adoption of solar is still much higher among wealthier homeowners and communities. A study by the Lawrence Berkeley National Laboratory shows that, as of 2022, the median solar adopter's combined household income was US$117,000—far above the U.S. median of US$69,000 for all households. However, there are hopeful signs; 45% of solar adopters in 2022 were considered low- or moderate-income (LMI), meaning that they earn less than 120% of the area median income. The U.S. Department of Energy's National Community Solar Partnership has a goal of powering the equivalent of 5 million households with community solar by 2025 and achieving US$1 billion in energy bill savings, with a focus on accelerating adoption among LMI households. Community solar can lead to substantial bill savings for customers (in the range of 5–25% depending on the location, according to the National Renewable Energy Laboratory's "Sharing the Sun" report), and new incentives available could potentially expand those savings.

With new federal and state incentives, significant opportunities exist to accelerate the adoption of solar and other clean energy technologies among low-income and marginalized communities. New state and federal programs and incentives laid the foundation for a rapidly expanding uptake of clean energy technology in low-income and marginalized communities in the coming years. For example, 23 states plus Washington, DC, have policies to encourage community solar to be offered to LMI households, either through mandates or incentives. In Illinois, for example, income-eligible community solar subscribers pay only up to half of their previous energy bill and have no upfront costs when they subscribe. Other states have established minimum thresholds for LMI household participation, such as 10–30%, or subsidized subscriptions for LMI participants. In addition, the federal Inflation Reduction Act (IRA) provides tax incentives and grants to encourage the LMI uptake of solar in disadvantaged communities (see the World Resources Institute [WRI] road map for maximizing community benefits from IRA implementation for more details).

Solar Energy as an Equitable Power Generation Asset

With the changing landscape of incentives and funding, approaches and business models are evolving to better serve LMI households and communities. To meet their needs, substantial energy bill savings and a reduction in energy burden are critical components. Rooftop solar can provide substantial bill savings to residents. However, not all LMI households can accommodate solar because of challenges with old electrical systems or structural issues that preclude placing a system on the roof. But for those who can support solar, savings can be achieved over the life of projects.

Community Solar in Kentucky and Nebraska for Household Bill Savings

In Kentucky and Nebraska, partnerships between electric utilities, state and local chapters of Habitat for Humanity, WRI, and philanthropy supported LMI community solar programs with the goal of providing substantial bill savings to households and reducing energy burden (Figure 1). As the Kentucky Habitat for Humanity (KyHFH) rehabilitated and constructed new homes, they started to recognize that their households were still experiencing the burden of high energy costs. Moreover, KyHFH wanted to do more to address climate change beyond their ongoing weatherization and efficiency work. To mitigate household energy costs and help address climate change, KyHFH used donations to purchase community solar subscriptions for participating

figure 1. The Louisville Gas & Electric and Kentucky Utilities Company solar share facility located along I-64 in Shelby County. (Source: Photo by Louisville Gas & Electric and Kentucky Utilities Company.)

LMI households and provided the associated monthly utility bill credit to those customers. The pilot program in Kentucky reduced the electricity bills by an average of US$28 per month, or as much as 50%, which will continue over the roughly 20-year life of the project.

Following the success of the pilot in Kentucky, WRI partnered with Lincoln Habitat for Humanity and Lincoln Electric System (LES) to set up a similar gifting arrangement in LES's service territory. The Lincoln pilot was estimated to provide US$26–27 per month in electricity bill savings for participating households, which amounts to roughly 46% of an average residential customer's electricity bill in Lincoln. LES has a goal of reaching carbon neutrality for its power generation by 2040, which inspired interest from the utility side in the program. With new federal incentives for solar in the IRA, there is further opportunity to provide bill savings from community solar to LMI households using other financing options as well.

The Asheville, NC, Inclusive Rooftop Solar Bulk Purchasing Campaign

The City of Asheville, NC, USA, was one of 21 cities that recently undertook an inclusive solar bulk purchasing campaign, often called a "Solarize" campaign, to increase the uptake of rooftop solar in the community to save residents money and meet the city's climate goals (Figure 2). The campaign was specifically designed to be inclusive and target the uptake of solar energy technology by LMI households. The City of Asheville has a goal of achieving 100% renewable energy for its municipal operations by 2030 and for the entire community of Buncombe County by 2042. Solarize campaigns can be an effective tool for increasing demand for solar by communicating the benefits through a range of trusted partners and lowering the price of systems, with bulk purchase discounts reaching as much as 10–20% when participants in a community collectively commit to installing systems. In Asheville and Buncombe County, the campaign was implemented by the city and county in conjunction with the Green Built Alliance and supported by local organizations, community members, WRI, and Rocky Mountain Institute (RMI) and focused on equity and inclusion to make sure benefits were seen across income levels.

The effort exceeded expectations and resulted in 1.45 MW of solar installations by 180 participants, yielding more than US$250,000 in annual utility bill savings and a total community investment in clean energy of approximately US$4.7 million. The project led to substantial installations of solar in moderate-income neighborhoods, and the program

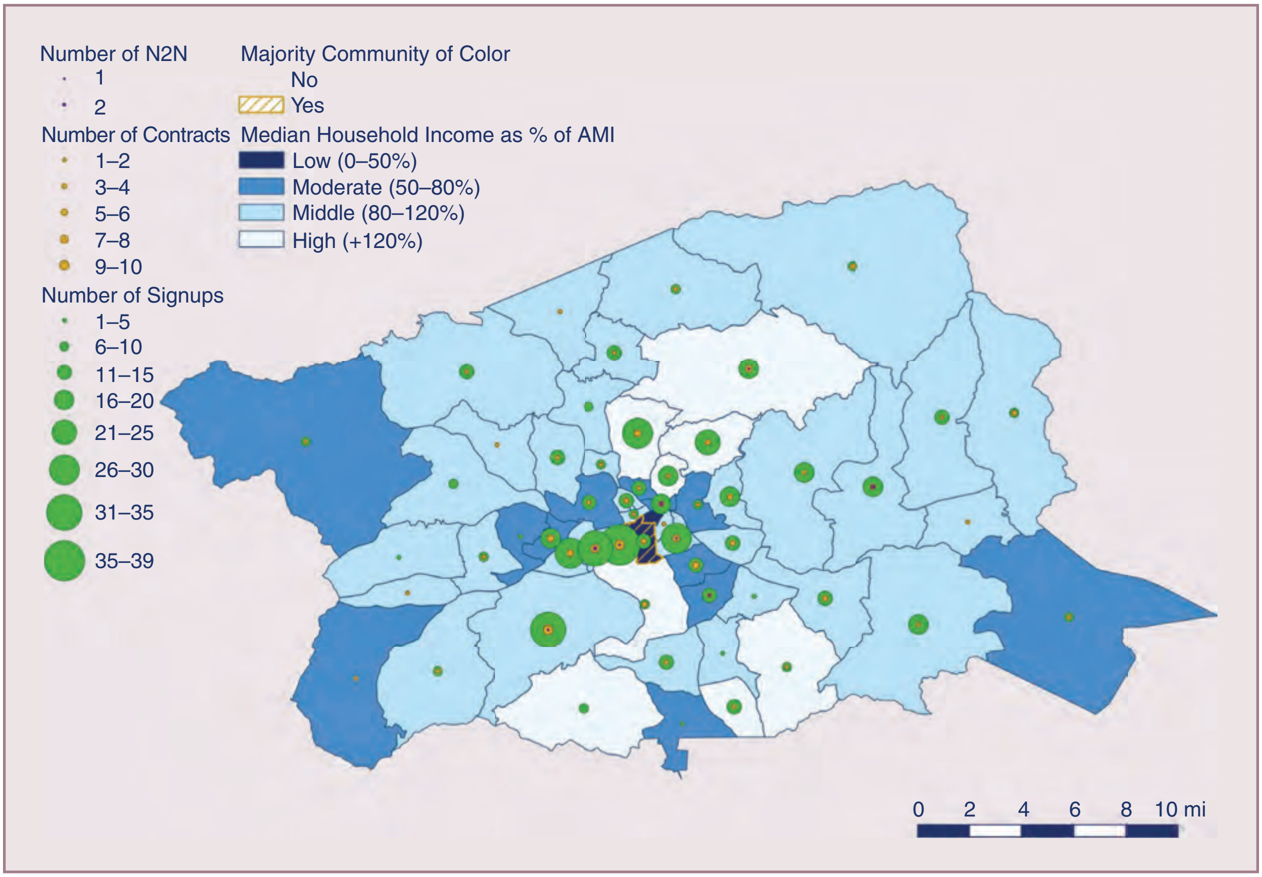

figure 2. The geographic distribution of Asheville Solarize campaign signups and contracts. (Source: Figure by Asheville and WRI.)

The electrification of vehicles, including cars and buses, can happen in ways that benefit tribes, low-income communities, and other marginalized communities.

provided grants to support systems in a dozen qualifying low-income households to maintain lasting bill savings for a range of residents.

Electric Vehicle and Vehicle-to-Grid for Energy Resilience

The electrification of vehicles, including cars and buses, can happen in ways that benefit tribes, low-income communities, and other marginalized communities. Vehicle-to-building or vehicle-to-grid (V2G) applications are emerging and can provide additional community values in the form of resilience and/or revenue from selling power back to the grid, providing additional revenue streams for communities.

Cajon Valley Union School District Electric School Bus V2G Program

The Cajon Valley Union School District (CVUSD) is committed to becoming a leader in environmental sustainability in Southern California (Figure 3). Under their Green Cajon Valley Plan, they have several sustainability strategies, one of which is transitioning their fleet of 42 school buses to electric. While cost is a significant challenge, they took the first step toward this goal in 2020 by partnering with San Diego Gas and Electric for a V2G pilot program. This pilot program made the CVUSD the first district in the Southern California region to test the use of electric school buses with V2G technology. To facilitate this, San Diego Gas and Electric helped secure federal funding to purchase seven Lion Electric Company-manufactured V2G electric school buses and install six Nuvve-manufactured 60-kW bidirectional dc fast chargers. The pilot program sunsets in 2025 and aims to alleviate the pressure on the grid, drive down energy expenses for the school district, and pave the way toward achieving net zero using cutting-edge technology.

The CVUSD is dedicated to providing equitable and accessible education to its more than 15,500 students, 55% of whom come from diverse backgrounds and 68.5% of whom are economically disadvantaged. The district provides transportation for about 800 students every day, and more than half of these are students with disabilities. In fact, 25 out of the 30 routes provided by the CVUSD cater specifically to special needs students. This emphasizes the district's commitment to providing safe, reliable, and inclusive transportation services to all its students.

In the summer of 2022, the CVUSD's V2G vehicles were put to the test during a historic 10-day heatwave. From May to October, these vehicles were able to supply up to 45 kW of power back to the grid during emergencies at a rate of US$2/kWh, according to Nuvve. In addition, the district received energy credits through the California Low Carbon Fuel Standard program. The energy stored in the vehicles theoretically supports the demand in the immediate vicinity/local circuit of the vehicles, if needed. An added benefit to partnering with a local company to conduct the V2G pilot is the job opportunities for those in the community.

figure 3. The Cajon Valley bus charging station. (Source: Photo by the CVUSD.)

Eastern Band of the Cherokee Indian Electric School Bus V2G Program

The Cherokee Boys Club (CBC) is a nonprofit organization that operates as a Cherokee Tribal Enterprise (Figure 4). The CBC provides school bus services to Cherokee Central, the tribally run school system for the Eastern Band of Cherokee Indians (EBCI) in North Carolina. As part of its efforts to be a leader in sustainable transportation, the EBCI aims to be the first school system in the state to have a fully electrified fleet. Currently, the fleet consists of 26 school buses that serve 1,407 pre-K-12 students, and they run on a B20 fuel blend consisting of 20% biodiesel and 80% diesel.

The EBCI made history in 2021 by becoming the first tribal school in the United States to procure an electric school bus. The EBCI's decision was made possible by the EBCI Tribal Council's resolution to set reasonable goals for the deployment of electric vehicles and charging stations across their territory. To fast-track the electrification of their fleet, the EBCI partnered with Duke Energy to leverage their V2G technology demonstration and study program. This strategic initiative has provided the EBCI with four electric school buses equipped with V2G systems and four chargers.

Since the launch of the pilot in 2022, the CBC's focus has been on working with partners and researching the most efficient ways to deliver power back to the grid. The V2G system is expected to be tested before the end of the year, and drawdown events will be monitored throughout the first quarter of 2024. While the pilot is anticipated to deliver reduced energy costs once activated, it is already delivering benefits despite the fact that the V2G technology has not yet been deployed or tested. It provides an opportunity to train current staff on emerging technology and will become a resource for districts across the state as V2G becomes more widely adopted. The EBCI's Air Quality Program is engaging students in the project with a student train-the-trainer program.

DERs for Tribal Communities: Electrification, Resilience, and Energy Independence

The U.S. Census estimates that there are more than 6.79 million Native Americans and Native Alaskans, alone or in combination, making up about 2.09% of the U.S. population. There are currently 574 federally recognized tribes and 324 Native American reservations in the United States plus some state-recognized tribes. The tribes are also referred to as villages, nations, pueblos, communities, bands, rancherias, etc. The terms *Native Americans* and *Alaska Native* may also be used interchangeably as a collective reference to tribal communities and peoples unless a tribal affiliation is specifically stated. Tribal lands comprise about 5.8% of the land area in the conterminous U.S. land, and the utility-scale renewable energy potential is approximately 6.5% of the total national potential. However, there are still more than 54,200 people in the United States who live without electricity on tribal lands.

Each tribe is a sovereign nation with its own government, lifeways, traditions, and culture, and each tribe has a unique relationship with the federal and state governments. Tribal governments have a single point of authority over their critical infrastructure, including alternative energy deployment. In the past decade or so, the tribes have transitioned to become more energy-sovereign nations by deploying DERs on tribal lands, including renewable energy generation and distributed energy storage. Many of the tribal lands are isolated or in remote locations, so very often, electricity supply might be costly or unreliable. The Tribal Energy Storage Program at Sandia National Laboratories (SNL) has provided technical assistance to Native American tribes in regard to future energy storage deployments. This section offers project examples of how DERs in the form of energy storage systems can be applied to tribal communities in the United States.

Analysis of Isolated Power Grid at the Levelock Village of Alaska

The Levelock Village of Alaska has more than 71 enrolled members (Figure 5). The tribal reservation covers more than 10,000 acres of land in the Lake and Peninsula Borough of Alaska, on the right bank of the Kvichak River. Because of its remote location, the tribe has to be self-sufficient in terms of electric power generation. Three small diesel generators currently power this islanded electric power system. The tribe is considering a microgrid project with energy storage due to low reliability, high fuel and electricity costs, and high emissions from the generators. The integration of an energy storage system into the microgrid could extend the overall generator system life, reduce fuel and electricity costs, and improve the reliability of the power supply. These benefits could be achieved by dispatching the energy storage system to maximize the efficiency of the generators, reduce the impacts of the startup and shutdown process, and avoid low-load operation that leads to inefficiency and reduced system life.

figure 4. A representative from the CBC receiving the keys to the electric bus upon delivery. (Source: Photo by the EBCI.)

figure 5. The Levelock Village of Alaska Power Station, Levelock, AK, USA. (Source: Photo by Stanley Atcitty)

As a consequence, the energy storage system improves the overall economic performance of the power supply system by reducing fuel usage, decreasing capital costs by replacing redundant diesel generation units, and increasing generator system life by shortening yearly runtime. Furthermore, energy storage systems could facilitate the integration of solar photovoltaic (PV) systems into the microgrid by maintaining load and generation balance during generation fluctuations and by providing an energy buffer to ease the transition between solar and diesel generation. An analysis has suggested that a project that integrates the current system with 50 kW/25 kWh of energy storage plus 50 kW of solar would have a potential net present value of more than US$30,000.

Analysis of Behind-the-Meter Energy Storage and Solar Array, San Carlos Apache Tribe, Arizona

The San Carlos Apache Tribe has approximately 17,000 members (Figure 6). The 1.8 million acres of the reservation are located in southeastern Arizona. Even though three electric power utilities serve the tribe, local power generation and transmission assets are inadequate. Tribal members report more than 100 power interruptions per year, which are more frequent during the monsoon season. When inclement weather is expected, the hospital located within the reservation disconnects from the grid and runs on the backup power diesel generators to avoid damage to electric equipment due to power outages. To maintain a highly reliable operation, multiple units have to operate to provide redundancy in the case of equipment failure, so the generators operate under low loading conditions. Sustained low-load operation causes wet stacking, sludge formation, adverse emissions, and the loss of efficiency because of the blow-by of combustion gases.

figure 6. The San Carlos Apache Tribe, San Carlos Reservation, AZ, USA. (Source: Photo from https://www.knau.org/knau-and-arizona-news/2021-05-31/san-carlos-apache-tribe-brings-covid-19-cases-down-dramatically.)

Seeking energy independence, the reduction of costs, and better power quality, the tribe is planning to develop a multimegawatt solar PV system colocated with the hospital. The energy generated by this system could offset the hospital's energy costs by reducing the amount of electricity consumed when the system is being served by the local utility and reducing the amount of fuel required by the backup power generators. Battery energy storage systems can be paired with the solar and diesel generation costs to reduce electric demand costs, promote fuel savings, and capture excess solar energy. An analysis has projected that investing in an energy storage system could result in a net present value of between US$11,000 and US$130,000 depending on energy prices and energy storage capital costs. The local utility, however, does not have a net energy metering program. This means that there is no tangible benefit to injecting excess power into the grid.

Microgrid Project at Picuris Pueblo, NM, USA

The Pueblo of Picuris is home to more than 270 tribal members (Figure 7). The 294 acres of tribal land are nestled in the Sangre de Cristo Mountains in northern New Mexico, about 60 mi north of Santa Fe. This tribal reservation is the state's smallest with very limited resources and limited economic development opportunities. The cost of electricity is relatively high. Due to its location, the pueblo experiences frequent power interruptions. In line with the Picuris Pueblo's traditional values of self-determination, Picuris Pueblo's solar power initiative has undertaken and successfully funded the first 1-MW PV project through a combination of funds, including a U.S. Department of Energy grant and a conventional loan. This first PV project has been operational since January 2018, selling its energy to the local utility through a power purchase agreement. This revenue is not only used as a return on investment, but it also partially subsidizes the electricity bills of pueblo households. The pueblo has successfully secured another grant from the U.S. Department of Energy to fund a second grid-tied solar project. They have also expressed interest in evaluating whether the addition of an energy storage system to this project could provide additional benefits.

figure 7. Picuris Pueblo Village, Penasco, NM, USA. (Source: Photo by Stanley Atcitty.)

An analysis done by SNL concluded that a battery energy storage system can be applied to improve power supply resilience and to obtain revenue for the Picuris Pueblo in certain conditions. Part of that condition is that a grant is essential to cover the capital costs of the project. Spending in excess of a grant does not seem to provide good economic benefit since the marginal benefit of adding more capacity is very small. That does not take into account the increased resilience benefits, which are hard to quantify in monetary terms but are likely the most important component that a battery system can provide. Making sure the energy storage system has enough power capacity to balance the loads should be prioritized over having capacity for long emergency backup times. While it would be ideal if the system could provide backup power to the pueblo's loads for several days, that would require a very large and costly system. A more reasonable alternative is to consider protocols for reducing the energy consumption of the loads supported by the microgrid during power interruptions and increasing energy reserves before weather events. Furthermore, by incorporating the new solar system into a microgrid serving the Pueblo, it will be possible to mitigate the effects of power outages.

Navajo Tribal Utility Authority Remote Power System, Navajo Nation, Dilkon, AZ, USA

The Navajo Nation has more than 350,000 tribal members, is the United States' largest Native American reservation, and is approximately the size of the U.S. state of West Virginia (~17.5 million acres) (Figure 8). Due to the vast size of the reservation, several homes are distant from existing electric distribution feeders. Currently, there are more than 18,000 residents without electricity due to the expense of installing electrical infrastructure.

The Navajo Tribal Utility Authority (NTUA), established in 1959, provides electrical, water, and natural gas services. To electrify the remote homes, the NTUA has installed more than 500 PV and/or wind generators with energy storage turnkey systems. The off-grid energy storage and generation systems are designed to provide electricity to homes for several days, even when weather conditions for energy generation are unfavorable. These systems use traditional lead acid batteries and have proven dependability but come at the cost of replacing them every three to five years.

To investigate the possibility of using a more durable alternative, Urban Electric Power and SNL are installing a new technology—rechargeable zinc manganese oxide batteries. This chemistry utilizes aqueous zinc chemistry in the anode, which is safe and nonflammable, and a cathode composed of manganese dioxide—an Earth-abundant material. The new energy storage systems are sized to power homes for about 8–12 days, and the first of three systems has 3 kW/13 kWh. Once installed, the performance of these batteries will be compared to the lead acid batteries.

DERs for the Global South: Electrification for Basic, Social, and Productive Needs

A clean energy transition cannot be achieved without universal energy access. The World Energy Outlook 2023 estimates that 775 million people still lack electricity access globally, and this gap is visible in various development sectors. Globally, nearly 1 billion people in low-income and low-middle-income countries are served by health facilities without an electricity connection or with unreliable electricity supply. More than 62% (171 million hectares) of irrigated cropland globally are in water-stressed regions and are in urgent need of innovative irrigation practices.

While the national electricity grids expand coverage to urban areas, challenges related to terrain and low population density in rural and remote areas drive up the cost of extending and maintaining grid connectivity to provide reliable electricity access. Rural populations face more frequent outages from the energy infrastructure in their vicinity in comparison to urban areas. There are economic and environmental costs associated with frequent outages, such as the costs of using and maintaining backup energy sources (e.g., battery storage, diesel generators, etc.) or alternate sources of primary energy, which is particularly challenging for underserved and under-resourced populations as energy costs account for a higher percentage of their incomes and can result in energy insecurity.

DERs can contribute to resolving some of these challenges. However, DERs, especially those designed for a 24/7 electricity supply, have high capital costs. Several DER-powered applications are still at the pilot stage and require support from philanthropy and grants for implementation, with a few livelihood technologies, such as solar irrigation pumps, being scaled to more than a thousand users. Therefore, the importance of directing financial support to those who need it the most is crucial for DER energy systems to scale.

figure 8. The NTUA remote power system, Navajo Nation, Kayenta, AZ, USA. (Source: Photo by Stanley Atcitty.)

Basic Needs: DERs for Safe Drinking Water

The state of Rajasthan, India, has a significant population that is reliant on groundwater due to a lack of surface water availability and accessibility. About 90% of the state's drinking water and more than 70% of irrigation water come from groundwater. Many habitations previously relied on hand pumps as the primary source of water. However, due to receding groundwater levels, most hand pumps ran dry, leading to women and children bearing the brunt of fetching water. Due to the interior location of the habitations, poor accessibility/road connectivity to external services, and the scattered nature of the population, these habitations have poor access to safe drinking water at a nearby distance from the household.

The Centre for microFinance worked with these communities to provide a community drinking water supply scheme, with water pumps and overhead tanks (Figure 9). The energy system consisted of a 3.2-kWp off-grid solar PV panel connected to a 3.2-hp pump and a 5,000-L overhead tank, which provides piped water supply to around 70 tribal community households. While the energy system does not have battery storage, the water tank acts as a storage to provide some autonomy. The Water User Group (WUG) model adopted by the Centre for microFinance found success in solar powering drinking water schemes. The WUG in this model is governed by elected community members who represent the various sociodemographics of the community. The WUG makes the decisions to identify the water source, land availability, the route of pipelines for distributing water to various households, and its cost implications. For the operational sustainability of the drinking water supply scheme, the WUG initiates the collection of financial contributions from each household that wants to be part of the scheme. Keeping the decision-making process within the community has helped sustain the drinking water supply schemes.

figure 9. A solar-powered water pump and overhead tank. (Source: Photo by Namrata Ginoya.)

figure 10. A primary health center in Northeast India, powered by solar and battery storage. (Source: Photo by Lanvin Concessao.)

Social Needs: DERs for Powering Health Service Delivery

Access to reliable electricity serves as an enabler toward universal health coverage. The Indian Public Health Standards encourage health facilities to adopt DERs, especially where feasible or where reliable grid connectivity is a challenge. In India, the Ministry of Health and Family Welfare, through its National Program on Climate Change and Human Health, helps finance the adoption of DERs through state budgets. Recent research across various health facilities in six states of India documents how access to electricity helps improve health service delivery, including staff living and working environment (Figure 10). In a particular case in the northeastern state of Assam, the adoption of a 4 kW off-grid DER system in an unelectrified health facility enabled the commencement of crucial health services, such as laboratory tests, vaccination, and reagent storage, due to uninterrupted power supply.

In another case, from the coal-producing state of Jharkhand, a 24-bed nonprofit hospital adopted a 10-kW hybrid DER system with battery storage (and provision to also charge batteries from the grid) to save on electricity bills and reduce diesel generator usage so that the savings could be utilized to subsidize the cost of health services for the poor and marginalized served by the hospital. The hospital serves nearly 2,500 patients per month on average. The power is also supplied to the medical staff quarters to provide a conducive working and living environment for staff and increase staff retention. A challenge across multiple sectors is that of operating and maintaining these energy systems, wherein the staff or community members are in most cases responsible for the routine maintenance of these DERs. While there is awareness in terms of cleaning solar panels or the topping up of batteries, users are unclear of the recommended frequency of these activities since these vary based on the location of the installation and the usage of the system. Two health facilities within the same district can have varying cleaning needs. For example, one health facility located next to a coal plant requires panel cleaning

> Another use of DERs has been observed with solar-powered water pumping for irrigation, coupled with community ownership models to deliver water to small farms.

every two days, while the other health facility requires panel cleaning once every seven to 10 days. Similar situations can happen with batteries based on their usage and temperature, which can change the top-up time needed for these batteries.

In places where the grid is more reliable, renewable energy service company models have found success, where a renewable energy developer installs, finances, operates, and maintains the energy system. The integration of net-metering arrangements makes sure that health facilities pay only for any excess electricity consumed from the grid. This provides a cost-effective alternative to upfront capital models, where access to finance, especially for rural and remote facilities, has been a challenge.

Productive Needs: DERs for Agricultural Irrigation

Another use of DERs has been observed with solar-powered water pumping for irrigation, coupled with community ownership models to deliver water to small farms (Figure 11). In this model, a single large solar-powered irrigation pump would serve several small farms around the vicinity of the pump. Farmers would pay an hourly, daily, or monthly fee for the water pumping service. This fee would be collected by the WUG to maintain the system. Prior iterations of the service delivery model implemented hourly charges for the service irrespective of the water usage or distance from the pump. However, this proved to be an inequitable model as hourly rates would mean that the farmer who is farthest from the pump site would receive the least amount of water per hour. Thereby, this would benefit only farmers with farmlands closest to the pump.

To overcome the challenge and advance equitable access to irrigation water, Oorja Solutions introduced innovative service delivery models like the water-as-a-service model, where a 5-hp brushless dc or ac water pump serving 15–20 small farms delivers up to 250 m^3 of water in a day. The water output is metered using digital flow meters and sold on a volumetric basis (per m^3 of water delivered) to the farmer. This allows for a fair price to farmers irrespective of the distance from the pump, time of day, or hours of usage. This also indirectly provided water conservation benefits as farmers would consume only as much water as needed. Oorja prices the water service up to 60% cheaper than the cost of using diesel for pumping water.

On the productivity of the energy system, one challenge to several DER technologies has been their utilization. Given that irrigation is a seasonal activity, the solar pumps lay idle for more than 200 days of the year. To overcome this barrier, the Ministry of New and Renewable Energy proposed the integration of universal solar pump controllers to realize the enhanced utilization of these irrigation pumps. During off seasons, these controllers can power other agro-processing applications (cold storage, milling machines, etc.) of a capacity not exceeding the solar pump capacity.

Expanding DERs as Equitable Assets: The Path Forward

The examples discussed in this article demonstrate the variety of approaches to expanding the adoption of DERs in disadvantaged communities and their potential to bring many different benefits to communities and households, including long-term energy savings, increased resilience, support for community services, and energy independence. To achieve these benefits and equitably deploy DERs, communities can play several important roles, such as hosting projects that yield public benefits, educating community members, removing development barriers, fostering strategic partnerships, and communicating the benefits of successful models.

One of the most critical elements to successful equitable DER adoption is community education and outreach, which can be achieved through local partnerships and engagement with utilities, developers, government agencies, and local community groups. By partnering with these organizations, school districts like the CVUSD and the EBCI have been able to secure funding and gain community

figure 11. Community solar irrigation pumping services. (Source: Photo by Oorja Development Solutions India.)

buy-in, which has laid a strong foundation for the future success of these projects.

There is also a need for further evidence to inform policymaking on how DERs can be adopted by disadvantaged and underserved communities. More importantly, further evidence could be used to formalize existing community models for governing, operating, and maintaining these energy systems, which would ultimately enable the equitable development of energy-poor regions and increase access to resources for people in disadvantaged communities. India, for example, has released a policy framework for promoting DER livelihood applications that involves the assessment of demand for DERs in various sectors, the standardization of applications, awareness building, and interdepartmental coordination. Such frameworks need to be operationalized to establish greater policy uptake, which can support leveraging finance for scaling up.

In the United States, new state and federal policies and programs hold tremendous opportunities to expand the deployment of DERs that can benefit a diverse set of communities. While we have explored a variety of recent examples from various regions, new models and approaches are needed to achieve the full potential of DERs as equitable energy assets.

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Lori Bird, Carla Walker, and Joseph Womble provided the examples in the "DERs for Low-Income Communities: Energy Resilience and Affordability" section, Stanley Atcitty and Rodrigo Trevizan provided the examples in the "DERs for Tribal Communities: Electrification, Resilience, and Energy Independence" section, and Lanvin Concessao and Harsha Meenawat provided the examples in the "DERs for the Global South: Electrification for Basic, Social, and Productive Needs" section.

For Further Reading

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