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Achieving Cooperative Community Equitable Solar Sources (ACCESS) Valuation Report

A Guide for Electric Co-ops

NRECA®
America's Electric Cooperatives

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A Guide for Electric Co-ops

Prepared By:

The National Rural Electric Cooperative Association (NRECA)
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Authors:

Kendall Mongird
Jan Alam
Abhishek Somani

Pacific Northwest National Laboratory

NRECA Subject Matter Expert:

Adaora Ifebigh
ACCESS Project PM
Program Director, Energy Access
Adaora.Ifebigh@nreca.coop

Debra Roepke
ACCESS PI/Technical Advisor
Debra.Roepke-contractor@nreca.coop

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The ACCESS Project includes seven lead cooperatives and a broad group of industry stakeholders who provide diverse expertise that is essential to the project's analysis and resulting tools and resources. The participating cooperatives include the following:

- Anza Electric Cooperative, Anza CA
- BARC Electric Cooperative, Millboro VA
- Kit Carson Electric Cooperative, Taos NM
- Oklahoma Electric Cooperative, Oklahoma City OK
- Orcas Power and Light Cooperative, San Juan Island WA
- Ouachita Electric Cooperative Corporation, Camden AR
- Roanoke Electric Cooperative, Aulander NC

The list of participating stakeholders can be found on our ACCESS website on cooperative.com. Stakeholders who reviewed and provided feedback to this report are: ACT Commodities

Contributors to this specific report are mentioned throughout the report and include:

- Oklahoma Electric Cooperative
- Orcas Power and Light Cooperative
- Roanoke Electric Cooperative

We would like to thank all of these cooperatives and other industry stakeholders for sharing their experiences and ideas to support the success of the ACCESS project and for the benefit of cooperatives nationwide.

For questions or inquiries, please contact our team at: SolarAccessProject@nreca.coop

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Background: The ACCESS Project

NRECA's solar energy project, *Achieving Cooperative Community Equitable Solar Sources* (ACCESS), is the flagship project of NRECA's *Advancing Energy Access for All* initiative. This initiative spotlights the innovative ways cooperatives approach community development and support for their consumer-members, as technology advancements continue to transform our industry.

ACCESS will explore and amplify the use of innovative, cost-effective energy access programs to help increase solar affordability, with particular focus on assisting low and moderate income (LMI) consumers. ACCESS will research varying financing mechanisms and program designs to help identify solutions for electric cooperatives and other small utilities, including field tests of diverse co-op solar projects around the country. Through this project, tools and resources will be developed to assist electric co-ops and the broader industry deploy solar projects to benefit LMI consumers.

Introduction

National Rural Electric Cooperative Association (NRECA) is working with multiple electric cooperatives (co-ops) through the Achieving Cooperative Community Equitable Solar Sources (ACCESS) project to research how to make solar energy affordable for communities with fewer financial resources and extend the benefits of solar development to low-and moderate-income (LMI) customers. NRECA has partnered with multiple co-ops across the country to implement projects that utilize solar photovoltaics (PV) and other distributed energy resources (DERs) such as battery energy storage system (ESS) to demonstrate and promote renewable energy delivery and opportunities to LMI customers. DERs such as storage systems, solar PV, wind turbines, and similar technologies are all unique grid assets that can provide flexibility to operators working to maintain a balanced system and provide high value to utilities and their customers. DERs are often in a unique position, whether by themselves or aggregated in a microgrid, to deliver services that can provide benefits to multiple parties. Despite these beneficial opportunities, accurate valuation of these assets is often difficult to achieve due to inherent complexities and unknowns associated with the valuation process.

DER projects often require third-party financial assistance or grants to get off the ground and financial investors have indicated that there are several factors that can determine the strength of their interest. Whether or not they choose to invest in one or more projects may depend on the contract term length, the associated credit risks, how the project is generating value, and what benefit streams that value is coming from. In order to satisfy these information requirements, co-ops need to be equipped to properly evaluate their assets and demonstrate the full range of available opportunities.

Pacific Northwest National Laboratory (PNNL) has worked with both NRECA and a selection of the co-ops to provide clarity around potential benefit streams for their projects and the process for accurate DER valuation. The information included in this report is intended to give a high-level introduction to each of these topics. The first section will cover some of the technologies that appear in the ACCESS projects. This is followed by key concepts in valuation as well as an overarching taxonomy of services that may be available from DERs as well as some of the available tools for evaluating those services. The final section includes a case study overview of three of the participating co-ops and discusses the details of their ACCESS projects and the potential benefits available to them. The three co-ops discussed in this report are: Roanoke Electric Cooperative (Roanoke), Oklahoma Electric Cooperative (OEC), and Orcas Power & Light Co-op (OPALCO). A discussion of the co-op project backgrounds, the technologies included in those projects, and the potential value streams is included in the report.

This report is intended to distribute information regarding the valuation of these types of projects to a wider audience of co-ops across the U.S. so that they can best provide value to their members and explore potential avenues within their own communities. Overall, the analytical overview provided here aims to be replicable or adaptable to other environments. Results may vary based on each co-op’s unique circumstances.

Overview of Solar PV and Energy Storage Assets

Introduction

There are a variety of DER technologies that can make up a microgrid or be dispatched independently that provide value to utilities and their customers. These DERs can range from variable energy resources (VERs) such as wind turbines and PV solar arrays which have variable output throughout the day, and more controllable assets such energy storage and diesel generators. Additionally, technologies such as smart inverters can help to integrate these technologies and make microgrids more effective.

Each of these asset types are defined in more detail below.

Technologies

Photovoltaic (PV) Solar Arrays

PV solar arrays, solar modules, or PV are all names for the photovoltaic cells that are mounted on fixed-tilt or solar tracking structure and use sunlight as a source of energy generation. PV arrays generate DC power and inverters are necessary for direct current (DC) to alternate current (AC) conversion to properly integrate them into the traditional AC electric grid. Panels can be ground, or roof mounted. The energy generated is highly dependent on factors such as weather, shading, and other environmental and climate aspects. PV arrays are a type of VER in that their output fluctuates throughout both the day and the year and they are not dispatchable (i.e. controllable) in the same way that a diesel generator can be dispatched so long as there is available fuel.

Various programs exist across the U.S. to incentivize the adoption of solar PV at the utility, community, or customer-level. These can include renewable energy certificates (RECs), federal tax credits, grants, and subsidies for investing in renewable energy resources. In addition to the various incentivizing programs that exist, solar PV has achieved cost reductions over the past decade with installations growing six-fold worldwide in the same timespan [1].

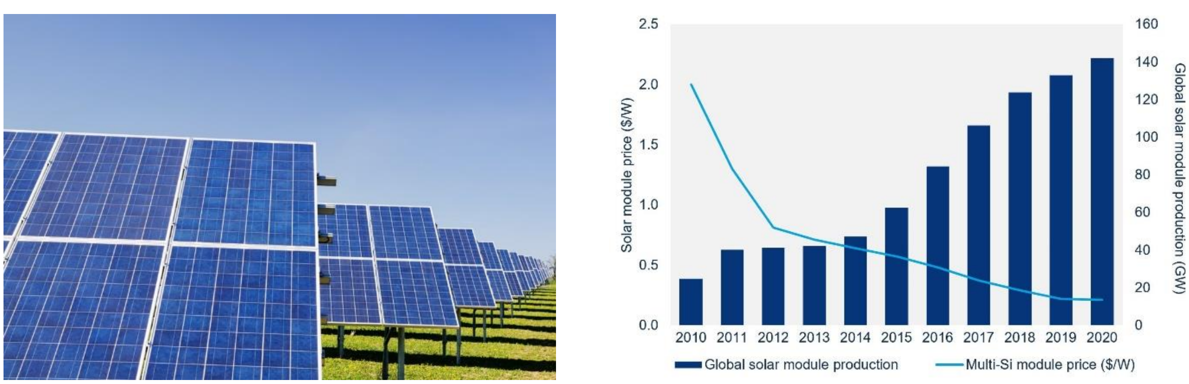

Figure 1: PV Solar Arrays (left); Solar Module Price ($/W) and Global Module Production (GW) Over Time (right), Source: Sun [1]

Solar PV benefits will be discussed in higher detail later in this report as part of the co-op case study overviews.

Energy Storage Systems

Energy storage systems (ESSs) are unique assets in that they are capable of being both an energy "consumer" (charging mode) and an energy "generator" (discharging mode). The benefits they provide to the system are typically associated with the shifting of energy consumption to time periods where costs are lower and shifting energy generation to when the energy is needed or most valuable. Additionally, energy storage can help to integrate VERs by mitigating their lack of dispatchability and can enhance the benefits they provide. Pairing energy storage with renewable assets that have their generation output curtailed due to oversupply, for example, can shift the energy generated to time periods where it can fill demand (e.g., using a battery to store energy generated by solar to meet nighttime demand).

There are a wide variety of energy storage technologies available and choosing the correct technology will often depend on project scale and load demand as well as the applications that are being pursued. Larger energy storage technologies (e.g., pumped storage hydro) in the hundreds of MW range can provide bulk energy services for large areas but may have limitations in their operational capabilities as well as high upfront costs. Likewise, smaller assets (e.g., battery energy storage) may be able to provide services that rely on fast response times or the ability to quickly switch between energy generation and energy consumption. Battery storage, however, may have limitations in the total amount of energy they can provide and may be subject to higher rates of degradation over time compared to other assets.

For smaller-scale projects, batteries are the ESS technology most often pursued. Of these systems, lithium-ion batteries are the most commonly deployed due to their comparatively lower cost and high maturity level. However, various battery chemistries such as redox flow, lead acid, or others may be chosen for specific advantages they may offer. For example, in the case of redox flow, though comparatively less mature as a technology and typically higher cost on a $/kW-basis than lithium-ion battery systems, they can offer less degradation over time and scalability benefits in some cases.

Figure 2 below, reproduced from EIA (2020) shows the deployment breakdown by battery type over time as well as annual investments by power capacity (megawatts (MW)) and energy capacity (megawatt-hour (MWh)). This demonstrates both the growing prevalence of ESSs on the grid as well as lithium-ion's dominance in the market (> 90%) [2].

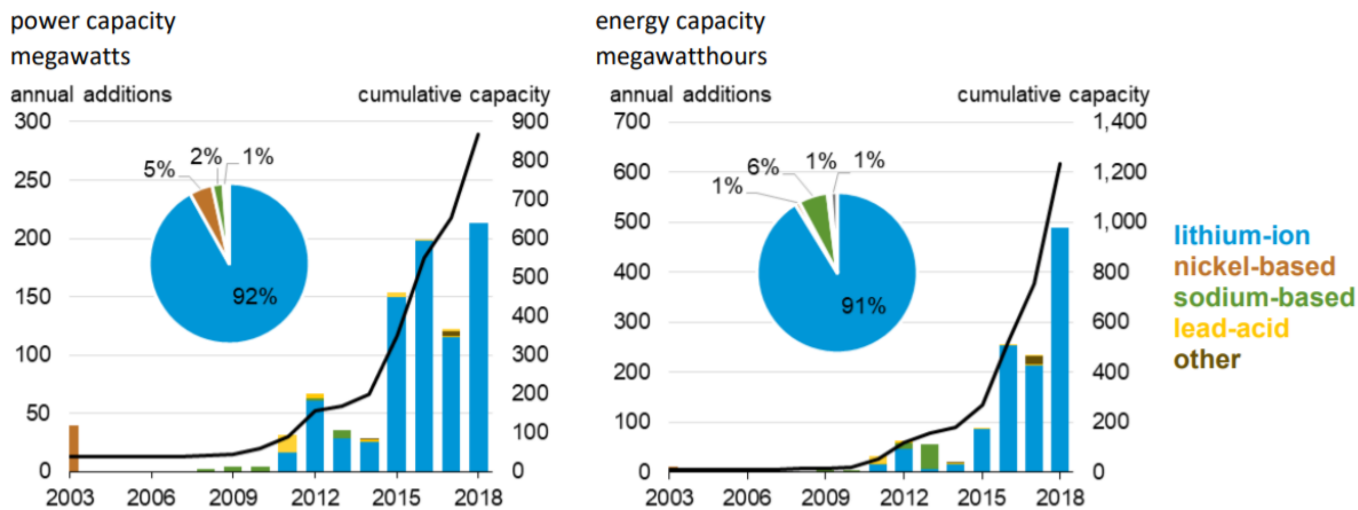

Figure 2: Annual Battery Energy Storage Deployment by Chemistry Type (Source: U.S. EIA [2])

Smart Inverters

Smart inverters, though still considered to be an emerging technology, have become a more common asset for their ability to be adaptive and to share information in real-time, as well as their active control capabilities. Smart inverters provide the standard function of an inverter (i.e. converting DC power to AC power) but also go a step beyond and open opportunities for additional benefits and services. Grid support functions such as voltage and frequency support, for example, are where smart inverters can provide value. Their software infrastructure not only increases the capabilities of installations but also often includes an interface so that owners/operators can learn, adapt, and improve their asset's performance in an easy to understand manner.

With more DERs and VERs coming on to the grid each year, the expectation is that smart inverters will become more important and necessary to pursue the full range of achievable applications [3]. In fact, in states like California, basic levels of smart inverters are now required on new solar projects with plans to expand these requirements in the future [4].

Valuation of Services

Introduction

Depending on the technology, capacity, and location of DERs as well as the other assets they are paired with, a wide variety of benefit streams may be available to pursue. These can range from bulk energy services to customer-focused ones such as outage mitigation and electricity bill savings. Proper valuation and “stacking” of these services are important to consider when evaluating what a project can provide and whether there are improvements that can be made to enhance the value further. This section will discuss key concepts in valuation, provide an overview of different service categories, and list tools that are available for evaluating them.

Location and Grid Configuration Dependency

A variety of benefit streams are available from energy storage assets, PV arrays, and other technologies that are highly dependent on the configuration of a project, its connection to the grid, as well as other location-specific aspects. Figure 3 shows where various services appear in different levels of the grid ranging from bulk services such as energy capacity to customer services such as demand charge reduction. Whether a DER asset is installed in front of the meter (FTM) or behind the meter (BTM) will additionally change the value streams that are available to pursue. For example, a customer-owned energy storage device located BTM at an industrial facility will likely not be able to provide some of the grid services that an FTM storage device would be capable of. It is important to understand how choice of location and configuration of assets will impact the potential applications available.

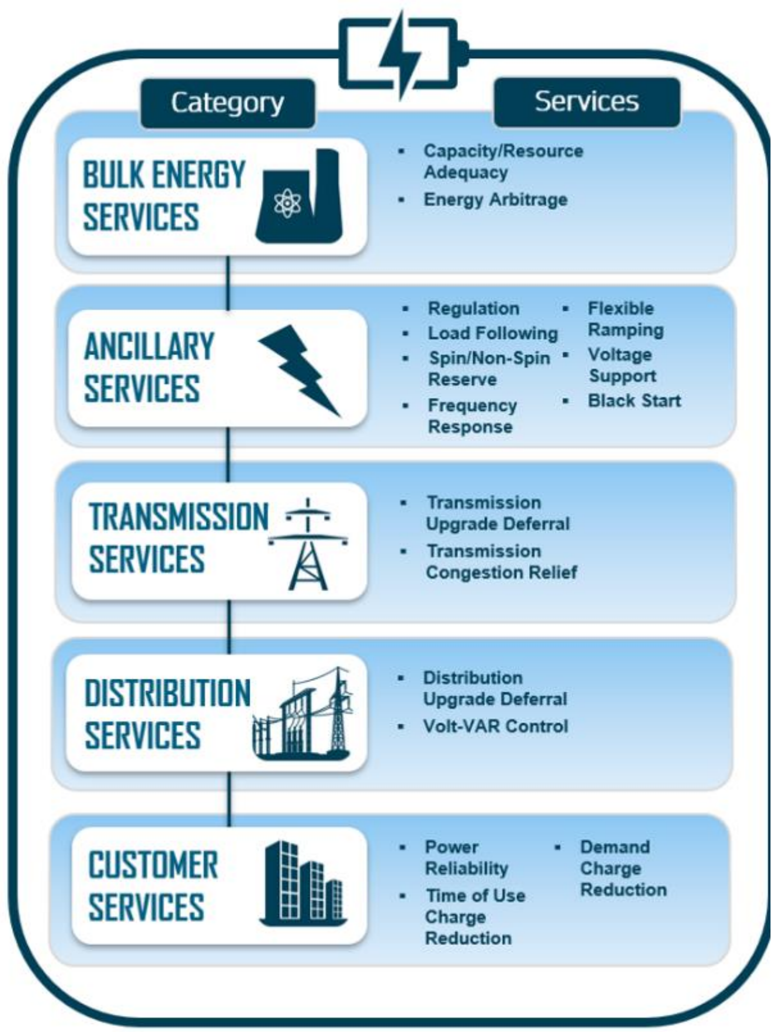

Figure 3: Use Case Categories and Associated Services

The services ("values") shown in Figure 3 are not an exhaustive list as there are often unique benefit streams that may be available to a specific project. The overarching benefit categories, however, include the following, some of which have been adapted from Akhil, et al. [5]:

- **Bulk Energy Services** – Includes services related to the shifting or production of energy and/or reduce the need for alternative generation capacity.
- **Ancillary Services** – Ancillary services typically involve applications intended to maintain a balanced grid. This can include balancing fluctuations in supply and demand of energy (e.g., frequency response, and regulation), providing black start services necessary to energize transmission and distribution lines in the event of a grid failure, providing voltage support to maintain voltage within specified limits, or others.
- **Transmission Services** – This category includes services that support the transmission of energy and provide value by either delaying investment in additional transmission or providing energy in congested areas, avoiding the use of higher cost generation resources.
- **Distribution Services –** This category encompasses benefit streams associated with support of the distribution of energy and provide value by delaying investment in new distribution systems. Voltage support, which also falls under this category, can be provided by assets that can regulate voltage within specified limits. These applications can assist in reducing wear and tear on existing utility assets (e.g., voltage regulating equipment).
- **Customer/Energy Demand Management Services –** Services within this category typically include those that incorporate electricity bill savings from shifting consumption to lower cost time periods, reducing energy demand overall, or other customer-facing services such as the mitigation of power outages. In addition to the avoided costs in the form of bill savings or lost load from power outages, tax credits, renewable energy credits (RECs), and voluntary demand shifting programs (e.g. demand response) would also typically fall within this category.

Potentially Applicable Benefit Streams to ACCESS Co-op Members

The co-ops participating in the ACCESS project have the potential to achieve a variety of benefit streams across the categories described above. After discussions with the three co-ops whose projects are provided in more detail later in this report, the following use cases were identified as those that could be potentially attainable in their projects. Note that while the list of potentially applicable benefit streams is described briefly here, value streams identified as highly relevant or applicable by each co-op within their projects are described in greater depth within their individual sections later in this report.

- **Energy arbitrage** – Energy arbitrage in this scenario would involve charging the battery during hours when energy prices are low and discharging at later hours when the prices are higher. The benefit is derived by the difference in price, subject to efficiency of the battery. This benefit can be obtained as an avoided energy purchase benefit or it can be obtained through participation in a wholesale energy market.
- **Peak shaving** - Peak shaving is a demand management application intended to reduce the highest energy demand points throughout a day. By bringing down demand at peak hours when energy prices are higher, overall energy costs are reduced. This can be achieved

through solar array energy generation directly reducing peak demand or by battery dispatch during peak hours. The benefit calculation is simply the net energy demand reduction multiplied by the on-peak electricity price.

- **Distribution upgrade deferral** – DERs can be used to defer investment in additional distribution infrastructure. Additional infrastructure is often needed to replace aging existing infrastructure or to support growing energy demand. By reducing wear and tear and putting off the need for additional assets, DERs can provide value. To calculate distribution upgrade deferral, the net present value (NPV) of deferring the cost of the required investment by an estimated number of years can generate substantial savings depending on the cost of capital. For a detailed example of a similar calculation, see Mongird, et al. [6] which provides a techno-economic analysis of a solar array and energy storage system.[1]
- **Renewable Capacity Firming** - Capacity firming involves using energy storage to take the intermittent and variable energy generation profile from a VER and “smooth” it out over time. Variation in generation output can cause rapid voltage and power swings on the grid that must be balanced and maintained to avoid damage or disruption. The benefit derived from this application is the avoided cost of using alternative, more expensive assets to stabilize the power swings and maintain grid functionality.
- **Electricity charge reduction** – This application is the direct benefit of energy generation from the solar arrays and is reflected in the reduction of the owner’s energy bill. The generation source supplies a variable amount of energy each month that the customer no longer must purchase at retail rates from their energy supplier.
- **Outage mitigation** – Outage mitigation is the ability to supply energy during a power disruption event. The avoided cost of lost load differs depending on customer type as well as the duration of the avoided outage. For example, a 1-hour power outage for a residential customer will be far less expensive than a large industrial plant that must shut down operation. Sullivan et al. (2015) provides values for each customer type for various outage durations. Avoided outages are typically modeled based on historical data of outages and is constrained by the total number of customers that can be effectively “islanded”. A worked example of this application can also be found in Mongird, et al. [6].
- **Renewable Energy Certificates (RECs)** - RECs are credits that renewable energy generation owners receive at a rate of 1 REC for every 1 MWh of renewable energy generated. These certificates are often sold to utilities so that they can meet renewable portfolio standards outlined in their state. RECs are sold in markets and their value depends on timing, demand, and type of REC. More information on RECs is provided in Case Study 2 later in this report.
- **Demand Response** – Demand response programs are opportunities provided to energy consumers through which they agree to reduce their energy demand during specified time periods in exchange for direct compensation for every kW they reduce. Demand response programs differ greatly along with the available compensation and they are not necessarily available in all areas or by all generation and transmission providers.

[1] The example provided in Mongird et al. [6] is for transmission upgrade deferral, however, the mechanisms for estimating benefits are very similar to that of distribution upgrade deferral.

- **Power Factor Penalty Avoidance** – Power factor reflects the ratio between power (kW) and kilovolt-amperes (kVA). A power factor of one, i.e., when kW = kVA, is referred to as unity and customers that vary from a perfect unity power factor by a specified amount may face penalties on their bill depending on their rate structure. The associated penalty for deviation can vary based on a variety of factors such as the electric rate, demand, and load characteristics. Improving the power factor can also result in a variety of additional benefits besides penalty avoidance including reducing energy and distribution costs, lowering distribution line losses, increasing available capacity to serve power requirements, and providing more consistent voltage regulation [7]. By using the energy storage systems to maintain the power factor closer to one, any associated penalty can be decreased, and other benefits can be captured. The value derived from this application is the avoided penalty cost that may apply and any avoided distribution losses and costs that would have otherwise occurred.
- **Volt-VAR/CVR –** Volt-VAR optimization is used to reduce energy losses by controlling reactive power flow through conservation voltage reduction (CVR). It works as a tool that can adjust the distribution system voltage in order to both minimize demand and reduce system losses. The technology to obtain this benefit is deployed at the system level. ESSs can be used to provide power locally, thereby reducing energy losses and releasing upstream network capacity. The total benefit under this application is dependent on the DER inverter's available capacity to sink/source VAR. The value of energy consumption reduction is typically based on an hourly energy index. In order to capture Volt-VAR/CVR benefits, various system upgrades or adjustments may be required that may make it an uneconomical value stream to pursue. It may require line regulators, transformer load tap changers, additional capacitors, wire replacement, and supervisory control and data acquisition architecture [8].

Benefits to the LMI Community

There are a variety of ways that benefits can accrue to LMI customers from the co-op ACCESS projects and others like it. These can include resiliency-based benefits such as outage mitigation in the event of a power disruption event or more direct benefits such as lower electricity bills. The details on how these may apply within a project will oftentimes depend on the project contract structure, the configuration of the asset within the grid, the location chosen for deployment, and any existing programs made available to different customers. Co-ops can work to increase these benefits specifically for LMI customers by investigating where projects may provide the highest value. This can involve researching areas within their customer-base with high LMI customer concentration and ensuring that these are prioritized, locating projects directly on distribution lines that feed LMI customers, or creating community solar, energy efficiency, or similar programs that return value to these customers directly and carving out space for their participation. How these values accrue and the specifics of where on the system they are generated will vary by program and customer participation scheme.

Specific benefits to the LMI community for each of the ACCESS project case studies are described within each of the project summaries later in this report.

Market Value vs. Avoided Cost Value Methodology

If an asset is located within the area of jurisdiction of an electricity market, it may be able to participate in wholesale energy markets and receive compensation for services such as capacity, regulation, or others directly. However, it is important to understand that there typically exist a number of market rules that dictate requirements for participation. For example, there may be certain criteria on the size and technical features of the assets that may participate as well as constraints on operation or minimum run times that must be followed. Failing to meet these requirements can prevent an asset from participating overall or can lead to penalties for inadequately providing offered services. Whether or not a co-op asset can participate in energy markets will depend on multiple factors such as where their asset is located on the grid and the contractual relationship with their generation & transmission provider.

Energy markets are typically operated by Independent System operators (ISOs) such as California ISO, ISO New England, or Regional Transmission Organizations (RTOs) such as the PJM Interconnection. Additional wholesale energy markets exist outside of these frameworks, such as the Mid-Columbia trading hub (Mid-C) which operates in the Pacific Northwest. Figure 4 shows the location of various ISOs, RTOs, and energy market regions in the US; more information on each can be found in FERC [9].

Figure 4: Electric Power Markets in the US; Source: FERC [9]

If a microgrid or an individual asset exists outside of a market area or does not meet participation requirements, value streams are typically monetized through avoided cost methods. That is, the value provided is the avoided cost of using an alternative asset to provide the necessary service to the grid or customer. In the case of ancillary services, which are applications responsible for maintaining grid reliability and stability, this would typically involve using a diesel generator. With the presence of storage and other DERs with adequate control capabilities, the diesel generators would no longer have to be called upon to provide the service for all or a portion of the required time. The value provided, therefore, is the avoided fuel costs and/or additional operating costs for the diesel generators subject to availability discounts on the DERs. This last component is important to consider when conducting a valuation as DERs may not always be available and therefore, their total value is subject to their capability of providing a service at a given time.

Co-optimization & Accurate Technological Characterization

When conducting valuations of one or more assets and investigating potential benefits, it is important to not only know what services are available but also to properly model those services. Electrical energy used in pursuing the benefits is often competed for on both a time and per-application basis depending on the technology. That is, not all services can be provided simultaneously and simply "stacking" available services could be overestimating what your battery, solar array, or microgrid can provide. A battery, for example, providing outage mitigation services for customers may not be able to simultaneously participate in an energy market. In order to properly co-optimize between services, modeling and simulation tools must be used that can account for these constraints and limitations. The next section discusses some qualities found in good modeling tools as well as a table of some example tools and their features.

In addition to co-optimizing between value streams, proper characterization of each technology is highly important to ensure that value being estimated is within the bounds of feasibility. Understanding the full range of both capabilities and limitations of a technology will paint a more accurate picture of achievable benefits. This can include state of charge limitations on a battery typically outlined in its technical specification document, rated generation output of a solar array, as well as other factors.

Valuation Tools

Energy storage, PV solar, and other assets need to be properly characterized and modeled in order to capture all operational characteristics and be accurately evaluated. Various tools exist to model and simulate operation of assets, co-optimize value streams, and estimate energy generation over a specified time period in the case of VERs. Finding the proper tool for a specified task will ultimately depend on various characteristics that can differ by project as well as desired outcomes.

Some sought-after characteristics of valuation tools include the following:

- **Publicly available and open source** – An ideal model will not only be comprehensive and accurate, but free to use by the public, accessible to a wide audience, and customizable by users.
- **Accurate representation of the technology –** The limitations and capabilities of a technology will set the framework for achievable benefits and good models will be able to accurately capture the characteristics of those technologies. This could include factors such as accounting for asset deterioration and degradation of performance over time, the state of charge of a battery, or other parameters.

- **Broad applicability** – Some tools are limited in their scope of applicability, typically on a geographical basis. A good tool is flexible enough to provide analysis across a variety of locations so that the user may accurately value location-specific applications, compare potential projects that vary by location, and see how their project compares to a similar one located elsewhere.
- **Co-optimization of services** – As previously described, co-optimization of available services is necessary to accurately conduct valuation of benefit streams, especially in the case of dispatchable assets. A tool that is capable of co-optimizing should be able to choose a dispatch schedule over a specified time period that generates the most value. With energy storage, for example, the ideal model will be able to mathematically determine how to best use the energy available in each time step and dictate when it is best to charge and discharge in pursuit of value streams.

Table 1 below provides a list of some available models as well as their characteristics and accessibility. This list is far from exhaustive and only intended as a short example.

Table 1 Selection of Modeling Tools, their Capabilities, and Accessibility

Tool	Developer	Technologies	Description	Cost	Accessibility
PVWatts Calculator	NREL	☑ Solar	Web-based calculator for estimating PV array production by location for each month and calculated an annual expected value based on energy rates ($/kWh).	Free, publicly available	Highly accessible, web interface that is easy to use.
Storage Value Estimation Tool (StorageVET)	EPRI	☑ Energy storage	This tool provides a framework to be able to optimally place and install ESSs on the grid. It also includes options for choosing the right size system and evaluating value streams.	Free, publicly available, and open source	Highly accessible, python-based program. EPRI's site provides tutorials, user guides, and other information for ease-of-use.
Distributed Energy Resources Value Estimation Tool (DER-VET) (beta)		☑ Solar ☑ Wind ☑ Energy storage ☑ Combustion engines	An optimization-based energy valuation tool that also assists on planning. The tool was built as an expansion on EPRI's StorageVET tool to include additional DERs. The tool also has the capability of planning larger, centralized resources.	Free, publicly available, and open source	The tool is still in beta and less mature than EPRI's StorageVET tool, however, guides and tutorials are similarly provided on EPRI's website.

Tool	Developer	Technologies	Description	Cost	Accessibility
Battery Storage Evaluation Tool (BSET) **Energy Storage Evaluation Tool (ESET)**	PNNL	☑ Energy storage	BSET is a model that simulates the use of an energy storage system to meet multiple objectives. BSET can determine how to control the battery in an optimal manner such that total benefits are maximized. ESET is a recent and ongoing development at PNNL to convert BSET into a web-based tool.	Free, publicly available, and open source.	BSET is easy to install and operate while the web-based tool aims to increase ease-of-use. Public version is a simplified version of what PNNL uses to conduct in-depth analytics.
Renewable Energy Integration and Optimization (REopt)	NREL	Lite version: ☑ Solar ☑ Wind ☑ Battery energy storage Full version: ☑ Custom technologies	A techno-economic decision platform to optimize systems such as microgrids, buildings, communities, and others. The program can find the optimal mix of assets to meet cost, resilience, or performance goals.	Lite version is free and publicly available. Custom version requires technology partnership agreement for private sector clients and federal agencies can request funding from DOE Federal Energy Management Program.	The REopt model provides optimization and technology integration capabilities. The lite version is a free, web-based tool – no download required. It offers a guided process with simple input infrastructure and the ability to save results.
Distributed Energy Resources Customer Adoption Model (DER-CAM)	LBNL	☑ Solar ☑ Energy storage ☑ Unspecified DERs	A decision support tool used to find optimal DER investments in building or microgrids. It can be used to find optimal sizing, siting, and dispatch of various assets and co-optimize value streams.	Free, publicly available, open source	Access to DER-CAM requires registration on their website. Includes a public-facing graphical user interface. LBNL's DER-CAM website includes video tutorials and a data processing template.

Tool	Developer	Technologies	Description	Cost	Accessibility
Hybrid Optimization of Multiple Electric Renewables (HOMER)	UL/Homer Energy	☑ Solar ☑ Wind ☑ Energy storage ☑ Hydro ☑ Hydrokinetic ☑ Biomass ☑ Diesel generators ☑ Custom Technologies	Provides an optimization and sensitivity analysis algorithm to evaluate economic and technical feasibility of various technology options.	$42-175/month depending on chosen plan/software[2]	There are many online resources on how to use the software. Options are available within the tool to use placeholder data.
PLEXOS	Energy Exemplar	☑ Custom Technologies	Full utility-scale simulation model capable of optimizing for power generation, reliability, capacity expansion planning, renewable energy integration, dispatch optimization, portfolio optimization, and other capabilities. Typically used by transmission and generation planners, market participants, system planners, and consultants.	Obtaining price requires consultation with Energy Exemplar.	High learning curve and considerable time and effort to establish model but ultimately will give highly accurate output that is system-dependent.

[2] https://www.homerenergy.com/products/pro/pricing/index.html

Co-op Case Studies

Introduction

This section will discuss three cooperative-led ACCESS projects based in different locations across the U.S. and their unique configurations, the contracting mechanisms they have either established or plan to establish, and the benefit streams they are looking to achieve or may have the ability to additionally pursue.

Case Study 1 – Roanoke Electric Cooperative

Introduction

Roanoke serves over 14,000 industrial, residential, agricultural, and other members located in West Aulander, North Carolina [10]. They are a member co-op of North Carolina Electric Membership Corporation (NCEMC) – a generation and transmission co-op that provides electricity to 25 different member co-ops in North Carolina (Figure 5). One of NCEMC's stated goals is to purchase electricity through contracts and own power generation assets in order to coordinate transmission of electricity to its members. With NCEMC's assistance, Roanoke EC plans to deploy four solar PV arrays paired with four battery ESSs at sites within their service territory.

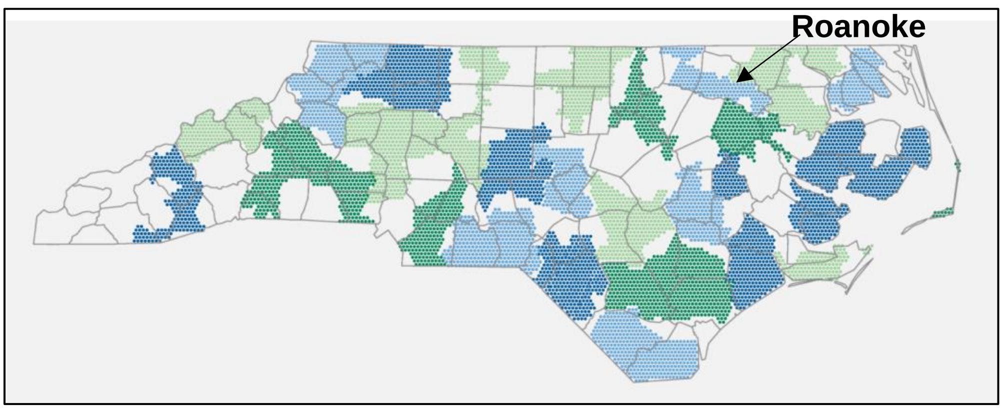

Figure 5: NCEMC Co-op Member Map Showing Roanoke EC within North Carolina;
Source: NC Electric Cooperatives [10]

Project Details

Contracting & Ownership Structure

Though Roanoke is handling the project, the solar PV and ESSs will be owned by NCEMC with whom Roanoke holds a solar power purchase agreement (PPA). The procurement process for the PV arrays is being handled by NCEMC who is working with the National Renewables Cooperative Organization (NRCO) – a national organization of cooperatives working to facilitate the installment of new renewable energy resources.

In addition to the PPA, each site has an extended land lease agreement of 45 years with the associated landowners. Remote locations and those that could provide greater opportunities for DERs were also taken into high consideration when choosing the locations. The DERs are expected to be capable of providing network support (e.g., voltage support) in these areas.

Benefits to the LMI Community and Other Co-op Member Groups

Roanoke has taken this project as an opportunity to help support the underserved community through various programs intended to increase energy efficiency, community engagement with solar, and land use benefits to some of their members. Roanoke is using three different existing programs to make up their SolarShare program. These include (1) The Sustainable Forestry and Land Retention (SFLR) project – a partnership between the U.S. Forest Service, the American Forest Foundation, the Natural Resources Conservation Service, and the U.S. Endowment for Forestry and Communities to create land investment opportunities and promote sustainable forestry; (2) Roanoke's Upgrade to $ave Program which promotes energy efficiency upgrades and cost savings for members; and (3) Roanoke's community solar program which allow members to directly participate in renewable energy generation. These three programs allow Roanoke to provide benefits to their LMI and other disadvantaged community members in multiple ways.

The first of the three programs described, the SFLR project, aims to assist in land investment opportunities that may have been historically difficult due to land ownership complications (i.e., heirs property). The program helps to provide land conservation opportunities as well as estate planning, wills, and deed assistance for the landowners. Compared to lease rates for agriculture, solar development leases typically generate much higher revenue. Roanoke believes that this will greatly benefit the customers they work with and be a great opportunity for members who may face the land ownership difficulties mentioned [11]. As previously described, the four separate land lease agreements will last 45 years and are expected to generate benefits throughout that time period. The four sites for the ACCESS project were selected by first identifying viable locations within Roanoke's service area and then choosing those which are participating in SFLR.

Upgrade to $ave, the second program, is intended to aid co-op members who may be struggling with their energy bills by providing energy efficiency upgrades to their homes at no direct cost to the customer. The upgrades are instead financed through a low fixed tariff on the energy meter. In the past, Roanoke has seen lower participation in the Upgrade to $ave program than desired due to member homes not meeting minimum health and safety requirements to receive the energy efficiency upgrades. As part of the SolarShare program, therefore, Roanoke will add in further assistance by leveraging credits to offset home repairs so that the homes reach the qualifying level of health and safety to also receive Upgrade to $ave benefits. Through this program, members could receive both home improvements as well as greater energy efficiency, enabling them to gain benefits they would otherwise be unlikely to achieve.

Combining the Upgrade to $ave program, the SFLR, and Roanoke's community solar participation program into a single initiative will allow Roanoke to help their members in a wider variety of ways. They hope that SolarShare will increase community interest in Upgrade to $ave as well as their community solar program. Additionally, to further boost involvement, grant and donation funds will be pursued in order to assist LMI community members in their participation of the program as well as to offset investments required to participate [11].

Technical Specifications

Roanoke's ACCESS project includes the following assets:

- Four 250 kW PV solar arrays at four different distribution sites in their service territory
- Four co-located 500 kW, 1500 kWh (3 hour) battery ESSs
- Smart inverters

The four projects will be connected to the feeders at each of their locations instead of the substation in order to reduce line loss. This has the added benefit of more easily enabling additional installations in the future, as the available opportunities for substation connections within their service territory is fewer than for feeder connections [11].

All of Roanoke's substations are connected to Dominion North Carolina Power, a large utility which operates across 16 different states. While Dominion resides within the PJM Interconnection, the RTO which coordinates wholesale electricity across 13 states in the eastern US, Roanoke does not directly engage in market opportunities on their own and instead relies on NCEMC to do so on their behalf. Roanoke Electric does not anticipate engaging directly with the PJM market soon.

Project Value Streams

The primary benefit stream that the co-op aims to achieve with their deployed assets is peak shaving. Peak shaving is an energy demand management application intended to reduce the highest demand points throughout a day. By bringing down demand at peak hours when energy prices are higher, overall energy costs are reduced.

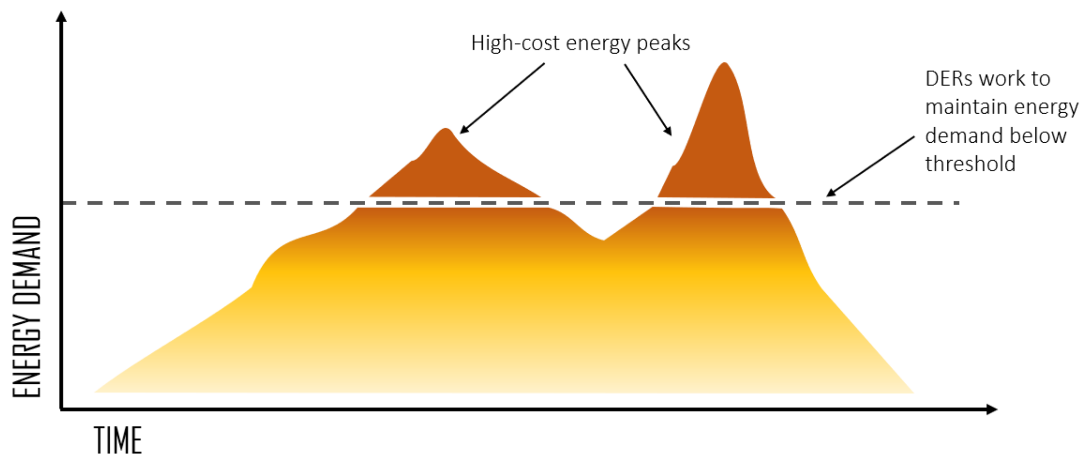

Figure 6: Peak Shaving Use Case Diagram

By using the solar arrays to meet demand at peak hours, they will reduce energy purchases during those time periods. Any excess energy generated can be used to charge the ESSs or can also be discharged at these hours to reduce energy demand not covered by the solar generation. This will provide value through energy purchase avoidance. The benefit calculation is the net energy demand reduction multiplied by the on-peak electricity price. The total value will be dependent on total solar generation as well as the battery dispatch schedule.

In addition to achieving a daily peak shaving benefit from reducing energy purchases, there is also a demand charge reduction benefit. Each month Roanoke pays NCEMC a fee that is determined by their peak load over a specified time period. By using both the solar PV generation as well as battery dispatch at peak hours, the benefit under this use case is simply the reduction in total kW demand at the peak time period multiplied by the associated $/kW cost.

Potential Additional Applications

In addition to those that Roanoke aims to capture, additional benefit streams could include those in the following list. For descriptions of each, see the Location and Grid Configuration Dependency section which has briefly described how value is derived.

- Distribution upgrade deferral
- Outage mitigation
- RECs
- Demand Response
- Power factor penalty reduction or avoidance
- Volt-VAR/CVR

This list is not exhaustive and some of the applications listed above may not be applicable as project details change over time or as new information is found. The list is instead intended to demonstrate that the valuation process should be exploratory and/or iterative to ensure that the full range of value streams is being captured.

Case Study 2 – Oklahoma Electric Cooperative

Introduction

For their ACCESS project, Oklahoma Electric Cooperative (OEC) plans to install a 2 MW FTM PV solar array at Norman Public Schools (NPS) located in the city of Norman, Oklahoma. The purpose of the project is to ultimately establish the Norman Solar Park and Learning Center which will aim to lower the school district's energy costs through renewable energy generation and provide educational opportunities for the students. The project will encompass 15 acres of land and include over 7,000 solar panels when complete. The finished Norman Solar Park and Learning Center is expected to be capable of generating the equivalent of 30% of NPS's annual energy consumption [12].

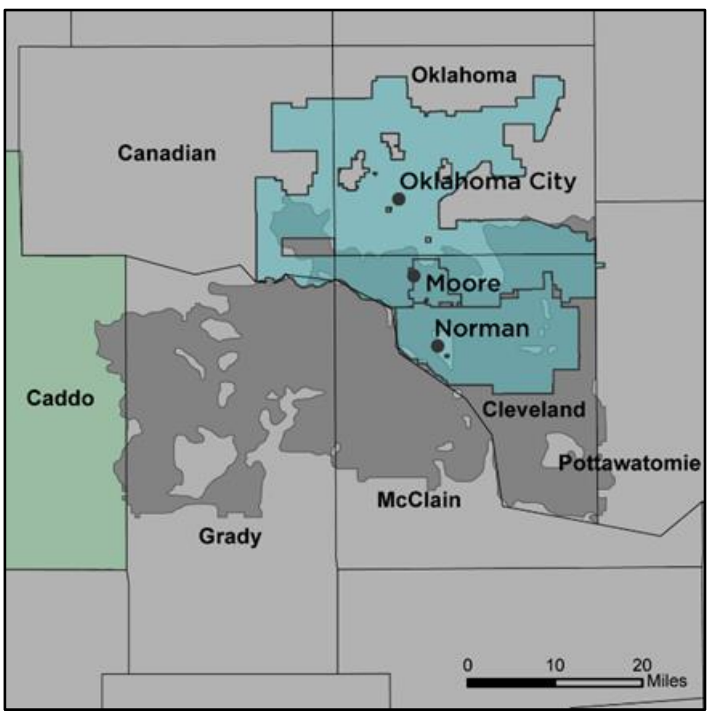

Figure 7: Location of Oklahoma EC
Source: NRECA

Project Details

Contracting & Ownership Structure

NPS will provide the land required for the project to OEC and receive the lease payments directly. The solar array will be owned and operated by NextEra Energy, LLC. – an electric utility holding company that invests in new infrastructure. NextEra Energy, LLC. will receive the associated 30% federal tax credit benefit for the project and take on associated risk as well as project maintenance costs. OEC is coordinating the project and will have a PPA with both NextEra Energy, LLC. as well as Western Farmers Electric Cooperative (WFEC) who supplies energy to OEC as their generation and transmission provider. Under the defined structure, WFEC will sell energy to OEC using a solar rider mechanism. Under this contract structure, the energy (kWh) and demand (kW) output delivered from the solar facility to the metering point is "added back into the delivery points to arrive at a gross load and demand for billing purposes" [13].

Benefits to the LMI Community and Other Co-op Member Groups

By locating the solar array at NPS, OEC will provide an opportunity for both community and school engagement in addition to any energy benefits generated. The Renewable Science Education Center will demonstrate renewable energy operations to students as well provide information on career opportunities in energy.

In addition to the educational opportunities, OEC is also exploring a mechanism to indirectly deliver energy cost savings to the school district and its students within the LMI community. Given that the project is located FTM, energy generation benefits will not directly impact NPS's electricity bill. While the exact mechanism for delivering the benefits remains under development, OEC is investigating a variety of options such as community partnerships or donations that can be passed on to the school. This benefit and the potential mechanisms are described in greater detail later under the project value streams section.

Overall, this project aims to provide the LMI community with access to renewable energy, potential energy savings and scholarship opportunities, and an increase in educational opportunities for both the students and the community at large. Additionally, the project will help the city of Norma, Oklahoma reach their goal of 100% renewable energy by 2030.

Technical Specifications

The 2 MW solar array will be connected to a 14.4kV feeder, includes single axis tracking, and will generate energy at 600V AC. The site of the solar array is within the "denser" part of the distribution system and the expectation is that there will be additional system benefits as it relieves congestion and defers investment in additional resources to meet demand. A Delta MH125HV inverter will be used in the solar PV system.

Project Value Streams

There are a handful of available value streams that the Norman Solar Park and Learning Center can provide to both NPS and OEC. The primary benefit streams identified as those of high interest for the project, however, include the following:

- Energy cost savings for NPS
- RECs

Each of these will be defined and their general valuation methodologies will be briefly discussed in the subsections that follow.

Potential Energy Savings for NPS

As mentioned, the 2 MW solar array is expected to generate enough energy to cover approximately 30% of NPS's annual energy consumption. NPS will receive direct payments for leasing the land for the project, however, given that the solar facility will be connected in front of the meter and directly feeding into the distribution system, energy benefits will have to be provided indirectly rather than as a reduction on the school's energy bill. As part of the ACCESS project, OEC is investigating potential mechanisms to pass on the energy benefits to the school. These could potentially include the donation of panels or possibly scholarships from the energy generation that will benefit the school system and LMI students, specifically. The former option, the donation of panels, would include community members leasing panels within the solar park and donating the generated kWh to the school so that they may receive the energy benefits. The ultimate value of this benefit will vary based on the mechanism chosen, community engagement and support, as well as other factors.

Renewable Energy Certificates

RECs are certificates that renewable energy generation owners receive at a rate of 1 REC for every 1 MWh of produced renewable energy. These certificates are often sold to utilities so that they can meet renewable portfolio standards outlined in their state. Electricity providers must obtain RECs as proof that they have met renewable guidelines and mandates and can either generate it themselves or purchase certificates from others. Different programs exist across states that offer varying compensation for RECs that can also differ based on market structure.

REC tracking systems are regionally based. For Oklahoma, tracking each REC generated by the solar array would likely be done through the North American Renewables Registry (NAR) or the M-RETS platform which allow registration from any generators located in the US that do not have their own formal tracking system. The platform is responsible for reviewing and validating renewable production and issues unique (serial coded) RECs. These RECs can then be sold to another platform account holder, and after the purchase, the platform is responsible for transferring the credits to the new owner who uses them towards their renewable energy goals and/or requirements [14, 15]. Figure 8 below shows the various systems across regions of the US [16].

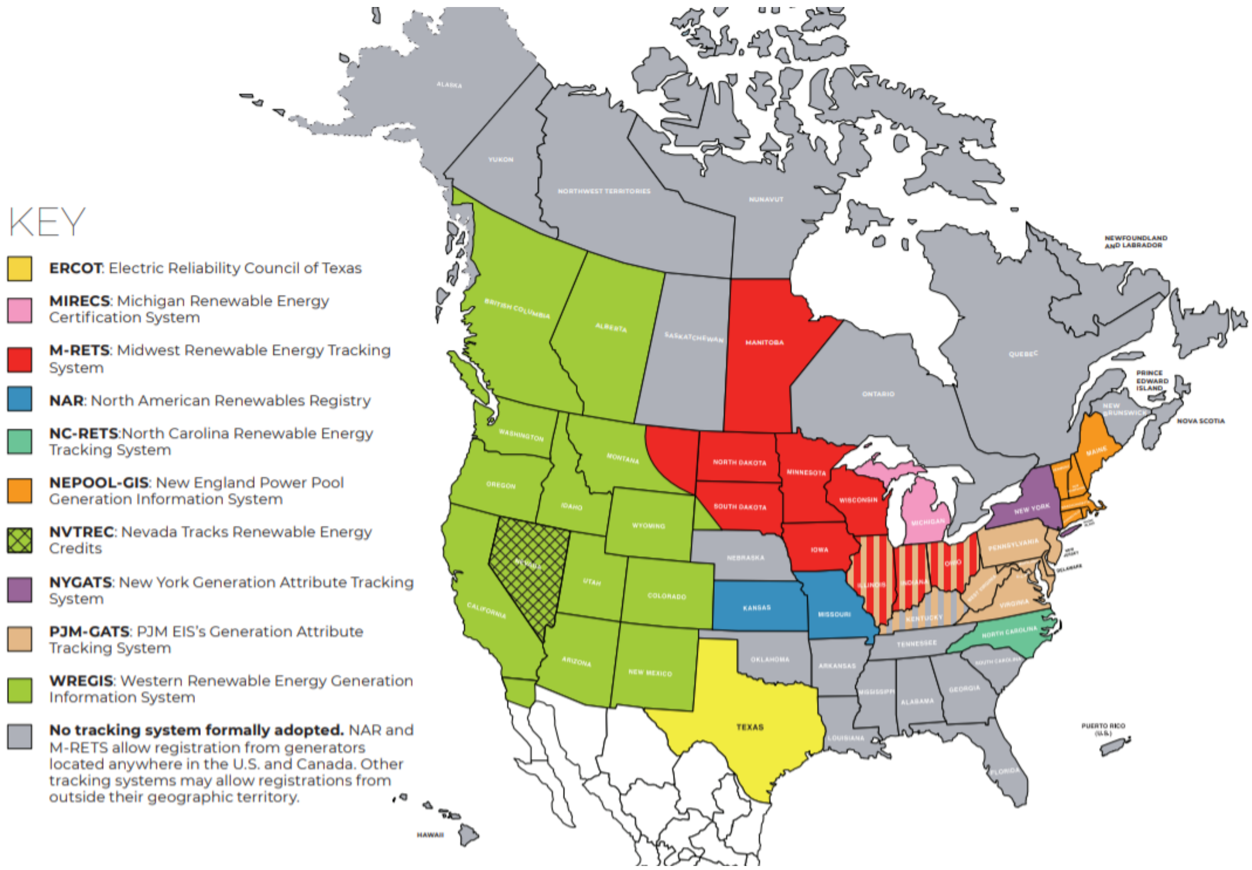

Figure 8: REC Tracking Systems in North America, Source: CRS [16]

OEC has indicated that they are looking into the option of the RECs being transferred over to NPS so that students in the community will have a "touchpoint" for receiving renewable energy. Given the market structure, $/MWh compensation for RECs can vary over time and by location and depend on demand variability, volume purchased, the type of renewable resource providing the RECs, and the certification status, as well as other factors.

Potential Additional Applications

Additional benefit streams from the project could include those in the following list. Given the location on the distribution system, the benefits listed from the solar project will primarily be directly applicable to OEC and their operations.

- Demand charge reduction
- Energy charge reduction/time of use (TOU) benefits
- Distribution deferral

For descriptions of each, see the Location and Grid Configuration Dependency section which has briefly described how value is derived from each or the more detailed descriptions in Case Study 1. Though the individual metrics may vary project to project, the methodology for estimating value often remains the same. For example, for the customer side of outage mitigation, customer profiles may be different and frequency of outages changes across the locations, but the approach to establishing the avoided cost of mitigating the outages will follow the same procedure.

The above list is not exhaustive and some of the applications listed may not be applicable as project details change over time or as new information is understood. The list is intended to demonstrate that the valuation process should be exploratory and/or iterative to ensure that the full range of value streams is being captured.

Case Study 3 – Orcas Power & Light Co-op (OPALCO)

Introduction

OPALCO provides energy to a variety of customer types located within the San Juan Islands – an archipelago located off the northwestern coast of Washington State. To start, their ACCESS project includes a 1 MW solar array that they intend to grow over time and a 1 MW, 4 MWh (4 hour) battery system consisting of two different battery technologies. The project will be located on San Juan Island and is based on an existing solar project that covers a smaller amount of land.

Figure 9: Location of Orcas Power & Light EC
Source: NRECA

Project Details

Contracting & Ownership Structure

The solar array will be procured through community-based funds (i.e., through those participating in the community solar program), however, OPALCO aims to obtain a grant for the portion that would benefit LMI customers which will offset some of the cost. Potential sources of the additional LMI grant funds include the Washington State Department of Commerce (Clean Energy Fund (CEF), Bonneville Environmental Foundation (BEF) and the U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP). BEF is a Pacific Northwest-based non-profit that is partnered with Bonneville Power Administration (BPA) – the entity that supplies energy to OPALCO. BEF offers grants for renewable energy and carbon reduction projects [17]. REAP, on the other hand, is a program that provides guaranteed loan financing and grant funding for renewable energy systems owned by rural small businesses [18]. In addition to pursuing grants from BEF and REAP, Washington state has a low-income solar grant program which will also put approximately $3-4 million towards the project.

The battery storage component of the project will also be procured through community-based funds; however, OPALCO will also receive a matching grant worth $2.4 million from the Washington Clean Energy Fund (CEF). Washington CEF co-funds projects within the state that work towards the development and demonstration of clean energy technologies through matching-fund grants [19]. OPALCO has participated in a previous round of the Washington CEF and received a grant for a battery system and community solar array currently located on Decatur Island within their service territory. PNNL provided analysis and preliminary techno-economic support for the previous CEF project [6]. The overall proposed financial structure will be a combination of local institution partnerships, non-profit organizations, and government agencies. The ownership structure of the project will be ultimately determined by the financial mechanisms and contracts that are decided upon.

Benefits to the LMI Community and Other Co-op Member Groups

The OPALCO solar plus storage project is intended to display the unique benefits of renewable energy generation supported through energy storage and will pass those benefits on to LMI members within the community. The plan for the community solar array is to allow participation from any OPALCO member who wishes to be involved, however, OPALCO is intending to set aside a portion of the availability to LMI community members who may not otherwise have the capability to participate. As mentioned previously, the goal is to support the LMI community's involvement through grants and external funds. OPALCO is hoping this will lead to overall greater renewable benefits for their community as well as directly provide opportunities for those that are more disadvantaged.

In order to also deliver a minimum of 10% electricity cost savings for LMI members, OPALCO will explore an on-bill financing program offered through the USDA Rural Utilities Services Renewable Energy Savings Program. They believe that this may be an easy avenue to allow LMI customers to participate in the community project that doesn't involve contributing their own funds. In addition to the expected bill savings for these customers, OPALCO aims to also use the project for education and training opportunities for students and other community members [20].

Technical Specifications

The PV system is expected to be 1 MW for the initial buildout and grow over time. As the cost of solar decreases and member participation interest increases, there will be more room for expansion of this project component.

The PV system is to be co-located with two battery ESSs consisting of two different technologies – a lithium-ion battery and a redox flow battery system. Each of the batteries will be .5 MW, 2 MWh in size.

Project Value Streams

For the current project, there are various load types on San Juan Island that the combined solar and ESS would benefit including a hospital, airport, warehouse facility, as well as small businesses. Additionally, OPALCO purchases its energy from BPA and it is believed that the presence of the solar generation could hedge against volatile energy prices in the future.

The portfolio of available value streams is highly dependent on the procurement of the battery systems that would be co-located with the solar array. Bringing energy storage into the project also provides additional opportunities and can enhance the benefits of the PV. If the energy storage assets do not ultimately get procured, the primary benefit stream from the standalone solar array will simply be the injection of as much renewable energy onto their grid as possible.

The individual use cases described below assume the presence of the battery systems.

Renewable Capacity Firming

Capacity firming involves using energy storage to take the intermittent and variable energy generation profile from a VER and "smooth" it out over time. Variation in generation output can cause rapid voltage and power swings on the grid that must be balanced and maintained to avoid damage or disruption. The benefit accrual from this use case would be the avoided cost of using an alternative asset (e.g., diesel generators) to smooth the energy generation. The total value provided, however, must be discounted by the efficiency and availability of the battery system comparatively. That is, the batteries located on San Juan Island could potentially be depleted when capacity firming is needed and unable to perform the service. Diesel generators, on the other hand, are capable of providing generation so long as there is adequate fuel on hand.

Load Shifting/TOU Energy Charge Reduction

Within OPALCO's energy purchases from BPA are low load hour (LLH) and high load hour (HLH) energy prices. That is, energy consumed during specified high demand time periods are more costly than low load hours. The ability to generate energy using the solar array during HLH time periods or use the energy storage systems to shift energy demand away from these hours will ultimately reduce the overall energy cost OPALCO pays to BPA. The total benefit from this use case is simply the reduced energy cost each month.

Potential Additional Applications

Other potential benefits include those that were analyzed for the previous Washington CEF battery and solar PV project located on Decatur Island. Though not all will be applicable, additional benefits that could be explored include:

- Demand charge reduction
- Transmission upgrade deferral
- Outage mitigation[3]
- RECs

More detailed information on some of these use cases and their associated methodologies and value can be found in Mongird, et al. [6]. This list is not exhaustive and some of the applications listed above may not be applicable as project details change over time or as new information is found. The list is instead intended to demonstrate that the valuation process should be exploratory and/or iterative to ensure that the full range of value streams is being captured.

[3] OPALCO has an existing micro-grid project

Conclusion

NRECA's ACCESS project is intended to help electric cooperatives make solar energy more affordable for co-op members that have fewer financial resources or opportunities. NRECA has partnered with multiple co-ops across the country in support of projects that utilize solar arrays and energy storage to demonstrate and promote renewable energy opportunities to LMI customers. PNNL has been tasked with providing an overview of three of the ACCESS co-op projects including Roanoke Electric Cooperative, Oklahoma Electric Cooperative, and Orcas Power and Light Cooperative, and discussing both their potential benefit streams and how they will help the LMI community. In addition, so that this report may best be most useful as a guide for other co-ops interested in pursuing similar projects, key concepts in benefit valuation and a discussion of some of the available valuation tools and their capabilities has been provided.

DERs such as energy storage and solar PV can provide flexibility to the grid and are well positioned to deliver services and benefits to multiple parties. Despite the beneficial opportunities, accurate valuation can be difficult. Important concepts to consider when conducting an analysis include accounting for locational differences in available value streams, investigating potential energy market opportunities, accurate modeling and co-optimization of services, and proper technological characterization to define achievable opportunities. Without including these steps or components, it is possible to under or overestimate the potential benefits that can be generated by a project.

All three of the co-op ACCESS projects summarized in this report plan to implement PV solar arrays as part of their projects and two of them, OPALCO and Roanoke, will deploy energy storage assets as well. The value streams across these projects differ in their specific methodologies but generally incorporate energy charge reduction benefits, renewable energy credits, and peak reduction benefits. There are a variety of additional value streams that may be available to the co-ops to capitalize on which will be dictated by project decisions and the configuration of the systems that are eventually procured.

In addition to grid benefits, these projects also demonstrate and pursue opportunities to offer support to the LMI community. Roanoke's project involves the culmination of three separate programs that aim to improve landownership benefits, health, safety, and energy efficiency upgrades, energy cost savings, and community solar participation to their members. OEC's solar project, on the other hand, will offer educational opportunities and potential energy savings for NPS. The school district will also receive the associated land lease benefits from the project. Additionally, the co-op will seek out opportunities for community involvement in the project in order to pass along energy saving benefits and scholarships to the school district and its students within the LMI community. Lastly, OPALCO's community solar and energy storage project will allow LMI community members to obtain the benefits of renewable energy generation without contributing funds of their own – an opportunity they may not have been able to pursue otherwise.

Projects like those summarized in this report can bring a variety of benefits to both co-ops and their members. It is important to investigate and explore all opportunities, properly investigate locational opportunities and limitations, co-optimize available benefits, and understand to whom value is accrued in order to obtain the highest amount of benefit. This document is intended to serve as both a guide and example to other co-ops to help them better understand potential opportunities for their own projects and how they may provide value to their community members, particularly the LMI community.

Future opportunities extending from this report may include conducting more detailed techno-economic analyses for the ACCESS projects described herein. Using key concepts and other information discussed in this document, more detailed analysis on the available value streams that co-op projects can bring to their organization and their customers directly can be investigated. While this report has documented opportunities and benefits at a very high level, additional analyses guided by this high-level assessment could provide more insights on the opportunities as well as potential barriers that other co-ops may find conducting their own techno-economic studies.

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