CENTER FOR SCIENCE, TECHNOLOGY, AND ENVIRONMENTAL POLICY

Planning for Equitable Solar Deployment with Electric Cooperatives

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The research and findings in this report were developed in a collaborative research effort led by researchers at the Center for Science, Technology, and Environmental Policy at the University of Minnesota in partnership with East River Electric Power Cooperative in 2020-2021. The research team included representatives of five distribution utility member cooperatives of East River (Renville-Sibley Cooperative Power Association, Sioux Valley Energy, Bon Homme Yankton Electric Association, Lyon-Lincoln Electric Cooperative, and Clay-Union Electric), STAR Energy Services, South Dakota State University, the Clean Energy Resource Teams (CERTs), and the Great Plains Institute (GPI). Technical assistance was provided to the team by Andy Satchwell and Naïm Darghouth (Lawrence Berkeley National Laboratory) and Pieter Gagnon, Paul Gilman, and Sara Farrar (National Renewable Energy Laboratory).

The goal of the study was to understand how electric cooperatives can design equitable solar photovoltaic (PV) projects consistent with the goals of their organizations. To understand the possibilities for equitable solar deployment, the project team carefully defined cross-subsidy by delving into the multi-level structure of electric cooperatives. Understanding that utilities and analysts apply different cost-categorization perspectives was key to developing a transparent analytic model that traces the economic value flows of new solar PV projects across the tiers of a cooperative system.

This report synthesizes the key findings of this study for electric cooperative managers and stakeholders. The report was authored by researchers based at the Center for Science, Technology, and Environmental Policy at the University of Minnesota under Subcontract No. SUB-2020-10338 as part of the Solar Energy Innovation Network, a collaborative research effort administered by the National Renewable Energy Laboratory under Contract No. DE-AC36-08GO28308 funded by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed herein do not necessarily represent the views of the Alliance for Sustainable Energy, LLC, the DOE, or the U.S. Government.

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1. Overview

The increasing viability of distributed energy resources (DERs)[1] and variable renewable energy resources is creating a host of opportunities and challenges across the energy sector. Electric cooperatives face a unique set of opportunities and challenges with respect to DERs and renewables. An important concern for electric cooperatives, as consumer-owned utilities, is the fairness of DER and renewable deployment. This report focuses on the specific opportunities and challenges of solar photovoltaic (PV) electricity generation for electric cooperatives, focusing on frameworks, methods, and deployment models for cooperatives to develop equitable approaches to solar deployment.

Key Findings

1. **Electric cooperatives are exploring a wide array of deployment models for solar PV tailored to their local contexts.** Solar deployment in cooperatives has accelerated in the past 10 years, and new deployment models are altering where solar projects are interconnected on the grid, the ownership of projects, the offtaker of project, and whether specific parties are able to opt-in to projects.

2. **Whether DERs, including solar PV, challenge or support a cooperative's ability to deliver equitable service requires clarity on frameworks and assumptions.** Utilities and researchers have deployed many alternative frameworks for considering fairness and cross-subsidization which vary in their temporal frame of reference and approaches to considering cost allocation.

3. **Understanding cross-subsidy from an incremental costing perspective can be an effective and transparent framework for understanding the fairness of new solar PV projects over the long-run.** By using a forward-looking long-run incremental cost perspective, as opposed to a short-run incremental cost perspective, solar models can be designed to ensure that non-participants are not unfairly bearing the costs of solar PV projects.

4. **Evaluation tools, such as the Multi-Level Incremental Cost (MLIC) model that we developed in this project, can help cooperatives evaluate the potential for solar PV deployment to avoid cross-subsidization.** The MLIC model is fit-to-purpose for cooperatives seeking to prospectively evaluate innovative solar PV deployment models that introduce new value flows across the levels of the cooperative.

5. **The collaborative and iterative research process we engaged in in this project helped ground participants in shared learning.** Various forms of engagement, such as structured interviews and discussion groups, were crucial processes that brought about effective learning among all of the involved stakeholders and were critical for the research team to apply cutting-edge research. The project included personnel that could translate and understand utility practices, researchers, and professional facilitators across 15 months of collaboration. This approach could be a model for future collaborative efforts with electric cooperatives.

[1] There is no universally agreed upon definition of distributed energy resources (DERs). The term generally refers to electricity generation technologies at the distribution-grid level, such as customer-sited solar and diesel distributed generators. DERs can also include non-generating technologies, such as energy storage, energy efficiency, and demand response, as well as programs that affect consumer behavior, such as time-of-use tariffs which encourage peak shaving or load shifting. (Chan et al. 2019; Lenhart et al. 2020; Schwartz et al. 2017; SEPA 2016; Weinrub 2017)

2. Cooperatives Across the Country are Deploying Solar PV

Rural electric cooperatives were first created by local communities in the United States in the early twentieth century and later expanded by federal government programs to electrify rural America. (Klass and Chan 2021) Today, more than 800 "**distribution cooperatives**" across 48 states serve (and are owned by) their 42 million "**member-owners**," amounting to 15% of U.S. electricity consumers. (EIA 2021; DOE 2017) Over time, approximately two-thirds of distribution cooperatives worked collaboratively to form "**generation and transmission cooperatives**" (G&Ts) to serve their collective interests. (NRECA 2020a) More than 60 G&T cooperatives now provide wholesale power and transmission services to distribution cooperatives across the country. As cooperatives themselves, G&Ts are owned and governed by their distribution members, establishing a "multi-level," federated structure of energy-service delivery and governance (see Figure 1).

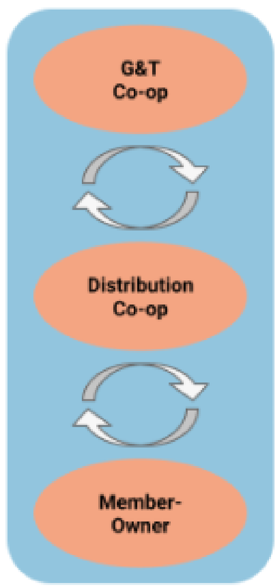

Figure 1. The multilevel management and governance structure of electric cooperatives

Member-owners of distribution cooperatives own and govern their distribution utility. Two-thirds of distribution cooperatives are themselves members of generation and transmission cooperatives. Other distribution cooperatives purchase power from other utilities or merchant generators.

The member-owners served by cooperatives are demographically distinct from consumers served by other utilities, reflecting the history of electric cooperatives as providers of initial electricity access to rural communities. While some cooperatives now serve rapidly growing suburban areas of the country, cooperatives largely maintain distinct consumer bases from other utilities, serving over 90% of the counties identified as being in persistent poverty by the U.S. Treasury Department. (NRECA 2018) Rural electric cooperatives operate in decision-making environments fundamentally distinct from other parts of the energy system, as they are not-for-profit, tax-exempt utilities that are owned by the consumers they serve. The seven Cooperative Principles guide cooperative decision making (see Section 3). Further, electric cooperatives are governed by boards elected by the member-owners that both own the cooperative and purchase electricity from it. (Klass and Chan 2021)

Rural electric cooperatives are rapidly transitioning their energy supply mixes toward greater renewable energy. In 2020, on average renewables made up 19% of the retail fuel mix of cooperatives across the country. Historically, renewable capacity in cooperatives has primarily comprised of 10 GW of federally owned hydroelectric energy sourced under preference-based contracts established following the New Deal. (NRECA 2020b) But from 2010 to 2020, electric cooperatives nearly tripled their other renewable capacity (owned and under contract, excluding federal hydroelectric energy), from 3.9 GW in 2010 to 11.4 GW in 2020. Today, cooperative renewable power supply is increasingly comprised of wind energy (8.6 GW in 2020) and solar PV (1.3 GW operational in 2020, with an additional of 4.8 GW announced for development by 2023). (Moorefield and Roepke 2021; NRECA 2021)

The structure of renewable energy development in cooperatives is distinct from other parts of the energy system and changing rapidly, particularly for solar PV. (Moorefield and Roepke 2021) Cooperatives have developed and are contemplating a wide range of deployment models for solar PV. Across this "solution space," we identified four essential dimensions of solar PV deployment models relevant for cooperatives:

1. **the interconnection level** (is the solar PV project connected at the member-owner level, distribution level, or transmission level?)

2. **the ownership of the project** (is the solar PV project owned by a member-owner, distribution cooperative, G&T cooperative, or third party?)

3. **the primary offtaker of the project's output** (does the solar PV project provide energy directly to a member-owner, distribution cooperative, or G&T cooperative; how is excess energy beyond self-consumption handled?)

4. **the primary party opting into the project** (is the solar PV project an available option for member-owners, distribution utilities, or G&T utilities?)

Across these dimensions, there is a wide range of permutations of solar PV deployment models that cooperatives could consider. In Table 1, we show solar PV deployment models on these four dimensions and provide examples of projects (primarily in cooperatives) described in more detail in Appendix B.

Table 1. Solar PV deployment models relevant for cooperatives

Solar PV deployment models vary by their interconnection level, ownership, primary offtaker, and opting-in party. The table includes references to case studies that are described in Appendix B.

	Interconnection Level	Ownership	Primary Offtaker	Opting-In Party	Case Study (see Appendix B)
A. Member-Sited, Behind the Meter	member-owner	member-owner	member-owner	member-owner	Valley Electric Association
B. Utility-Owned, Behind the Meter	member-owner	distribution or G&T cooperative	distribution or G&T cooperative	member-owner	CPS Energy; Arizona Public Service Electric
C. Member-Sited, in Front of the Meter	member-owner	member-owner or third-party	distribution or G&T cooperative	member-owner	Ouachita Electric Cooperative[2]
D. Distribution-Sited Community Solar	distribution cooperative	distribution cooperative or third-party	member-owner(s)	member-owner(s)	Cherryland Electric Cooperative
E. G&T-Directed Community Solar for Distribution Members	distribution cooperative	G&T cooperative or third-party	distribution cooperative	distribution cooperative	Wabash Valley
F. Distribution Self-Supply	distribution cooperative	distribution cooperative or third-party	distribution cooperative or G&T cooperative	distribution cooperative	Connexus Energy
G. G&T Power Supply Blend	G&T cooperative	G&T cooperative or third-party	G&T cooperative	G&T cooperative	Basin Electric Power
H. Power Supply Passthrough to Distribution Member	G&T cooperative or distribution cooperative	G&T cooperative or third-party	distribution cooperative	distribution cooperative	Green Power EMC

In Section 5, we return to a quantitative evaluation of several examples of solar PV deployment models described in Table 1.

3. How Cooperatives Can Frame and Evaluate Fairness in Solar PV Deployment

Across solar PV deployment models, cooperatives have prioritized that as the electric system changes, it should continue being safe, reliable, affordable, and equitable for their entire membership. (Moorefield and Roepke 2021) In this report, we focus on the last dimension, **how solar PV can support or challenge cooperatives' ability to maintain fairness and equitable service to their entire membership**. In the sections that follow, we explore how cooperatives can operationalize their priorities for fairness as they explore a wide array of solar PV deployment models.

Fairness across consumers is a universal concern of public utilities and their consumers that has played a particularly important role in considerations of solar PV deployment in electric utilities. (Rule 2014; Klein and Noblet 2017; Granqvist and Grover 2016) Fairness is particularly important for electric cooperatives because the resource pool of a cooperative is self-governed according to principles that prioritize collective member benefits. Electric cooperatives, like many other forms of cooperative businesses, are guided by the seven Cooperative Principles: open and voluntary membership; democratic member control; members' economic participation; autonomy and independence; education, training, and information; cooperation among cooperatives; and concern for community. (NRECA 2016; ICA 2015)

[2] This case is only a partial example of this model, as only generation above self-consumption is sold to the utility in this case.

The Cooperative Principles highlight several important considerations for electric cooperatives as they consider how to deploy solar PV (see Box 1). Taken together, the seven Cooperative Principles offer a grounded basis for electric cooperatives to evaluate and support equitable solar PV deployment.

Box 1. Equitable Solar PV Grounded in the Seven Cooperative Principles

Principle 1, **Open and Voluntary Membership**, provides that costs and benefits associated with membership in a cooperative should not fall discriminatorily based on race, religion, gender, or economic circumstance. This principle implies that, in the context of cooperative membership, the impacts of solar PV deployment should be equitable across the measurable differences of members.

Principle 2, **Democratic Member Control**, establishes that cooperatives are democratic organizations controlled by—and accountable to—their members. As cooperatives consider new efforts to deploy solar PV, this principle highlights the importance of working with members to address their specific and collective needs.

Principle 3, **Members' Economic Participation**, asserts that cooperative members should contribute equitably to the capital of the cooperative. For electric cooperatives, considerations of equitable economic participation also extend to the rates, economic burdens, and economic development opportunities cooperatives develop with and for their member-owners. Equitable economic participation is a fist-order concern of electric cooperatives considering solar PV deployment and a key focus of this report.

Principle 4, **Autonomy and Independence**, affirms that cooperatives act as autonomous, self-help organizations controlled by their members and work with other organizations while ensuring their unique identity. Cooperative autonomy therefore gives way to significant flexibility and room for innovation for cooperatives to explore solar PV deployment that can achieve the multiple goals of the cooperative, consistent with other agreements and policy.

Principle 5, **Education, Training, and Information**, emphasizes the important information-sharing role of cooperatives with members, boards, and the general public. This principle provides an important rationale for cooperatives exploring new programs, including programs for solar PV, to conduct studies that are expansive of multiple perspectives and that are clearly explained for different audiences.

Principle 6, **Cooperation Among Cooperatives**, highlights the important ways in which cooperatives collaborate at different scales, addressing local community needs as they simultaneously coordinate at the regional and national scale. Over two-thirds of distribution cooperatives have voluntarily entered agreements to form generation and transmission (G&T) cooperatives whose primary function is to pool the capital of distribution cooperatives (and their member-owners) to achieve economies of scale in jointly owned generation and transmission assets. The multilevel structure manifested from this form of cooperation among cooperatives provides the critical financial context studied in this report in which cooperatives can innovate to deploy solar PV.

Principle 7, **Concern for Community**, offers an overall goal for cooperatives to work toward the sustainable development of their communities. For cooperatives considering solar PV deployment, this principle implies that cooperatives should consider long-run and holistic costs and benefits, as guided by the priorities of their members now and into the future.

Cross-Subsidy in Electric Cooperatives

For a utility to remain financially healthy, it must recover all the costs it incurs to provide the service needed to meet the demand of its consumers (plus an adequate margin to account for uncertainty). Utilities primarily recover their costs of providing service by collecting revenue from their consumers. But because utility consumers are heterogeneous,[3] utilities have implemented various standards to collect revenue in concordance with an individual consumer's (or group of consumers') specific impact on the system. Most often, the rules that determine the rates by which utilities collect revenue are grounded in analysis of the cost of serving particular consumers, although other considerations, including policy and regulatory factors, can also be included.

All else equal, when one consumer pays below their cost of service, another pays above their cost of service.[4] The resulting mismatch between the cost of serving certain consumers and the revenue collected from those consumers creates distributional inequities. Distributional inequities, if they grow too large, raise general concerns of fairness that impact everyone in the resource pool of a utility.[5] Distributional inequities in infrastructure systems, such as the electric system, are often framed in terms of "cross-subsidization." (Brooks 2018) **Cross-subsidization occurs when the revenue one consumer generates in relation to the costs they are responsible for on the system[6] is disproportionate to other consumers within the same resource pool.** We develop greater specificity in the definition of cost responsibility later in this section.

Cross-subsidization across a utility's consumers can be mitigated or enabled by utility programs and policy. For example, utility rate design can more precisely relate the utility's variable costs with its variable charges to mitigate temporal cross-subsidization that can occur between ratepayers with different hourly load profiles. (Borenstein, Jaske, and Rosenfeld 2002) Or alternatively, utility rate design can maintain relatively high volumetric charges as a means of recovering utility fixed costs, thereby incidentally incentivizing energy efficiency and enabling a cross-subsidy to ratepayers that adopt energy efficiency technology. (National Action Plan for Energy Efficiency 2009)

In virtually all infrastructure systems, some amount of cross-subsidization is inevitable and, in some cases, can even be intentional and desirable. (Faulhaber 1975; 2005; Fjell 2001; Amundsen, Andersen, and Jensen 2011) Some degree of cross-subsidization is almost always inevitable because of the impracticalities of developing rates at a fine enough specificity to account for all differences in cost of service (for example, rates are often based on class-average cost-of-service studies). And cross-subsidization can be intentional and desirable to achieve social and policy goals, such as encouraging energy efficiency (as described above), attracting economic development opportunities, treating

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[3] Utility consumers differ in their usage of the utility systems, the benefits they derive from the services provided by the utility system, the specific costs they impose on the system, their ability to pay for commonly used utility infrastructure, the spillover benefits they create for other consumers, and other factors. Each of these dimensions can be considered in developing cost allocation rules in utility rate setting, but most often, rates are based on an analysis of the cost of serving a particular group of consumers (a rate class) and revenue is collected through a fixed charge and a volumetric charge based on usage. However, utilities typically implement multiple rate structures simultaneously that can include other constructs, such as standby/demand charges (proportional charges based on maximum usage overall and during coincident system peaks) and time-varying rates. (Wood et al. 2016)

[4] For simplicity, we frame the discussion here as a concern about fairness between consumers of the same utility but the same logic applies across any increment of energy supply or demand within the same infrastructure system. In other words, fairness concerns arise not just between consumers but also across groups of consumers (e.g,. between rate classes), across energy producers (e.g., between merchant generators and utility generators), across types of energy consumption (e.g., between standard residential consumption and electric vehicle charging), or across utilities that share infrastructure (e.g., between utilities within the same transmission network).

[5] We define the "resource pool" of a utility as actors that bear full set of direct costs and benefits across a utility system, inclusive of utility ratepayers, investors, and financiers. Defining the resource pool of a utility is an important consideration to distinguish cross-subsidy that occurs within a resource pool (e.g., between ratepayers, or from ratepayers to investors in an investor-owned-utility context) from other forms of subsidy, such as public subsidy from taxpayers to actors within the resource pool (e.g., federal tax credits for owners of renewable generators that serve ratepayers in a resource pool).

[6] In this definition of cross-subsidization, we use a more general framing of "cost responsibility," in contrast to the more institutionally formal notion of "allocated costs." Cost allocation generally follows specific rules in a formal ratemaking process (Lazar et al. 2020), whereas "cost responsibility" is a conceptual term that encompasses ratemaking cost allocation as well as other conceptual possibilities, as described further in this section.

consumers in disparate parts of the system non-discriminatorily, guaranteeing reliable service continuation after specific system failures, and providing low-income rate discounts. In fact, some utility observers have argued that the original purpose of electric utilities was to intentionally create cross-subsidies as a means of providing universal service. (Casten and Meyer 2004)

We posit that cross-subsidization is important to manage strategically and is not necessarily a problem to eliminate in all circumstances. Instead, cross-subsidization is an important outcome for utilities to manage strategically as they simultaneously manage for affordability, reliability, and safety.

Empirical evaluation of the fairness of utility programs requires specificity in the operationalization of the conceptual definition of cross-subsidization. Specifically, analyzing cross-subsidy requires transparency in defining the "**baseline cost responsibility**" of a user or service. If a user or service generates revenue below its baseline cost responsibility, then that user or service is cross-subsidized by other actors in the resource pool; and if a user or service generates revenue above its baseline cost responsibility, then that user or service cross-subsidizes other actors in the resource pool.

Across contexts and circumstances, utilities and analysts have developed different frameworks for defining baseline cost responsibility that can each be applied to analyze cross-subsidy. In a review of academic literature and utility practices, we find two essential dimensions of how baseline cost responsibility can be defined:

1. **the temporal frame of reference** (to what extent does a user or service bear responsibility for historic costs, or should evaluation be based on impacts on current and/or future costs?)

2. **the allocation of utility costs** (how are utility costs, especially indirect fixed costs that are associated with joint or commonly used assets, allocated to a user or service?). See Appendix A for a discussion of utility cost categories.

Table 2 details five alternative frameworks of baseline cost responsibility that differ across their temporal frame of reference and their allocation of utility costs.[7]

[7] Within the five alternative frameworks for defining baseline cost responsibility, operationalizing cross-subsidy analysis also must consider two additional factors: (1) the inclusion or exclusion of specific cost and benefit categories, especially cost and benefit categories that are uncertain or dependent on other decisions, such as avoided transmission and distribution costs; and (2) defining system boundaries to clearly include or exclude costs and benefits that accrue outside of the resource pool, such as environmental benefits.

Table 2. Frameworks for defining baseline cost responsibility in analysis of cross-subsidization

Frameworks for cross-subsidy analysis define a baseline cost responsibility for a user or service. The cost and revenue impact of serving a particular user or service can be compared to that user or service's baseline cost responsibility to quantify net cross-subsidy.

Framework Name	Description	Temporal Frame of Reference	Allocation of Utility Costs
Fully Distributed	Users or services are responsible for their allocated share of total "**embedded cost**." For electric utilities, this takes the form of a revenue requirement or a class cost of service.	historic	direct and indirect costs
Commonly Distributed	Users or services are responsible for their allocated share of indirect costs (all fixed costs other than those directly related to a single user or service), referred to as "**standalone cost**". For electric utilities, this takes the form of the joint, common, and administrative fixed costs needed to run the grid.	historic	only indirect costs
Short-Run Marginal	Users or services are responsible for the immediate **marginal cost** on the system of increasing or decreasing supply by one unit. For electric utilities, this may include the wholesale power price of energy or the cost of fuel.	current	only direct costs
Short-Run Incremental	Users or services are responsible for the **near-term cost of adding or subtracting a new increment of supply**. For electric utilities, this can take the form of (short-run) avoided costs based on next available new supply and could also factor in avoided costs of avoiding or deferring specific investments.	future	specific direct and indirect costs
Long-Run Incremental	Users or services are responsible for the **long-term cost of adding or subtracting a new increment of supply**, given other changes across the electric grid. In the long-run, all fixed costs can be considered variable, and the baseline cost responsibility of a future user or service could have the ability to avoid or induce investments not under consideration currently. For electric utilities, this can take the form of marginal cost of service studies, long-run cost-benefit tests, and integrated resource planning.	future	specific and/or probabilistic direct and indirect costs

Managing for cross-subsidization requires empirical evaluation of "**value flows.**" Value flows specify the costs and benefits that accrue to specific actors in a resource pool like an electric grid. New infrastructure and policy, such as a new rate design structure or investment in a generation facility, change the value flows. Therefore, when there is cross-subsidization associated with an incremental service or user, new value flows from one part of the utility system to another. In the next section, we develop the notion of value flows to develop a methodology of quantifying cross-subsidization through value flows that arise from solar PV deployment.

4. An Analytic Tool That Can Support Cooperatives Considering Solar PV Deployment Models

In theory, any solar PV deployment configuration shown in Table 1 can be made equitable to the members of an electric cooperative given certain rates that allocate costs and benefits within a utility resource pool and absent policy constraints. But in practice, the necessary rates to achieve an equitable allocation of costs and benefits may preclude the feasibility of some solar PV deployment models in individual cooperatives based on the specific characteristics, needs, and interests of their members. To estimate the necessary rates that enable equitable solar PV deployment across deployment models, we developed an analytic tool that can support cooperatives seeking to identify the rates necessary to arrive at an equitable allocation of costs and benefits within their resource pool.

We propose an analytic tool, the **Multi-Level Incremental Cost (MLIC) Model**, that operationalizes three steps of an incremental cross-subsidization analysis for solar PV deployment:

1. formalizing a framework for determining baseline cost responsibility (among the frameworks shown in Table 2);

2. analyzing how a particular solar PV deployment model (shown in Table 1) would induce value flows within a cooperative (e.g., by avoiding some direct and indirect costs and inducing other direct and indirect costs);

3. accounting for the multi-level structure of cooperatives and designing rates within a solar PV deployment model to rebalance any net changes in cost responsibilities across the cooperative levels

These three steps are discussed in turn below.

Operationalizing a Framework of Solar PV Costs and Benefits

The MLIC model applies to future solar PV deployment and therefore adopts a framework of **long-run incremental costs and benefits**. A long-run incremental framework focuses the analysis on whether a new solar PV project has greater prospective benefits than costs over the long run. If so, nonparticipants in a solar PV project may enjoy its benefits, but if a new solar PV project has greater long-run incremental costs than benefits, nonparticipants may cross-subsidize the beneficiaries of the project.

A long-run incremental framework is similar to that typically used in cost-benefit tests.[8] However, the MLIC model's approach has several innovations over common cost-benefit tests:

1. The MLIC model uses transparent assumptions derived from modelling tools developed by the National Renewable Energy Laboratory and datasets collected by the Lawrence Berkeley National Laboratory. The MLIC model utilizes the System Advisor Model to model energy output of solar PV projects with specific project characteristics (including location-specific solar irradiation and project design parameters) and hourly and sub-hourly estimates of output over multiple years. (Freeman et al. 2018) The MLIC model also utilizes long-run projections (through 2050) of direct and indirect energy costs at a balancing area, a level of spatial resolution relevant for most cooperatives, from the Cambium model. (Gagnon et al. 2020) Capital cost data for the MLIC model is derived from industry-wide data assessments of residential solar PV projects and utility-scale solar PV projects. (Barbose et al. 2020; Bolinger et al. 2020)

2. The MLIC model is probabilistic, not deterministic, in how it accounts for energy production and demand charge avoidance. This is important, as cooperatives that purchase power from a G&T commonly face demand charges based on their energy usage during system peaks, often based on

[8] Cost-benefit tests are often used in areas of economic assessment, including assessment of utility programs, such as Utility Cost Tests applied to energy efficiency programs. (Daykin, Aiona, and Hedman 2012)

net consumption in the 30-minute window in which energy usage peaked within the month in the power-supply system. Properly accounting for the probability of system-peak windows lining up with solar production, the MLIC model can identify probabilistic distributions of value that will allow cooperatives to incorporate risk mitigation in their decision making.

3. The MLIC model considers direct, variable avoided costs of wholesale energy and capacity and avoided energy and demand charges over 30 years of modeling results and incremental project, program administration, policy incentive, and interconnection costs. The MLIC model's approach does not consider indirect costs and benefits that would accrue as a result of utility revenue impacts that are not already fully captured in assumptions of future rates.

4. The MLIC model is modular in how it captures the key features of solar PV deployment models. The model can capture value flows across the different ownership, offtake, and contract design options of solar PV deployment models described in Table 2. While the value flows across the cooperative system are captured by the model, the model also simplifies normally complex solar financing transactions to provide a strategic-level assessment of the net benefits or costs of a solar project across the cooperative that can be complemented with more detailed subsequent analysis.

Analyzing the Value Flows of Solar PV Deployment

The analytic core of the MLIC model is a cash flow pro forma model. The model draws inspiration from cash flow models of utilities used for analysis of DERs more generally. (Satchwell, Cappers, and Goldman 2017; Satchwell, Mills, and Barbose 2015; National Action Plan for Energy Efficiency 2012) Similar spreadsheet pro forma models exist to help evaluate the viability of developing a solar project, including for electric cooperatives. (Mongird et al. 2021) These pro forma models can track project costs and associated revenue streams of solar projects and report analyses, usually for only a handful of perspectives, including the project owner, tax equity provider, and perhaps offtakers.

The MLIC model provides analysis to identify the **levelized costs of energy (LCOE)** of a solar project and its associated **levelized value of energy (LVOE)**. LCOE and LVOE are created from streams of costs (or avoided costs) and offtaker or subscriber revenue. The underlying pro forma in the MLIC model accounts for upfront costs, policy incentives (the Federal Investment Tax Credit and Modified Accelerated Cost Recovery System), ongoing costs, avoided capacity or demand costs, avoided energy costs, and the potential for additional revenue from an offtake contract or other policies. [9] Example output of LCOE and LVOE is shown in Figure 2.

[9] We introduced specific modeling of the California Low Carbon Fuel Standard (LCFS) which can create additional revenue for solar projects that are co-located with ethanol production.

Figure 2. Example calculation of the components of levelized costs and values.

The MLIC model allows for calculation of the levelized costs and values of solar deployment at each level of a multi-level electric cooperative system. In this example of a 20-kW member-site system, the levelized cost of electricity is calculated at 11.62 cents/kWh, which accounts for upfront debt and equity, ongoing costs, the federal investment tax credit, and modified accelerated depreciation. The levelized value of electricity is shown as 6.26 cents/kWh, accounting for avoided capacity/demand and energy charges. Additional revenue from an offtake contract is optimized to equate LCOE and LVOE to provide 5.36 cents/kWh in value. The MLIC model calculates the offtake value as the required revenue from an offtaker to equate LCOE with LVOE. Note: incremental costs are shown in red and incremental values are shown in blue, with summations of previous columns given darker shading.

Subtracting LVOE from LCOE, a solar project can realize either a surplus or deficit that users in the multi-level cooperative resource pool—at the G&T, transmission, distribution, C&I, or residential member level—must pay. If the project does not create sufficient LVOE to match its LCOE, even when accounting for offtaker and subscriber revenue and policy incentives, then cross-subsidy becomes an issue for different levels of the cooperative.

However, even if LCOE does equal LVOE, this suggests only that there *could* be no cross-subsidization; the equality of LCOE and LVOE only conveys that there are no *net* cross-subsidies in the system. The MLIC model assesses LCOE and LVOE at each level; therefore, if LVOE is greater than or equal to LCOE at each level, there is no cross-subsidization across levels. Even if this condition is met, there could still be some degree of within-level cross-subsidization that cancels out. In other words, when LCOE equals LVOE at each level, a solar project does not add or subtract to the system costs at that level, and fully cost-causal rates can be designed to eliminate cross-subsidy. In contrast, when LCOE is greater than LVOE, a solar deployment would require an additional revenue stream from outside of the current system to have the potential of no cross-subsidization. In this way, **LCOE being less than or equal to LVOE is a necessary but not sufficient condition for an equitable solar project under an incremental costing perspective.**

One additional caveat is that because the MLIC perspective does not account for solar deployment's potential impact on long-run embedded costs—except insofar as these costs are incorporated into assumptions about future rates—cross-subsidization can still occur if solar deployment or other future changes to the system induce a misalignment of cost causation and revenue collection under assumed future rates. A multi-level long-run incremental costing approach could capture this but would require additional assumptions about how solar deployment and other future changes would be incorporated into the long-run cost of service and rates of utilities.

Accounting for Value Flows within a Multilevel Cooperative

The MLIC model is most relevant for assessing solar PV deployment models within a multilevel electric cooperative where a key concern for managers is potential value flows within and across the levels of the cooperative. Across these levels, cooperatives coordinate governance and operational functions. As a result, utility costs and benefits are pooled and allocated across the levels of the cooperative, creating an important role for analysis to support equitable cost allocation across and within the levels of the cooperative.

The MLIC model accounts for costs and benefits at the different levels of the cooperative simultaneously, from avoided wholesale purchases at the G&T level, down to the distribution utility, and finally to the individual member-owner. Additionally, some G&Ts, primarily located in the Southwest, Midwest, Texas, and Missouri, are also member-owners of "super G&Ts," introducing an additional level that the MLIC model is able to capture.

5. Case Study: How East River Electric Cooperative is Exploring Equitable Solar Deployment

From March 2020 – May 2021, our research team collaborated with East River Electric Power Cooperative based in Madison, South Dakota, as part of the Solar Energy Innovation Network (SEIN). SEIN is led by the National Renewable Energy Laboratory (NREL) and supported by the U.S. Department of Energy. Through this collaboration, which also included staff from five of East River's distribution members, the Clean Energy Resource Teams, the Great Plains Institute, STAR Energy Services, and researchers at South Dakota State University, Lawrence Berkeley National Laboratory, and NREL, our research team was able to pilot the MLIC model and provide strategic insights into how equitable solar models could be piloted in East River's system. This section describes insights from this collaboration.

At the outset of the project, the team co-developed guiding principles for considering solar deployment: members are central, context matters, equity and fairness matter, and cooperatives strive to innovate and stay ahead of changing conditions and emerging opportunities in service to their members. These guiding principles were used throughout the project with an eye towards identifying solar PV pilot models. Throughout the project, team members emphasized that an equitable project would have mutual benefits for not only the system, but also for the member-owners. Deploying solar in the right spot at the right time with the right member on the right line makes a lot of sense. These projects have the opportunity to be mutually beneficial, but coordination, planning, and intention are needed to determine what the "right" member, location, time, and line would look like.

The research team developed a broad set of possible solar PV deployment models (see Table 1), which were then narrowed down to a smaller set of test cases that could be analyzed with the MLIC model. In this section, we present a summary of the analysis we developed of two solar PV deployment models: (1) commercial-owned solar with a buy-all-sell-all power supply contract and (2) an East River-owned community solar project.

C&I-Owned Solar with Buy-All, Sell-All Contract

Commercial and industrial (C&I) member-owners have become more prominent over the past decades for East River and its members. In the 1980s, C&I members comprised less than 10% of East River's load. Today, they comprise more than 40%. Among East River's large C&I members are ethanol plants, where corn is refined into biofuels.

Recent years for ethanol facilities in East River members' service areas in South Dakota have seen ups and downs. Many farmers' corn crops have experienced flooding, creating supply shortages for the ethanol plants. From 2020-2021, the COVID-19 pandemic has indirectly lowered fuel demand and created volatility in prices for crude oil, thereby dropping the market for ethanol. Subsequently, however, the market has been regaining its composure, as sales from these ethanol facilities are up from projections.

East River and its members are considering how to support the ethanol industry and their member farmers by exploring equitable solar deployment, while making sure costs aren't shifted onto other member-owners and rate classes. In this pilot proposal, we consider tying a solar project directly into the ethanol facility. Done this way, the solar PV project can help increase the credit value of ethanol exported to California and consumed under California's Low Carbon Fuel Standard (LCFS). The LCFS creates a financial incentive for vehicle fuels based on their lifecycle carbon intensity, which takes into account the carbon intensity of electricity consumed in ethanol production. By physically siting solar with ethanol production, ethanol exported to California can generate more revenue (virtual green power does not lower site-specific emissions in the LCFS program). There is interest in exploring a buy-all, sell-all contract for such a new solar facility, meaning the C&I member-owner could buy all their electricity under their current retail rate while selling all their solar to Basin and monetizing benefits through the LCFS.

While the project wouldn't offset electricity purchases for the ethanol facilities (because they still buy all their electricity under existing rates), the avoided costs Basin would see from purchasing power from the C&I solar project instead of the wholesale market, as well as the LCFS credits, make the project potentially very attractive to both East River and the ethanol plants that already sell into the LCFS market.

One of the important uncertainties for this model is volatility in the LCFS credit price. The LCFS credit price is based on the supply and demand of low-carbon fuels, which has historically been volatile. From mid-2018 through mid-2021, the LCFS credit price has hovered around the price ceiling of $200/metric ton.[10] Therefore, we explored under different scenarios of the LCFS credit price based.

The MLIC model estimates that solar produces long-run incremental levelized value of approximately $0.054/kWh. As with all levelized values estimated by MLIC, this estimate is based on the long-run avoided wholesale energy and capacity purchases estimated by the Cambium model that coincide with the temporal profile of solar production estimated by the SAM model. On top of the $0.054/kWh in levelized electricity-system value, scenarios of future LCFS credit value add between $0.022/kWh and $0.087/kWh in additional levelized value, bringing total levelized value to between $0.076/kWh and $0.141/kWh. In comparison, we estimated that the LCOE of solar projects range from $0.061/kWh for a 10-MW project to $0.078/kWh for a 1-MW project. Figure 3 shows the contribution to total LVOE from LCFS revenue (green) and electricity-system value (blue) relative to LCOE of projects from 1 to 10 MW.

[10] For a complete time series, see https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

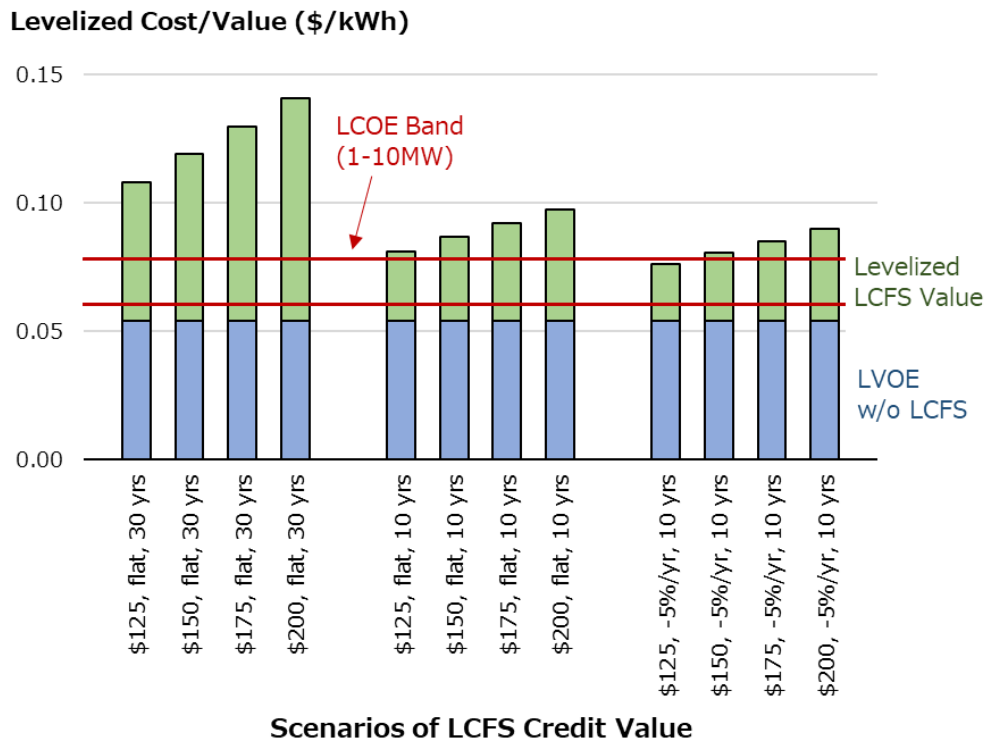

Figure 3. MLIC calculations of levelized value of electricity and levelized value of LCFS revenue.

Scenarios of LCFS credit value are shown for a 30-year flat $125/ton to $200/ton credit, a 10-year flat $125/ton to $200/ton credit, and a 10-year declining credit starting at $125/ton to $200/ton. In all scenarios, the levelized cost of electricity for a 10-MW solar project is less than the combined levelized value of electricity with LCFS revenue, which holds for 1-MW projects in all but the most conservative LCFS outlooks.

While the MLIC model paints an optimistic picture for siting solar at ethanol producers to take advantage of LCFS revenue, it is important to keep in mind that the MLIC model estimates long-run incremental costs levelized over the lifetime of a solar project (assumed to be 30 years). This long-term perspective may not be the most appropriate frame of reference for C&I members in industries with volatile market conditions that require a shorter time horizon to recoup investments.

East River-owned Community Shared Solar Scenario

Cooperatives have historically led in deploying community shared solar (CSS) programs. (Moorefield and Roepke 2021) Community solar allows cooperative member-owners to voluntarily subscribe to a portion of an offsite solar array and receive the financial benefits of their subscribed solar generation's output. As of 2020, there are more than 3-GW of CSS projects across the country, including over 150 cooperatives that have deployed at least one community solar project. (Heeter, Xu, and Chan 2021).

East River and its membership are interested in exploring the viability of CSS, following other cooperatives that have pursued CSS for its ability to get "the best of both worlds," as one team member put it. CSS offers some economies of scale that utility-scale solar can achieve while also allowing a pathway to solar energy for member-owners who have become more interested in actively supporting solar themselves.

Many cooperatives have expressed concern with cross-subsidy in their system arising from customer-sited renewables. CSS stands as a potential bulwark to this concern because it allows for utility coordination and ownership of solar assets. By setting subscription terms to intentionally avoid cross-subsidization, CSS could be designed to provide the most benefits for the widest range of member-owners, both those participating and not. While some team members reported only minor interest in solar among their member-owners, other team members reported getting calls from their member-owners about solar almost every day of the week.

There's motivation now to understand what CSS could potentially do in a new arrangement for East River and its membership. Instead of the distribution cooperatives owning the arrays and subscribing out to member-owners, our team wanted to explore the viability of a model whereby East River would own the array, distribution cooperatives would purchase energy from it, and member-owners in turn opt-in to subscribe. Learning from a small number of other G&T families and municipal utility associations, our research team applied the MLIC model to assess the viability of this form of multilevel CSS in East River's context.

To assess this solar PV deployment model, first, we estimated solar deployment's impact on East River's energy and demand purchases, assuming that solar acts as a load offset during the modeled hours over the course of a year that solar produces in alignment with historic East River system peaks. Then, the total avoided purchases between East River and Basin are translated by the MLIC model into the flat subscription cost or benefit, assuming that the distribution utility is able to fully pass through the cost or value of East River's avoided purchases. The MLIC model estimates that a solar PV project would need to be greater than 5-MW before subscribers could see a net benefit without cross-subsidization. However, adding an assumption of single-axis tracking to the solar project significantly increased energy output (and therefore the levelized value of energy) and enabled subscribers to see benefits with projects as small as 500-kW. Figure 4 shows the relationship between project size (horizontal axis) and the flat 30-year subscription cost or benefit of a CSS subscription that fully passes through the expected value of avoided purchases between Basin and East River. The greatest benefit to subscribers that we estimated was for a 5-MW project with tracking, which could create up to a flat $0.028/kWh in subscriber benefit over 30 years without cross-subsidization.

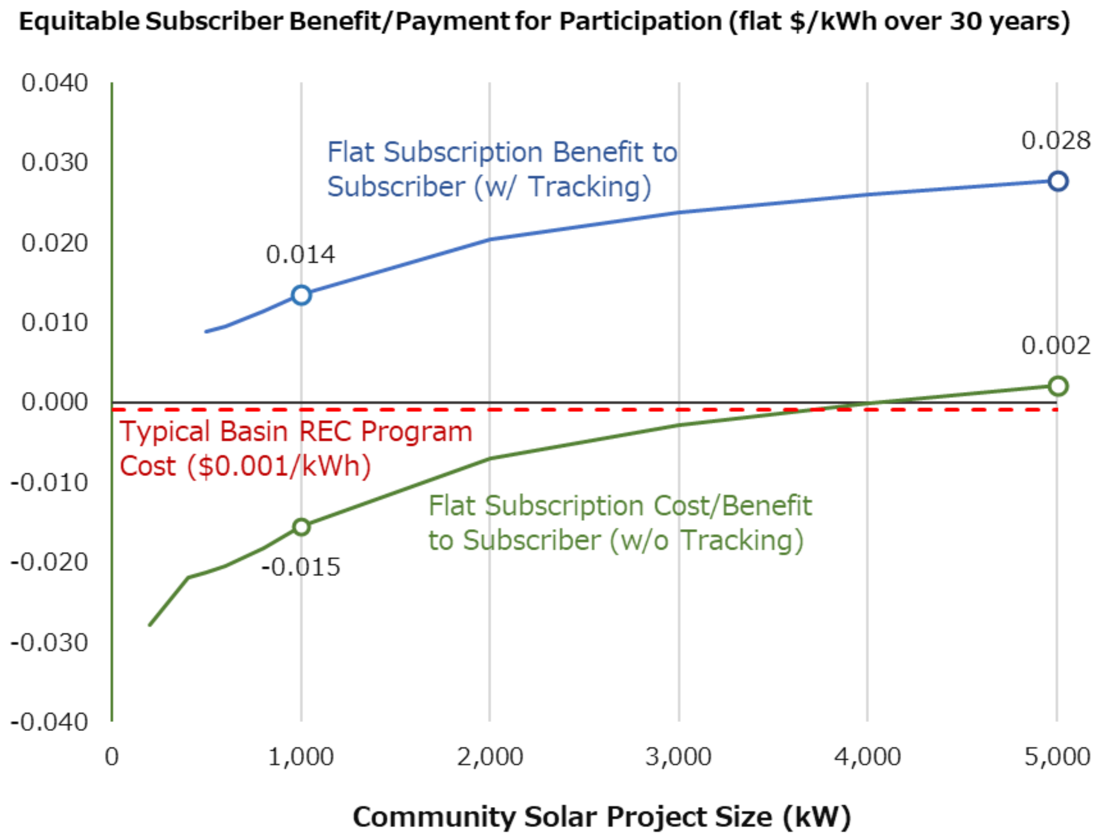

Figure 4. MLIC calculations of CSS subscription value under different project assumptions.

Scenarios of various community shred solar project sizes with (blue) and without (green) tracking. The vertical axis show the total value of East River's avoided purchases from Basin as passed through to subscribers in the form of a flat per-kWh subscription contract over 30 years. Projects above 4-MW without tracking and all projects above 500-kWh with tracking are able to provide a benefit to subscribers.

One important consideration to interpret the results above is that the multiple layers of this CSS arrangement can create risk at the different levels, as benefits will vary from year to year due to variation in solar production and in solar production's alignment with East River's system peak. Therefore, a realistic model of multilevel CSS may require East River and possibly the distribution utilities to retain some of the value of the project as a risk premium. For example, a 1-MW project with tracking creates sufficient value, on average, to pass through a $0.014/kWh benefit to subscribers. But due to variability, there is a 50% probability that the project will underperform and lead to cross-subsidization to the subscribers. If instead subscription benefits were reduced to $0.010/kWh, the MLIC model estimates that there would be only a 4% probability that the project underperforms so significantly as to lead to a cross-subsidy to subscribers (and therefore, there is a 96% probability that non-participants will also benefit from the project).

6. Next Steps

Throughout this project, our research team built a mutual understanding of the requirements for solar PV to be designed equitably to align with the goals of cooperatives. Through researching case studies and exploring new possibilities, there is significant room for creative thinking for designing value flows to mitigate cross-subsidization.

We developed the MLIC model to help cooperatives navigate innovative opportunities for solar PV deployment to assess how models can align with cooperative values, especially in light of the multilevel structure of G&Ts and distribution cooperatives. The MLIC model is flexible so as to accommodate a wide range of possible models and cooperative circumstances. The model continues to be housed at the University of Minnesota's Center for Science, Technology, and Environmental Policy, and our research team would welcome opportunities to partner with other electric cooperatives to explore ways in which the model can be tailored for new purposes.

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Appendix A: Categories of Utility Costs

The costs a utility incurs to provide electric service are typically categorized by their incidence to meet specific or general increments of supply and demand. Figure A1 provides a schematic representation of the categories of utility costs.

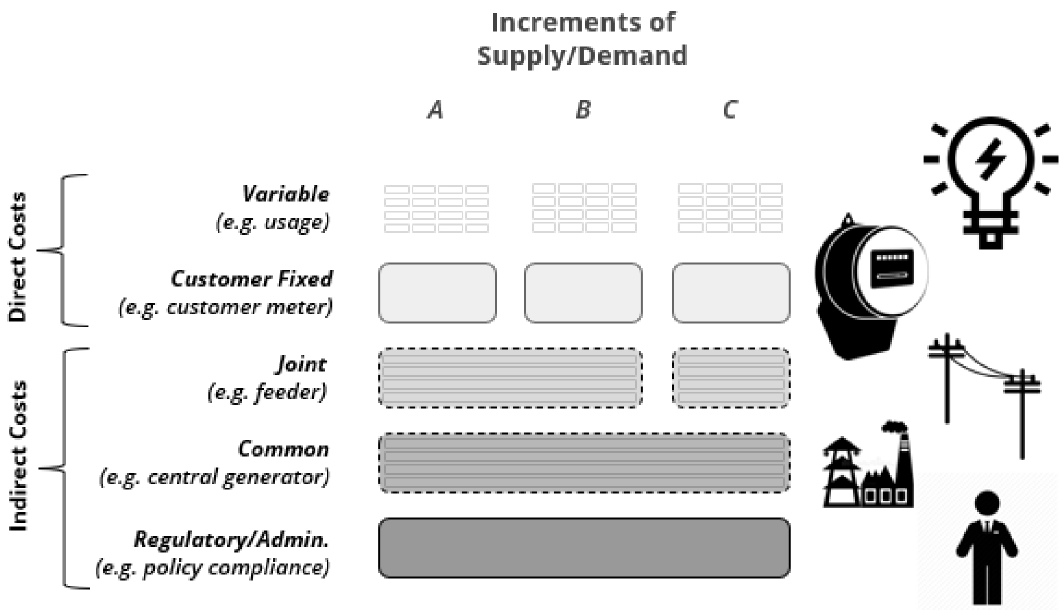

Figure A1. Schematic representation of categories of utility costs

The costs of providing utility service can be categorized in different ways. Here we present a comprehensive categorization of utility costs based on the incidence of costs to meet increments of supply and demand (labeled "A," "B," and "C"). Direct costs are shown to come in small and large increments, all related to specific usage or consumers, whereas indirect costs are shown in increments small and large that stretch horizontally across increments of supply/demand, representing that their costs are typically not attributable to any particular usage (Common and Regulatory/Administrative costs stretch across all increments of supply/demand, but joint costs are shown as just applying to a subset of increments.)

Variable costs are those costs that are incurred to meet the most specific increments of energy demand. For example, the cost of fuel is a variable cost which can be allocated to specific units of delivered energy.

Customer fixed costs are fixed costs that are incurred to provide service to a specific customer. For example, the cost of an electric meter is a fixed cost (the cost of the meter does not vary with increments of supply and demand) that can be allocated to a specific customer.

Joint costs are fixed costs that are incurred to provide service to a specific group of customers but not all customers in the resource pool of a utility. For example, the costs of a feeder on a distribution grid serves multiple customers in proximity to the feeder and can, in principle, be allocated to a specific group of customers.[11]

[11] While joint costs can in principle be allocated to a specific group of customers based on utilization of the joint asset, joint costs can also be treated as common costs. For example, feeder costs could be proportionally allocated across the utility resource pool rather than specifically allocated to just those customers who utilize that feeder. However, in other cases, joint costs could be distinguished from common costs. For example, a "non-wires alternative" project could be incentivized based on its ability to avoid specific joint costs on the distribution grid near where the project is deployed.

Common costs are fixed costs that are incurred to provide service across the entire resource pool of a utility. For example, the fixed costs of a central station powerplant are incurred to provide reliable service across all customers of a utility.

Regulatory and administrative costs are costs incurred by a utility as a business or regulatory cost to provide service to all customers in the resource pool. Similar to common costs, regulatory and administrative costs are generally not possible to allocate to any specific increment of supply or demand. Regulatory and administrative costs could be considered a form of overhead cost of doing business and strengthening the utility business.

Together, variable costs and customer fixed costs are referred to as "**direct costs**," highlighting that these costs can be directly and straightforwardly allocated to specific customers. Joint, common, and regulatory and administrative costs are referred to as "**indirect costs**," highlighting that these costs are only indirectly impacted by new increments of supply and demand. Understanding the impact on indirect costs requires making different assumptions about causality and responsibility, as discussed in Section 3.

Generally, the costs associated with the historic investments made by a utility are referred to as "**embedded costs**" whereas the costs associated with future investments (or avoided investments) are referred to as "**incremental costs**." For consistency, we use the term "**marginal cost**" to refer to instantaneous, variable costs but we acknowledge that the term "marginal cost" can be used inconsistently in practice and scholarship to refer to other cost categories defined above.

The frameworks for defining baseline cost responsibility in analysis of cross subsidy described in Section 3 and Table 2 are represented schematically in Figure A2. In Figure A2, the cost categorization shown in Figure A1 is disaggregated into costs associated with supplying historical versus future increments of supply and demand. Current variable costs are also shown in the center.

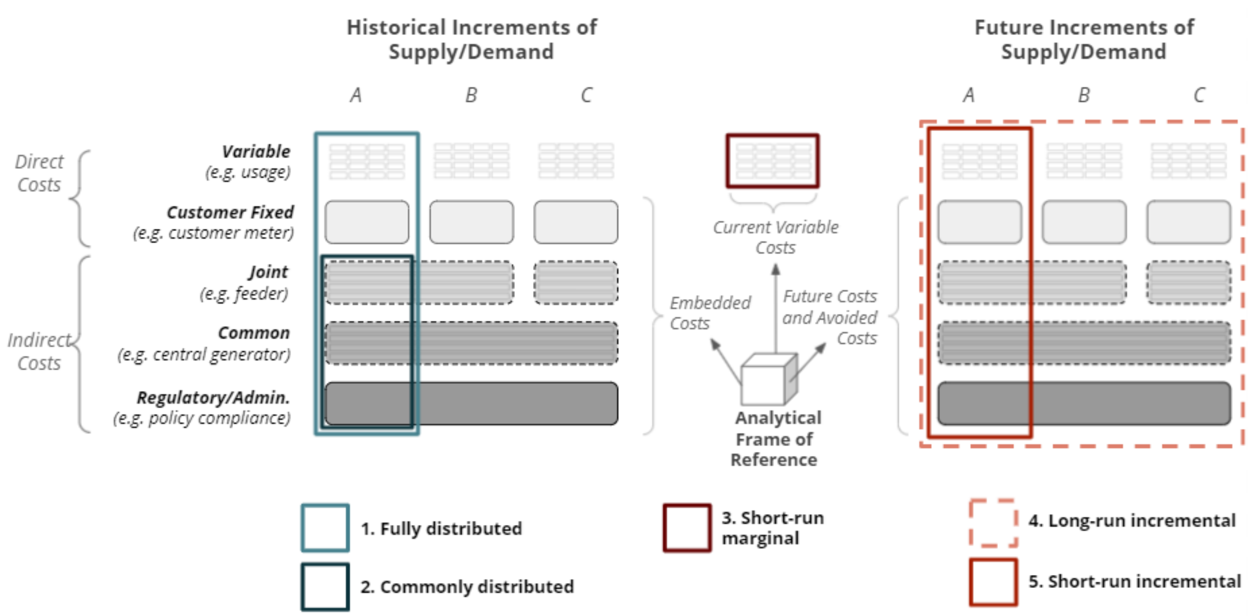

Figure A2. Schematic representation of alternative frameworks for defining baseline cost responsibility

Different frameworks for defining baseline cost responsibility offer different assumptions of responsibility for historic, current, and future costs across direct and indirect cost categories.

Appendix B: Case Studies of Cooperative Solar PV Deployment

The following case studies describe solar PV deployment models that highlight myriad approaches to considering equity and cross-subsidy. These case studies range in size, location, utility type, ownership, and the approaches to their definitions of equity. The cases were chosen to illustrate the wide variety of ways in which solar can be deployed in an electric cooperative. While most cases are from electric cooperatives, we have also included one example from a municipal utility and one example from an investor-owned utility to illustrate a wider range of possibilities that might be relevant for cooperatives. Details for the cases were sources from publicly available information and interviews with utility staff. Table B1 summarizes the cases in this section.

Table B1. Overview of solar PV deployment case studies

	Aggregate Size	Interconnection Level	Ownership
Green Power EMC	503 MW, 1,200 MW goal by 2022	Multiple at transmission and distribution utilities	Third Party or Utility
Connexus Energy	245kW community solar array, 15MW array co-sited with 30MWh of energy storage	Connexus Energy (distribution utility) in Ramsey, MN	Utility
Cherryland Electric Cooperative	1.2 MW	Transmission (50 low-income customers join community solar program)	Utility
Valley Electric Association	230 kW total installed through SolPower subsidiary	Rooftop and Commercial	Third Party
Ouachita Electric Cooperative	12 MW	BTM Industrial (sited at Aerojet Rocketdyne)	Third Party
Basin Electric Power Cooperative	128 MW	Transmission, in Pennington, South Dakota	Third Party
CPS Energy[12]	Panel by panel rental, 5 MW goal reached in February 2018	Rooftop	Third Party
Arizona Public Service[13]	4kw - 8kw rooftop installations, 940 installations as of May 2020 (approx. 4 to 8 MW)	Rooftop at income-limited homes	Utility
Wabash Valley	6.68 total MW in 6 arrays	At 6 distribution members	Utility

[12] CPS Energy is a municipal utility serving San Antonio.
[13] Arizona Public Service is an investor-owned utility.

Green Power EMC (Georgia)

Background and Context

Green Power EMC is a generation cooperative located in Tucker, GA, that provides utility grid scale and community solar facilities for 38 of the state's 41 customer-owned EMCs (Electric Membership Corporations)/distribution cooperative members. Using a number of green resources, the cooperative serves more than 4 million people, almost half of Georgia's population, across 65 percent of the state's land area in 151 of 159 counties. The cooperative's primary efforts have been to find, screen, analyze, and negotiate PPAs with Georgia-based renewable resource providers for interested EMCs.

While there are no requirements, goals, or state tax incentives to compel cooperatives to use renewable sources, the Georgia Public Service Commission has encouraged and provided sufficient incentives to create a favorable market opportunity. Utility-scale solar is more cost-effective than smaller distributed energy resources in Georgia, offering a unique opportunity to meet the interest of member cooperatives and add value to wholesale supply portfolios. The solar developer Silicon Ranch, for example, has built and operated three solar projects over the past decade in Hazlehurst, GA, from which Green Power EMC and subscribing members receive all of the energy. Silicon Ranch recently partnered with Mortenson, another leading solar firm, and announced in May 2020 that it had begun building yet another solar facility (86 MW) in Hazlehurst. 30 EMCs will share in the energy produced from the new facility. Silicon Ranch now stands as one of the largest taxpayers in Jeff Davis County, providing significant additional tax revenues for the local community for years to come.

Project Summary

Type/Ownership: Distribution (subscribed by multiple distribution cooperatives)
Size: 503 MW capacity, 1,200 MW goal by 2022
Development Details: Founded in 2001, Green Power EMC continues to manage the construction and maintenance of 500kW to 1MW solar facilities for local EMCs.

Mission Alignment with Equitable Solar

Green Power EMC is prioritizing power supply flexibility by facilitating electricity from cleaner, greener sources for members throughout the state of Georgia. This cooperative supports equitable solar deployment by taking on the risk of ownership and maintenance while providing advantageous opportunities for oft-overlooked residents. Furthermore, Green Power EMC prioritizes community engagement and awareness, such as through their SPARK Energy Education Program, which promotes learning experiences for middle school and high school STEM students while installing solar arrays on schools.

Resources

- http://www.greenpoweremc.com/
- https://www.greenpoweremc.com/content/solar-energy
- https://greenpoweremc.com/content/silicon-ranch-and-mortenson-partner-construct-solar-project-jeff-davis-county-georgia-green
- https://www.cooperative.com/programs-services/bts/documents/sunda/doe-ee0006333%20-%20nreca%20-%20sunda%20-%20final%20technical%20report.pdf (at 109)

Connexus Energy (Minnesota)

Background and Context

The two new Solar plus Storage sites in Ramsey and Athens Township are leading the way in the solar community with their addition of battery storage. Batteries store the power that solar panels collect to use at times when electricity demand is at its peak, especially in the summer months, which helps save power supply costs.

The Solarwise community solar approach is a pay as you go subscription, where members pay either $10 (on top of their monthly bill) to offset their whole house's energy or $5 for half their house's consumption.

Third party-owned solar allows for myriad outcomes. On one hand, when logistics are outsourced from the electricity provider, third parties can think through large- or small-scale projects, ranging from megawatts sited in one area to numerous rooftop installations sited around a service area. Third parties benefit from networks of labor, contractors, and solar panel providers and often benefit from economies of scale. Third parties can especially benefit from federal tax incentives, unlike not-for-profit cooperatives. Third party solar installers often competitively bid to install solar projects, providing competitive pricing to subscribers. Third parties must overcome organizational barriers such as trust, historic power purchases from another party, and changing tax incentives.

Project Summary

Type/Ownership: Utility owned, storage sited at Ramsey and Athens
Size: Solar + Storage: 15MW, 30MWh storage; and SolarWise community solar garden: 245kW
Development Details: Solar + Storage: Operational as of the end of 2018, situated on 54 acres the two storage sites consist of a total of 3,150 Lithium Iron Phosphate batteries that store energy collected from a total of 41,040 solar panels. The batteries can store roughly equivalent to 6,742 home' energy consumption. The Solarwise community array was developed in 2014 in collaboration with a third-party financier to benefit from federal tax incentives and minimize rate impacts to non-participants. The National Renewables Cooperative Organization, a cooperative renewable developer owned by 21 cooperatives across the country, helped develop the project.

Mission Alignment with Equitable Solar

Connexus Energy is a cooperative seeking to expand the scope of technological solutions for equitable solar deployment. Connexus has a portfolio of solar projects to benefit their membership. Connexus takes advantage of solar plus storage where it discharges solar during peak hours when its power supply costs are the highest. Customers may opt-in to participate in the Solarwise community solar program, which ensures that Connexus will retire renewable energy credits from the solar project on the behalf of participants, but participants do not receive any credits on their bill. Solarwise aims to eliminate the cost-shifting for non-solar members since it is only funded by those who subscribe to the program.

Resources

- https://www.connexusenergy.com/save-money-and-energy/programs-rebates/go-green/solarwise
- https://www.connexusenergy.com/blog/2018/connexus-energys-innovative-solar-plus-storage-project-under-construction/
- https://www.cleanenergyresourceteams.org/connexus-energy-celebrates-its-innovative-solar-plus-storage-project
- https://www.connexusenergy.com/blog/2018/solar-storage-in-ramsey-and-athens-township/
- https://nrco.coop/nrco_projects/connexus-energy-community-solar/

Ouachita Electric Cooperative Corporation (Arkansas)

Background and Context
Ouachita Electric Cooperative Cooperation (OECC) is a distribution cooperative in Arkansas formed in 1938. Aerojet Rocketdyne provides aerospace and defense technologies to national agencies and is Ouachita cooperative's largest customer, accounting for about 10% of the utility load. It's main facility in OECC has been based in Camden, Arkansas since the 1980s. After experiencing the loss of a different large C&I member, OECC sought to help Aerojet stay in its service area. Aerojet had also been searching for a green energy project for its Arkansas plant for years due to federal incentives for contractors to use renewable energy. Starting in 2015, the two entities worked with Silicon Ranch Corporation, a solar developer that works with many southeastern co-ops, to build and site a 12.5-MW solar array behind the meter of Aerojet. While building behind the meter was a stipulation of Arkansas law and the physical constraints of the grid at Aerojet's location, Ouachita found that the solar array helped reduce the co-op's summer demand charge (reducing summer peak demand by as much as 30% from 52MW to 40MW) and offsetting lost revenue. In return, Aerojet secured a fixed price for solar energy, and Ouachita's G&T, Arkansas Electric Cooperative Corporation (AECC) purchases the excess energy from the system.

The project had substantial economic development benefits. Aerojet was able to add 250 employees and stabilize their power costs, which helped build Ouachita's residential load and allowed the co-op to further offer broadband and efficiency services to their new member-owners. In 2019, the co-op reported its first rate reduction in at least 20 years, due to Aerojet's solar facility reducing the co-op's peak demand purchases. AECC and OECC have also since further worked to develop four additional renewable energy projects. The solar sites will cumulatively produce over 4,000 MWh of energy in year one.

Project Summary
Type/Ownership: 3rd Party, Sited at Aerojet Rocketdyne BTM Industrial
Size: 12 MW behind-the-meter solar farm installation
Development Details: Two PPAs in 2015 with Aerojet and AECC

Mission Alignment with Equitable Solar
Ouachita Electric Cooperative is prioritizing economic development to accomplish equitable and fair deployment of solar energy. Solar was marketable, helping stabilize the local economy in 2015 (by creating jobs and adding customers to Ouachita's residential load) after PPA's kept the largest employer in town, Aerojet Rocketdyne. Ouachita runs most of its operations off a 943-kW solar array installed during that project, and the Arkansas Electric Cooperative Corps has since built a number of other community solar projects for cooperatives. Ouachita works with member-owners through the Pay-As-You-Save (PAYS) program, as well as with local schools, to improve energy efficiency and lower energy bills.

Resources
- https://www.siliconranch.com/portfolio-item/aerojet-rocketdyne/
- https://aecc.com/2015/02/04/aerojet-rocketdyne-arkansas-electric-cooperative-corporation-ouachita-electric-cooperative-deploy-solar-energy-rural-arkansas/
- https://sepapower.org/knowledge/a-solar-story-from-arkansas-shines-light-on-q1-utility-scale-market/
- https://energynews.us/2017/07/27/how-an-arkansas-co-op-used-solar-power-to-help-retain-a-major-employer/

Cherryland Electric Cooperative (Michigan)

Background and Context

Cherryland Electric Cooperative is a distribution cooperative in Northwest Michigan that serves 35,000 members in six counties. Cherryland joined the Solar Up North (SUN) Alliance in 2013, contributing to the planning and construction of the 2016 solar array sited in Cadillac. The cooperative offers buy-all sell-all, net metering, and community solar programs to participate in renewable energy. Cherryland touts its community solar option as the most affordable way to participate in solar.

In 2017, Cherryland was approached by the Michigan Agency for Energy (MAE) with an opportunity to address weatherization and low-income member's energy bills. Northwest Michigan Community Action Agency (NMCAA) qualifies the members as income qualified for receipt of the solar credits. In addition to income qualifications, each household had to have previously received some form of energy assistance through NMCAA and live in a single-family dwelling unit, either owner-occupied or rental. In addition, the households are required to share their before and after energy consumption data from the weatherization and energy efficiency upgrades. An energy advisor from Cherryland reached out to these households to offer further energy efficiency opportunities, discuss energy usage, and energy use decision making. Under the program, each of fifty carefully screened, low-income households in Cherryland's Grand Traverse region receives the benefit of energy output from nine solar panels at a community solar project in Cadillac, Michigan. Enrollment in the program is for fifteen years.

Project Summary

Type/Ownership: Generation (3rd party, transmission sited at Wolverine Power Supply Cooperative)
Size: 1.2 MW 'Spartan Solar' solar array, 4,352 panels
Development Details: 1.2 MW solar array built after 18 months of planning, and four months of construction that commenced in December 2016. Sited in Cadillac, Michigan, across from headquarters of Wolverine Power Supply Cooperative.

Mission Alignment with Equitable Solar

The Cooperative has prioritized weatherization and solar opportunities for its low-income members. After receiving weatherization upgrades, 50 qualifying low-income members were assigned at no cost, nine solar panels from the Spartan Solar Community Solar Array. They were credited 10 cents per kWh or on average about $350 a year to their electric bill. Cherryland's goal is "to model a scenario that enables access to solar by low-and-moderate-income households and lowers the energy cost through weatherization." The aim is to move "low-income families toward economic self-sufficiency by reducing energy costs." Cherryland leads Michigan with its renewable and carbon free energy portfolios where around 62% of the Cooperatives electricity is carbon-free. The Cooperative is home to Michigan's first utility scale wind and solar farms.

Resources

- https://www.cooperative.com/programs-services/bts/energy-access/Documents/Advisory-Advancing-Energy-Access-for-All-Case-Study-Cherryland-June-2019.pdf
- https://www.cherrylandelectric.coop/2018/02/cherryland-pilots-low-income-solar-program/
- https://www.electric.coop/michigan-cherryland-electric-co-op-trims-member-bills-community-solar

Basin Electric Power Cooperative (South Dakota)

Background and Context
Basin Electric Power Cooperative is a "super G&T" that spans nine states, delivering generation and transmission services to its members, which include both distribution utilities and other G&Ts. Basin has been diversifying its power supply to include more renewables, including solar PV. Basin has prioritized utility-scale solar in its overall power-supply portfolio as an economic strategy to provide safe, affordable, clean, and reliable power to its members.

The Wild Spring Solar Project is a 128-MW project located in the service area of West River Electric Association, a distribution cooperative member of Basin. The project's output will be blended into Basin's power supply mix to provide benefits to all 131 members of Basin across nine states. This is the first time Basin will buy solar generation through a large-scale project to serve its members.

Project Summary
Type/Ownership: Owned by National Grid Renewables (a third party), Basin is the offtaker under a power purchase agreement
Size: 128 MW
Development Details: Anticipated to begin operations in 2022

Mission Alignment with Equitable Solar
Equitable solar in this case considers the benefits that Basin members receive through blending large-scale solar PV in Basin's power supply. Basin and its development partner on the project, Geronimo Energy/National Grid, have also assessed the economic benefits 20 years into the future of the project, including positive impacts in new tax revenue, construction jobs, new full-time jobs, and charitable funds through the project's Education Fund.

"Our cooperative network is always looking to ensure we have a mix of power resources to meet the needs of our membership and renewable energy is an important part of that strategy," said Vic Simmons, general manager, Rushmore Electric, a G&T member of Basin. "This project with Geronimo Energy is an important strategic step as we look to the future in continuing our strong history of providing safe, affordable and reliable power."

Resources
- https://www.solarpowerworldonline.com/2020/02/geronimo-energy-developing-south-dakota-solar-project/
- https://www.basinelectric.com/news-center/news-releases/basin-electric-and-geronimo-energy-announce-power-purchase-agreement
- https://puc.sd.gov/commission/dockets/electric/2020/EL20-018/Presentation.pdf

Valley Electric Association (Nevada)

Background and Context

Valley Electric Association (VEA) is at a distribution cooperative located in Southwestern Nevada. Valley Electric Association was formed in 1965 when four power companies came together. They serve 45,000 members across 6,800 square miles. VEA says that their existence as a rural electric cooperative allows them to focus on serving those rural and underserved communities, because this mission is "in their DNA."

Project Summary

Type/Ownership: Utility owned solar engineering, procurement, and construction company, which installs solar for customers at residential and commercial sites

Size: 230 kW total installed at 29 residential sites as of May 2021

Development Details: Company began in September 2020 and has reached 17% market share as of May 2021

Mission Alignment with Equitable Solar

SolPower is Valley Electric Association's own solar company with an aim to serve their members. They are "a full-service solar company specializing in design, installation, finance, maintenance, and warranty of solar electric systems." Their mission is to "provide Valley members who choose solar with the high quality, utility-grade solar power systems they deserve. We are not focused on making a quick sale or selling customers an over-sized system. We are here solely to serve Valley members who choose solar. Our focus is on our community and the needs of our members." Valley Electric also owns a separate arm for financing as well as a broadband. When asked about details for solar installation, Steve Morrison said that instead of thinking of solar installations as losing sales, they see an opportunity to find revenue by financing these projects as well as an opportunity to install broadband with solar installations. Broadband provides the owner and Solpower real-time information about production.

Resources

- https://vea.coop/2020/08/introducing-solpower/
- https://www.solpower.com/
- https://pvtimes.com/news/valley-electric-association-moves-on-solar-91945/

CPS Energy (Texas)

<u>Background and Context</u>
CPS Energy is the country's largest municipal utility and serves the city of San Antonio, Texas, which has excellent solar potential. CPS Energy received widespread interest in solar programs. CPS Energy developed two community solar programs in 2016 and 2019 but has continued to see significant interest in rooftop solar. To meet demand even while pursuing community solar, CPS Energy partnered with PowerFin Partners to develop a rooftop solar program called "SolarHost." Originally announced in 2015, under this program, Powerfin Partners owns the panels as well as manages their installation and maintenance. Participants in the program include renters (with permission of their landlords) and moderate-income households. Participants, or "hosts," in the program are paid $0.03/kWh for generation and typically receive $20.00 each month in the summer. In 2017, there were 300 SolarHost participants. Powerfin's goal of 5 MW of installed solar through this program was reached in February of 2018. SolarHost benefits CPS Energy in helping meet renewable energy goals set by the city of San Antonio, which includes carbon neutrality by 2050.

Separate from SolarHost, CPS Energy also provides $2,500 rebates per project with a $500 incentive to utilize local modules. These rebates were a response to a call for more access to solar energy installation options.

<u>Project Summary</u>
Type/Ownership: utility-directed, third party owned, sited at customer rooftops
Size: panel by panel rentals, 5 MW total installed capacity
Development Details: 600 solar power systems by 2018

<u>Mission Alignment with Equitable Solar</u>
The program is similar to a solar roof lease program, where subscribers earn bill credits for participating, at no cost to them. This program allows customers from any economic background to host solar panels since they don't purchase the panels outright.

<u>Resources</u>
- https://newsroom.cpsenergy.com/powerfin-brings-solarhost-first-of-its-kind-rooftop-solar-program-to-san-antonio/
- https://www.bizjournals.com/sanantonio/news/2018/02/26/solarhostsa-program-reaches-5-megawatt-goal.html
- https://www.sanantonio.gov/Portals/0/Files/Sustainability/SAClimateReady/SACRReportOctober2019.pdf
- https://www.cpsenergy.com/en/my-home/savenow/rebates-rebate/solar-photovoltaic-rebate/comm-solar-rebate-incentive-tiers.html

Arizona Public Service Electric (Arizona)

Background and Context
APS is an investor-owned utility serving 2.7 million people in 11 of Arizona's 15 counties. Since 2018, over 3,940 applications for the APS Solar Communities have been submitted, with 940 completed installations as of May 2020. Today, the solar program is full, and APS is not taking applications at this time. APS had a similar program before Solar Communities that was not limited to income eligible participants.

Energy credits are given to income-limited residential, non-residential, and multifamily households interested in participating. Rooftop solar systems are installed on an eligible residential customer's rooftop or outdoor space at multi-family/ non-residential buildings. The size varies from 4kW to 8kW in exchange for a $30 monthly bill credit for 20 years ($7,200 across the life of the program). Essentially, residents rent out their rooftops to APS in exchange for bill credits and solar investment.

Project Summary
Type/Ownership: utility-owned, sited at customer rooftops
Size: Solar Storage: Installing 4 kW to 8 kW rooftop solar systems
Development Details: Program began in 2018

Mission Alignment with Equitable Solar
Arizona Public Service Electric addresses income disparities of their customers with equitable access to utility-owned rooftop solar. The Solar Communities Program provides low to moderate income families and multifamily dwellings access to solar power. Investing in the grid, APS provides their customers with clean, reliable, and affordable power. APS scouted and modeled potential solar production and approached homeowners to enroll in the program.

Resources
- https://www.aps.com/en/About/Sustainability-and-Innovation/Technology-and-Innovation/Solar-Partner-Program
- https://www.utilitydive.com/news/arizonas-utility-owned-solar-programs-the-new-business-models-utilities-a/348331/
- https://www.westernenergy.org/news-resources/utility-owned-rooftop-solar/

Wabash Valley Power Alliance (Indiana, Missouri, Illinois)

<u>Background and Context</u>
Wabash Valley Power Alliance is a G&T with 23 member distribution cooperatives in Indiana, Illinois, and Missouri. These member cooperatives power more than 321,000 homes, schools and businesses. After hearing significant interest in solar from distribution members, Wabash worked with its members to create a program of six distributed solar projects located at different Wabash members. These projects act as community shared solar projects, whereby Wabash owns the solar PV projects, distribution members market subscriptions, and Wabash purchases back any energy that is not subscribed. This increases the economic benefits of solar PV while minimizing risks to Wabash distribution members. As of last year, over 6.5-MW of solar PV has been built by Wabash and 47% of capacity is subscribed.

Wabash is also purchasing electricity from three new utility-scale solar sites with a combined output of 400 megawatts, showing a holistic strategy for sourcing energy and developing new engagement programs.

<u>Project Summary</u>
Type/Ownership: Wabash Valley-owned, sited at distribution members
Size: Phase 1: 3 arrays of 0.54 MW each; Phase 2: Perryville, Illinois at .65 megawatts; LaOtto, Indiana at .96 megawatts; and Wheatfield, Indiana at 3.45 megawatts
Development Details: Phase 1 in March 2017, Phase 2 in December 2018

<u>Mission Alignment with Equitable Solar</u>
Wabash Valley Power Alliance has pursued community solar at the G&T cooperative level. This approach has allowed Wabash Valley to keep rates down for its members while encouraging participation in community solar for their distribution members. This model also is designed to minimize risk for participants. Under their "Co-op Solar" model, Wabash's community solar arrays are sited at a distribution member with an eye towards optimal land lease contracts, production, substation capacity, and subscription interest. Wabash developed a scoring metric that evaluated sites that best balanced the cooperative's goals. To manage expectations and to prepare for the future, Wabash set certain levels of subscriptions to understand when to begin a second phase of development. When the first phase reached 50 percent subscription, Wabash Valley started looking for Phase 2 locations. At 75 percent subscribed, Phase 2 construction was set to begin.

<u>Resources</u>

- https://www.solential.com/wabash-valley-power-alliance-makes-it-easy-for-co-ops-to-be-green-with-community-solar/
- https://www.powermoves.com/co-op-solar/solar-dashboard/
- https://www.wvpa.com/wabash-valley-co-ops-dedicate-new-arrays-launch-co-op-solar/