The Locational Value of Energy Efficiency on the Distribution Grid

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ABSTRACT

Utility electric energy efficiency programs started life back in the 1970's as a "system" level resource. Indeed most cost-benefit tests today still rely on the system concept of the "avoided cost of generation." However, with the rapid deployment of distributed energy resources (DER) due to both economics and state regulatory proceedings encouraging that deployment, there is a need to develop mechanisms to reflect DER's locational value. Energy efficiency, which is increasingly thought of as one of several DER measures, needs to incorporate locational value into its value assessment. This paper explores a methodological approach assessing the locational value of energy efficiency. Past approaches to calculating the "value of solar" are not sufficient. This paper introduces the concept of "locational net value" of energy efficiency. The starting point is a hosting capacity evaluation at the feeder level which can be used to identify the ability of the distribution system to integrate a variety of distributed resources onto the system. Hosting capacity is the maximum DER penetration for which a distribution grid can operate safely and reliably. Power flow modeling coupled with probability based penetration scenarios are used to help quantify the impact of these scenarios on thermal overloads, voltage stability, power quality, and relay protection limits. Energy efficiency can be applied as a causal and mitigation option (the interaction effects between DER types will influence capacity value). Finally at least 10 year forecasts should be used in the analysis to align with longer term infrastructure planning. When the modeling is applied, the gap between forecasted load and feeder capacity represents the potential locational net value of energy efficiency with regard to deferred distribution capital expenditures at that location. In this paper we describe an analysis undertaken for a California utility as an example, though more work is needed in this area.

Why Value of DER Matters, Today and in the Future

Utilities and regulators are trying to understand the potential opportunities and systemic implications of increasing customer adoption of Distributed Energy Resources (DER). They are recognizing that as DER assumes a larger role in how energy is generated, consumed, and managed, there are potentially both beneficial and detrimental implications for distribution, transmission, and generation system operations and planning, both now and into the future. For example, Pacific Gas and Electric is analyzing the effects of targeted energy efficiency on transmission and distribution reliability (Aslin 2015), and has addressed localized distribution issues using a range of targeted measures in the past (Kinert et al. 1992).

Some of these effects could create real and substantial net benefits for all stakeholders: a potential for lower system costs, better resiliency, savings for customers, and emissions reductions. There are also serious concerns to navigate: operating a system with greater variability in net load, challenges in managing distribution voltage, integration costs, and fair and reasonable cost allocation. The more highly distributed future also will have tremendous potential implication for use of the grid. There are also implications for the utility operational and business model, including the role of a Distribution System Operator (DSO).

For some states, the future is now, as they are being pushed by (or want to enable) rapid DER adoption and have already launched groundbreaking regulatory initiatives to consider far-reaching changes in tariffs, distribution planning policies, and markets to enable and integrate DER. For example, California, New York, and Hawaii are converging toward reconsidering the basic utility model. Each state fundamentally envisions the future regulated utility as an enabler of customer choice to manage energy costs through advanced distribution planning, modern integrated grids, and opportunities for DER, including energy efficiency, to provide market based grid services (Fine, De Martini, and Robison 2015a). Other states are not at that point and are focusing on a more traditional suite of policies to accommodate (or incentivize) DER interconnection. An evolutionary progression toward the future has been depicted in California through the "Walk, Jog, Run" framework, shown in Figure 1 (More Than Smart 2015). It shows the increasing sophistication of analysis needed over time to progress from understanding and delivering distribution-level DER value to system-wide and societal value.

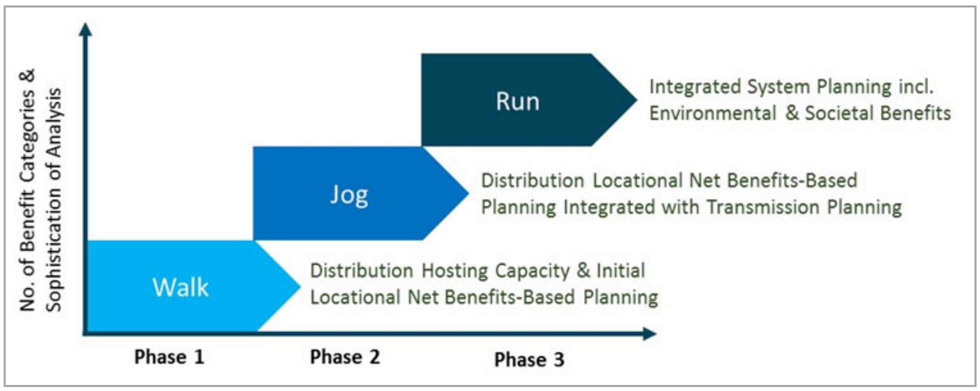

Figure 1. Increasing potential DER benefits and sophistication of analysis needed over time.
Source: More than Smart. 2015.

However, regardless of the current trajectory of a particular state, Figure 1 underscores the degree to which determining both the hosting capacity of the distribution system (ability of the distribution system to operate safely and reliably with increased penetration of DER) and the true, locational net value of DER, including energy efficiency, are important both now and as the foundation for managing a transition into a high-DER future. A comprehensive, consistent framework that appropriately weighs benefits and costs is the basis for rate design, programs (such as utility-sponsored energy efficiency programs), integrated system planning and platforms, and market mechanisms for sourcing DER services. Getting it wrong could leave a utility or an entire state misaligned, with inefficient capital allocation, misaligned tariffs that benefit some customers over others, and increased costs to maintain reliability. Getting it right — and consistent — unlocks opportunities for customers, market participants, and utilities to optimize products and services, create new markets, and ultimately grow revenue sustainably.

Table 1 summarizes the benefits of effective locational planning. As energy efficiency expands its role from a system level resource to a locational resource with differing values on the distribution system, new opportunities to optimize the system across multiple DERs and resource options will materialize. This can lead to smarter and more targeted investments and a more reliable and optimized system. Adaptive planning processes may be necessary as technology changes rapidly, and what may be optimal in the short term, may not be in the longer term. For example, increased penetration of certain DER, such as distributed generation, or energy storage, may lessen the value of energy efficiency in certain locations. Ultimately, some states may envision energy efficiency competing with other DER on a locational basis.

Table 1. How utilities and customers can benefit from accurate value of DER analysis today.

- **Smarter Investments**: Utilities can plan and justify better distribution system capital expenditures, achieving required system characteristics at lower cost. Not all savings will match Con Edison's proposed and much-heralded Brooklyn-Queens Demand Management program to save a net $750 million in new substation and transmission line costs through a reduction of 52 megawatts. However, even on a less bold scale, there are meaningful opportunities in every distribution system to optimize investments through a better understanding of hosting capacity and locational DER benefits.
- **Designing Rates:** Determining net locational DER value can help utilities and regulators move beyond net energy metering to intelligent value of solar/DER tariffs that incorporate locational and temporal value — and that deliver fair and reasonable value for all customers.
- **Optimized Programs:** Value of DER analysis can drive assessments of customer programs and incentives to rationalize them and reflect true costs and benefits of energy efficiency, demand response, energy storage, and renewables deployments, both in terms of locational targeting and incentives.
- **Adaptive Planning:** End-use, DER, and control technologies are changing rapidly, and in many cases costs are decreasing. Adaptive planning processes can provide the flexibility to keep up with these changing parameters, as well as other system changes to maintain overall system-wide economic efficiency.
- **Greater Reliability:** DER alternatives to traditional system investments can enhance resiliency and reliability.
- **Anticipating Customer Adoption**: Customer adoption of DER, including energy efficiency, is driven by both policy and technology innovation. This means that forecasting adoption becomes paramount for planning the use of the distribution grid and related investments, including integration costs. Probabilistic scenario-based planning that includes both hosting capacity and net value of DER analyses is critical for meeting customers' needs.

Source: Fine et al. 2015b.

Valuing DER Up to Now

The focus in valuing DER until now has been the narrower value of solar (VOS). This has made sense given solar's leading position among non-energy efficiency deployed DER, with over 9,000 MW installed in the U.S. as of Q1 2015 (Baca et al. 2015). But, the approaches used previously to determine benefits and costs for distributed solar are woefully insufficient for both the current reality and the future of DER for three reasons.

First, integrating and optimizing other forms of DER requires a benefit-cost analysis (BCA) framework that can be applied across DER technologies. This framework needs to address a range of resource characteristics such as dispatchability, the ability to provide voltage support, and whether they are inverter-based or generate alternating current (AC) directly. Most conventional energy efficiency measures may not be considered by planners to be dispatchable, although there may be exceptions such as communicating thermostats. Also most energy efficiency technologies do not generate either direct current (DC) or AC. Any methodology needs to capture these and other capabilities appropriately across all DER, or risk being wildly off the mark. An inaccurate BCA not only fails to optimize investments and programs, it will lead to misallocation of capital and potentially undermine market strategies. Many distribution planners historically have not valued the economic or reliability effects of energy efficiency in their distribution planning approaches. This will likely need to change in the future as states seek to address the contribution of all resources (central and distributed) in a consistent planning framework which can reflect market forces in best meeting system needs.

Second, value of solar (VOS) analysis has sorely lacked a consistent and accurate approach (Anich et al. 2014). As shown in Figure 2, many previous studies have been skewed by the fact that they either seem to incorporate an implicit assumption — without empirical validation — that distributed solar PV has inherent value, or they explicitly include "social" or other values that are not applied on the same basis to wholesale connected renewables. Predictably, the results have been all over the map, with some studies calculating overall values at many multiples of others, benefit categories variously included or excluded and derived from differing methodologies, and integration costs considered inconsistently or not at all. Such studies, even the most methodologically rigorous, have therefore tended to contribute to confusion and discord rather than promoting progress on aligning DER tariffs and regulations around enabling all DER. How are regulators supposed to weigh one study that says the value of solar is $125/MWh against another that claims nearly $350/MWh, and make a fair and rational policy (Norris et al. 2015 and Farrell 2014)? These numbers could be correct for their jurisdictions, but wildly different numbers and inconsistent methodologies and assumptions for the same phenomenon can result in misleading conclusions. Also, how do utilities plan investments, optimize value, and figure out whether added solar is a cost or a benefit to their system? Another issue is how can locational solar (or other distributed generation) be compared to locational energy efficiency?

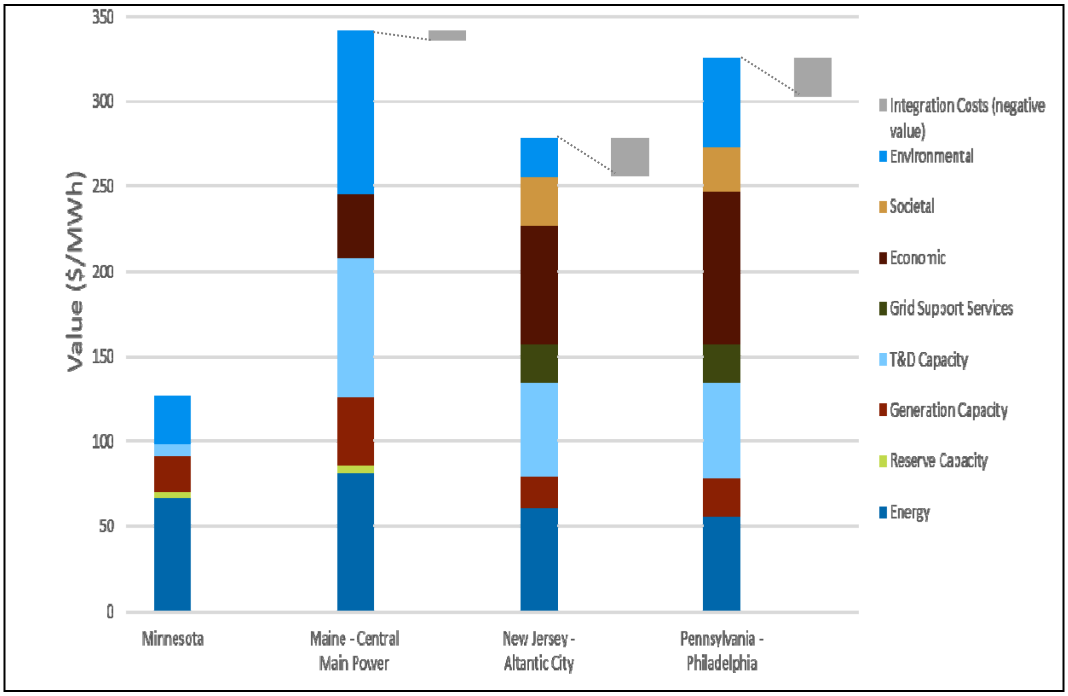

Figure 2. Illustrative value of solar studies: A wide range of methods, inconsistent results. *Sources:* Farrell 2014 (MN), Perez, Norris, and Hoff 2012 (NJ and PA), Norris et al. 2015 (ME)

Third, many existing studies have focused only on system value, not locational net value. They rely on generic, top-down, system-wide values assigned to items such as avoided transmission and distribution (T&D) losses and deferred capacity investments. Indeed this is part of the traditional planning framework for energy efficiency programs. But location matters. The value of DER, including energy efficiency, within the distribution system is highly dependent not only on its technological capabilities, but also where it is placed and the topology of the system. Therefore, DER benefit-cost analysis must include methods for assessing locational net value. This is important regardless of whether a state is trying to aggressively integrate DER to address environmental policy, reduce system costs, or is simply trying to maintain an appropriate policy for solar PV interconnection. It is also vital for determining fair tariffs that reflect costs of the system and allocates them to users reasonably. Achieving a “true” net value of DER creates a path for utilities to drive an integrated planning process to realize net positive value for all customers.

Valuing DER and Locational Energy Efficiency Today — Best Practices

To be clear, the process of figuring this out and getting it right is far from easy. There are several steps to establishing the locational benefits and costs of deploying DER on a given distribution system, and they are both more technically demanding and more complex than traditional analysis.[1]

- The starting point is a hosting capacity evaluation at the feeder level. Hosting capacity is the maximum DER penetration for which a distribution grid can operate safely and reliably. In general, locational targeted energy efficiency and its associated locational peak demand impact would tend to increase hosting capacity, however snap back effects or other load shifting effects must be accounted for. Also, to the extent that energy efficiency programs lower off-peak load, and thus exacerbate the problem of excess locally generated power being back fed to the distribution grid at a particular location and time, they can be a locational detriment to the overall problem. (In this case, energy efficiency reduces the amount of local load available to absorb the excess local generation.) A hosting capacity analysis establishes a baseline for identifying incremental investments needed to integrate scenario-forecasted DER, including energy efficiency, and net load growth.[2]
- Power flow models coupled with probability-based scenarios can then help quantify the impact that increasing DER adoption with variable characteristics has on specific distribution circuits with regard to thermal overloads, voltage stability, power quality, and relay protection limits. Traditional distribution engineering analysis based on deterministic assumptions of DER operation and net load will need to shift to probabilistic methods, to capture the operational impacts of DER variability. This could be a significant change to current utility distribution planning approaches.
- In addition, a scenario-based approach, using at least 10 year scenario-based forecasts, in order to align with other system level infrastructure plans, enables planners to evaluate DER growth across technologies and under varying levels and patterns of adoption. In addition, the impact of DER on load profiles and variability of net load, and persistence of energy efficiency measures, can be evaluated. California is using Base, High, and Very High DER penetration scenarios to inform this planning analysis.

It is then possible to examine, on a feeder-by-feeder basis, the incremental infrastructure or operational requirements that DER can meet either by providing grid services and/or through better locational adoption. In other words, utilities can assess whether they can avoid or defer other investments through DER, subject to certain levels of reliability and resiliency, and thereby achieve better value at lower cost for their systems and their customers.

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[1] We refer in several places below to examples drawn from California, which has the most developed requirements in its Distribution Resources Plan regulatory proceeding thus far.

[2] Hosting capacity will also change over time as a function of aging infrastructure replacement, grid modernization investments, net load growth, and DER penetration rates. So, this analysis needs to be periodically updated.

Case Study: Pioneering New Methods for a California Utility

California investor-owned utilities were required to file Distribution Resource Plans (DRP) on July 1, 2015, providing a framework and methodology for valuing DER. As part of this filing, ICF worked closely with a California investor-owned utility to develop the methods for quantifying locational value in terms of avoided costs that could be realized under various DER adoption and net load scenarios.[3] We focused initially on one value category required by the California Public Utilities Commission (CPUC): Avoided Distribution Utility Capital and Operating Expenses.[4]

The framework identified by the CPUC and More Than Smart (MTS) working group was used to affix a value to deferred distribution investments based on a detailed analysis framework around the DER value components.[5] The first step in evaluating the ability of DER to defer conventional utility investments under this framework is to identify the values that each DER can provide and then overlay them with the anticipated needs in the system over the relevant planning horizon. To the extent that a given DER's performance characteristics can address an engineering need — and if anticipated adoption levels are sufficient to address the projected deficiency — then that DER would be a potential alternative to enable deferment of utility investment.

For the utility, we evaluated the distribution capacity and the projected loading on each feeder in the system. The feeder headroom (i.e. capacity minus loading) was the key metric used to characterize the amount of capacity needed and identify areas where capacity was likely to become deficient. If DER is sourced to occur at the right locations and if the relevant DER (for example, selected energy efficiency measures) can reliably reduce circuit loading when net load is highest, DER could reduce the effective loading on a circuit.

It is important to recognize that the correlation of system output with net load will impact the capacity value of variable resources like distributed solar. The degree to which solar contributes to distribution capacity will vary with location, resource characteristics, and the shape of net load on that part of the system, which will in turn depend on the amount of solar already on the system. The contribution of DERs can be additive, but interaction effects between DER types, such as energy efficiency and distributed solar, will influence capacity value, and it may be possible that in certain locations these resources compete with each other. This will become increasingly important as DER adoption increases.

The analysis identified the feeders and substations where capacity value from DER could defer the need for incremental capital expenditures on the distribution grid. Figure 3 illustrates an example of how a portfolio of DER could reduce effective net loading on a feeder, thereby

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[3] For this paper, we have not provided specific results or locations and have described methodologies generally for illustrative purposes. (See Fine et al., 2015b)

[4] This analysis focused primarily on distribution capacity, which is only one of the four required DER BCA elements under California's DRP filing. However, the locational value methods developed here provide insights into building the other required elements. In addition, these same techniques, or similar ones, will inform the analysis taking place elsewhere, as New York utilities make their Distributed System Implementation Plan (DSIP) filings in January of 2016, and other states contemplate similar requirements in the years ahead.

[5] More than Smart (MTS) is a 501(c)(3) nonprofit organization that brings industry, advocacy and government experts together to develop solutions for integrating more distributed generation resources gradually into state electricity distribution grids. A key focus is in providing assistance to states to follow the MTS Walk/Jog/Run® Framework for modernizing distribution grids through an engineering-based framework that acknowledges the unique energy policies of each state.

effectively addressing a projected capacity deficiency and mitigating the need for upgrades. The area in blue shows capacity, while the solid orange line illustrates forecasted net load growth, including organic (i.e., ad hoc and unplanned) adoption of DER. Peak net load begins to exceed the capacity of the feeder between 2020 and 2021, and this deficiency only grows even though capacity is added through replacing aging infrastructure between 2018 and 2019. The gap between load and capacity therefore represents the opportunity for a sourced DER portfolio, which may include targeted energy efficiency, to address capacity needs, and therefore, the potential locational net value of DER. That value equals the utility avoided costs stemming from the upgrades otherwise needed for incremental distribution to avoid a deficiency, and now provided by DER.

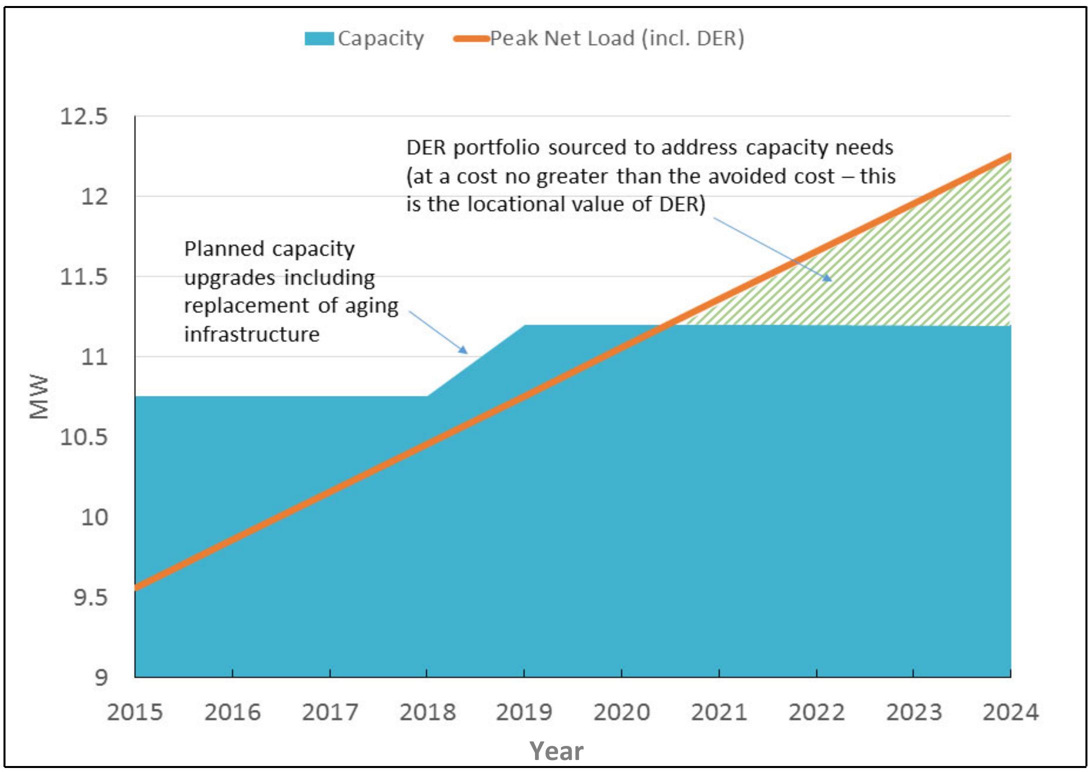

Figure 3. The impacts of DER on distribution capacity by feeder.
Source: Fine et al. 2015b.

Figure 4 shows the probability distribution for relative headroom on the system under three scenarios of DER adoption (low, high, and very high) aligned to locational value. The shift of the distribution curves to the right (i.e. toward more positive headroom) with increased DER illustrates how adoption, if structured through rate designs and incentives aligned to locational value, could allow for additional DER adoption by maintaining or increasing capacity headroom. This is still only theoretical, of course — today, DER adoption is unstructured as rates and incentives generally do not consider the locational value on a distribution system. As a result, unstructured DER adoption, particularly solar PV, may not actually create any benefit and instead may result in current flowing back into the distribution system during periods of low customer consumption that in turn creates a new net peak loading condition that requires distribution upgrades to address. This is represented by the base case and other scenarios that have negative headroom (for example, in Figure 4, Scenario 1 of DER adoption still shows over 100 feeders with negative headroom). Utilities and regulators may therefore wish to develop policies which guide DER investment to areas of the distribution grid with greatest value (possibly through incentives) while perhaps penalizing DER in areas where it will have negative effects and increase overall system costs.

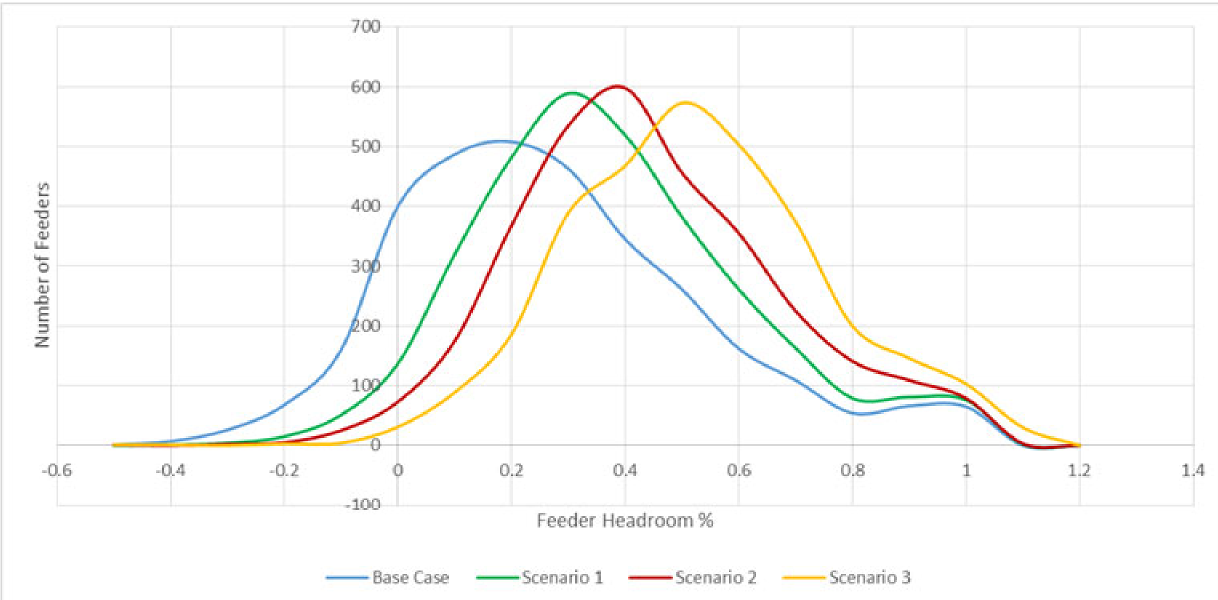

Figure 4. Feeder headroom distribution in 2024, DER combined impacts.
Source: Fine et al. 2015b.

Overall, this analysis shows that thoughtful rate design and incentive structures — with active utility participation and input — are essential to realize the net locational benefit of DER, including energy efficiency, for all customers.

Benefits and Next Steps for DER Portfolio Development

Insights into the locational benefits of DER within the distribution system are starting to enable a process in which utilities can specifically evaluate the ability of DER, including energy efficiency, to defer specific projects and upgrades, all within the context of developing a DER portfolio. This sets the stage for being able to value DER differently in different locations, depending on the benefits they might provide and the integration costs they might incur on the system.

The development of a process to enable greater visibility into the value of DER on the system will then enable a distribution planning process framework, through which the full value (and cost) of DER can be accounted for in how they are deployed. That deployment could come through one of three ways – prices, programs, or procurements, all of which will need to be thoroughly thought through.

Conclusion and Key Lessons

Our experience with DER benefit/cost analysis and with clients like our partners in the case study discussed above suggests several takeaways for utilities, regulators, and other stakeholders engaging in the question of determining the “true” value of DER.

1. Locational net value is key. Getting the net value of DER, including locational energy efficiency, right opens up opportunities for delivering greater value, lowering cost, ensuring reliability, and investing wisely. This is important for customers and utilities, and will be increasingly critical in a high DER-adoption future.

2. Structured DER adoption is essential. Aligning DER rate designs (for Net Energy Metering and others as proposed in CA) and incentive mechanisms to hosting capacity and locational value analysis is essential to scale customer adoption of DER. Failure to account for locational value will likely lead to unnecessary capital expenditures to address unstructured (ad hoc) adoption and very challenging operating conditions.

3. Analysis needs to improve. Our evaluation of locational value demonstrates that DER value within a system is variable, that methodologies applied until recently and mostly to value of solar are inadequate, and that inaccurate and inconsistent approaches have real consequences.

4. This is hard, but achievable. Determining a value of DER — on a locational basis factoring in hosting capacity, scenario-based planning, and probabilistic methods — is hard. However, our experience shows that better approaches are rapidly being developed and can yield smarter results to inform utilities’ investments and demand-side resource programs.

5. Scalable. The results of our case study, for example, using a consistent and rational true value of DER framework, can be applied across an entire distribution system. Over time, the aggregation of locational value can improve system-wide planning and provide the basis for new market mechanisms and utility business models.

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