OPTIMIZING THE GRID

A REGULATOR'S GUIDE TO

Hosting Capacity Analyses for Distributed Energy Resources

IREC
Interstate Renewable Energy Council

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Acronyms and Abbreviations

API	Application Program Interface
CPUC	California Public Utilities Commission
DER	Distributed Energy Resource
DG	Distributed Generation
DOE	United States Department of Energy
DRP	Distribution Resources Plan (California)
DSIP	Distribution System Implementation Plan (New York)
EPRI	Electric Power Research Institute
GIS	Geographic Information Systems
HCA	Hosting Capacity Analysis
ICA	Integration Capacity Analysis (California)
IDP	Integrated Distribution Planning
IOU	Investor Owned Utility
IREC	Interstate Renewable Energy Council, Inc.
LNBA	Locational Net Benefits Analysis (California)
MW	Megawatt
MN PUC	Minnesota Public Utility _Commission
NREL	National Renewable Energy Laboratory
NY PSC	New York Public Service Commission
PG&E	Pacific Gas & Electric
PV	Solar Photovoltaic
REV	Reforming the Energy Vision (New York)
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric Company
SDSIP	Supplemental Distribution System Implementation Plan (New York)
VDER	Value of Distributed Energy Resources (New York)

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Executive Summary

From coast to coast, states are experiencing unprecedented growth in distributed energy resources (DERs) – resources located on the electric distribution system, such as renewable energy, energy efficiency and energy storage. With much of this activity being driven by consumers, changes to the nation's outdated electric system are underway. To ensure that the benefits of these DERs are fully optimized, there is a need to proactively integrate them into grid planning, operations and long-term investment decisions. Rather than simply "tolerating" DERs, there is an opportunity to utilize a new tool known as Hosting Capacity Analysis (HCA), which can help more Americans enjoy the benefits and full potential of these resources on the grid.

The term "hosting capacity" refers to the amount of DERs that can be accommodated on the distribution system at a given time and at a given location under existing grid conditions and operations, without adversely impacting safety, power quality, reliability or other operational criteria, and without requiring significant infrastructure upgrades.

HCAs allow utilities, regulators and electric customers to make more efficient and cost-effective choices about deploying DERs on the grid. If adopted with intention, HCA may also function as a bridge to span information gaps between developers, customers and utilities, thus enabling more productive grid interactions and more economical grid solutions.

Hosting Capacity Analyses (HCAs) allow utilities, regulators and electric customers to make more efficient and cost-effective choices about deploying distributed energy resources on the grid.

Utility regulators play a key role in ensuring HCAs are deployed strategically, prudently and for the benefit of all energy customers. *Optimizing the Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources* will assist state regulators in guiding and overseeing utilities as they conduct hosting capacity analyses on their distribution circuits, as part of a broader grid modernization or distribution planning efforts and/or in support of their state's near- and long-term energy policy goals.

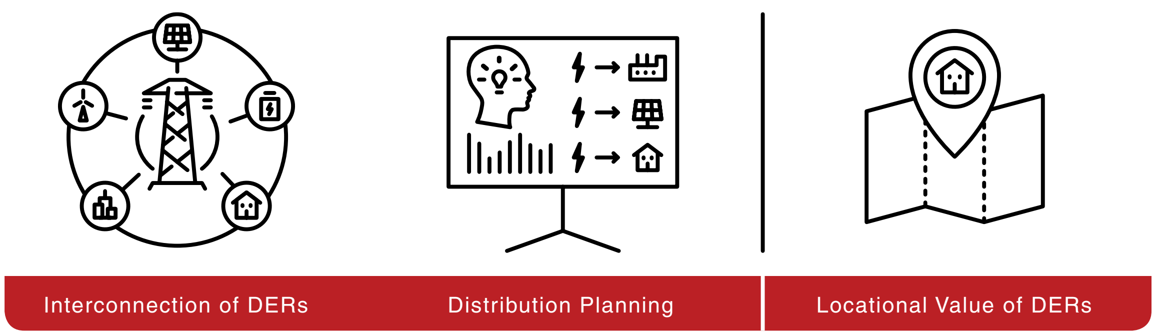
Based on lessons from the handful of states and utilities that have begun to prepare HCAs, this guide focuses on the *process* that will help regulators realize HCAs' full promise in their respective states. The experiences and key takeaways from the states and utilities undertaking these analyses, including California, New York, Minnesota, Hawaii and Pepco Holdings, Inc., provide important insights for other states and utilities to take into consideration as they pursue similar efforts. Details on each can be found in *Appendix A* of the full guide.

Hosting Capacity Analysis Use Cases

There are two principal applications, or use cases, for an HCA: 1) assist with and support the streamlined interconnection of DERs on the distribution grid; and 2) enable more robust distribution system planning efforts that ensure DERs are incorporated and reflected in future grid plans and investments. A third, complementary function of an HCA could be to inform pricing mechanisms for DERs based on separate analyses to assess the benefits of DERs based on their physical location on the grid and their performance characteristics (see Figure ES-1). To achieve an effective HCA, regulators and utilities should carefully consider and articulate their goals and use cases at the outset of an HCA effort.

Use cases can be selected to reflect the unique characteristics and identified goals of states and utilities. These use cases should inform and guide the development of an HCA methodology and its implementation. A process should also be in place to refine the selected use cases as new regulatory, social, and technological conditions emerge. The two major HCA use cases—interconnection and planning—as well as the complementary function of optimizing the locational benefits of DERs are discussed in detail in Section III of the full guide.

Figure ES-1. Hosting Capacity Use Cases



Hosting Capacity Analysis Methodologies

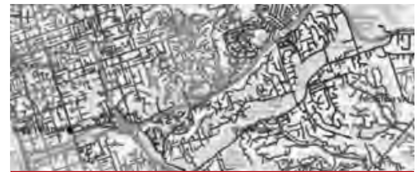
A well-considered methodology for determining hosting capacity is necessary given the variety of factors that affect the grid's ability to host a wide range of DERs. IREC has identified three principle categories of methodologies that are currently being tested and employed by utilities to analyze hosting capacity, generally known as the stochastic, iterative, and streamlined methods. This paper describes these methodologies, including the tradeoffs between them that may make them more or less suited to the various use cases that regulators may select. Briefly, the three methodologies are characterized as follows:

The streamlined method applies a set of simplified algorithms for each power system limitation (typically: thermal, safety/reliability, power quality/voltage, and protection) to approximate the DER capacity limit at nodes across the distribution circuit.

The iterative method directly models DERs on the distribution grid to identify hosting capacity limitations. A power flow simulation is run iteratively at each node on the distribution system until a violation of one of the four power system limitations is identified. The iterative method is also sometimes referred to as the detailed method.

The stochastic method starts with a model of the existing distribution system, then new solar PV (or other DERs) of varying sizes are added to a feeder at randomly selected locations and the feeder is evaluated for any adverse effects that arise from this random allocation. This essentially results in a hosting capacity range.

Different methodologies can result in different hosting capacity values due to different technical assumptions built into the models, and the methodological choices in an HCA can significantly impact whether the results are sufficiently reliable and informative for grid-related planning and decision-making. Section IV of the full guide outlines several key considerations when evaluating and selecting HCA methodologies.



Use cases can be selected to reflect the unique characteristics and identified goals of states and utilities. These use cases should inform and guide the development of an HCA methodology and its implementation.

Regulatory Process Underpinning Hosting Capacity Analyses

The *process* underpinning HCA efforts is key to ensuring that the HCA tool is deployed to support relevant state policy goals and sufficiently reflects the input from stakeholders, ultimately enhancing the benefits for all ratepayers. Still an emerging grid modernization tool, the benefits and drawbacks of different HCA methodologies are being revealed, and likely will become even more apparent with time. However, rather than wait for the perfect HCA methodology to emerge, regulators can take initial steps to gain familiarity and understanding of the different HCA methodologies, their function, their capabilities, and their limitations. Given the substantial investment in time, energy and resources that HCA efforts require, there is value in taking the time early in the process to ensure that the tool being developed is capable of meeting identified objectives. Questions or concerns about what an HCA can do should be addressed before widespread implementation, lest substantial resources be invested in something that proves invaluable or ambiguously useful. This paper identifies the key process steps and considerations therein, summarized as follows:

Establish a stakeholder process to work with utilities and other interested stakeholders to select, refine and implement the HCA. Ideally, this process should involve one or more working groups consisting of utility and non-utility participants with oversight from regulators to guide the HCA development. Regulators should also retain a process to improve on the selected HCA methodology over time and establish clear timelines for utilities to meet near and long-term HCA goals. Figure ES-2 outlines best practices for stakeholder engagement, drawing from lessons learned in states such as California, Minnesota and New York.

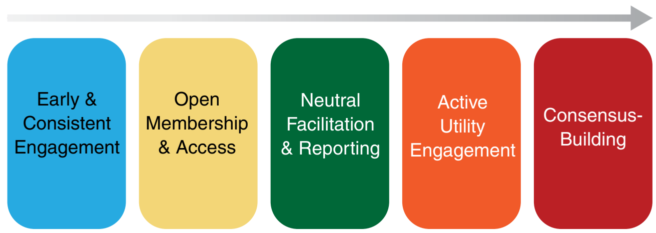
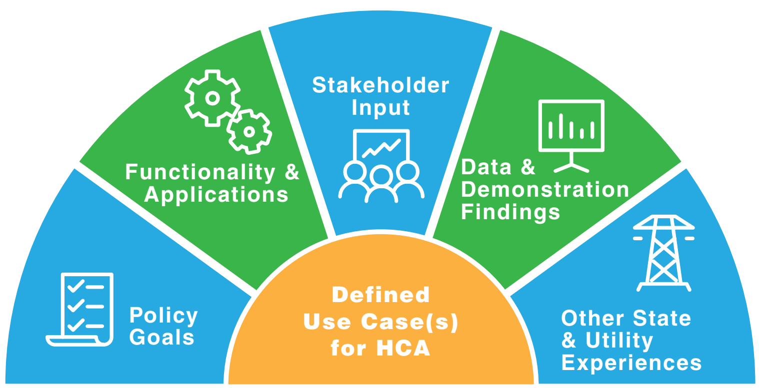


Figure ES-2. Regulatory Stakeholder Engagement Strategies

Select and define the use cases for the HCA with input from diverse stakeholders, ensuring they are clearly designed to address and achieve identified goals, including state energy policy goals. These use cases should inform and guide the development of an HCA methodology and its implementation. As regulators and utilities consider undertaking an HCA, it is critical that all stakeholders carefully consider and select desired use cases for HCA together at the beginning of the process. Defining use cases ensures that the cart is not put before the horse and will also prevent potentially costly and inefficient undertakings that do not produce useable results.

Figure ES-3. Key Elements to Defining Use Case(s) for HCA



Identify criteria to guide implementation of the HCA at the outset. Working through the established stakeholder process to identify and answer key questions regarding the scope, duration and other key elements of the HCA can help ensure a more efficient process throughout (and greater buy-in from all involved). The *frequency of updating* the HCA results, the *extent of the grid covered by HCA*, and *criteria for ensuring transparency* in the selected HCA methodology and its results are all important to discuss and define. In addition, regulators may consider whether to create a phased roadmap for implementation of HCA, depending on the level of sophistication of the utilities and the timeline for achieving state energy goals. However, care should be taken not to create an endless implementation timeline that quickly becomes obsolete or fails to miss near term opportunities for deployment and use.

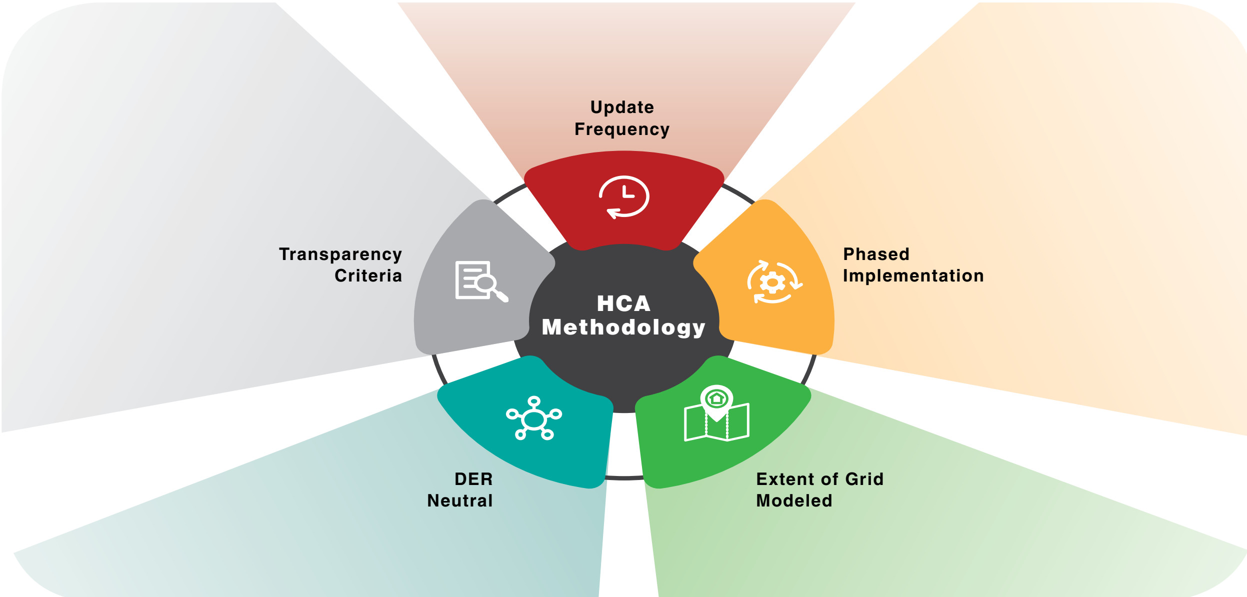


Figure ES-4. Criteria to Guide Implementation of HCA

Develop an HCA methodology (or methodologies) most appropriate to the use cases. Regulators will need to provide sufficient guidance for utilities to clarify what HCA should be capable of doing and how it can be used to support identified goals, such that the final tool is designed appropriately to meet such goals. This can be accomplished by providing clear and specific guidance and ensuring that the methodologies and assumptions are transparent and informative to all involved stakeholders and end-users. Regulators should ensure that the HCA methodology is scalable so that, even under an incremental approach, the full grid and range of DERs can eventually be analyzed. Different methodologies can result in different hosting capacity values due to different technical assumptions built into the models. Given the variety of factors that affect the grid's ability to host a wide range of DERs, it is necessary to select a well-considered methodology for determining hosting capacity based upon its intended use.

Validate the results of the HCA over time. As with any model or analysis, real-world validation can help improve accuracy and functionality over time. Transparency in the methodology and assumptions and ready access to HCA results will ensure that they can be easily validated and any problems with the methodology identified and resolved. Ideally, sufficient information about the methodology should exist so that a third party could perform an independent analysis to validate the results reached by utilities. Regulators will need to consider the most useful manner for utilities to publish and display hosting capacity data, and set milestones over time to evaluate the performance of the HCA, relative to identified goals.

Regulators will need to provide sufficient guidance for utilities to clarify what HCA should be capable of doing and how it can be used to support identified goals, such that the final tool is designed appropriately to meet such goals.

As regulators oversee the implementation of HCAs, there are other key considerations to keep in mind, noted throughout the guide. For example, requiring consistency in approaches and methodologies among utilities (where there are multiple utility services territories within a state) will help simplify the implementation and oversight process, while also ensuring a more consistent and efficient utilization of this tool among DER project developers and customers. Data sharing is another key factor shaping the evolution of the electricity grid, and the data collected and generated as part of an HCA will help utilities, regulators, and DER customers better capture the diverse value streams of DERs. Concerns surrounding data sharing can and should be managed proactively and should not be a reason to not pursue HCAs or related efforts.

In addition, given swift changes to technologies, performance and markets, HCAs should be agnostic to the type of DER analyzed to ensure that it remains useful over time. Technology agnosticism can also help utilities identify opportunities to expand hosting capacity with other DERs and deploy non-wires alternatives as part of utility grid upgrades and investment plans.

Perhaps most importantly, HCAs should not be developed or implemented in a vacuum, and should be considered in the context of other policy choices and how they may impact how DERs are deployed. As consumers and the market responds to new programs, policies and price signals, so too should the HCAs reflect the anticipated and planned changes to DER adoption. More robust DER forecasting methodologies will need to be developed in order to provide greater accuracy of the HCA.

Ultimately, as utilities plan for and pursue (or solicit from third parties) grid infrastructure improvements over time, HCAs can help ensure that DERs are optimized, not discouraged, on the system as an integrated and functional feature of affordable, quality and reliable electricity service provided to all ratepayers.

With this guide in hand, regulators can provide the leadership and direction needed to ensure the process, function, and implementation of HCA supports and enables the critical grid transformations underway across the country.

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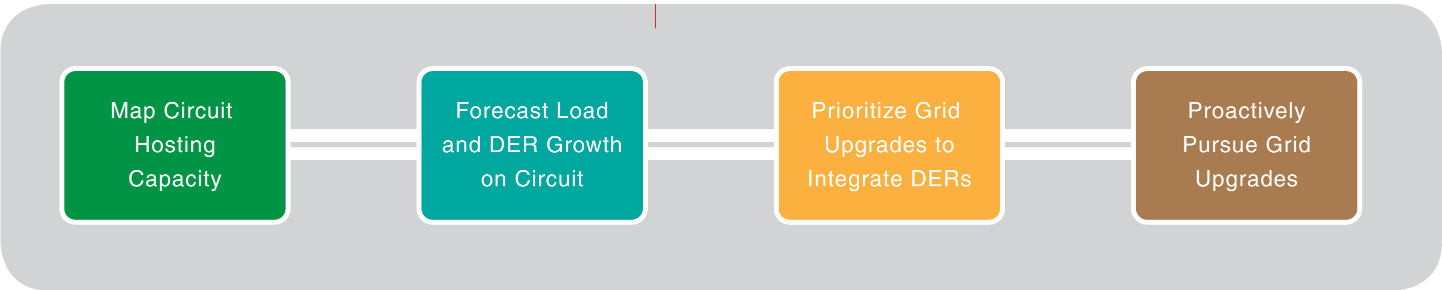
I. Introduction

Hosting capacity analysis, or HCA, has emerged as a key tool for capturing and optimizing the benefits of distributed energy resources (DER)[1] on the grid, while also proactively managing increasing penetrations of DERs and ensuring the reliability of the grid. HCA is used to determine the amount of DERs that the distribution system can accommodate at a given time and a given location. HCA allows utilities, regulators, and DER customers to make more efficient and cost-effective choices about whether to pursue interconnection of a DER technology at a specific grid location by providing data about the amount of new DERs that can be accommodated at a particular node[2] on the grid. Mapping the hosting capacity of the entire distribution grid provides even more powerful benefits: customers can identify optimal locations to install and interconnect DERs; regulators and utilities can develop price signals to direct DERs to locations on the grid where they can provide the greatest benefit; and utilities can better plan for grid infrastructure improvements that expand hosting capacity at locations with high demand for DERs. Ultimately these actions will optimize the deployment of DERs on the system to preserve and improve the quality of service they provide to all ratepayers.

IREC and Sandia National Laboratories set forth the concept of Integrated Distribution Planning (IDP) as an approach to proactive planning for DER growth at high penetrations. IDP consists of four principal components: (1) mapping a circuit's hosting capacity; (2) forecasting the expected growth of DERs on that circuit; (3) prioritizing grid

Hosting capacity analysis, or HCA, has emerged as a key tool for capturing and optimizing the benefits of distributed energy resources (DERs).

Figure 1. Principal Components of Integrated Distribution Planning



upgrades to integrate DERs; and (4) proactively pursuing grid upgrades (including traditional capital upgrades as well as DERs themselves) to meet anticipated grid needs. By combining HCA with DER forecasting, a utility can better plan for grid upgrades to facilitate and enable the integration of forecasted DER growth in specific areas. Regulators and utilities can also steer DERs to the grid locations where they can provide the greatest system benefits at the least cost. States and utilities around the country are beginning to adopt IDP approaches.[4] The widespread adoption of IDP holds tremendous promise for enabling the modernization of the distribution grid, but the hosting capacity piece of the IDP puzzle remains at a nascent stage.

The purpose of this paper is to assist state regulators in guiding and overseeing utilities as they prepare hosting capacity analyses on their distribution circuits. Based on lessons from the handful of states and utilities that have begun to prepare hosting capacity analyses, the paper focuses on the process that will help regulators realize the full promise of HCA in their respective states. The experiences and key takeaways from the states undertaking these analyses are fully outlined in the case studies which can be found in Appendix A. Key process steps discussed in this paper include:

- Definition and selection of use cases[5] for HCA tailored to the needs and goals of their states;
- Selection of the hosting capacity methodology best suited to realizing identified use cases; and
- Establishing rules and criteria to implement and improve on that methodology.

A number of resources exist to guide regulators and utilities in exploring the technical aspects of hosting capacity methodologies.[6] Exploring the technical nuances of those methodologies is beyond the scope of this paper, which will instead highlight some of the tradeoffs between methodologies that may make them more or less suited to the various use cases that regulators may select. In sum, the intent of this paper is to support regulators as they guide and inform the implementation of a hosting capacity analysis, as part of a broader grid modernization or distribution planning effort and in support of their state's near- and long-term energy policy goals.

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II. Hosting Capacity Fundamentals

A. HOSTING CAPACITY DEFINITION

As used in this paper, the term "hosting capacity" refers to the amount of DERs that can be accommodated on the distribution system under existing grid conditions and operations without adversely impacting safety, power quality, reliability, or other operational criteria, and without requiring significant infrastructure upgrades.[7] HCA evaluates a variety of circuit operational criteria—typically thermal, power quality/voltage, protection, and safety/reliability[8]—under the presence of a given level of DER penetration and identifies the limiting factor or factors for DER interconnections.[9] The hosting capacity is the greatest amount of a DER with a specific operational profile, such as that of solar photovoltaics (PV) or an energy storage system, that can be accommodated before a violation of one or more of the technical criteria occurs on a line section or feeder.[10] To provide the accuracy needed to guide distribution-level decision-making and/or inform the interconnection process, the HCA needs to be performed at a granular level (typically at every selected node on assessed feeders) across the entire distribution circuit.

HCA reveals snapshots of the amount of different types of DERs that can be hosted at a particular point in time across the grid. These snapshots are not fixed but change constantly as grid conditions change: that is, as new DERs are interconnected, as new controls are added to the circuit, and/or as load curves shift.

The main factors that drive the amount of DER that can be hosted on the grid, without requiring upgrades or modifications to the distribution system are:

(1) precise DER location,

(2) nature of the load curve on the feeder,

(3) the feeder's design and physical and operational characteristics, and

(4) DER technology.[11]

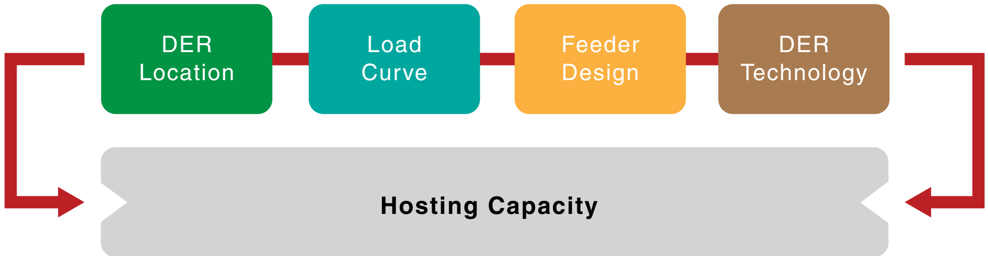


Figure 2. Factors Impacting Hosting Capacity

Distribution Grid Terms:

Distribution Circuit—The conductors and devices downstream of the substation feeder breaker and including all laterals, primary and secondary portions.

Feeder—A single distribution line which connects the substation at primary voltage to laterals or secondary circuits.

Line section—A portion of a distribution circuit between two automatic sectionalizing devices or an automatic sectionalizing device and the end of the distribution line. Automatic sectionalizing devices would typically refer to the feeder breaker or line reclosers, but could include other devices.

Node—A node is a point on a feeder between two line sections. Circuit characteristics may be analyzed at each selected node along the circuit.

The hosting capacity of any given feeder is a range of values, which depend on the specific location and type of resource in question.[12] For instance, a feeder may be able to accommodate 2 MW of solar PV at a node close to the substation but only 0.5 MW (500 kW) at a node further from the substation, or a feeder may be able to accommodate more solar PV with advanced inverters than solar PV without advanced inverters.[13] The hosting capacity also varies significantly between DER technologies, feeder characteristics, such as a voltage class, regulating devices, and load profile.

A well-considered methodology for determining hosting capacity is necessary given the variety of factors that can affect the grid's ability to host a wide range of DERs. IREC has identified three principal categories of methodologies that are currently being tested and employed by utilities to analyze hosting capacity, generally known as the stochastic, iterative, and streamlined methods. These methodologies, including the tradeoffs between them, are described in detail below. There is overlap between the methods, as well as iterations of each type. For example, the Electric Power Research Institute (EPRI) recently developed the DRIVE tool, which EPRI characterizes as a version of the streamlined method.[14] Information has not yet been published detailing the differences between EPRI's version of the streamlined methodology and the streamlined methodology tested in California and discussed below.

Importantly, the methodologies can result in different hosting capacity values due to different technical assumptions built into the models. Certain assumptions, such as how many load hours or nodes are evaluated, may also result in more or less precise hosting capacity assessments. The methodological choices in an HCA can significantly impact whether the results are sufficiently reliable and informative for grid-related planning and decision-making. To achieve a rigorous HCA, regulators and utilities should carefully consider and articulate their goals and use cases at the outset of an HCA effort, and then select and tailor the methodology best suited to achieve those objectives.

B. HOSTING CAPACITY USE CASES

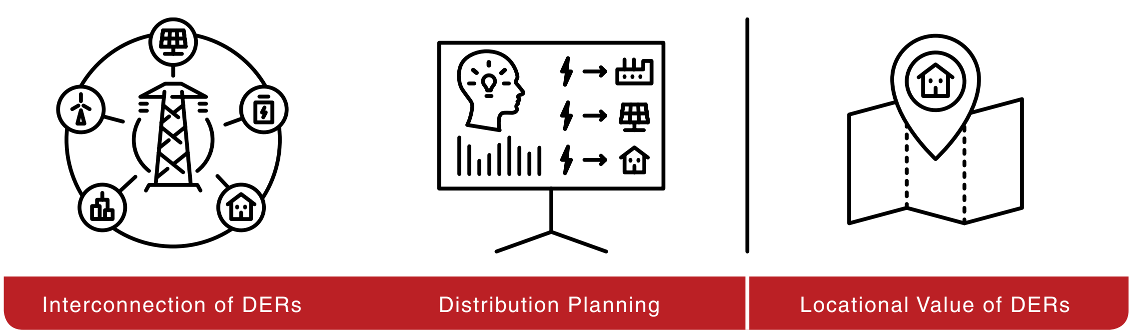
There are two principal applications, or use cases, for an HCA: 1) assist with and support the streamlined interconnection of DERs on the distribution grid; and 2) enable more robust and granular distribution system planning. The third complementary function of an HCA could be to inform pricing mechanisms for DERs based on separate analyses to assess the locational benefits of DERs.

Use cases can be selected to reflect the unique characteristics and identified goals of the state and utility. These use cases should inform and guide the development of an HCA methodology and its implementation. A process should also be in place to refine the selected use cases as new regulatory, social, and technological conditions emerge. The two major HCA use cases—interconnection and planning—as well as the complementary function of optimizing the locational benefits of DERs are discussed in detail below.

As regulators and utilities consider undertaking an HCA, it is critical that all stakeholders carefully consider and select desired use cases at the beginning of the process. Selecting an HCA methodology before defining the use cases puts the cart before the horse; a methodology may need to be dramatically altered or discarded entirely if it turns out to be ill-suited to meeting the state's or utility's goals. As described in the case studies in Appendix A, the failure to consider the use cases prior to selecting the methodologies has resulted in a potential need to revise the methodologies in California. In addition, stakeholders have voiced concerns about whether the methodologies used in Minnesota and New York will actually be able to achieve those states' goals.

As regulators and utilities consider undertaking an HCA, it is critical that all stakeholders carefully consider and select desired use cases at the beginning of the process. Selecting an HCA methodology before defining the use cases puts the cart before the horse; a methodology may need to be dramatically altered or discarded entirely if it turns out to be ill-suited to meeting the state's or utility's goals.

Figure 3. Hosting Capacity Use Cases



Regulators, with input from involved stakeholders, should not only identify desired HCA use cases up front, but they should also do so with specificity. Regulators will need to provide sufficient guidance for utilities to clarify what HCA should be capable of doing and how it can be used to support identified goals so that the final tool is designed appropriately to meet those goals. For example, if more streamlined interconnection processes is the goal, then there should be some early discussions, before the tool is built, around what level of precision in the HCA would be needed to accomplish this objective.

Regulators, with input from involved stakeholders, should not only identify desired HCA use cases up front, but they should also do so with specificity. Regulators will need to provide sufficient guidance for utilities to clarify what HCA should be capable of doing and how it can be used to support identified goals so that the final tool is designed appropriately to meet those goals.

In addition to identifying use cases, regulators may consider identifying specific elements to guide utilities in developing the HCA methodology. Such elements can include:

(1) specification of the desired level of granularity (i.e., performing HCA down to the line section and node level),

(2) specification of the desired level of scalability (i.e., whether HCA should be performed across the entire distribution system at the outset or only on those feeders with the greatest projected DER demand, and whether it should be performed on single-phase feeders in addition to three-phase feeders),

(3) guidance for repeatability as new DERs are interconnected and feeder characteristics change,

(4) transparency in the methods and results,

(5) validation of techniques to ensure confidence in the results obtained through the HCA,

(6) readily accessible data for easy use by consumers, developers, and planners,[15]

(7) frequency of publication (i.e., annual, quarterly, real-time, etc.), and

(8) types of DERs to be modeled (i.e., distributed generation, energy storage, electric vehicles, or all DERs).

At the same time, regulators may want to avoid being overly prescriptive in their goals so that utilities have the space to develop a workable tool for their service areas in a timely manner. Conducting an open dialogue about the pros and cons of approaches that have been piloted by states and utilities (including those discussed in the case studies in Appendix A) can help regulators determine how best to strike a balance between prescribing detailed goals and allowing some flexibility for utilities.

III. Selecting the Hosting Capacity Use Cases

The use cases that regulators, stakeholders, and utilities select for HCA will inform the choice of HCA methodology and the guidelines for deploying it, such as the frequency of updating and the portions of the grid to be covered by the initial HCA rollout. The two primary use cases for HCA— interconnection and planning—are described herein. In addition, the following section includes a discussion of how the HCA can be used in a complementary fashion along with efforts to identify locational benefits of DERs to fully optimize DER siting.

A. INTERCONNECTION USE CASE

In many states, interconnection standards and utility interconnection processes are not keeping pace with DER growth and are replete with inefficiencies and time- and resource-intensive protocols that cause backlogs and interconnection gridlock.[16] For example, a 2015 study by NREL found that utilities in five states failed to meet review time requirements for up to 58% of residential and small commercial solar interconnection applications.[17] In states, such as in North Carolina, where there have been significant amounts of larger-scale distributed generation deployed (e.g., projects 1 MW or greater), the utilities have fallen drastically behind on their ability to keep up with the interconnection study process. As an example of this interconnection gridlock in North Carolina, Duke Energy regularly takes more than a year to complete the study process for the interconnection of a 2 to 5 MW solar PV generator on its distribution system.[18]

While a number of factors can contribute to interconnection gridlock, a prominent one is that customers wanting to adopt DERs have traditionally had limited access to information about the conditions on the grid to help them select optimal and appropriate sites and design projects that are responsive to (and not in violation of) the available hosting capacity at their chosen site. Another barrier to streamlined interconnection processes is the time- and bandwidth-limited utility staff who are tasked with processing increasing volumes of DER interconnection requests. Even requests that are not likely to move forward—because they require costly grid upgrades to accommodate them on the system—still require the time and attention of utility staff to review and study the interconnection applications. Providing customers with more information upfront, such as through an HCA and accompanying distribution system map, can help reduce the number of ill-suited projects proposed and result in better designed projects that are within the hosting capacity at that particular site and thus could require fewer utility resources to be spent individually studying their impacts.[19]

1. Streamlining the Interconnection Processes for DERs

HCA can help address the challenges of interconnection gridlock in two important ways. First, HCA can provide reliable data about the hosting capacity of nodes across the circuit for use in streamlining and expediting the review of interconnection applications. When a customer seeks to interconnect at a given node, the utility can check to see if its proposed DER project falls within the hosting capacity value for that location. If it does, the project can be approved to interconnect with little to no additional review or study with assurance that it will not compromise system safety or reliability. Second, if the project falls outside the identified hosting capacity, it can be directed to the study process or the customer can be provided information that allows her to redesign the project to fit within the hosting capacity limits (and/or address known constraints through system or operational redesign). Perhaps most importantly, HCAs based on the actual engineering specifications of the circuit are able to yield *more precise indicators of the amount of DER that can be accommodated than the simplified interconnection screens in place in many states today*,[20] such as the 15 percent of peak load screen commonly used to determine whether a project connecting to the distribution grid will raise islanding concerns or cause backfeed beyond the substation.[21] By providing a more accurate and efficient method of reviewing a project, HCA allows more DERs to connect to the grid more promptly, *without compromising grid safety and reliability*.[22]

Ultimately, with frequent updating of HCA, utilities can move toward automated interconnection processes. Interconnection customers can also use the detailed HCA data to identify potential project alternatives that would help them avoid hosting capacity limits, such as use of on-site storage to shift peak demand or interconnection agreements that allow curtailment during limited peak hours of the year.[23]

2. Maps to Identify Grid Locations for DERs

Mapping the hosting capacity of entire circuits and making these results publicly available can help guide DER customers to locations where they can provide more value to the grid and minimize project costs. User-friendly maps displaying HCA results and downloadable data files will also help customers understand what project sizes and technologies can be most easily accommodated in a particular location, which can help them better predict the cost and timeline of the interconnection process.[24] Giving customers the ability to self-select optimal interconnection sites will in itself speed up the interconnection process by channeling applications to the grid locations where they are most likely to be quickly approved. Early grid mapping efforts and adoption of pre-application reports,[25] in states such as California and Hawaii, have been widely accepted as a useful tool by both DER customers and utilities. They appear to be positively redirecting projects and reducing the number of speculative or non-viable projects that ultimately seek to interconnect.[26]

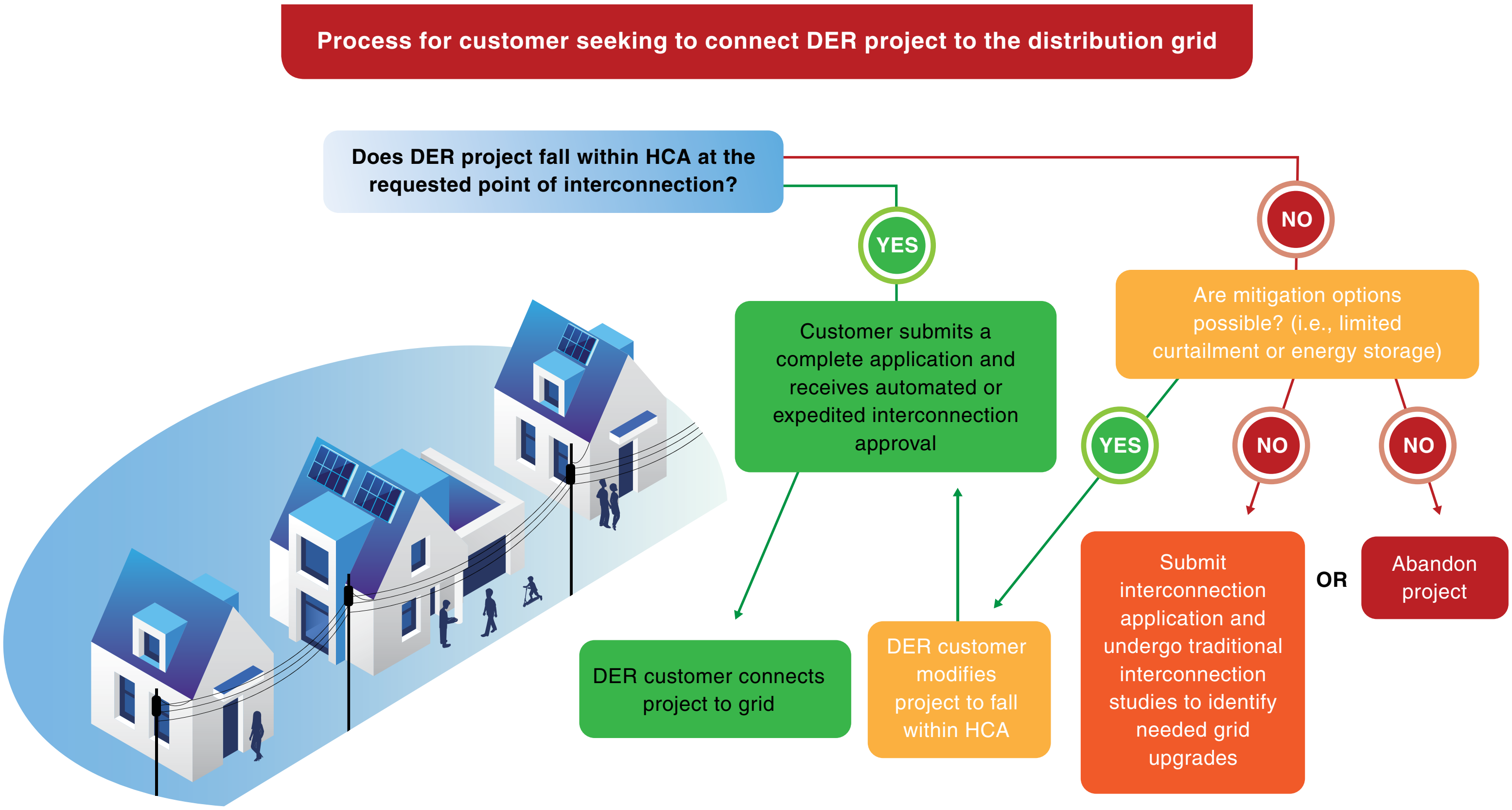


Figure 4. Illustrative Interconnection Use Case for HCA

As discussed below, an HCA map can also be combined with efforts to identify precise locational values to further optimize DER siting.

When interconnection is selected as a use case for HCA, regulators should ensure that the methodology chosen and implemented by utilities yields sufficiently reliable, robust, and granular results and is deployed with sufficient frequency to achieve identified goals and use case functionality. For example, the accuracy of the hosting capacity results is critical to ensuring safe and reliable interconnection while also increasing efficiency and avoiding an overbuilt distribution system. Frequency and accuracy are closely connected and impact the usefulness of the tool for more streamlined interconnection processes. Maps and data files should be updated with new HCA results each time they are generated to ensure that customers have the most current information to make their siting and application decisions.

3. State Experiences with the Interconnection Use Case for HCA

Early experiences in three states demonstrate the value of setting forth interconnection as a use case at the *beginning* of the HCA process (see the case studies in Appendix A for more details regarding individual state experiences).

1 of 1

Asset Info | DER Capacity

Feeder name: BULLARD 1107 Zone Id:253961107.001

DER	Zone DER Capacities (kW) Minimal Impacts	Zone DER Capacities (kW) Possible Impacts	Substation DER Capacities (kW) Feeder Limit	Substation DER Capacities (kW) Substation Bank Limit
Uniform Generation (Inverter)	1,492	–	1,492	10,252
Uniform Generation (Machine)	959	1,087	1,087	7,614
Uniform Load	2,161	3,420	3,420	3,420
PV	2,161	2,294	2,294	15,519
PV with Storage	2,161	2,552	2,552	17,232
PV with Tracker	1,836	–	1,836	12,486
Storage – Peak Shaving	1,599	–	1,599	10,622
EV – Residential (EV Rate)	2,161	3,708	6,409	19,000
EV – Residential (TOU Rate)	2,161	3,708	5,351	6,804
EV – Workplace	2,161	3,708	4,852	8,900

Notes:

- Integration Capacity Values last updated on July 1 2015
- Capacity values are based on existing system conditions and do not consider queued projects that are not installed. Please refer to public queue status to see if capacity is possibly already being used by queued projects.
- Capacity values do not guarantee Fast Track approval and/or do not exempt customers from the Interconnection process.
- Capacity values are mutually exclusive. Using available capacity for one DER and/or zone will affect other DER and/or zone results.
- Capacity values do not take into account possible impacts to the Transmission system.
- Capacity values are results based on a new theoretical methodology as part of PG&E's Distribution Resource Plan (DRP) filed July 1 2015 to the CPUC. The methodology and results will be improved and refiled in a phased approach outlined in the DRP.

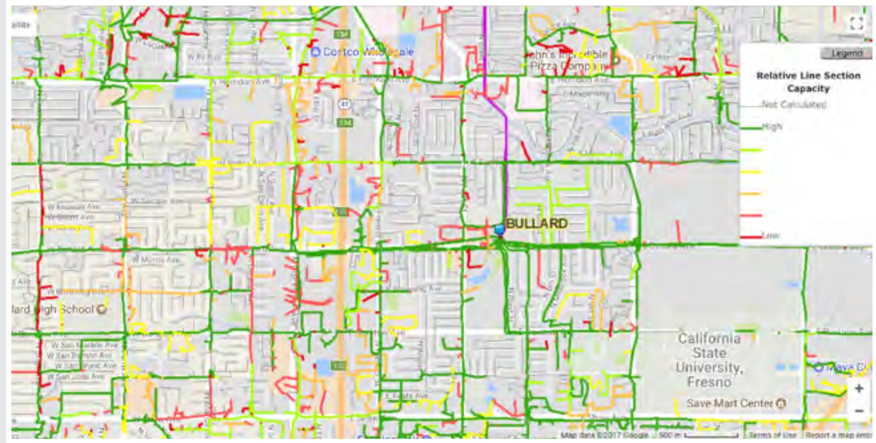


Figure 5. Sample Hosting Capacity Map & Feeder Data

Source: *PG&E, Demonstration A, Integration Capacity Map, available at: https://www.pge.com/b2b/energysupply/wholesaleelectricsuppliersolicitation/PVRFO/PVRAMMap/index.shtml*

In California, the Public Utilities Commission (CPUC) initially ordered the state's major investor owned utilities to prepare an initial integration capacity analysis (synonymous with a hosting capacity analysis) as one part of a Distributed Resources Plan (DRP).[27] The CPUC's guidance ruling specified that one of the goals of the analysis was to "improve the efficiency of the grid interconnection process" and included some specific details in terms of number of circuits, granularity, and modeling methods.[28] After the utilities completed their initial limited deployments, the CPUC took comments and then authorized a more comprehensive demonstration project that would ultimately test out two different methodologies, in consultation with a working group of diverse stakeholders.[29] The lesson learned from this process was that to properly evaluate the methodologies tested, use cases needed to be developed that identified the state's concrete interconnection goals. After identifying those goals more precisely and developing the use cases, the majority of the working group concluded that the streamlined methodology, as tested, was inadequate to meet the goals and that the iterative methodology was better suited to achieve the accuracy and precision required for the interconnection use case.[30] The CPUC ultimately adopted the recommendations of the working group and ordered the utilities to deploy the iterative methodology system-wide for the interconnection use case.[31] The utilities in Hawaii are using a method similar to the iterative method selected in California for use in the interconnection process,[32] and they have identified interconnection as a clear use case for hosting capacity in the state, although the Commission has not yet approved its incorporation into the interconnection procedures.[33]

In New York, by contrast, as part of the Distribution System Implementation Plans (DSIP) docket[34] within the much-larger New York Reforming the Energy Vision (NY REV), the Joint Utilities[35] established the goal of providing HCA maps for customers to use in identifying optimal interconnection grid locations for large-scale solar PV. However, the utilities declined to clearly identify and define interconnection as a use case for the HCA, instead noting only that stakeholders were interested in "exploring the possible implementation of interconnection use cases for hosting capacity."[36] Despite comments from stakeholders urging the New York Public Service Commission (NY PSC) to clearly define use cases and to require examination and transparency regarding whether the selected methodology provides results accurate and reliable enough to meet those use cases, the NY PSC declined to further investigate.[37] The Joint Utilities are thus moving ahead with EPRI's DRIVE Tool (a version of the streamlined method) for their HCAs, but considerable uncertainty remains about whether HCAs developed using this method will help process interconnection requests and shorten timelines, or even whether the current results can accurately guide customers to appropriate interconnection locations. The Joint Utilities' HCAs are also unlikely to be useful in informing scenarios for other DERs, including non-solar distributed generation, smaller-scale solar, distributed energy storage, and/or electric vehicles.

Lastly, the Minnesota Public Utilities Commission (MN PUC) has identified some value to using HCA to inform interconnection as a long-term goal of Xcel Energy's (the state's major investor owned utility) HCA effort, but it has not gone so far as to precisely define the use case.[38] The MN PUC required Xcel Energy to "conduct a distribution study to identify interconnection points on its distribution system for small-scale distributed generation resources,"[39] but the initial distribution-system study released by Xcel Energy announced that its HCA results were "not intended to be used for approving interconnection requests," and did not to set forth a process or timeline for producing HCA results that would help to streamline interconnection approvals.[40] After considering stakeholder written and oral comments, the MN PUC required Xcel to file hosting capacity reports with sufficient detail to provide customers "with a starting point for interconnection applications."[41] The MN PUC also directed Xcel to provide information requested by staff and parties on the accuracy of its HCA results, including by conducting a comparison of results in its 2016 report with actual hosting capacity determined through interconnection studies.[42] This information was provided in a subsequent filing[43] and the MN PUC and parties are evaluating the results of the accuracy assessment and what it means for next steps.

As these state experiences illustrate, commencing a hosting capacity process without clear uses and goals creates a real risk of duplicative expenditures by utilities, which are ultimately borne by ratepayers. For instance, if a state selects an HCA methodology not suited to interconnection processing and invests in optimizing that method, utilities will not only expend substantial resources processing individual interconnection applications in the interim, but they may ultimately expend far more resources switching in the future to an HCA method capable of streamlining the interconnection process if that is ultimately desired. To avoid these pitfalls, IREC recommends that regulators learn from the comparative analysis done in California and involve utilities and stakeholders in early discussions about whether interconnection is an appropriate use case for the HCA. If it is adopted, regulators should require utilities to develop and implement an HCA methodology appropriate to that use case.

As these state experiences illustrate, commencing a hosting capacity process without clear uses and goals creates a real risk of duplicative expenditures by utilities, which are ultimately borne by ratepayers.

B. PLANNING USE CASE

Planning is the other primary use case for HCA. Although distribution planning is often framed as an important goal for HCA, no regulator or utility has specified exactly how HCA will be used in the distribution planning process. Failing to specifically define the planning use case can impede regulators' ability to ensure that the HCA methodology developed and deployed will ultimately serve the planning goals. While fewer details are available about the planning use case, based on a lack of concrete examples to draw from, there are emerging grid planning reforms that states are adopting as part of broader grid modernization efforts, which provide useful guidance to regulators considering how to best approach the planning use case for HCAs.

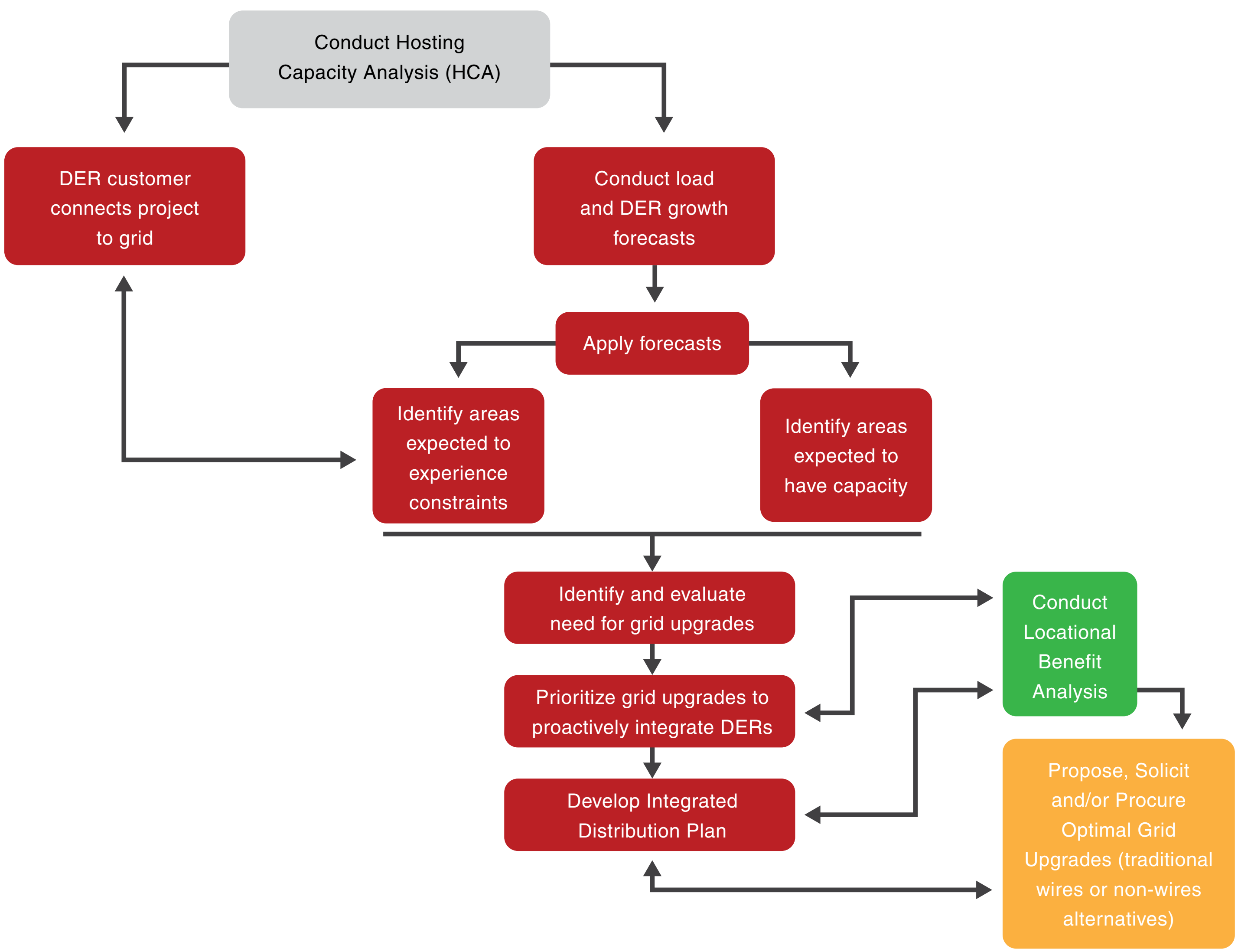
1. Shifting to Proactive, Integrated Distribution Planning

Traditionally, distribution system planning has remained within the exclusive purview of the utilities, and there has been minimal transparency or public involvement in the planning process.[44] In addition, utility-owned assets are normally the preferred solutions to meet identified distribution needs.[45] However, this traditional model for distribution system planning is continuing to evolve with, among other changes, increasing penetration of distributed generation, increased deployment of demand-response technologies, growing customer investments in energy storage and energy management technologies, and policy directives to utilities to build cleaner, more reliable, and more efficient electricity systems. In response to these new conditions, planning the grid for the future warrants new approaches that take into account the growth, benefits and impacts of DERs on the grid, including revised load forecasting and the ability of DERs to offer "non-wires" solutions to distribution grid needs. Both vertically integrated and deregulated states are beginning to recognize that the role of the distribution system is fundamentally changing and the planning process must evolve accordingly.[46] In response, regulators are requiring increasing transparency in the distribution planning process, including by requiring utilities to publicly file distribution resource plans and to increase access to grid data.[47]

The Integrated Distribution Planning process consists of four basic components: (1) mapping the hosting capacity of the system; (2) forecasting DER growth and load growth, (2) identifying and prioritizing grid upgrade needs by comparing growth to available circuit hosting capacities, (3) proactively pursuing grid solutions, including non-wires alternatives, to meet identified needs and integrate and optimize DERs on the grid.[48]

As depicted in Figure 6, an HCA is a central component of more proactive, integrated distribution system planning. Among other functions, an HCA can facilitate utility efforts

Figure 6. Illustrative Planning Use Case for HCA



to integrate DERs under high penetration scenarios, to meet renewable or distributed energy mandates, and to procure and/or deploy DERs as cost-effective, non-wires alternatives to traditional grid investments.[49]

As an alternative to the current reactive process to making distribution system upgrades (wherein the customer with the DER project that triggers the need for a grid upgrade is expected to bear the entire upgrade cost), an HCA can help utilities (and regulators) more proactively identify in advance strategic locations where cost-effective infrastructure investments can increase hosting capacity,[50] thereby benefiting a number of DER customers and other ratepayers. This proactive planning approach permits more efficient and economic allocation of system upgrades, while also optimizing benefits across sources of generation and load and across any number of distribution feeders. It can also speed up the process of interconnecting DERs since steps to expand hosting capacity will have been taken, where appropriate, prior to applications being submitted. By planning for and performing proactive upgrades, utilities can also consider ways to spread upgrade costs more evenly between parties that benefit from them (thus avoiding the scenario where a single customer gets left holding the bag for costly grid upgrades, which ultimately improve hosting capacity for other customers that come after them), including both customers with new generation and load on the distribution system. Lastly, they can procure third-party solutions, including DERs, to meet projected grid needs in lieu of, or in addition to, traditionally procured infrastructure investments.[51]

Clearly defining IDP as a goal of the HCA use case can help ensure that the analysis is fully supportive of this more proactive approach to grid planning. In addition, to ensure that planning goals are realized, it may be necessary to make further improvements to the interconnection processes to facilitate DER integration and capture "the value of DER linked to planning results and opportunities to realize net benefits for all customers through the use of DER provided services."[52]

By articulating with precision the goals of the HCA planning use case, regulators can ensure that an effective HCA tool is developed. For instance, where IDP is part of the planning use case, the HCA may need to be run on the entire distribution system under different scenarios about assumed DER growth overlying varying time horizons.[53] The HCA results would enable the utility to determine when and where the distribution grid is projected to reach its hosting capacity such that solutions can be deployed or procured *before* that location is closed to new DER projects. Regulators should consider how frequently the HCA needs to be run and the level of precision in the HCA results necessary to meet the planning use case goals.

2. Using HCA to model and plan for changes in customer behavior

An HCA, as part of the planning use case, can also be used as a tool to help understand how other policy choices may impact how DERs are deployed and how the hosting capacity of the distribution system would change as a result. For example, if a utility is exploring the impact of time-of-use rates for electric vehicle owners, the HCA can be

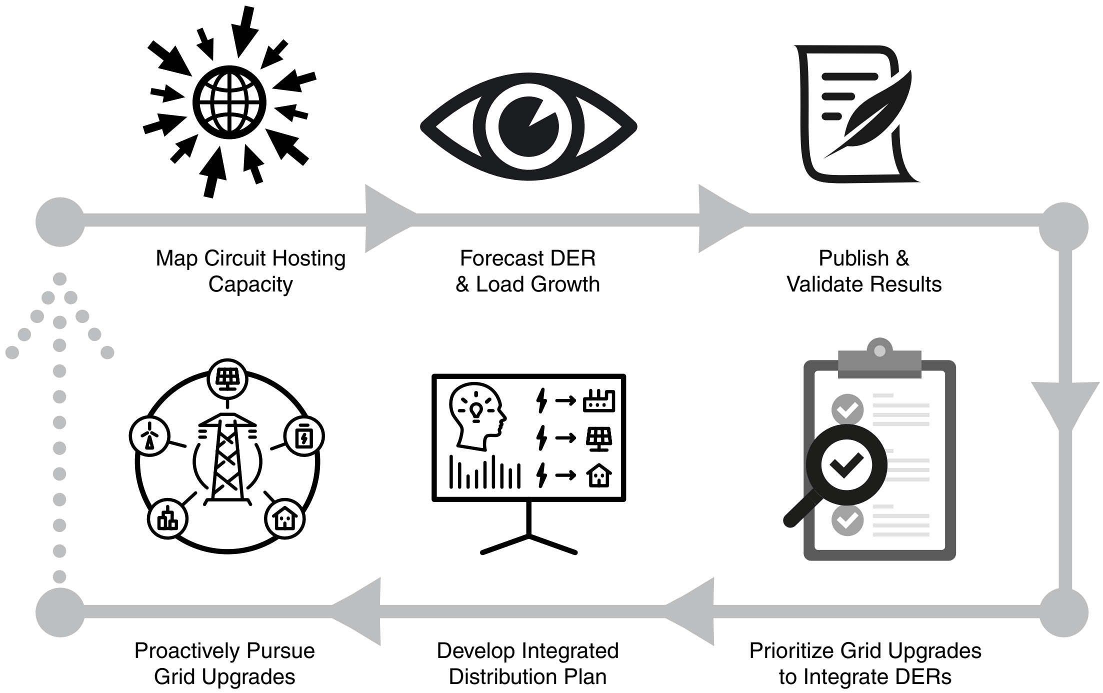


Figure 7. Integrated Distribution Planning (IDP)

layered with a corollary customer behavior analysis to see what impact, if any, such a change would have on the needs and capabilities of the distribution system under certain adoption scenarios. While this concept is not yet being implemented, there is potential to utilize the HCA in conjunction with other system planning tools to better understand how various policies and shifts in customer behavior can alter the distribution grid (which in turn should inform the long-term planning process). This aspect of the planning use case is currently under consideration in the long-term refinements phase of California's ICA working group where parties are discussing its feasibility and value and whether the existing methodologies are suited to providing accurate results for this use.[54]

3. State Experiences with the Planning Use Case for HCA

Among the states and utilities currently exploring HCA as part of their grid modernization proceedings, most have identified a role for hosting capacity in the planning process, but none have defined the planning use case with specificity. In New York, the Joint Utilities have been vague in setting forth planning as an explicit HCA use case and in providing information on how they intend to use the results of HCA to inform or improve the planning process.[55] Likewise, even after some discussion, the ICA working group in California concluded that while there was agreement that a planning use case was valuable, there needed to be further refinement of its details in order to properly evaluate the methodologies used to serve the use case.[56] As a result, stakeholders in both states have not yet had the opportunity to fully review and provide feedback and guidance on the HCA methodology most appropriate to support planning goals.

As with the interconnection use case, states are likely to get the greatest benefits from the HCA in the planning context if they clearly consider the goals of the distribution planning process and articulate a vision for how the HCA will be used to help achieve those goals. As states and utilities work to update distribution planning protocols in response to the demands and changes of the evolving electricity grid, the HCA should be considered an important tool to help achieve a more efficient, equitable and reliable grid.

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C. A COMPLEMENTARY FUNCTION: OPTIMIZING LOCATIONAL BENEFITS OF DERS

DERs have the potential to provide a range of electrical services beyond generation, capacity, and storing energy for later use. These include increasing transmission and distribution capacity, voltage support, reliability and resiliency services, equipment life extensions, and ancillary services.[57] As Southern California Edison has reported, by providing these services, DERs can increase the hosting capacity of feeders and "offset some of the load growth in an area and mitigate or even eliminate the need for capital-intensive upgrade projects."[58] DERs also provide additional environmental and public health benefits.[59] However, DERs will have greater energy, capacity, and grid values in some locations than others, depending on the characteristics and needs of the feeder and on the range of electrical services that the particular DER can provide.[60] When DER siting is effectively matched to grid needs, the DER customer, the utility, consumers, and other DER interconnection applicants all benefit.

Recognizing that the benefits of DERs may be, in some cases, location-specific has led some states to begin to develop tools to assess and identify values for DERs at precise locations on their distribution system. Separate from HCAs, locational benefits analyses can in theory be used to facilitate the matching of DER siting with grid needs by assigning greater or lesser value to DERs based on the location-dependent benefits they provide.[61] When the results of locational benefits analyses are combined with accurate hosting capacity and DER forecasting results, utilities and states will theoretically have a more robust suite of tools that can be used to deploy, direct and incentivize DERs to "optimal" grid locations (low cost and/or high benefit locations). Using these tools, programs and tariffs can then be designed to encourage DERs to operate in an optimal manner (bringing the greatest benefits to the grid) and provide compensation to the DER customers providing the benefits. "The objective is to achieve net positive value (net of costs to implement the DER sourcing) from DER integration for all utility customers."[62] However, it should be noted that extant state efforts on locational benefits analyses are not without controversy and there is not yet agreement on the methodology and assumptions underpinning such analyses (such nuances are important but are beyond the scope of this report, and thus are not discussed further).[63]

While locational benefits are not a direct use case for the HCA, since a separate modeling effort is required to identify these values on the system, the HCA is an important complementary tool to optimize locational benefits of DERs on the grid.

While locational benefits are not a direct use case for the HCA, since a separate modeling effort is required to identify these values on the system, the HCA is an important complementary tool to optimize locational benefits of DERs on the grid. At the same time that California has been working to develop the HCA, it has been developing a Locational Net Benefits Analysis (LNBA) that will identify locations where the low costs and/or high benefits of DER deployment favor increased DER activity.[64] California has proposed an updated distribution planning process that will combine the HCA with DER forecasts to develop an annual picture of the grid updates needed to support DER growth.[65] DER providers would then have an opportunity to propose DER solutions to grid needs, based on the HCA and the LNBA.[66] California may explicitly direct utilities to prioritize grid upgrade projects at locations that have both low hosting capacity and high net benefits.[67] New York is working on a similar effort through their Value of Distributed Energy Resources (VDER) proceeding. There, the state has begun to implement a valuation framework aimed at more granular determination of the temporal and locational values of DERs.[68] While the state has not yet taken this step, it could eventually pair the VDER with New York's HCA. This location-based valuation information will allow customers to assess the full costs and benefits associated with potential DER sites and direct their efforts to the most cost-effective locations.

IV. Select a Hosting Capacity Methodology Suited to Defined Use Cases

After selecting and defining use cases, the next process steps are to develop an HCA methodology (or methodologies) most appropriate to the use cases and to select criteria for implementation. Regulators play a critical role in both these steps. Clear and specific guidance from regulators ensures that the HCA effort does not become balkanized, with each utility employing a different methodology with varying suitability to statewide use cases. Regulators can also require that the methodologies and assumptions are transparent, thus ensuring the HCA produces results that are informative and instill confidence in how they are derived. Importantly, regulators also play a critical role in ensuring that the HCA is designed to address and achieve state energy policy goals.

To ensure HCA efforts are meaningful for all involved stakeholders and end-users, regulators should set up a process through which they work with utilities and stakeholders to select and refine HCA methodologies and set forth implementation rules. Ideally, this process should involve one or more working groups consisting of utility and non-utility participants with oversight from regulators to guide the HCA development. Utility tests of HCA methodologies can help the working group evaluate and refine the methodologies to meet identified use cases. Regulators should also create a process to improve on the selected HCA methodology over time and establish clear timelines for utilities to meet near and long-term HCA goals.

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A. THE METHODOLOGIES: STREAMLINED, ITERATIVE, AND STOCHASTIC HOSTING CAPACITY METHODS

There are an array of HCA methodologies under development and more likely on the horizon. For ease of discussion we have identified three primary methodological categories: streamlined, iterative and stochastic. They are briefly defined as follows:

- **The streamlined method** applies a set of simplified algorithms for each power system limitation (typically: thermal, safety/reliability, power quality/ voltage, and protection) to approximate the DER capacity limit at nodes across the distribution circuit.[69]
- **The iterative method** directly models DERs on the distribution grid to identify hosting capacity limitations. A power flow simulation is run iteratively at each node on the distribution system until a violation of one of the four power system limitations is identified.[70] The iterative method is also sometimes referred to as the detailed method.
- **The stochastic method** starts with a model of the existing distribution system, then new solar PV (or other DERs) of varying sizes are added to a feeder at randomly selected locations and the feeder is evaluated for any adverse effects that arise from this random allocation. The results are a hosting capacity range.[71]

While there is overlap between the methods, there is still considerable variation among the three methods in terms of basic methodological choices, results, and assumptions. Utilities and commissions may be tempted to simply select the HCA methodology that will be the least costly and least computationally complex to implement. For instance, the New York Joint Utilities and Xcel Energy in Minnesota have selected HCA methodologies based on a version of the streamlined hosting capacity method developed by EPRI—the DRIVE tool—possibly due to its computational efficiency relative to iterative methods and the off-the-shelf nature of the tool being offered by EPRI.[72] But experience from California's detailed HCA demonstration projects has shown that the version of the streamlined method used by the California utilities was not appropriate for certain use cases, particularly interconnection. It is not yet clear whether any differences between the streamlined method used in California and the one deployed by EPRI result in appreciably different outcomes, but it is clear that EPRI has not identified interconnection as a direct use case for the DRIVE tool.[73]

The failure to select an appropriate HCA methodology at the outset can lead to wasted time and money for utilities and their ratepayers if utilities must later develop and deploy a different method that is better suited and/or more appropriate to achieving the identified goals or policy objectives. As such, it is important to carefully select the methodology best suited to the state's use cases and regulatory goals. To the extent a state or utility chooses to pursue a more phased approach to HCA, a clear framework for moving through the phases and a process for iterating on and improving the HCA over time should be identified at the outset of the effort.

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It is important to recognize that the HCA methodologies available today will likely evolve and improve over time with increased use as a variety of utilities deploy them. As multiple utilities deploy and trial different methods, stakeholders are learning more about the benefits and drawbacks of each. However, over time it will likely be far less resource intensive if a consistent methodology (or methodologies) can be available and applied "out of the box" for utilities beginning the process. EPRI's DRIVE tool is a step in this direction. However, as a proprietary tool, questions remain about its capabilities and level of transparency that need to be resolved before it is clear whether this is an appropriate methodology for widespread deployment. Despite the fact that extant tools are apt to evolve over time, state regulators should not hesitate to begin the process of initiating stakeholder efforts and proceedings to define goals, identify use cases, assess utility needs, and set a timeline for statewide implementation. HCA is not only a timely tool that all states and utilities should begin exploring, but early efforts will establish an important foundation of transparency, accuracy and stakeholder consensus once the tool is adopted and implemented. Rather than wait for the perfect HCA methodology to emerge, regulators can take initial steps to gain familiarity and understanding of the different HCA methodologies, their function, their capabilities, and their limitations.

Along with selecting a methodology, regulators should carefully consider the criteria that will guide its implementation.

B. IDENTIFY CRITERIA TO GUIDE IMPLEMENTATION OF HCA

Along with selecting a methodology, regulators should carefully consider the criteria that will guide its implementation. For instance, regulators may wish to consider:

(1) **Phasing:** Regulators may consider whether to create a phased roadmap for implementation of HCA. New York utilities, for instance, have proposed a four-stage roadmap, "with each subsequent stage increasing in effectiveness, complexity, and data requirements."[74] If a phased approach is used, regulators should ensure that the tools developed and deployed in earlier stages are compatible with the goals of later stages, and the phasing reflect the priority of the state's goals.

(2) **Frequency of updating:** Will HCA results be updated in real-time, weekly, monthly, annually, or on some other time scale? For interconnection automation and streamlining purposes, very frequent HCA results across the entire grid may be necessary. For planning purposes, less frequent updating may be required if scenarios are only needed on a periodic basis (such as annually or as appropriate). Regulators may also consider regular updating (weekly or monthly) of results for the entire grid, coupled with targeted updating of particular grid segments for interconnection purposes. For instance, the hosting capacity of the entire grid could be mapped annually, and these results could be updated incrementally each time the hosting capacity of a feeder is assessed as part of the interconnection process. The frequency of updates should align with the goals and use cases, though tempered by cost and technical feasibility.

(3) The extent of the grid covered by HCA: Will the entire distribution grid be mapped at the outset, or will only high priority portions of it be mapped initially, coupled with incremental expansion until the entire grid is analyzed? The California utilities, for instance, mapped all three-phase lines in the test areas and are exploring expanding the HCA to single-phase lines and reserving for future analysis interactions with the transmission system (such iteration of the tool is a good example of how HCA efforts can be phased over time to become more sophisticated and robust). Xcel Energy in Minnesota has proposed excluding feeders serving low voltage networks in downtown Minneapolis and St. Paul areas, which have not been previously modeled.[75] Regulators should ensure that the HCA methodology is scalable so that, even under an incremental approach, the full grid can eventually be covered.

(4) DER Neutral: Making HCA agnostic to the type of DER will ensure that it remains useful as technologies and their market saturation change over time. Agnosticism is also essential for the HCA to be capable of identifying ways to expand hosting capacity or use non-wires alternatives. Under direction of the California PUC, California utilities have, for this reason, provided "agnostic" hosting capacity values "that can be used by DER providers to analyze other DER portfolio combinations."[76] They have also made an "ICA translator" available to users to determine the hosting capacity values for different types of DERs.[77] In contrast, New York and Minnesota are just focusing on solar of a certain scale in their initial analysis, and it appears that Pepco's approach is also focused only on PV.[78]

(5) Transparency Criteria: Regulators should carefully set forth the criteria for ensuring transparency in the selected HCA methodology and its results. For instance, utilities should be open about the methodology selected and any assumptions built into it. Ideally, third-parties should be able to independently test and validate the methodology to ensure its accuracy and reliability. Where multiple utilities operate in a state, regulators may also consider requiring utilities to run their respective methodologies on a test circuit and compare results. Utilities should also be open about any limitations in their analysis—i.e., to what extent it is limited in capturing the HCA under highly distributed DER scenarios, whether anticipated DER additions are built into the analysis, whether certain feeders or feeder types are excluded, whether the methodology relies on any heuristics, etc.[79]

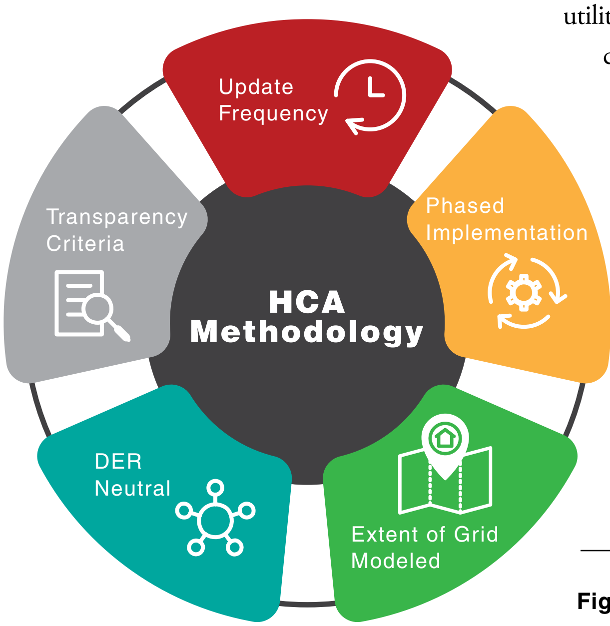


Figure 8. Criteria to Guide Implementation of HCA

C. VALIDATE RESULTS

Transparency in the methodology and assumptions and ready access to HCA results will ensure that they can be easily validated and any problems with the methodology identified and resolved. Ideally, sufficient information about the methodology should exist so that a third party could perform an independent analysis to validate the results reached by utilities. Running and publishing results on test circuits and comparing actual interconnection study results will also assist in the validation process. In states like California with multiple utilities, regulators may consider requiring the utilities to run their HCA analysis on a test circuit and publicly compare results. In doing so, the California utilities were able both to confirm that they are aligned on methodology, producing largely consistent results on the test circuit,[80] and to identify areas where their different software packages and model simulations led to discrepancies so that any bugs can be worked out.[81]

D. IDENTIFY HOW DATA WILL BE SHARED

Data sharing is a key factor shaping the evolution of the electricity grid, and the sharing of data produced by the HCA will significantly impact its value as a next generation grid tool. In the hosting capacity context, data sharing enables the validation of results, allows customers to evaluate potential locations for DER siting and enables third parties to compete in offering non-wires alternatives for grid upgrades to expand hosting capacity.

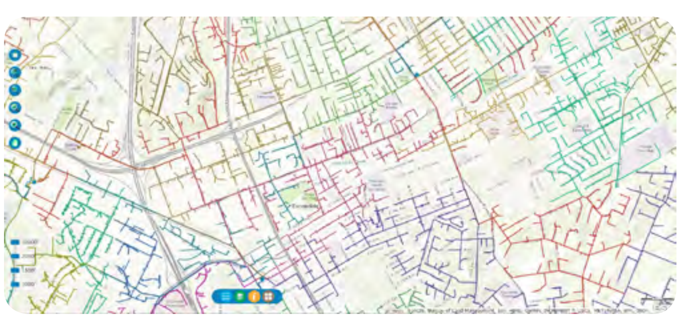
Regulators will need to consider the most useful manner for utilities to publish and display hosting capacity data.

1. Hosting Capacity Maps

Maps illustrating the hosting capacity of grid sections can be a useful tool to enable easy visualization of hosting capacity results.[82] Maps provide a high-level display of hosting capacity values on feeders throughout a circuit. Early examples of hosting capacity maps have employed color-coding of line segments and feeders according to their hosting capacity range to help customers easily identify those grid sections where DERs can be most readily interconnected.[83] They have also used quick-display boxes, allowing the viewer to easily see summary hosting capacity information for a given node or feeder.

Figure 9. Sample Hosting Capacity Maps

Source: *SDG&E, Demonstration A, Integration Capacity Map available at:https://energydatarequest.socalgas.com/ICM/*



Considerations regarding maps include:

- **Visual Display Format:** What kind of color-coding, if any, should the maps employ? If color-coding is required, will all the utilities in the regulated territory be required to use a uniform color-coding system or can they select a unique color-coding system tailored to their service area?
- **Data Displays:** If quick-display boxes are used, what information should utilities be required to display in those boxes? Should, for instance, the boxes include the hosting capacity value for each power system limitation, or only the overall hosting capacity at that point? Should the boxes also include basic circuit information in addition to the hosting capacity values? Will quick-display boxes be available for every node on the circuit or at less granular levels like line segment or feeder?
- **DER Technology:** Will the hosting capacity maps only display data for a uniform generation profile or a standard solar PV profile? Or can they instead be filtered by the viewer to display information relevant to different DER technologies so that, for instance, different color-coding and data would appear depending on whether the viewer selects energy storage, PV with or without advanced inverters, or another DER type. If the latter, what kinds of DER technologies will be available for the viewer to select?
- **Which Data:** If a blend of hosting capacity methodologies is used, which hosting capacity results will be displayed on the map? How will results be displayed if multiple scenarios are run for a circuit?
- **Data Format:** Will the map data be made available in standard GIS formats?

2. Downloadable Hosting Capacity Data

In addition to the maps, DER customers may need access to more granular underlying data than can be easily provided through a map to file an interconnection application or design a DER to fall under hosting capacity limits. Separate considerations apply to production of maps and underlying data.

Considerations with respect to provision of underlying data include:

- **Access:** Will the underlying data be publicly accessible? How soon after the HCA is run will the publicly available data reflect the new results? Will old results be archived in a publicly available manner? Will the data be free for all users, or will there be access-related costs?
- **Content:** What information will be provided in the underlying data? I.e. what hourly load profile data will be available? Will the underlying hosting capacity criteria violations be provided on the map or through the underlying data? What other types of data might be necessary to share in order to make the HCA results meaningful and actionable?

DER customers may need access to more granular underlying data than can be easily provided through a map to file an interconnection application or design a DER to fall under hosting capacity limits. Separate considerations apply to production of maps and underlying data.

Figure 10. Sample Load Curve Data

Source: *SDG&E, Demonstration A, Integration Capacity Map, available at: https://energydatarequest.socalgas.com/ICM/*

- **Data Format:** In what format(s) will the data be made available (e.g. a downloadable database, a JSON or CSV text file, etc.)? Alternatively or additionally, will the data be provided in a machine queryable fashion (e.g. through a RESTful Application Program Interface (API))? A RESTful API would allow users to query a web service running on a server operated by the utility, facilitating tailored requests for timely access to relevant raw data.[84]

- **Documentation:** How will the data format or API be documented and how will the documentation be made available? Data files can be difficult to parse if the organization of the data is not well documented—for instance if the permissible values of a data field are not explained.

- **Usability:** If downloadable databases are used, how will the databases be engineered to facilitate usability by customers and other stakeholders? Will they be annotated so that, for instance, a developer could identify locations by hosting capacity value and area screens?

- **Granularity:** Highly granular data across a distribution circuit can result in large data files that could be practically difficult for utilities to store and users to download. An API could help overcome some of these issues. If downloadable files are instead provided, what level of granularity is appropriate to give customers the information they need without rendering the data inaccessible due to its volume? Will, for instance, hosting capacity values for every hour of a load curve be provided or rather a single value for a load curve? Are there other methods available to help manage the data efficiently without unduly constraining access?

- **Data Privacy:** Should privacy concerns constrain access to the data? While it is impossible to provide perfectly anonymized data, can the data be sufficiently anonymized to overcome privacy-related constraints? Will there be a process in place to remove personally identifiable information if highly granular underlying data is provided?

- **Security:** Are there any cyber or physical security considerations to take into account when sharing HCA data? If concerns are raised by utilities or others, the specific information that raises concerns should be identified so that parties can evaluate whether the HCA data sharing poses real risks, and if so, how best to manage those risks.

V. Stakeholder Engagement Strategies

A number of best practices for engaging stakeholders in the HCA development and implementation process can be garnered from the experiences of states like California, Minnesota and New York. Principal among lessons learned are:

(1) **Early and Consistent Engagement.** Stakeholder should be engaged as early as possible in the process, before critical path decisions are made. If regulators permit utilities to commit to a specific HCA method in advance, stakeholders engaged later may raise issues and insights, which show that method not to best suited to the state's needs, leading to wasted time and expense. To avoid this pitfall, stakeholders should be engaged in the process of setting and refining the uses cases and goals for HCA and involved in every step of the HCA development and implementation process thereafter, including in selecting and refining the HCA method used, in evaluating results, and in updating it as lessons are learned and methodologies improved. The back-and-forth dialogue that occurs in a working group can be particularly constructive, but this feedback can also be valuably obtained through a well-structured comment process.

(2) **Open Membership.** Membership in the stakeholder group should be open to all those who wish to participate to ensure diversity of perspectives and optimal buy-in from interested and affected communities. It may be possible to designate representative members from different groups of stakeholder interests to better manage input, but this needs to be done without unnecessarily constraining party participation. If written comments are used, there may need to be active efforts by the Commission to elicit sufficient participation to ensure an adequate range of perspectives are considered.

(3) **Neutral Facilitation and Reporting.** The stakeholder group facilitator should be carefully selected. Ideally, the facilitator will be a neutral party, either selected from within the Public Utility Commission or from a third party, rather than selected and appointed by the utilities. The facilitator should also have experience and skills in stakeholder engagement. The facilitator should ensure effective and neutral reporting of stakeholder group outcomes, including by producing detailed minutes and by either producing reports herself with stakeholder input or coordinating production of reports by involved stakeholders.

Stakeholders should be engaged in the process of setting and refining the uses cases and goals for HCA and involved in every step of the HCA development and implementation process thereafter, including in selecting and refining the HCA method used, in evaluating results, and in updating it as lessons are learned and methodologies improved.

California's Distribution Resource Plan working groups provide a useful model. The ICA (i.e., hosting capacity) working group is facilitated by a third-party consultant paid for by the utilities, but California PUC staff has oversight responsibility for the group and could assume direct management at any point to ensure meaningful stakeholder engagement.[85] The working group does its own reporting, with all stakeholders helping to draft the group's reports such that conflicting viewpoints are accurate captured for consideration by the PUC. The neutral facilitator guides the production of the reports, and while utility representatives engage in iterative discussions with the stakeholders and contribute their insights and feedback, they do not filter the reports' recommendations and conclusions. As an alternative, a working group could produce a non-utility stakeholder specific report. Utilities would then have an opportunity to file their own reports and the commission would have the two perspectives for comparison and reference in their decision-making.

If written comments are used in lieu of a working group, it is important to ensure stakeholder comments are considered by the utilities and that the decision makers are provided with a complete understanding of party perspectives.

(4) Active Utility Engagement. Utilities should be required to actively participate in the stakeholder process. When utilities participate only passively, stakeholders may not be informed of utility concerns and/or may feel that their concerns are not being critically considered by the utilities. There should also be checks in place to ensure that utilities are meaningfully considering stakeholder insights and revising their methods where appropriate based on those insights.

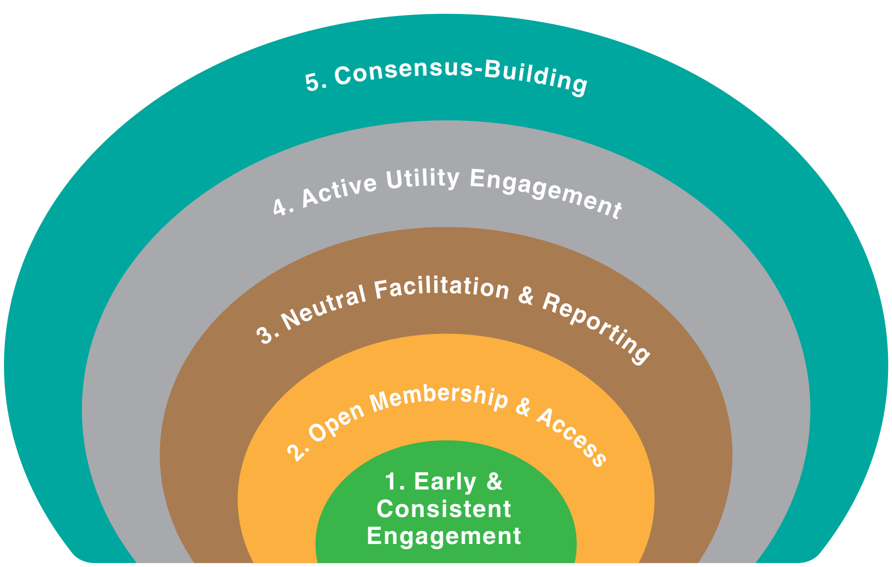
In the California ICA working group, the utility and non-utility stakeholders have engaged in productive, iterative, and ongoing negotiations, with the utilities fielding stakeholder questions, responding to recommendations and concerns, and dialoguing with stakeholders about possibilities during in-person and web-based working group meetings and in written form. This interactive process has enabled non-utility stakeholders to play a meaningful role in shaping the use cases and criteria for and the selection of an appropriate HCA methodology in California. It also helps stakeholders understand and often support utility approaches that might otherwise seem objectionable. By contrast, stakeholders in New York's Reforming the Energy Vision engagement groups reported that utilities had already made critical decisions before talking to stakeholders at engagement group meetings. And when stakeholders provided input, the utilities did not report back during the working group process about what input would or would not be taken into account, thereby allowing for the iteration and discussion that could lead to consensus. As a result, the meetings seemed to serve more as an opportunity to inform stakeholders of utilities' plans than a meaningful opportunity for stakeholders to help shape the outcome of the process.[86]

(5) Consensus-Building: Regulators and facilitators should ensure that the stakeholder process maximizes opportunities for stakeholders to actively voice their perspectives and concerns. Working group meetings and discussions should promote active dialogue among stakeholders in order to build consensus. Where there are areas of disagreement, there should be opportunities to communicate divergent views to utilities and regulators, including through stakeholder reports. If a hosting capacity-specific working group is convened as part of a broader grid modernization proceeding, regulators should ensure that there are opportunities to coordinate with working groups addressing other topic areas. In the New York REV proceedings, the narrowness of the engagement group topics impeded stakeholders in engaging effectively on issues with cross-subject relevance, such as tying HCA development to interconnection and planning and to questions regarding overall grid data access.[87]

(6) **Open Access.** Access to stakeholder meetings and results should be made as easy as possible. Measures to optimize access include noticing stakeholder meetings well in advance, holding meetings in a neutral location, establishing a mix of in-person and telephonic conferences (New York, for instance, held three in-person and three telephonic meetings, all run by a third-party facilitator), employing technology to maximize meaningful participation, and maintaining detailed minutes. Minutes, reports, and other stakeholder group documents should be posted in in an accessible electronic forum to allow interested parties to keep track of proceedings.

Regulators and facilitators should ensure that the stakeholder process maximizes opportunities for stakeholders to actively voice their perspectives and concerns

Figure 11. Regulatory Stakeholder Engagement Strategies



VI. Conclusion: Realizing the Promise of HCA for All Ratepayers

As more states and utilities work to modernize the electric grid and to proactively integrate and optimize DERs on the electric system, new tools and approaches are needed. HCA has emerged as a key tool that allows utilities, regulators, and DER customers to make more efficient and cost-effective choices about deploying DER technology on the grid. HCAs can also speed up the process of interconnecting DERs since steps to expand hosting capacity will have been taken, where appropriate, prior to applications being submitted. Ultimately, as utilities plan for and pursue (or solicit from third parties) grid infrastructure improvements over time, HCAs can help ensure that DERs are optimized, not discouraged, on the system as an integrated and functional feature of affordable, quality and reliable electricity service provided to all ratepayers.

Regulators play an important role in guiding and overseeing utilities as they prepare HCA on their distribution circuits. Given the vanguard nature of this topic, regulators can and should seek to inform their efforts with lessons from the handful of states and utilities that have begun to prepare hosting capacity analyses. Over time the software, methods and assumptions may become standardized, but in the early stages of HCA it is important that states conduct a thorough process to understand and properly vet their rollout.

Paying close attention to the process underpinning HCA efforts will help regulators realize the full promise of HCA for all ratepayers. The key process steps, recapped, are as follows:

(1) Establish a stakeholder process to work with utilities and other interested stakeholders to select, refine and implement the HCA. Ideally, this process should involve one or more working groups consisting of utility and non-utility participants with oversight from regulators to guide the HCA development. Regulators should also retain a process to improve on the selected HCA methodology over time and establish clear timelines for utilities to meet near and long-term HCA goals.

Regulators play an important role in guiding and overseeing utilities as they prepare HCA on their distribution circuits. Given the vanguard nature of this topic, regulators can and should seek to inform their efforts with lessons from the handful of states and utilities that have begun to prepare hosting capacity analyses.

(2) **Identify criteria to guide implementation of the HCA** at the outset. Working through the established stakeholder process to identify and answer key questions regarding the scope, duration, and other key elements of the HCA can help ensure a more efficient process throughout (and greater buy-in from all involved). The *frequency of updating* the HCA results, the *extent of the grid covered by HCA*, and *criteria for ensuring transparency* in the selected HCA methodology and its results are all important to discuss and define. In addition, regulators may consider whether to create a phased roadmap for implementation of HCA, depending on the level of sophistication of the utilities and the timeline for achieving state energy goals. However, care should be taken not to create an endless implementation timeline that quickly becomes obsolete or fails to miss near term opportunities for deployment and use.

(3) **Select and define the use cases for the HCA**, with input from diverse stakeholders, ensuring they are clearly designed to address and achieve identified goals, including state energy policy goals. These use cases should inform and guide the development of an HCA methodology and its implementation. There are two major HCA use cases—interconnection and planning—and a complementary function of HCA—optimizing the locational benefits of DERs. As regulators and utilities consider undertaking an HCA, it is critical that all stakeholders carefully consider and select desired use cases for HCA together at the beginning of the process. Defining use cases ensures that the cart is not put before the horse and will also prevent potentially costly and inefficient undertakings that do not produce useable results.

(4) **Develop an HCA methodology (or methodologies) most appropriate to the use cases**, providing clear and specific guidance and ensuring that the methodologies and assumptions are transparent and informative to all involved stakeholders and end-users. Regulators should ensure that the HCA methodology is scalable so that, even under an incremental approach, the full grid and range of DERs can eventually be analyzed. Currently, most HCA methodologies fit within three categories: streamlined, iterative and stochastic methodologies (though more are under development, and each individual application may have important variations). Importantly, different methodologies can result in different hosting capacity values due to different technical assumptions built into the models. Given the variety of factors that affect the grid's ability to host a wide range of DERs, it is necessary to select a well-considered methodology for determining hosting capacity based upon its intended use.

(5) **Validate the results** of the HCA over time. As with any model or analysis, real-world validation can help improve accuracy and functionality over time. Transparency in the methodology and assumptions and ready access to HCA results will ensure that they can be easily validated and any problems with the methodology identified and resolved. Ideally, sufficient information about the methodology should exist so that a third party could perform an independent analysis to validate the results reached by utilities. Regulators will need to consider the most useful manner for utilities to publish and display hosting capacity data, and set milestones over time to evaluate the performance of the HCA, relative to identified goals.

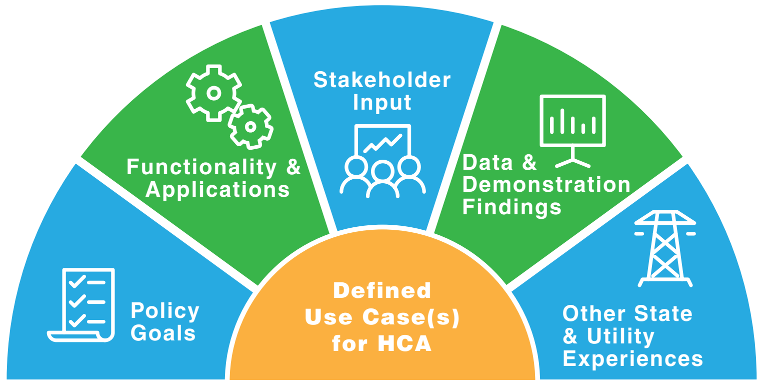


Figure 12. Key Elements to Defining Use Case(s) for HCA

In addition to the above process steps, regulators should keep in mind other key considerations, noted in the report, as they help guide and oversee the implementation of HCAs.

First, the HCA methodologies available today will likely evolve and improve over time, particularly as more utilities adopt and deploy HCA and trial different methods. Still a nascent grid modernization tool, the benefits and drawbacks of different HCA methodologies are being revealed, and likely will become even more apparent with time. Yet rather than wait for the perfect HCA methodology to emerge, regulators can take initial steps to gain familiarity and understanding of the different HCA methodologies, their function, their capabilities, and their limitations. Given the substantial investment in time, energy, and resources that HCA efforts require, there is value in taking the time early in the process to ensure that the tool being developed is capable of meeting identified objectives. Questions or concerns about what an HCA can do should be addressed before widespread implementation, lest substantial resources be invested in something that proves invaluable or ambiguously useful.

Second, requiring consistency in approaches and methodologies among utilities (where there are multiple utility services territories within a state) will help simplify the implementation and oversight process, while also ensuring a more consistent and efficient utilization of this tool among DER customers. Balkanized efforts, with each utility employing a different methodology with varying suitability to statewide use cases, will likely result in more confusion among those seeking to use the HCA and reduce efficiencies for all, including utilities and regulators. Consistent methodologies among utilities also allows for peer learning and exchange of information among utilities, which will help improve the accuracy and functionality of the HCAs over time.

Third, given swift changes to technologies, performance, and markets, HCAs should be agnostic to the type of DER to ensure that it remains useful over time. Technology agnosticism can also help utilities identify opportunities to expand hosting capacity with other DERs and deploy non-wires alternatives as part of utility grid upgrades and investment plans.

Fourth, data sharing remains a key factor shaping the evolution of the electricity grid, and the data collected and generated as part of an HCA will help utilities, regulators, and DER providers and customers better capture the diverse value streams of DERs. However, data sharing requires attention to related issues such as customer confidentiality, access permission, and cyber security. In this data-driven era, regulators will be increasingly tasked with balancing grid optimization, transparency and competition, consumer protections and grid security. Yet, concerns surrounding data sharing can and should be managed proactively and should not be a reason to not pursue HCAs or related efforts.

Lastly, HCAs should not be developed or implemented in a vacuum, and should be considered in the context of other policy choices and how they may impact how DERs are deployed. Similarly, the HCA can and should be used as a tool to evaluate and understand how the hosting capacity of the distribution system might change as a result of these policies. As consumers and the market responds to new programs, policies, and price signals, so too should the HCAs reflect the anticipated and planned changes to DER adoption. More robust DER forecasting methodologies will need to be developed in order to provide greater granularity and accuracy of the HCA.

HCAs should not be developed or implemented in a vacuum, and should be considered in the context of other policy choices and how they may impact how DERs are deployed. Similarly, the HCA can and should be used as a tool to evaluate and understand how the hosting capacity of the distribution system might change as a result of these policies.

As state regulators, utilities, and other involved stakeholders work to build an electricity grid better suited for the challenges and opportunities of the 21st century, the HCA will be a formative tool. Not only will HCA be a critical vehicle to improve the planning and operations of the grid, but, if deployed with intention, may also function as a bridge to span information gaps between developers, customers and utilities, enabling more productive, efficient, and cost-effective grid solutions for the benefit of all ratepayers. Regulators, with this report in hand, can provide the leadership and guidance needed to ensure the process, function, and implementation of HCA support and enable the critical grid transformations underway.

Appendix A: Case Studies on Current State and Utility Approaches to Hosting Capacity

CALIFORNIA CASE STUDY

In the Fall of 2017 the California Public Utilities Commission (CPUC) authorized full rollout of HCA across the three major IOU territories.[88] The path that California went through to arrive at this decision is both informative and instructive for other states that may be undertaking similar efforts. The process started in 2013 when the California legislature passed a bill requiring the IOUs to identify optimal locations on their grid for DERs.[89] In order to achieve this goal the CPUC determined that the utilities needed to develop "Integration Capacity Analyses" or ICA (California's name for HCA) for their territories.[90] The CPUC first required each of the utilities to develop and roll out an ICA on at least a few test feeders using a common methodology as part of their Distributed Resources Plans that were due in July of 2015.[91] From the outset, the CPUC indicated that the projects should look to support both planning and streamlining of the interconnection process.[92]

Although the CPUC specified that a common methodology was required, the California utilities—Pacific Gas & Electric (PG&E), San Diego Gas & Electric Company (SDG&E), and Southern California Edison (SCE)—initially elected to implement different HCA methodologies in their Plans. PG&E did an initial rollout using what they called the "streamlined" method, while SDG&E and SCE utilized an "iterative" method. Following review of these Plans, the CPUC authorized the IOUs to collaborate with a stakeholder Working Group[93] to implement Demonstration Projects for the ICA that would further refine the methodologies and details prior to full system rollout. Intending to standardize their methods, the PUC initially ordered all three to implement a streamlined HCA methodology. However, after SDG&E and SCE raised significant concerns with the accuracy of the streamlined approach that had been initially deployed by PG&E,[94] the PUC, at the Working Group's urging, ordered the demonstration projects to test and compare both the streamlined and iterative methods.[95]

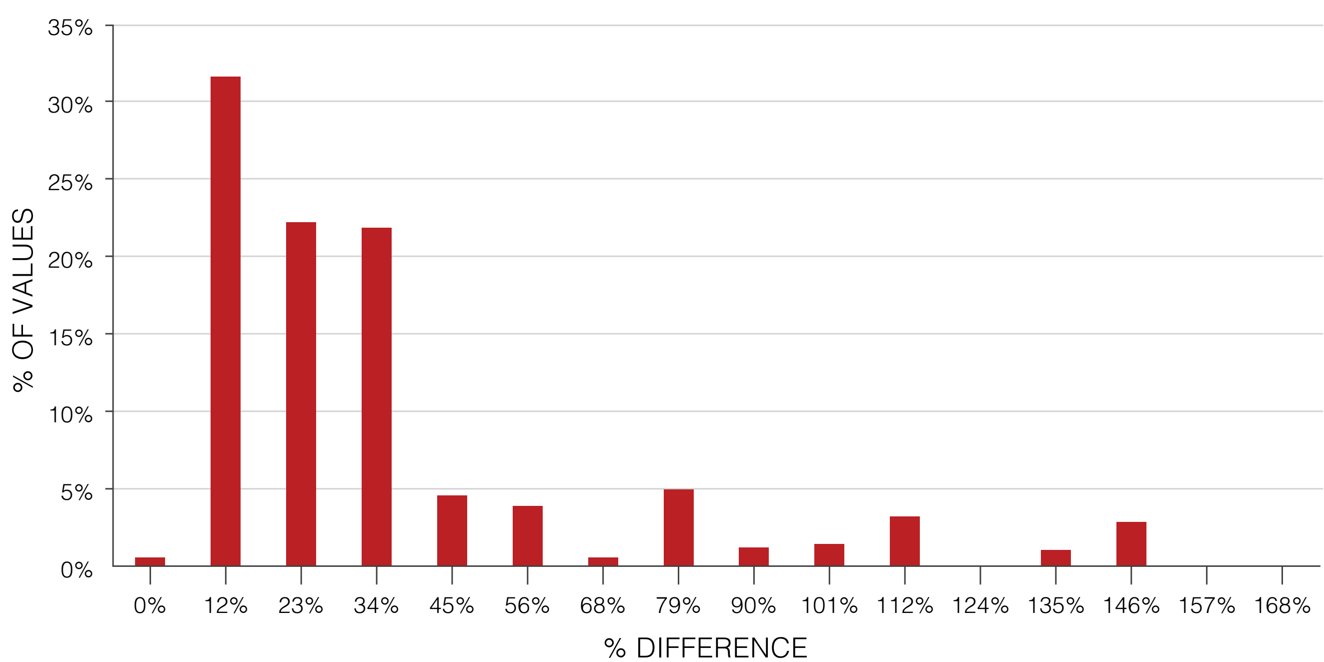
For the demonstration projects, each IOU performed an iterative and streamlined analysis of a portion of their distribution grids in an urban and a rural demonstration area within their respective service territories and additionally ran both analyses on a single test feeder to compare results and identify discrepancies across IOUs. For roughly seven months the IOUs met regularly with the Working Group to refine the details and work through challenges encountered in their development. In December 2016, the utilities published reports analyzing their results and released the HCA data through maps and downloadable data files. Regulators in other states can utilize these results and data to guide HCA methodology selection without replicating the California studies.

The California results revealed the essential tradeoff between the two approaches to be accuracy vs. computational speed. That is, the iterative method optimizes precision because it measures the actual technical capacity of the system, and it proved to be particularly well suited to complex feeders "where the streamlined approach may have difficulty in streamlining the dynamic voltage device operations on longer circuits."[96] The streamlined method, by contrast, can provide only a rough approximation of hosting capacity levels due to its reliance on abstract algorithms, however it is less data intensive and thus could allow more simulations to be run in a timely manner.[97] The discrepancy between the two sets of results varied by power system criteria and feeder location. For instance, SDG&E found that for thermal limitations, the results of the two methods were generally within 30% of each other, with the streamlined method typically resulting in a larger, but less accurate hosting capacity value.[98] By contrast, the results of the two methods were much further apart for the steady state voltage and protection criterion, with the streamlined method yielding more conservative hosting capacity values.[99] The difference in results was particularly pronounced for nodes close to the substation where the feeder's hosting capacity is at its peak and on feeders with higher numbers of voltage regulation devices.[100]

The degree of difference between the hosting capacity values returned by the two methods was surprising. For instance, while SDG&E found that the iterative vs. streamlined results differed by between 12 to 34%, the difference between the results on any one feeder could be as great as 146% (see Figure 13 below). With respect to computational speed, the streamlined approach proved to be significantly faster to perform than the iterative approach, though the discrepancy depended on software and hardware choices. PG&E, for instance, was able to reduce run times by using a combination of local machines and servers.[101] The use of cloud computing may further decrease computational times. The utilities were also able to lower run times by strategically reducing the number of hours and nodes being analyzed.

Figure 13. SDG&E Statistical Differences Between the Streamlined and Iterative Methods

Source: *San Diego Gas & Electric Company, R. 14-08-013, Demonstration Projects A & B Final Reports of San Diego Gas & Electric Company (U 902-E), Demonstration A—Enhanced Integration Capacity Analysis, p. 46 (Dec. 22, 2016)*



All three utilities concluded that the iterative approach is better suited for analyzing circuit conditions for interconnection purposes, although they shared concern about the computational demands of that approach.[102] By contrast, the utilities suggested that the streamlined approach may be more applicable for a planning use case because of its ability to efficiently perform scenario analyses.[103] As a consequence, the utilities initially recommended utilizing a blended approach, with iterative analysis used for interconnection and streamlined use for planning, and PG&E further suggesting that both methods should also be used together for the interconnection use case.

The Working Group intensively analyzed these results in making its recommendation to the CPUC on how to proceed. As part of this effort the group defined what the precise goals were for the interconnection use case and compared the ability of the different methodologies to achieve those goals. The Working Group found that due to the relative inaccuracy of the streamlined method that it was inadequate to support the goal of substantially automating the interconnection process for projects falling within the identified hosting capacity. All but PG&E agreed, thus, that the iterative methodology should be used for the interconnection use case. PG&E recommended using a combined method,[104] but the CPUC ultimately adopted the recommendation of the majority of the Working Group.[105]

With respect to the planning use case, the Working Group found that it required further development before it could adequately assess which methodology or combination of methodologies would best serve the needs of that case. The Group thus agreed to continue working on refining this use case during 2017 and a decision will come in 2018 which will determine how the ICA can be used to best achieve the refined goals of the planning use case.[106]

Refinement of the use cases and selection of the core methodology was not the only focus of the Working Group. The Group also worked with the utilities to agree upon how the results would be displayed on the publicly available maps, what data would be made available for download, and how to address particularly methodological hurdles regarding operation of voltage regulating devices, smart inverters and other system issues.

Regulators can learn a great deal from evaluating the California experience and results:

- The California experience illustrates the importance of a carefully designed and inclusive process for HCA methodology selection. While the demonstration projects ultimately used have been highly valuable, time and expense could have been saved by putting into place at the outset a process to compare HCA methods. This process made sense in California as this was really the first full rollout done through a public process, but the issues discussed are not unique to California and thus other states can likely jump ahead if they build on this experience.

- The California demonstration project results provide a helpful analysis of the tradeoffs between streamlined and iterative methodologies and a framework for evaluating their suitability to the different use cases. In general, they reveal that, between the two methods as designed at the time, only the iterative analysis produced accurate enough results for use in interconnection decision making. While the streamlined method may have value for planning because of its suitability for scenario analysis, it remains unclear whether the streamlined method can be made accurate enough for interconnection or planning purposes. As in other states, the lack of a precise definition and goals for the planning use case has impeded the ability to make this determination.

- Working groups and utilities should explore ways to revise methodologies to overcome obstacles. It may be possible to reduce hour and node profiles for the iterative method, for instance, to shorten computational times without unduly sacrificing accuracy. Likewise, different hardware choices (i.e. use of servers and cloud computing) can significantly speed up computing. Regulators should make sure that when utilities report on computational challenges, they also report on the expense associated with overcoming them.

- When tests of HCA methodologies are performed, raw data should be released along with analysis of results to help working group participants and third parties provide the most useful feedback.

- Dialogue between utility and non-utility stakeholders is critical in selecting and refining the HCA methodology and can be done in a constructive and collaborative manner with the right framework in place.

NEW YORK CASE STUDY

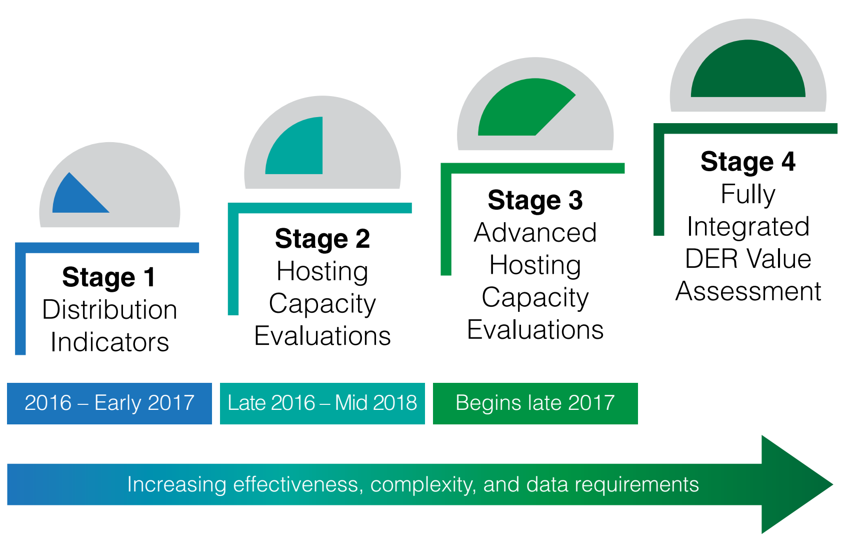
The efforts to develop HCA in New York arose as part of the state's Reforming the Energy Vision (REV) proceeding.[107] In 2015, the New York Public Service Commission (NY PSC) required the utilities to include hosting capacity efforts in their Distributed System Implementation Plans (DSIPs).[108] The NY PSC required the utilities to develop a common methodology and publish the known hosting capacity for all circuits on a map that includes relevant system information. The NY PSC did not initially specify the granularity of the analysis or the frequency with which it would be updated. Though the NY PSC alluded to the general value of having hosting capacity information, it did not identify use cases for the HCA to instruct the utilities in their selection of methodology or the ultimate functionality desired. The NY PSC ordered the utilities to engage with stakeholders around all aspects of their DSIPs, but did not require a specific structure for incorporating the feedback or for documentation of stakeholder input.[109]

The Joint Utilities[110] collaborated with the Electric Power Research Institute (EPRI) on the preparation of a paper that outlined the tiered approach the utilities would use to develop their hosting capacity analyses.[111] The paper and subsequent DSIPs identified that hosting capacity can be used to "inform" interconnection, planning and the identification of locational value.[112] The Joint Utilities chose to utilize EPRI's proprietary DRIVE tool,[113] which utilizes a version of the streamlined methodology that was also tested in California.[114] The utilities proposed using a four-tiered approach for the analysis, each step in the process is intended to add greater detail and granularity as utility data sets and modeling tools evolve.[115] The four steps identified were to develop: 1) distribution indicators, 2) hosting capacity evaluations, 3) advanced hosting capacity evaluations, and 4) fully integrated DER value assessments.[116] The first step involves each utility publishing a map with basic information about circuits (i.e. voltage of the line, already connected generation, etc.); these maps do not include any data analysis of the circuits. The second step entails the first iteration of the HCA, where the utilities will publish ranges of potentially available capacity. The HCA at this stage is only evaluating the hosting capacity for large-scale solar and not providing information on the capacity for small solar or other types of DER (e.g. electric vehicles or energy storage). In addition, the hosting capacity model does not include in the analysis DERs that are already connected to the grid.[117] Less detail is available on exactly what will be included in the third iteration, but it may include analysis down to the nodal level and further modeling of "operational flexibility" constraints.

Despite widespread dissatisfaction with the approach laid out by the utilities,[118] the Commission's Order largely approved the utilities' plans, however it required that they move ahead on a faster timeline, requiring that the stage 2 analysis be completed for all 12 kV circuits and above by October 1, 2017.[119] The NY PSC also required that basic information about the feeder be published in the maps, that the presentation of the data be more consistent across the utilities, and that some data be available to download.[120] The NY PSC approved the utilities plan to only update the analysis on an annual basis, with monthly updates of the interconnection queue data.

Figure 14. Joint Utilities of New York Hosting Capacity Road Map

Source: *New York Joint Utilities, Case 16-M-0411, Supplemental Distributed System Implementation Plan, p. 48 (Nov. 1, 2016)*



While the process underway in New York is certainly likely to produce considerably more information than has ever been available to third parties about the state of the distribution system in New York, it is unclear how valuable the results will be to guiding decision making, either in the regulatory context or for specific investment decisions by third parties. The NY PSC has thus far declined to identify specific use cases for the analysis and made no specific plans for ultimately being able to utilize this information in processing interconnection applications or in the distribution planning process. There also has not been any demonstration of the accuracy of the results of the methodology which will need to be done if the tool is to be used for decision-making purposes going forward.

Lessons learned from the New York process:

- The four-tiered approach in New York provides an illustration of how a state may approach the rollout of an HCA in a manner that will provide more detailed information over time as data and methodology improves.
- The New York experience illustrates some of the challenge of not identifying clear uses cases prior to commencing selection and development of the technical methodology for the HCA. Since there was no identification of desired uses, it is not clear exactly how the information coming out of the HCA produced will be used to guide or inform decision making.
- States should strive to ensure greater public transparency and vetting of the chosen methodology through the regulatory process. Thorough vetting of the methodology through publicly available studies, test runs, or comparative tests can demonstrate the accuracy of the tool and the relative consistency in its application across utility territories. Conducting this process publicly can utilize the collective knowledge of a wider range of stakeholders and also ensure broader support and confidence in the outcomes of the HCA.
- Commencing stakeholder engagement prior to utilities having made major decisions about methodology and approach increases the likelihood that utilities will not be path dependent by the time they reach out to stakeholders and will also help to ensure that the tool is designed to serve customers' needs. In addition, the stakeholder engagement process should be structured to ensure that stakeholder feedback is objectively recorded and reported on the record for review by regulators regardless of whether input is ultimately taken by the utilities.
- Including one segment of one type of DER (large scale PV) in the initial methodology may be an appropriate interim step from a resource standpoint, but it places severe limits on the usefulness of the information for expanding hosting capacity and allowing DERs to be used to address constraints on the system.

MINNESOTA CASE STUDY

HCA in Minnesota arose out of a 2015 statutory directive requiring Xcel Energy to file information regarding the interconnection of small-scale distributed generation (DG) projects within the biennial transmission planning process.[121] As part of this process, the Minnesota Public Utility Commission (MN PUC) required Xcel to complete an analysis of the hosting capacity of each feeder on Xcel's distribution system for DG of 1 MW or less and to identify potential distribution system upgrades necessary to support expected DG growth.[122]

On December 1, 2016 Xcel filed a distribution system study containing its initial HCA results.[123] As did the New York Joint Utilities, Xcel elected to use EPRI's proprietary DRIVE tool to assess the hosting capacity of individual feeders through a streamlined hosting capacity method. The DRIVE tool provided Xcel with a choice of three DER deployment scenarios to allocate DER across a feeder: large centralized, large distributed, and small distributed. Of the three, Xcel selected the small distributed generation scenario, which it deemed consistent with the PUC order's focus on small DG resources. Xcel ran the analysis on more than 1,000 feeders in its distribution system.[124] Owing to limitations in the DRIVE tool, Xcel did not include in its analysis existing or forecasted DERs, and it did not apply mitigations to determine if hosting capacity could be increased.[125] Xcel published its results in a summary chart that reported for each feeder the minimum and maximum hosting, the limiting violation, and the currently installed and proposed DG.[126] The initial report did not include a map showing the hosting capacity or any downloadable data in a sortable form.

The MN PUC initiated a new round of commenting on Xcel's hosting capacity study. The PUC issued an information request to Xcel requiring that the utility issue responses to a list of questions intended to clarify Xcel's hosting capacity model and to assist stakeholders in providing comments.[127] And it invited public comments on Xcel's hosting capacity report and its supplemental comments in response to the MN PUC's information request.[128] The MN PUC then held a public meeting at which stakeholders were given an opportunity to present their positions on Xcel's filings and the proposed MN PUC action.[129]

After considering stakeholder written and oral comments, the MN PUC issued an order on August 1, 2017 in which it set forth guidance for subsequent hosting capacity reports by Xcel.[130] The order required Xcel to file hosting capacity reports on an annual basis with sufficient detail to provide customers "with a starting point for interconnection applications" and "to inform future distribution system planning efforts and upgrades necessary to facilitate the continued efficient integration of [DG]."[131] The PUC directed Xcel to display the annual hosting capacity results in a color-coded map representing the available hosting capacity of Xcel's distribution grid down to the feeder-level and to provide downloadable hosting capacity results in spreadsheet format.[132] The PUC also directed Xcel to include in its November 1, 2017 report information requested by staff and parties through comments on its 2016 report and information on the accuracy of its hosting capacity results, including by conducting a comparison of results in its 2016 report with actual hosting capacity determined through interconnection studies.[133]

Xcel filed this updated HCA and supporting information requested by the MN PUC on November 1, 2017.[134] The New HCA includes some additional improvements and refinements, including the incorporation of existing known DERs, a change from modeling small DERs to instead using the "large centralized" DER option in DRIVE, and inclusion of some changes to allow for limited modeling of certain smart inverter and voltage regulation devices.[135] The results are now also published on a publicly available map.

In parallel, the MN PUC has begun considering HCA as part of its broader Grid Modernization proceeding, initiated in 2015. The PUC issued a distribution system planning questionnaire in which, among other things, it directed Minnesota's three investor owned utilities—Xcel, Minnesota Power, and Otter Tail Power Company—to report on any HCA they currently conduct, and invited cooperative and municipal utilities to do the same.[136] And it solicited comments from all stakeholders on the form that analysis should take.[137] The MN PUC has not yet clarified to what extent hosting capacity will be part of this broader proceeding and how it will relate to the separate Xcel proceeding.

The Minnesota proceedings are a unique case study in several respects: they have thus far utilized a predominantly written commenting process for stakeholder engagement with respect to hosting capacity; they represent one approach to tailoring hosting capacity requirements to utilities of very different sizes and types of service areas; and they have created parallel tracks within which HCA can be addressed.

Lessons learned from Minnesota include:

- The Minnesota experience highlights strategies for meaningfully incorporating stakeholder input through written comments. At each stage of Xcel's hosting capacity proceeding, the MN PUC solicited written comments from stakeholders, and it transparently considered and incorporated feedback into its recommendations and directives. The MN PUC demonstrated its consideration of stakeholder positions by summarizing comments in its orders and by directing the utilities to answer specific questions about their methodologies. Outcomes reflect the MN PUC's consideration of stakeholder input. For instance, the MN PUC's order on Xcel's hosting capacity report directed Xcel to address stakeholder concerns with the accuracy of its hosting capacity methodology.[138] Xcel responded with additional information on the methodology[139] and the Commission has invited stakeholder comments on Xcel's response.[140]

- The Minnesota experience suggests that solicitation of written comment can be particularly effective for considering stakeholder feedback on technical components of HCA. But it may have limitations when used as the only method to engage stakeholders in the broader policy dimensions of hosting capacity. In response to the MN PUC's questionnaire in its distribution study proceeding, a number of stakeholder groups recommended that the MN PUC couple written comments with working groups or workshops, particularly for developing hosting capacity goals and use cases.[141]

- Xcel is by far the largest utility in Minnesota but others—Minnesota's two smaller investor owned utilities and its municipal and cooperative utilities—are important players. The MN PUC has accounted for these distinctions by, consistent with the statutory directive, requiring Xcel to be the first mover in developing HCA while engaging all utilities in the exploration of hosting capacity in its distribution system planning proceeding. This latter proceeding represents a valuable potential opportunity to formulate hosting capacity goals and use cases applicable to all utilities as well as timelines tailored to the respective utilities' systems and needs.

- The Xcel hosting capacity proceeding, similar to the experiences in California and New York, illustrates the drawbacks of mandating HCA before establishing goals and use case. Significant concerns have been raised with the accuracy of Xcel's methodology and the usefulness of its results, and it remains to be seen whether the DRIVE tool can be tailored to meet the needs of the use cases ultimately selected. Significant costs and delays could be avoided by beginning with the broader policy discussion.

- Xcel's method initially focused on small DG and its most recent version focuses on large DG, although neither scenario is a likely representation of expected DG growth (which will likely include a mix of both small and large DERs). The initial version of its hosting capacity did not incorporate installed and pending DER, but the most recent version now includes installed DERs.[142] There have been a number of other improvements between the first and second iteration. However, stakeholder concerns regarding the lack of transparency of the DRIVE tool, which hinders their ability to provide effective feedback on its capabilities and limitations, persists.[143]

- The MN PUC has thus far considered hosting capacity as a guide for interconnection filings rather than a method that could eventually automate—or nearly automate—the interconnection process. This way of thinking may limit the state's broader grid modernization efforts or result in substantial costs if utilities are required to reinvent their hosting capacity methods when the interconnection use case changes.

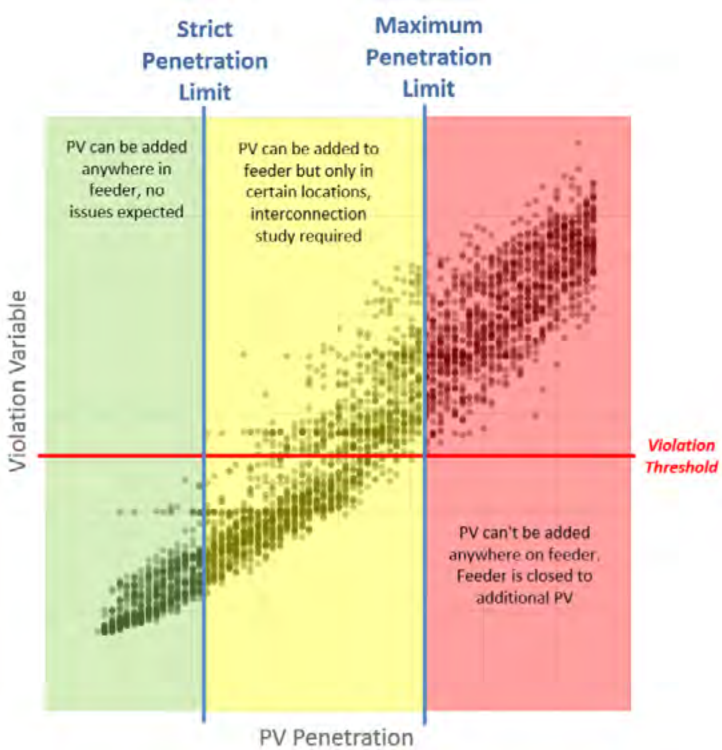
PEPCO CASE STUDY

Pepco Holdings, Inc. was one of the first utilities to deploy a hosting capacity model across their service territory which covers parts of New Jersey, Maryland, Washington D.C., and Delaware. Coming out of a study funded by the DOE in 2015, Pepco's model utilizes what is known as the "stochastic method" to determine the hosting capacity of its feeders.[144] Rather than identifying a specific hosting capacity amount for a feeder, the method runs various scenarios with solar PV randomly placed on a feeder to determine a range of possible hosting capacity figures. The chart below provides a visualization of the results of this method.[145] The green area on the left shows the scenarios that were run where no violations of hosting capacity limits would occur regardless of PV location, the yellow area shows scenarios where potential PV could be located without violations, but only in certain locations (thus a study might be required), and the area in red shows scenarios where there would be an absolute violation of the circuit limits regardless of location.

Pepco has begun to use the results of this analysis to help streamline the interconnection process in their territory. Using their HCA Pepco identifies "restricted circuits" on their system, which are circuits where "a major distribution infrastructure investment would be required to allow the DER to interconnect without creating a violation of utility system

Figure 15. Pepco Definition of Strict and Maximum PV Penetration Limits

Source: *Pepco Holdings, Inc., Model-Based Integrated High Penetration Renewables Planning Control and Analysis, p. 11 (Dec. 14, 2015)*



operational parameters."[146] There are three categories of restricted circuits: (1) those that are restricted to all sizes, (2) those that are restricted to systems below 250 kW, and (3) those that are restricted to systems below 50 kW.[147] Pepco publishes their hosting capacity map (or "restricted circuit map") on their website (updated at least quarterly) which color codes circuits based upon their restriction category.[148] Pepco is able to streamline the interconnection process for projects not located on a restricted circuit, or for those sized below the circuit restriction level, as long as they also meet a set of "criteria limits" the utility has defined.[149] While this approach has value in reducing the amount of individualized review that projects receive in the interconnection process, it may also underestimate hosting capacity for certain projects and provides a less precise result to guide the design of projects seeking to maximize hosting capacity. As part of the DOE project, Pepco has also identified mitigation strategies for increasing hosting capacity on a circuit.[150]

Pepco initiated this process absent any formal regulatory requirement as a way to help better manage their distribution system and the interconnections to that system. While this proactive approach by the utility can lead to some immediate and positive outcomes for customers, there are potential drawbacks to proceeding with a significant HCA rollout without the benefit of a robust stakeholder process. The HCA methodology used and the limits and assumptions built into that methodology have not undergone any public vetting for fairness or accuracy. Since the HCA is being used to facilitate, but also restrict, interconnection access it is important that regulators ensure that methods used are reasonable and valid.

Appendix B: References

Rachel Wilson and Bruce Biewald, *Best Practices in Electric Utility Integrated Resource Planning*, Regulatory Assistance Project (June 2013)

IREC, *Integrated Distribution Concept Paper: A Proactive Approach for Accommodating High Penetrations of Distributed Generation Resources* (May 2013)

IREC, *Easing the Transition to a More Distributed Electricity System* (Feb. 2015)

EPRI, *Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State* (June 2016)

EPRI, *Alternatives to the 15% Rule* (Dec. 2015)

EPRI, *Integration of Hosting Capacity Analysis into Distribution Planning Tools* (Jan. 2016)

EPRI, *Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV* (Dec. 2012)

Solar Energy Industries Association, *Hosting Capacity: Using Increased Transparency of Grid Constraints to Accelerate Interconnection Processes* (Sept. 2017)

Solar City, *Integrated Distribution Planning: A Holistic Approach to Meeting Grid Needs and Expanding Customer Choice by Unlocking the Benefits of Distributed Energy Resources* (Sept. 2015)

ICF International, *Integration Distribution Planning*, Prepared for MN PUC (Aug. 2016)

Regulatory Assistance Project, *Electricity Regulation in the United States: A Guide* (2d ed. June 2016)

Endnotes

1 The term Distributed Energy Resources, or DERs, refers to resources located on the distribution system (in front of or behind the customer meter). These resources may vary by jurisdiction. For purposes of this paper, the term includes distributed renewable generation resources, energy efficiency, energy storage, electric vehicles, and demand response technologies. The impact on hosting capacity varies significantly between DER technologies depending upon whether the technology is a new load source (e.g. electric vehicles), a load shift or reduction (e.g. demand response), a generating resource (e.g. solar PV) or some combination of these (e.g. energy storage).

2 A node is a point on a feeder between two line sections. Circuit characteristics may be analyzed at each selected node along the circuit.

3 Tim Lindl, et al., *Integrated Distribution Planning Concept Paper: A Proactive Approach for Accommodating High Penetrations of Distributed Generation Resources*, IREC and Sandia National Laboratories (May 2013) ("IDP Concept Paper"), http://www.irecusa.org/publications/integrated-distribution-planning-concept-paper/.

4 For examples of state grid modernization proceedings that integrated IDP, see Cal. Public Utilities Commission, Distribution Resources Plan Dkt., R. 14-08-013; NY Public Service Commission, Reforming the Energy Vision Dkt., Case 14-M-0101; and MN Public Utilities Commission, Staff Report on Grid Modernization, pp. 15-16 (Mar. 2016) (identifying integrated distribution planning as the first of nine key steps to explore in Minnesota's grid modernization efforts).

5 As used throughout this paper, the term "use case" refers to the primary function and/or application of the hosting capacity analysis. Refer to Section II.B for additional information.

6 Appendix B to this report provides a compilation of recent resources on hosting capacity and related distribution planning and interconnection topics.

7 *See* Electric Power Research Institute ("EPRI"), *Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State*, p.3 (June 2016) ("Defining a Roadmap") (defining "hosting capacity"); *see also* Cal. Public Utility Commission, R. 14-08-013, Assigned Commissioner's Ruling Re. Draft Guidance for Use in Utility AB 327 (2013) Section 769 Distribution Resource Plans, Attachment pp. 15-16 (Nov. 17, 2014) (introducing Integrated Capacity Analysis ("ICA") as a tool for determining distribution system hosting capacity).

8 *See, e.g.*, Defining a Roadmap at p. 10 (summarizing these four power system criteria); San Diego Gas & Electric Company, R. 14-08-013, Demonstration Projects A & B Final Reports of San Diego Gas & Electric Company (U 902-E), Demonstration A—Enhanced Integration Capacity Analysis, p. 30 (Dec. 22, 2016) ("SDG&E Final Report A") (explaining that the Assigned Commissioner's Ruling required the three California investor owned utilities to examine these "four major categories of power system criteria . . . to determine the DER integration capacity for the nodes and line sections on each distribution feeder"); *id.* at pp. 34-39 (describing the four criteria and their role in hosting capacity analysis).

9 Solar City, *Integrated Distribution Planning: A Holistic Approach to Meeting Grid Needs and Expanding Customer Choice by Unlocking the Benefits of Distributed Energy Resources*, p. 5 (Sept. 2015) ("Solar City IDP") (HCA "provide[s] an indication of how many DERs can be accommodated given existing utility and customer-owned equipment on a circuit").

10 EPRI, *Alternatives to the 15% Rule: Final Project Summary*, p. xii (Dec. 2015) ("Minimum hosting capacity is defined as the lowest amount of PV that causes the first violation on a feeder.").

11 EPRI, *Integration of Hosting Capacity Analysis into Distribution Planning Tools*, pp. 3-4 (Jan. 2016) ("EPRI Integration").

12 *Id.* at p. 3.

13 The hosting capacity of a feeder can also vary depending on the type of scenario selected—such as centralized versus highly distributed DERs and whether backfeed through the substation is permitted. *See* Defining a Roadmap at pp. 11-12.

14 Smith, Jeff and Matthew Rylander, PhD, *Overview of Hosting Capacity Methods: Detailed and Streamlined Methods*, Electric Power Research Institute, presented to the California Integration Capacity Analysis Workgroup, slides 9-10 (June 9, 2016), http://drpwg.org/wp-content/uploads/2016/06/EPRI_Hosting-Capacity-Methods_Smith.pdf.

15 *Id.* at p. 8; see also Pacific Gas & Electric Co., R. 14-08-013, Pacific Gas & Electric Company's (U 39 E) Demonstration Projects A & B Final Reports, Appendix A (Demonstration Project A—Enhanced Integration Capacity Analysis), pp. 146-55 (Dec. 27, 2016) ("PG&E Final Report A")

(describing metrics set out by the California PUC for utilities to meet in developing and testing ICA methods).

16 See Solar City IDP at p. 2; Erica McConnell & Cathy Malina, *Interconnection: The Key to Realizing Your Distributed Energy Policy Dream*, Greentech Media (Oct. 25, 2016), https://www.greentechmedia.com/articles/read/interconnection-the-key-to-realizing-your-distributed-energy-policy-dream#gs.ppLHx9k.

17 K. Ardani, et al., *A State-Level Comparison of Processes and Timelines for Distributed Photovoltaic Interconnection in the United States*, National Renewable Energy Laboratory, p. 13 (Jan. 2015).

18 See NC Utilities Comm., Dkt. E-100, Sub 101A, Duke Energy Carolinas, LLC, Quarterly Interconnection Queue Performance Report (Oct. 20, 2017) (over 61% of projects take between 360 to over 990 days from entering queue to receiving interconnection agreement).

19 For a more thorough discussion of the benefits of data sharing in the interconnection process, see Erica McConnell & Cathy Malina, *Knowledge is Power: Access to Grid Data Improves the Interconnection Experience for All*, Greentech Media (Jan. 31, 2017), https://www.greentechmedia.com/articles/read/knowledge-is-power-access-to-grid-data-and-improves-the-interconnection-exp#gs.SVY9Tdw.

20 For more information on the background of interconnection screening see Kevin Fox, Sky Stanfield, et. al., *Updating Small Generator Interconnection Procedures for New Market Conditions*, National Renewable Energy Laboratories, p. 2-10 (Dec. 2012).

21 See EPRI, *Alternatives to the 15% Rule: Final Project Summary*, p. vii (Dec. 2015)

22 *See Integrated Distribution Planning: Prepared for Minnesota Public Utilities Commission*, ICF International, p. vi. (Aug. 2016) ("ICF IDP") ("There is a recognition nationally by utilities, stakeholders, and regulators that improvements to processing and studying interconnection requests are needed to meet customers' expectations and manage work flow."); PG&E Final Report at p. 156 (reporting that the iterative method "could help streamline Fast Track studies and improve the outdated methods such as the 15% rule in screen M"); Hawaiian Electric Companies, Initial Statement of Position on Deferred Issues and Technical Track. Issues, , Exhibit C, Circuit Hosting Capacity Analysis: Benefits and Future Improvements, p. 1 (Aug. 2017) ("The use of circuit hosting capacity by the Hawaiian Electric Companies . . .has resulted in additional interconnection approvals." and "Circuit hosting capacity facilitates faster interconnections.").

23 *See* Cal. Public Utilities Commission, R. 14-08-013, Protest of the Interstate Renewable Energy Council, Inc. to Applications of San Diego Gas & Electric Company, Pacific Gas & Electric Company, and Southern California Edison Company for Approval of their Distribution Resources Plans, p. 23 (Aug. 31, 2015) ("IREC Protest of DRP Applications").

24 *See id*. at p. 22.

25 Pre-application reports provide readily available information about a particular point of interconnection on a utility's system. The information generally provided includes items such as the circuit and substation voltage, the amount of already connected and queued generation, the distance of the proposed point of interconnection to the substation, and peak and minimum load data. These reports are available in a handful of states where they help guide customers. But they have limitations: they do not contain any actual system analysis and can take over a month to receive. See Erica McConnell & Cathy Malina, *Knowledge is Power: Access to Grid Data Improves the Interconnection Experience for All*, Greentech Media (Jan. 31, 2017), https://www.greentechmedia.com/articles/read/knowledge-is-power-access-to-grid-data-and-improves-the-interconnection-exp#gs.SVY9Tdw; Zachary Peterson, The State of Pre-Application Reports, National Renewable Energy Laboratories (June 2017), https://www.nrel.gov/dgic/interconnection-insights-2017-07.html.

26 *See, e.g*. Quarterly Interconnection Reports for the California Investor Owned Utilities, http://www.cpuc.ca.gov/General.aspx?id=4117 (these reports show the number of pre-application reports that have been requested in recent years; although, given their relative newness, efforts to collect more comprehensive data to measure their full impact on interconnection applications are still underway).

27 Cal. Public Utilities Commission, R. 14-08-013, Assigned Commissioner's Ruling on Guidance For Public Utilities Code Section 769—Distribution Resource Planning, Attachment (Guidance for Section 769—Distribution Resource Planning), p. 3 (Feb. 6, 2015) ("Final CPUC Guidance").

28 *Id*.

29 Cal. Public Utilities Commission, R. 14-08-013, Assigned Commissioner's Ruling (1) Refining

Integration Capacity and Locational Net Benefit Analysis Methodologies and Requirements; and (2) Authorizing Demonstration Projects A and B (May 2, 2016); *see also* Cal. Public Utilities Commission, R. 14-08-013, Email Ruling of Administrative Law Judge Mason (June 10, 2016) (authorizing the utilities to conduct a comparison of both methodologies in their demonstration projects).

30 Cal. Public Utilities Commission, R. 14-08-013, Integration Capacity Analysis Working Group Final Report, pp. 7-14 (Mar. 15, 2017).

31 Cal. Public Utilities Commission, R. 14-08-013, Decision 17-09-026, Decision on Track 1 Demonstration Projects A (Integration Capacity Analysis) and B (Locational Net Benefits Analysis), pp. 29-33 (Sept. 28, 2017) ("CPUC Decision on Track 1 Demonstration Projects").

32 Hawaiian Electric Companies, Initial Statement of Position on Deferred Issues and Technical Track. Issues, Exhibit C, Circuit Hosting Capacity Analysis: Benefits and Future Improvements, p. 5 (Aug. 14, 2017) (HECO's "analysis is closer to that of an iterative methodology, where simulations are run until a hosting capacity number (with no criteria violations) is determined, which the [California] IOUs concluded yields higher hosting capacity values and more accurate results.").

33 *Id*. at p. 4 ("The [Hawaiian Electric] Companies have three use cases for the circuit hosting capacity analysis, applying it as a tool to (1) streamline the interconnection process for customers, (2) inform customers and DER developers where saturated circuits are located, and (3) inform the planning process and identify circuit constraints to be solved to expand DER growth.")

34 NY Public Service Commission, Dkt. 16-M-0411, In the Matter of Distributed System Implementation Plans; NY Public Service Commission, Dkt. 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision.

35 The Joint Utilities include: Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc. (Con Edison), New York State Electric & Gas Corporation, Niagara Mohawk Power Corporation d/b/a National Grid (National Grid), Orange and Rockland Utilities, Inc. and Rochester Gas and Electric Corporation, all investor owned utilities.

36 New York Joint Utilities, Case 16-M-0411, Supplemental Distributed System Implementation Plan, p. 49 (Nov. 1, 2016) ("SDSIP").

37 NY Public Service Commission, Case 16-M-0411, Order on Distributed System Implementation Plan Filings, pp. 10-15 (Mar. 9, 2017).

38 MN Public Utilities Commission, Dkt. E002/M-14-962, Order Setting Additional Requirements for Xcel's 2017 Hosting Capacity Report, p. 5 (Aug. 1, 2017).

39 Minn. Stat. § 216B.2425, subd. 8.

40 Xcel Energy, Dkt. E002/M-15-962, Distribution System Study: Distribution Grid Modernization Report, p. 13 (Dec. 1, 2016) ("Xcel Distribution System Study") (noting that the initial hosting capacity results are "not intended to be used for approving interconnection requests at this time").

41 MN Public Utilities Commission, Dkt. E002/M-14-962, Order Setting Additional Requirements for Xcel's 2017 Hosting Capacity Report, p. 5 (Aug. 1, 2017).

42 *Id*.

43 Xcel Energy, Dkt. E002/M-17-777, Distribution System/Hosting Capacity Study, p. 17-20 (Nov. 1, 2017).

44 *See* Herman K. Trabish, *How Utility Data Sharing is Helping the New York REV Build the Grid of the Future*, Utility Dive (Feb. 8, 2017), http://www.utilitydive.com/news/how-utility-data-sharing-is-helping-the-new-york-rev-build-the-grid-of-the/434972/ ("Currently, only utilities have full access to the data needed to fully understand the [distribution] system's limits and potential, and even they often lack visibility to understand exactly where all their assets are located.").

45 Coley Girouard, *Understanding IRPs: How Utilities Plan for the Future*, Advanced Energy Economy (Aug. 11, 2015), http://blog.aee.net/understanding-irps-how-utilities-plan-for-the-future ("Historically, utilities mainly considered generation, transmission, and distribution additions to meet growing demand.").

46 *See* Krysti Shallenberger, *The Top 5 States for Utility Grid Modernization and Business Model Reform* (Apr. 3, 2017), http://www.utilitydive.com/news/the-top-5-states-for-utility-grid-modernization-and-business-model-reform/439550/ (discussing grid modernization activities in California, New York, Minnesota, Massachusetts, and Rhode Island, as well as developments in other states).

47 *See, e.g.*, NY Public Service Commission, Case 14-M-0101, Order Adopting Distributed System Implementation Plan Guidance, p. 2 (Apr. 20, 2016) ("At the core of the new model is improved information—improved both in its granularity, temporal and spatial, and in its accessibility to consumers and market participants."); Cal. Public Utilities Commission, R.14-08-013, Assigned Commissioner's Ruling on Guidance for Public Utilities Code Section 769—Distribution Resource Planning, p. 5 (Feb. 6, 2015) ("Each iteration of the process will move California further down a path toward deeper penetration of DER, more effective analysis of where DER provides the most value to customers and to the electric distribution system, and a greater understanding of the policy framework that is necessary to achieve these goals.").

48 IDP Concept Paper at p. 10.

49 *See* SDSIP at pp. 28-29 (discussing role of HCA in competitive solicitation of non-wires alternatives).

50 Hawaiian Electric Companies, Initial Statement of Position on Deferred Issues and Technical Track. Issues, Exhibit C, Circuit Hosting Capacity Analysis: Benefits and Future Improvements, p. 4 (Aug. 2017) ("Finally, the hosting capacity analysis helps distribution planners to identify congested circuits and find solutions to integrate high forecasted levels of DER. Once current and near-term circuit constraints are identified, planners can find potential solutions for solving those constraints — whether the solution is a low-cost utility-side adjustment, a customer solution (i.e., advanced inverter), or a traditional circuit upgrade.").

51 *Id.*; Solar City IDP at pp. 7-8

52 ICF IDP at p. 4.

53 *See id.* at p. 9 ("A better approach [than using singular deterministic forecasts] is to use multiple DER growth scenarios to assess current system capabilities, identify incremental infrastructure requirements and enable analysis of the locational value of DERs.")

54 *See*, More Than Smart, *Integration Capacity Analysis Working Group - Group I Interim Status Report*, p. 2 (Aug. 31, 2017), http://drpwg.org/wp-content/uploads/2016/07/ICA-Group-I-interim-status-report-final.pdf

55 See SDSIP at p. 55 ("An evolution to this more detailed hosting capacity analysis [in Stage 3] will enable planners to more specifically identify locations along a feeder with higher levels of hosting capacity and determine how sub-feeder-level hosting capacity is impacted by current and prospective DER interconnections on the system.").

56 Cal. Public Utilities Commission, R. 14-08-013, Integration Capacity Analysis Working Group Final Report, p. 9 ("The WG determined that there is a role for a planning use case for the ICA, as it may be possible that the ICA can help determine and guide where and when future integration capacity is a limitation, among other possible planning uses. . . However, many components of this use case remain undefined, due to multiple ongoing efforts in other CPUC proceedings that will inform how ICA will be used in system planning, as well as the need for further clarity into the utility annual planning process itself.").

57 Southern California Edison, R. 14-08-013, Southern California Edison Company's (U338-E) Update Demonstration Projects A and B Final Reports, Appendix B (Locational Net Benefit Analysis Final Report), p. 2 (Jan. 4, 2017) ("SCE Final Report B").

58 *Id.*; ICF IDP at p. 16.

59 ICF IDP at p. 16

60 *Id.* ("[T]he value of DER on the distribution system is locational in nature—that is, the value may be associated with a distribution substation, an individual feeder, a section of a feeder, or a combination of these components.").

61 *Id.* ("The cost estimates of [planned infrastructure] investments form the potential value that may be met by sourcing services from qualified DERs as non-wires alternatives.").

62 *Id.*

63 Bebon, Joseph, *Solar Groups Speak Out Against Recent NY Ruling*, Solar Industry Magazine (Sept. 18, 2017), https://solarindustrymag.com/solar-groups-speak-latest-n-y-ruling.

64 Cal. Public Utilities Commission, R.14-08-013, Assigned Commissioner's Ruling Requesting Answers to Stakeholder Questions Set Forth in the Energy Division Staff White Paper on Grid Modernization, Attachment (Staff White Paper on Grid Modernization), pp. 20, 22 (May 16, 2017) ("Grid Modernization White Paper") (setting forth development of LBNA, as well as a Grids Needs Assessment based on LNBA and ICA results, in Staff's proposed Grid Modernization process for California investor owned utilities); see also LNBA Working Group reports, California's Distribution Resources Plan, R. 14-08-013, http://drpwg.org/sample-page/drp/.

65 Cal. Public Utilities Commission, R.14-08-013, Administrative Law Judge's Ruling Requesting Answers to Stakeholder Questions Set Forth in the Energy Division Staff Proposal on a Distribution Investment Deferral Framework, Attachment A (Energy Division Staff Proposal on a Distribution Investment Deferral Framework), pp. 11-13 (June 30, 2017) ("Distribution Investment Deferral Framework").

66 *Id*. at pp. 29-30.

67 Grid Modernization White Paper at pp. 23-24.

68 NY Public Service Commission, Case 15-E-0751, Order on Phase One Value of Distributed Energy Resources Implementation Proposals, Cost Mitigation Issues, and Related Matters, p. 5 (Sept. 14, 2017).

69 SDG&E Final Report A at p. 31.

70 *Id*. at pp. 19, 33, 49.

71 *See* Pepco Holdings, Inc., *Model-Based Integrated High Penetration Renewables Planning Control and Analysis*, pp. 7-8 (Dec. 14, 2015); EPRI, *Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV* (Dec. 2012).

72 *See* Xcel Distribution System Study at pp. 3-4; SDSIP at p. 52.

73 *See*, e.g. EPRI Integration at 7.

74 SDSIP at p. 49.

75 SDSIP at p. 52; Xcel Distribution System Study at p. 11.

76 PG&E Final Report A at p. 16.

77 *Id*. at p. 17.

78 *See* NY Public Service Commission, Case 16-M-0411, Order on Distributed System Implementation Plan Filings, pp. 10-15 (Mar. 9, 2017); Xcel Distribution System Study at pp. 3-4, 6 (focusing HCA analysis on small-scale distributed generation technologies); Xcel Energy, Dkt. E002/M-15-962, Supplemental Comments: Biennial Distribution Grid Modernization Report, pp. 9, 11 (Mar. 20, 2017) (explaining that "energy storage load characteristics were excluded from [Xcel's HCA] analysis" and excluding demand response and energy efficiency technologies from Xcel's definition of DER); Pepco Analysis (discussing only PV penetration).

79 See Xcel Distribution System Study at pp. 10-12; SDG&E Final Report A at p. 39 (regarding use of a heuristic approach to evaluate the operational flexibility criterion); Pacific Gas & Electric Co., R. 14-08-013, Demonstration A—Enhanced Integration Capacity Analysis: PG&E ICA Demo A Interim Report, p. 7 (Sept. 30, 2015) ("In order to ensure transparency and consistency within the methodology, the various assumptions and starting point parameters must be expressed" so that, for instance, results can be replicated by third parties.).

80 SDG&E Final Report A at p. 79.

81 PG&E Final Report A at p. 116.

82 See EPRI Integration at p. 7.

83 PG&E's PV RAM maps, for instance, "employ a coloring scheme that depicts the capacity level of a line section by a color gradient to better display the varying levels of capacity by location on each feeder. This coloring scheme is intended to help DER developers and customers better understand where on a circuit location of a DER is better suited." PG&E Final Report at p. 118. PG&E's RAM maps are available at https://www.pge.com/en_US/for-our-business-partners/energy-supply/solar-photovoltaic-and-renewable-auction-mechanism-program-map/solar-photovoltaic-and-renewable-auction-mechanism-program-map.page; Central Hudson's Hosting Capacity Map is available at https://www.cenhud.com/dg/dg_hostingcapacity ("Each distribution circuit is color coded based on its maximum hosting capacity value."); Pepco Holding LLC's Hosting Capacity Map is available at http://www.pepco.com/Hosting-Capacity-Map.aspx.

84 *See RESTful API*, SearchCloudStorage.com, http://searchcloudstorage.techtarget.com/definition/RESTful-API ("A RESTful API is an application program interface (API) that uses HTTP requests to GET, PUT, POST and DELETE data.").

85 Cal. Public Utilities Commission, R. 14-08-013, Integration Capacity Analysis Working Group Final Report, p. 5 (Mar. 15, 2017).

86 Interstate Renewable Energy Council, Case 16-M-0411, Comments of the Interstate Renewable Energy Council, Inc. on the Supplemental Distributed System Implementation Plan, p. 11 (Jan. 9, 2017).

87 *Id*.

88 Cal. Public Utilities Commission, R. 14-08-013, Decision on Track 1 Demonstration Projects, pp. 58-61 (Oct, 6, 2017).

89 Cal. Public Utilities Code § 769; *see also* Cal. Assembly Bill 327 (Perea 2013).

90 Cal. Public Utilities Commission, R. 14-08-013, Assigned Commissioner's Ruling on Guidance For Public Utilities Code Section 769—Distribution Resource Planning, Attachment, at pp. 3-4 (Feb. 6, 2015).

91 *Id*.

92 *Id*. at p. 4 (Ordering the utilities to: "Specify recommendations for utilizing the Integration Capacity Analysis to support planning and streamlining of Rule 21 for distributed generation and Rule 15 and Rule 16 assessments of EV load grid impacts, with a particular focus on developing new or improved 'Fast Track' standards.").

93 *See* California ICA Working Group materials, California's Distribution Resources Plan, R. 14-08-013, http://drpwg.org/sample-page/drp/ and http://drpwg.org/archive-ica-and-lnba-working-group/.

94 *See* Joint Motion of San Diego Gas & Electric Company (U 902 E), Southern California Edison Company (U 338 E), and Pacific Gas and Electric Company (U 39 E), R.14-08-013 (June 9, 2016) (seeking permission to perform a test of both methodologies as part of the demonstration project); Cal. Public Utilities Commission, R. 14-08-013, Email Ruling of Administrative Law Judge Mason (June 10, 2016) (authorizing the utilities to do a comparison of both methodologies in their Demonstration projects).

95 Cal. Public Utilities Commission, R. 14-08-013, Assigned Commissioner's Ruling (1) Refining Integration Capacity and Locational Net Benefit Analysis Methodologies and Requirements; and (2) Authorizing Demonstration Projects A and B (May 2, 2016).

96 PG&E Final Report A at p. 53.

97 PG&E Final Report A at p. 98 ("In general, the streamlined approach focused on speed and abstraction of analysis across components while the iterative is focused on detail and precision of power flow results closer to what may be seen in an interconnection study.").

98 SDG&E Final Report A at p. 45.

99 Southern California Edison, R. 14-08-013, Southern California Edison Company's (U 338-E) Update Demonstration Projects A and B Final Reports, Appendix A (Enhanced Integration Capacity Analysis Final Report), p. 80 (Jan. 4, 2017) ("SCE Final Report A"); PG&E Final Report A at p. 105.

100 SCE Final Report A at pp. 45, 47.

101 PG&E Final Report A at pp. 96, 143.

102 PG&E Final Report A at p. 11 ("The streamlined techniques are better suited to more appropriately analyze large amounts of scenarios for planning purpose, while the iterative is better suited for analyzing circuit conditions for specific interconnection purposes"); SDG&E Final Report A at p. 9; SCE Final Report A at pp. 2-3.

103 SDG&E Final Report A at p. 9; PG&E Final Report A at 155.

104 PG&E found that the iterative methodology was better suited for interconnection, while streamlined was better suited for planning purposes. PG&E proposed using the streamlined method for the mapping and then recommended the iterative results be applied when actually processing interconnection applications for software efficiency reasons. The ICA working group found this approach unworkable because it wanted ICA maps to accurately reflect the results an applicant could expect from the interconnection process. Cal. Public Utilities Commission, R. 14-08-013, Integration Capacity Analysis Working Group Final Report, pp. 12-14 (Mar. 15, 2017).

105 Cal. Public Utilities Commission, R.14-08-013, Decision on Track 1 Demonstration Projects, pp. 29-33.

106 For information on the ongoing ICA Working Group discussions regarding the planning use case see http://drpwg.org/sample-page/drp/.

107 For more about Reforming the Energy Vision, visit http://www3.dps.ny.gov/W/PSCWeb.nsf/All/CC4F2EFA3A23551585257DEA007DCFE2?OpenDocument.

108 NY Public Services Commission, Case 14-M-0101, Order Adopting Distributed System Implementation Plan Guidance, pp. 43-46 (Apr. 20, 2016).

109 *Id*. at pp. 19-22.

110 The Joint Utilities are comprised of Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc. (Con Edison), New York State Electric & Gas Corporation, Niagara Mohawk Power Corporation d/b/a National Grid (National Grid), Orange and Rockland Utilities, Inc. and Rochester Gas and Electric Corporation.

111 EPRI, Defining a Roadmap.

112 *Id*. at p. 4.

113 SDSIP at p. 52; see also EPRI Integration.

114 To date there has been no published analysis that compares exactly how the "streamlined" method tested in California compares with the current version of the DRIVE tool. However, PG&E stated in their distributed resources plan that it's "approach is similar to the Electric Power and Research Institute (EPRI) streamlined hosting capacity for PV Interconnection." Pacific Gas and Electric Co., R. 14-08-013, *Electric Distribution Resources Plan*, p. 23 (July 1, 2015). EPRI has yet to publish any public information that details the methodology used to support the DRIVE tool (though this information may be available to paying members) nor has there been an objective analysis done that analyzes the accuracy of the results produced by the DRIVE tool.

115 SDSIP at p. 48.

116 *Id*. at 49.

117 NY Public Service Commission, Cases 14-M-0101, 16-M-0411, Order on Distributed System Implementation Plan Filings, p. 11 (Mar. 9, 2017) ("Hosting capacity ranges are based on the circuit characteristics and assume that there are no DERs interconnected. Therefore, the maps will have pop-up boxes that display the DER s currently interconnected and DER projects that are in the interconnection queue process.").

118 *Id*. at p. 12 ("Hosting capacity was one of the most frequent topics discussed in the comments. Commenters on the Initial DSIPs generally noted that the information currently provided by the Utilities is insufficient and that more data related to hosting capacity is needed.").

119 *Id*. at p. 14.

120 *Id*. at pp. 14-15.

121 The directive came in the form of amendments to Minnesota's transmission-planning statute, Minn. Stat § 216B.2425, and required covered utilities "to conduct a distribution study to identify interconnection points on its distribution system for small-scale distributed generation resources and . . . identify necessary distribution upgrades to support the continued development of distributed generation resources." Minn. Stat. § 216B.2425, subd. 8.

122 MN Public Utilities Commission, Dkt. E002/M-15-962, Order Certifying Advanced Distribution-Management System (ADMS) Project Under Minn. Stat. § 216B.2425 and Requiring Distribution Study (June 28, 2016).

123 MN Public Utilities Commission, Dkt. E002/M-15-962, In the Matter of Northern States Power Company's 2015 Biennial Distribution Grid Modernization Report (Dec. 1, 2016).

124 *Id*. at p. 11.

125 *Id*.

126 *Id*. at Attachment A.

127 MN Public Utilities Commission, Dkt. E002/M-15-962, Information Request PUC #1 (Feb. 21, 2017).

128 MN Public Utilities Commission, Dkt. E002/M-15-962, Notice of Comment Period on Distribution System Study (Feb. 21, 2017).

129 MN Public Utilities Commission, Notice of Commission Meeting (June 2, 2017) (providing notice that the PUC would consider action on Xcel's initial hosting capacity report at its June 15, 2017 hearing).

130 MN Public Utilities Commission, Dkt. E002/M-15-962, Order Setting Additional Requirements for Xcel's 2017 Hosting Capacity Report (Aug. 1, 2017).

131 *Id*. at p. 5.

132 *Id*. at p. 6.

133 *Id*.

134 Xcel Energy, Dkt. E002/M-17-777, Distribution System/Hosting Capacity Study (Nov. 1, 2017).

135 *Id*. at p. 1-4.

136 MN Public Utilities Commission, Dkt. E999/CI-15-556, Notice of Comment Period on Distribution System Planning Efforts and Considerations (Apr. 21, 2017).

137 *Id*.

138 MN Public Utilities Commission, Dkt. E002/M-15-962, Order Setting Additional Requirements for Xcel's 2017 Hosting Capacity Report, p. 6 (Aug. 1, 2017).

139 Xcel Energy, Dkt. E002/M-17-777, *Distribution System/Hosting Capacity Study* (Nov. 1, 2017).

140 MN PUC, Dkt. E002/M-17-777, *Notice of Comment Period on Xcel's 2017 Distribution System Hosting Capacity Report* (Nov. 15, 2017).

141 See, e.g., Dkt. E999/CI-15-556, Comments of Interstate Renewable Energy Council, Inc. on Distribution System Planning Efforts and Considerations, pp. 12-14 (Aug. 21, 2017); Dkt. E999/CI-15-556, Comments of the Advanced Energy Economy Institute on Distribution System Planning, p. 5 (July 20, 2017).

142 Xcel Distribution System Study, pp. 6, 10-11; Dkt. E002/M-15-962, Xcel Energy Supplemental Comments on Biennial Distribution Grid Modernization Report, pp. 2-3 (Mar. 20, 2017).

143 *See*, e.g., Dkt. E002/M-15-962, Comments of the Interstate Energy Renewable Energy Council, Inc. Regarding Xcel Energy's Hosting Capacity Analysis and Supplemental Comments, pp. 16-19 (Apr. 20, 2017); Dkt. E002/M-15-962, Comments by Fresh Energy in Response to the Commission's February 2017 Notice, pp. 1-3 (Apr. 20, 2017); MN Public Utilities Commission, Dkt. E002/M-14-962, Order Setting Additional Requirements for Xcel's 2017 Hosting Capacity Report, pp. 3-4 (Aug. 1, 2017) (summarizing stakeholders' positions).

144 Pepco Holdings, Inc., *Model-Based Integrated High Penetration Renewables Planning Control and Analysis*, pp. 7-10 (Dec. 14, 2015) ("Pepco Analysis"); see also *EPRI, Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV* (Dec. 2012).

145 Pepco Analysis at p. 11.

146 Pepco Holdings LLC, *Interconnection of Distributed Energy Resources*, § 2.6 (Jun. 21, 2016), http://www.pepco.com/uploadedFiles/wwwpepcocom/Content/Page_Content/GPC/PHI%20Interconnection%20of%20Distributed%20Energy%20Resources.pdf.

147 *Id*.

148 Pepco Holdings LLC, Restricted Circuit Map, http://www.pepco.com/Restricted-Circuit-Map.aspx.

149 See Pepco Holdings LLC, Criteria Limits for Distributed Energy Resource Connections to the ACE, DPL and Pepco Distributions Systems (Less than 69KV), http://www.pepco.com/library/templates/Interior.aspx?Pageid=6442460710&LangType=1033

150 Pepco Analysis at pp. 12-16.

ABOUT IREC

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