BEFORE THE OREGON PUBLIC UTILITIES COMMISSION

In the Matter of Portland General Electric Distribution System Planning Report.	UM 2197

COMMENTS OF THE INTERSTATE RENEWABLE ENERGY COUNCIL, INC. ON THE PATH FORWARD FOR HOSTING CAPACITY ANALYSIS IN OREGON

Yochanan Zakai
SHUTE, MIHALY & WEINBERGER LLP
(415) 552-7272
yzakai@smwlaw.com

Attorneys for Interstate Renewable Energy Council, Inc.

DATED: December 3, 2021

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I. Introduction

On December 23, 2020 the Commission issued Order No. 20-485 in docket UM 2005, requiring utilities to file distribution system plans (DSPs) that describe three different options for the deployment of Hosting Capacity Analyses (HCAs). Order No. 20-485 envisions that the Commission will review the utilities' proposals for the deployment of HCAs and then "adopt[] a path forward for HCA in Oregon."[1] On October 15, 2021, Portland General Electric (PGE) filed its inaugural DSP. Pursuant to the Commission's request for public comment,[2] the Interstate Renewable Energy Council, Inc. (IREC) submits these initial comments on the path forward for HCA in Oregon.

IREC is a 501(c)(3) non-partisan, non-profit organization working nationally to build the foundation for rapid adoption of clean energy and energy efficiency to benefit people, the economy and our planet. In service of our mission, IREC advances scalable solutions to integrate distributed energy resources (DERs), e.g., renewable energy, energy storage, electric vehicles, and smart inverters, onto the grid safely, reliably, and affordably. IREC supports the creation of

[1] Dkt. UM 2005, Order No. 20-485, Appendix A, at 20 (Dec. 23, 2020).

[2] Distribution System Planning Docket Announcement (Nov. 1, 2021).

robust, competitive clean energy markets, though IREC does not have a financial stake in those markets. IREC is an unaffiliated, independent public interest organization, whose vision is a 100% clean energy future that is reliable, resilient and equitable. IREC works across numerous diverse states to improve the rules, regulatory policies and technical standards that enable the streamlined, efficient and cost-effective interconnection of DERs.

IREC has been involved in numerous of regulatory dockets and research projects associated with the development of DSPs and HCAs.[3] Through our engagement in these efforts, we have seen some states provide an HCA with detailed and actionable information for customers on the first day it is published. However, in other states the initial HCA data provided by utilities has not been trusted or used by the Commission's intended audience. There are

[3] CA Pub. Util. Comm., Dkt. R.14-08-013, Distribution Resources Plans; CA Pub. Util. Comm., Dkt. R.21-06-017, Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future; CO Pub. Util. Comm., Dkt. 19M-0670E, Distribution System Planning; MD Pub. Service Comm., Dkt. RM68, Small Generator Facility Interconnection Standards; NY Pub. Service Comm., Dkt. 14-M-0101, Reforming the Energy Vision; NY Pub. Service Comm., Dkt. 16-M-0411, Distributed System Implementation Plans; MA Dpt. of Pub. Util., Dkt. 19-55, Distributed Generation Interconnection; MA Dpt. of Pub. Util., Dkt. 20-75, Distributed Energy Resource Planning and Recovery of Costs; NV Pub. Util. Comm., Dkt. 17-08022, Rulemaking to Implement Senate Bill 146 (2017); MN Pub. Util. Comm., Dkt. E999/CI-15- 556, Investigation into Grid Modernization; MN Pub. Util. Comm., Dkt. E002/M-15-962, Xcel Energy Biennial Report on Distribution Grid Modernization; MN Pub. Util. Comm., Dkt. E002/M-17-777, Xcel Energy 2017 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E002/CI-18-251, Xcel Energy Distribution System Planning; MN Pub. Util. Comm., Dkt. E002/M-18-684, Xcel Energy 2018 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E002/M-19-685, Xcel Energy 2019 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E999/CI-20-800, Grid And Customer Security Issues Related to Public Display or Access to Electric Distribution Grid Data; MN Pub. Util. Comm., Dkt. E002/M-20-812, Xcel Energy 2020 Hosting Capacity Analysis; 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); IREC, *Optimizing the Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources* (December 2017); IREC and Nat. Renewable Energy Laboratory, *Data Validation for Hosting Capacity Analysis* (forthcoming).

several key decisions about the design of an HCA that make the difference between a tool that is used and useful for customers, and a tool that provides little relevant information. The most prominent among those key decisions is the completion of a stakeholder process that results in the Commission's selection of a use case, methodology, granularity (feeder or nodal), update frequency, and methods of public access to the HCA data. IREC identified and explained the common options available for making these and other decisions in a guide, *Key Decisions for Hosting Capacity Analysis*, attached to these comments.[4]

IREC supports the Commission's plans to provide more distribution system data to customers, and PGE's interest in performing its first HCA. We encourage efforts to make distribution system grid data and HCAs more transparent to customers and stakeholders. However, IREC is concerned that the proposal in PGE's DSP will circumvent the Commission's decision-making process by deploying an insufficient hosting capacity analysis before the Commission makes certain key decisions about the design of the analysis. More troubling, as described below, is that PGE proposes to resolve the key decisions regarding the HCA's granularity, update frequency, and public access to data in a manner that mirrors the choices made by utilities whose initial HCA results provided scant, if any, value to customers.

Accordingly, the Commission should not approve or acknowledge PGE's request to provide feeder-level HCA results or to update results at an infrequent interval. Instead, the Commission should follow the plan it set in Order No. 20-485 and, in the interconnection policy

[4] Sky Stanfield, Yochanan Zakai, Matthew McKerley, *Key Decisions for Hosting Capacity Analyses*, IREC (Sept. 2021), https://irecusa.org/resources/keydecisions-for-hosting-capacity-analyses (Chapter 2: Stakeholder Engagement Process, Chapter 3: Use Cases, Chapter 4: Phased Implementation, Chapter 5: Methodology, Chapter 6: Updating the HCA When System Changes Occurs, Chapter 9: Granularity of Analysis and Results; Chapter 11: Public Access to HCA Data) (provided as Attachment 1).

docket, make the key decisions necessary to implement an HCA that will provide tangible benefits to Oregonians. In the interim, the Commission should authorize and encourage utilities to organize, clean-up, and publish basic distribution system data.

II. The Commission should not authorize Portland General Electric to preempt its decision-making process by deploying a hosting capacity analysis before the Commission makes key decisions about the design of the analysis.

In Order No. 20-485 the Commission decided that it "will consider [the DSP's] cost and timeline estimates, concerns, and recommendations in adopting a path forward for HCA in Oregon."[5] Commission Staff further elaborated that the Commission plans to review the benefits of HCA and make decisions regarding the analysis and maps in its interconnection policy proceeding. The UM 2005 Technical Working Group's notes from the August 25, 2021 meeting state that:

> Benefits of hosting capacity analysis will be discussed as part of the broader conversation on interconnection reform in Docket No. UM 2111. Staff expects a Commission decision regarding hosting capacity analysis, including any maps, will be made in UM 2111.[6]

IREC agrees that the Commission should make the central decisions about the design of hosting capacity analyses. As explained above, there are several key decisions that make the difference between a tool that is used by and useful for customers, and a tool that provides little relevant information. In IREC's experience, when utilities perform their first HCA and acquire HCA software before a work group discusses the key decisions and regulators resolve any disagreements, customers do not end up using or trusting the HCA data. For example, in

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[5] Dkt. UM 2005, Order No. 20-485, Appendix A, at 20.

[6] Dkt. UM 2005, Distribution System Planning Work Group Announcements and Technical Work Group Aug. 25, 2021 Notes, at 6 (Nov. 15, 2021) (Technical Work Group Aug. 25, 2021 Notes).

Minnesota Xcel Energy deployed an HCA in 2016 before a work group discussed Xcel's proposal and the Commission decided on the granularity, update frequency, or public access to data.[7] Developers responded that the initial HCA, which provided results at the feeder level and was updated infrequently, did not provide a useful estimate of actual hosting capacity and was "of almost no value at all."[8] After Minnesota customers paid for the utility to perform three years of the HCA, one developer noted that the HCA "map is totally unreliable."[9] New York used the same formula, beginning by providing results at the feeder level using EPRI's DRIVE software and not updating the analysis frequently; IREC heard similar responses from customers.[10] Oregon should heed the lessons from these early adopter states.

Portland General Electric's plan to immediately perform an HCA on its own terms preempts and contradicts the Commission's role as the entity that should make the key decisions regarding Oregon's first deployment of HCA. PGE proposes to provide feeder-level results and to update results at an infrequent interval,[11] the same approach Minnesota and New York used in their first rollout. Oregon should expect more from its first HCA.[12] Performing PGE's first HCA

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[7] MN Pub. Util. Comm., Dkt. E002/M-15-962, Order Setting Additional Requirements For Xcel's 2017 Hosting Capacity Report, at 1 (Aug. 1, 2017).

[8] MN Pub. Util. Comm., Dkt. E002/M-18-684, Fresh Energy's Comments on Xcel's 2018 Hosting Capacity Study, at 20 (Feb. 28, 2019).

[9] MN Pub. Util. Comm., Dkt. E002/M-18-684, Fresh Energy's Comments on Xcel's 2018 Hosting Capacity Study, at 20.

[10] *See* NY Pub. Service Comm., Dkt. 16-M-0411, Distributed System Implementation Plans (IREC's discussions in HCA workshops and with participants in the Interconnection Technical Working Group).

[11] Portland General Electric 2021 Distribution System Plan § 6.6 (Oct. 15, 2021).

[12] For more information about granularity and update frequency, see *Key Decisions for Hosting Capacity Analyses,* Chapter 9: Granularity of Analysis and Results, and Chapter 6: Updating the HCA When System Changes Occurs.

and acquiring HCA software and will result in significant sunk costs. PGE quantifies these costs at around $274,000,[13] however IREC has not attempted to verify the accuracy of this cost estimate.

The Commission should not approve or acknowledge PGE's request to perform an HCA that only provides feeder-level HCA results or only updates results infrequently. In New York and Minnesota, customers did not use or trust the first HCAs with feeder-level results that were updated infrequently. Utilities that follow this same path and publish an initial HCA that provides little—if any—value to customers should not be eligible to recover from customers the costs of performing the analysis or acquiring HCA software. The Commission should first complete its consideration of the three options described in Order No. 20-485 before utilities spend ratepayer dollars performing their first HCA.

III. In the interim, the Commission should authorize and encourage utilities to validate and publish basic distribution system data.

While the Commission completes its stakeholder and decision-making processes to determine the path forward for HCA in Oregon, it should authorize and encourage utilities to validate and publish basic distribution system data in geographic information systems (GIS) shapefile, tabular, and online map format. Basic distribution system data can typically be readily accessed from a utility's GIS and asset management database. The basic distribution data is independent of the power flow simulations performed as a part of the HCA and the HCA results themselves. Accordingly, an early phase 1 map and downloadable files, *e.g.*, GIS shapefile and tabular spreadsheet, with basic data can be published before the conclusion of the stakeholder

[13] Portland General Electric 2021 Distribution System Plan, at 146.

process and before the utility performs its first HCA modeling.[14] Utilities likely need to validate basic distribution system data before it is used as an input to the HCA, which is one reason why cleaning up and preparing this data for publication before it is used in the HCA is useful. In California, utilities published early phase 1 distribution system data while utilities developed the first HCAs, and customers have a long track record of accessing and using this data.[15]

The basic distribution system data that customers have requested to help inform interconnection applications include the following:

FEEDER

- Name or identification number
- Which substation the feeder connects to
- Feeder voltage
- Number of phases
- Which substation transformer the feeder connects to
- Feeder type: radial, network, spot, mesh, etc.
- Feeder length
- Feeder conductor size and impedance
- Service transformer rating
- Service transformer daytime minimum load
- Existing generation (weekly refresh rate)
- Queued generation (weekly refresh rate)
- Total generation (weekly refresh rate)
- Load profile showing 8760 hours
- Percentage of residential, commercial, industrial customers
- Currently scheduled upgrades
- Federal or state jurisdiction
- Known transmission constraints that require study
- Notes (other relevant information to help guide interconnection applicants

SUBSTATION

- Name or identification number
- Voltages
- Substation transformer nameplate rating
- Existing generation (weekly refresh rate)
- Queued generation (weekly refresh rate)
- Total generation (weekly refresh rate)
- Load profile showing 8760 hours, by substation and transformer
- Percentage of residential, commercial, industrial customers
- Currently scheduled upgrades
- Has protection and/or regulation been upgraded for reverse flow (yes/no)
- Number of substation transformers and whether a bus-tie exists
- Known transmission constraints that require study
- Notes (include any other relevant information to help guide interconnection applicants, including electrical restrictions, known constraints, etc.)

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[14] Key Decisions for Hosting Capacity Analysis, at 11.

[15] California's first published maps included the location of electric distribution lines, substations, and transmission lines paired with basic distribution system data. *See, e.g.*, Southern California Edison, Distribution Resource Planning Data Portal, https://ltmdrpep.sce.com/drpep/ (showing publicly accessible distribution system data provided by California utilities today).

IREC's *Key Results for Hosting Capacity Analysis* provides examples of how customers can effectively use this data on page 12. As noted above, in states where utilities performed HCA before regulators issued an order making certain key decisions, customers did not use end up using or trusting the HCA data. Instead, customers asked for utilities to provide this basic distribution system data (and for regulators to order a more useful HCA deployment that includes more granular results and is updated more frequently). To be clear, an HCA can provide very valuable and useful data, but only if done correctly. A basic distribution system map can be more useful than an inadequate HCA map.

The Commission's November 15, 2021 Distribution System Planning Work Group Announcement includes a working subgroup on public accessibility of distribution system data.[16] IREC recommends that the subgroup discuss publishing the this distribution system data—ideally within the next several months—for the benefit of customers.

The Commission should authorize and encourage utilities to publish basic distribution system data at this preliminary stage in the Commission's HCA decision-making process.

IV. Portland General Electric's cost estimate is an order of magnitude higher than Pacific Gas and Electric's reported costs.

IREC urges the Commission not to rely exclusively on the cost estimates in PGE's DSP. PGE's cost estimate of $58 million is an order of magnitude higher than Pacific Gas and Electric's (PG&E's) reported actual cost of $7 million to deploy its HCA.[17] PG&E deployed a

[16] Dkt. UM 2005, Distribution System Planning Work Group Announcements, at 2 (Nov. 15, 2021).

[17] Portland General Electric 2021 Distribution System Plan, at 142-143; CA Pub. Util. Comm., Dkt. R.14-08-013, Pacific Gas & Electric's Integration Capacity Analysis Implementation Update, at 4 (May 7, 2020) (provided as Attachment 2) (HCA is called Integration Capacity Analysis or ICA in California).

full-featured iterative method HCA using the industry's best practices.[18] In addition, PG&E uses the same CYME software to build its distribution system feeder models as PGE and PacifiCorp.[19] Yet a report, provided as Attachment 2 to these comments, shows that the cumulative cost of PG&E's initial HCA implementation with monthly updates totaled only $7 million over three years.[20] Further, IREC would expect an Oregon utility's HCA deployment to cost considerably less than PG&E's because:

- PG&E is the largest utility in the nation, with a service territory that includes over 3,083 feeders; PGE's considerably smaller service territory includes only 653 feeders.[21]
- PG&E was one of the first utilities to perform an HCA, so it faced many problems associated with being a pioneer in the field that PGE is unlikely to face.
- PG&E's initial deployment was so error prone it was forced to stop, hire a consultant to redesign its entire HCA process, and then re-analyze its entire system using the new process. The costs of the initial error prone deployment, the consultant's work, and re-analyzing PG&E's entire system are all included in the $7 million.[22]

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[18] PGE uses the iterative method to produce an HCA with the following best practices: monthly updates; a 576-hour analysis; results for new generation and new load; nodal granularity; publication of all limiting criteria for each of the 576 analyses; a data portal including GIS shapefiles, tabular spreadsheets, Automated Programing Interface (API) access, and an online map; and a robust data validation process.

[19] Portland General Electric 2021 Distribution System Plan, at 145 ("PGE currently has its distribution system modeled in the CYME software"); Dkt. UM 2198, PacifiCorp 2021 Oregon Distribution System Plan, at 89 (Oct. 15, 2021); CA Pub. Util. Comm., Dkt. R.14-08-013, Pacific Gas & Electric 2021 Distribution Grid Needs Assessment, at 8 (Aug. 16, 2021) ("PG&E uses the CYME Power Engineering Software for modeling").

[20] The fourth year of costs included in Table 1 is an *estimate* of "annual[] . . . ongoing administration and monthly updates," not a report of *actual* initial implementation costs. Pacific Gas & Electric's Integration Capacity Analysis Implementation Update, at 4

[21] CA Pub. Util. Comm., Dkt. R.14-08-013, Pacific Gas & Electric Response to IREC's Fourth Data Request, Question 2(a) (Aug. 20, 2019) ("PG&E's electric distribution system contains 3,083 feeders upon which ICA calculations are performed."); Portland General Electric 2021 Distribution System Plan, at 145 ("In total, PGE serves 653 feeders in its service territory.");

[22] Key Decisions for Hosting Capacity Analysis, at 31 (Sidebar: California's Rock HCA Rollout); Pacific Gas & Electric's Integration Capacity Analysis Implementation Update, at 1-3 (provided as Attachment 2).

Finally, PGE claims that the DSP's costs "are in line with the costs estimated by peer utilities as shown in their HCA plans (e.g., SCE and MN Xcel)."[23] IREC is unclear what cost estimates PGE is referencing because there is no citation in the DSP to support its assertation. It is not appropriate for the Commission to rely on unsupported and unvetted cost *estimates* provided by other utilities; instead the Commission should look to *actual* costs like those found in Attachment 2 for PG&E.

Nonetheless, IREC has contested cost estimates provided by Xcel Energy in Minnesota as inadequate for use in regulatory decision-making processes.[24] And the cost estimates IREC has reviewed for Southern California Edison (SCE) encompass the utility's entire grid modernization program; they are not limited to HCA implementations costs.[25] As I explained in *Key Decisions for Hosting Capacity Analysis*:

> Some costs incurred are necessary only to complete the HCA, while others fall under a more general category of grid modernization investments that provide benefits to other distribution engineering activities. Regulatory proceedings vary in the depth of their review of HCA costs. Most states do not attempt to isolate all HCA costs because, as noted above, HCAs are often implemented as a part of a broader grid modernization effort. IREC is not aware of a regulatory proceeding in which HCA costs were thoroughly vetted by stakeholders . . . it is important for regulators to understand which HCA implementation tasks provide benefits to multiple distribution system engineering activities, and which only benefit the HCA.[26]

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[23] Portland General Electric 2021 Distribution System Plan, at 142.

[24] MN Pub. Util. Comm., Dkt. E002/M-20-812, Comments of the Interstate Renewable Energy Council, Inc. on Xcel Energy's 2020 Hosting Capacity Analysis, at 4-8 (April 7, 2021).

[25] CA Pub. Util. Comm., Dkt. A.19-08-013, Southern California Edison 2021 General Rate Case, Exhibit No. SCE-02, Vol. 4, Part 1, Grid Modernization, Grid Technology, and Energy Storage (Aug. 30, 2019).

[26] Key Decisions for Hosting Capacity Analysis, at 6 (citations omitted).

V. Conclusion

Based on the work group's note that "Staff expects a Commission decision regarding hosting capacity analysis, including any maps, will be made in UM 2111,"[27] IREC performed a preliminary review of PGE's DSP and in these limited comments only discusses issues that the Commission will likely need to address before its full consideration of HCA in the interconnection policy docket, UM 2111. IREC thanks the Commission for the opportunity to submit these comments, and looks forward to future discussions regarding the path forward for HCA in Oregon.

DATED: December 3, 2021

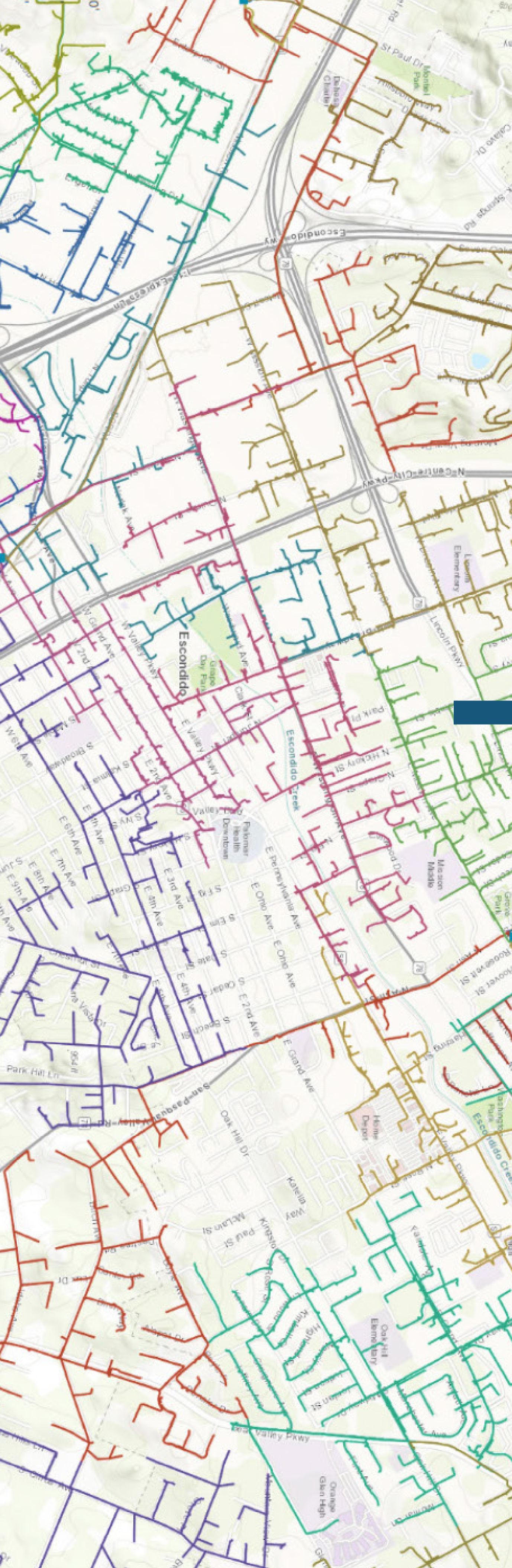
By: */s/ Yochi Zakai*

Yochanan Zakai, Oregon State Bar No. 130369
SHUTE, MIHALY & WEINBERGER LLP
396 Hayes Street
San Francisco, California 94102
(415) 552-7272
yzakai@smwlaw.com

Attorneys for Interstate Renewable Energy Council, Inc.

[27] Technical Work Group Aug. 25, 2021 Notes, at 6.

ATTACHMENT 1



KEY DECISIONS FOR

HOSTING CAPACITY ANALYSES

SEPTEMBER 2021

IREC

INTERSTATE RENEWABLE ENERGY COUNCIL

KEY DECISIONS FOR HOSTING CAPACITY ANALYSES

SEPTEMBER 2021

AUTHORS

Sky Stanfield
Yochi Zakai
Matthew McKerley
Shute, Mihaly & Weinberger LLP
Attorneys for the Interstate Renewable Energy Council

THE AUTHORS AND IREC WOULD LIKE TO THANK:

Radina Valova and Midhat Mafazy for their contributions to and assistance with research, writing, and editing; Nicole Wilson for layout and graphic design, with support from Mari Hernandez; and Gwen Brown for editing assistance.
The Barr Foundation for their funding and support of this report and IREC's work.
Katherine Cox-Arslan (Borrego Solar) and Clare Valentine (Western Resource Advocates) for their peer review of the guide.

The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the Barr Foundation or peer reviewers.

Cover map graphic source: San Diego Gas and Electric, Demonstration A, Integration Capacity Map

IREC

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SUGGESTED CITATION

Sky Stanfield, Yochi Zakai, Matthew McKerley. *Key Decisions for Hosting Capacity Analyses.* IREC (Sept. 2021), https://irecusa.org/resources/key-decisions-for-hosting-capacity-analyses.

1. INTRODUCTION

1.1 PURPOSE OF THIS GUIDE

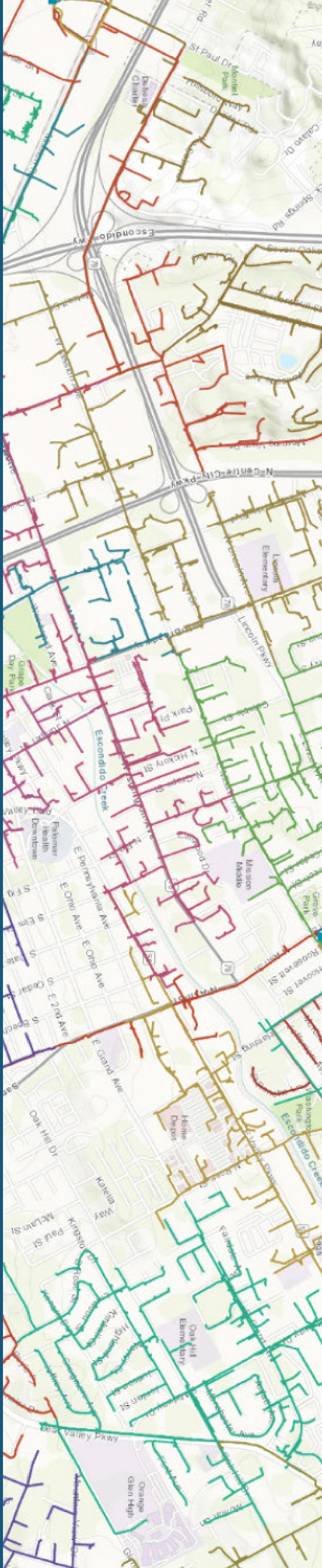
A hosting capacity analysis (HCA) is a grid transparency tool that provides an assessment of the ability of a distribution grid to host additional distributed energy resources (DERs) at specific locations, without the need for costly upgrades or lengthy interconnection studies.

Utilities first started conducting these analyses, either via a regulatory order or on their own initiative, around 2015. The popularity of HCAs has grown rapidly and multiple states now require, or are actively exploring, the development of HCAs as they look to better integrate a growing number of DERs. The process by which states and utilities have gone about developing these analyses varies and has produced a number of lessons learned about the factors necessary to produce a useful analysis.

The Interstate Renewable Energy Council (IREC) has been involved in a number of regulatory dockets and research projects[1] associated with the development of HCAs. Through our engagement in these efforts, and conversations with regulatory staff, stakeholders (including utilities), and the Department of Energy, we identified a need for a guide that will help regulatory staff and stakeholders understand the critical decisions that go into developing an HCA.

This guide is based on a recognition that there is not one way to develop an HCA and that decisions made during the development process can significantly affect the quality of the analysis and its ability to serve its intended function. Some early decisions can be difficult, expensive, or time intensive to change after the fact, while others can be built upon and evolve along with the analysis over time. Understanding those decisions and making conscious choices about how to proceed on each of them will make HCAs more useful tools to support the deployment of DERs, including both generation (*e.g.*, solar and storage) and load (*e.g.*, transportation and buildings electrification).

Thus, the goal of this guide is to help readers understand the variety of issues and decisions that may need to be considered as a public-facing HCA is developed. It is organized by topic, with an introduction to the decisions that may need to be made, a sample set of options to consider, and an explanation of the issues and the different considerations that go into making a decision on how to proceed for each topic. In addition to the more technical topics, this guide also includes regulatory process decisions that can help shape the decision-making process. Although IREC has opinions on preferred ways of approaching many of these topics, the goal of this guide is to present the different options that have been discussed to date and help the reader understand their implications, rather than expressly advocating for one approach over another.



1.2 BACKGROUND ON HCAs

PUBLICLY AVAILABLE HCA DATA

- Southern California Edison[2]
- Orange & Rockland NY, NJ[3]
- Xcel Energy MN[4]
- Dominion Energy VA NC[5]
- Pepco Holdings DC, MD, DL, NJ[6]

See end notes for the URLs of the above links. Additional HCA links are available at IREC's hosting capacity resources **webpage**.[7]

At its core, HCA is a complex modeling exercise that gathers detailed information about the distribution grid, including the physical infrastructure (the wires, voltage regulating devices, substations, transformers, etc.), the type and performance of load on the grid (load curves showing maximum and minimum load), and the existing generators and load control measures on the grid (including rooftop solar, energy storage, etc.).

The utility inputs this data into a feeder model* to create a "base case" for existing grid conditions, and then power flow simulations are run in order to see how the grid would perform with the addition of new DERs. There are three commonly identified use cases for HCA: interconnection, distribution system upgrade planning, and locational value. The process of selecting the use case, selecting the methodology, validating the input data, developing the feeder model, running the power flow simulation, and displaying the results includes numerous different decisions that can significantly shape the outcome, both in terms of the final hosting capacity result, and its accuracy when compared to real life conditions.

HCAs can be conducted by utilities for internal use or can be created with the intent of sharing them with the public or a more limited set of interested stakeholders. HCAs that are intended for public use are typically published on a map and are often simply referred to by the map rather than the underlying technical analysis. An HCA map provides a user interface that visually displays the distribution system and enables users to access information about particular locations in a pop-up box accessible by clicking on that precise location. However, the map is only one way of sharing or displaying HCA information. Hosting capacity information can also be accessed via other more widely used means such as downloadable files in tabular format (*e.g.*, spreadsheets and shapefiles) and Application Programming Interfaces (APIs).

In addition to the core power flow simulation results, HCAs typically also provide users basic information about the distribution grid, including the voltage of the lines, the amount of already connected and queued generation, load profiles, and other information. It is not uncommon for states to first start with publishing a map containing this basic, but useful, distribution system information prior to conducting the full power flow simulations required for an HCA. Sometimes utilities first publish maps that provide a potential capacity based upon rules of thumb that are less accurate and precise than a hosting capacity analysis. These more elementary maps are often referred to as "heat maps."

IREC is aware of 16 states and the District of Columbia that have published some form of HCA as of 2021. See sidebar: Publicly Available HCA Data. No two of these maps and underlying analyses are identical and all have been developed following different pathways. At least 11 states are in regulatory discussions about the initial publication of HCAs or improvements to existing HCAs.

For more information about HCAs, see IREC's hosting capacity resources **webpage**.[8]

*A feeder model is a computerized representation of the distribution system.

1.3 COSTS

Utilities will incur a variety of costs to implement HCAs. Performing an HCA involves validating the data used as inputs, preparing the feeder models used in the power flow simulations, running the power flow simulation, and providing the results to stakeholders. Each of these steps involves certain software, hardware, and human resources. In each step, the balance between human effort and automation, as well as between using the utility's rate-based hardware and cloud computing resources, will impact the cost, time, and accuracy of the HCA.

Most of the decisions described in this guide impact HCA costs. Rather than addressing the cost of each decision in each section of this guide, we note here that regulators should consider if and how to address the costs of each decision they make. Some costs could be offset by efficiencies gained. For example, utilities could receive less speculative interconnection requests in areas that indicate little available hosting capacity, which could free up engineering resources.

Some costs incurred are necessary only to complete the HCA, while others fall under a more general category of grid modernization investments that provide benefits to other distribution engineering activities. Regulatory proceedings vary in the depth of their review of HCA costs. Most states do not attempt to isolate all HCA costs because, as noted above, HCAs are often implemented as a part of a broader grid modernization effort.[9] IREC is not aware of a regulatory proceeding in which HCA costs were thoroughly vetted by stakeholders. However, costs have been described by utilities in certain proceedings.[10] When a stakeholder calls for a closer examination of HCA costs, it is important for regulators to understand which HCA implementation tasks provide benefits to multiple distribution system engineering activities, and which only benefit the HCA. When performing a cost-benefit analysis, regulators may consider what portion of those costs should be attributed to the HCA and what portion should not.

Some costs incurred are necessary only to complete the HCA, while others fall under a more general category of grid modernization investments that provide benefits to other distribution engineering activities.

For example, the utility's initial task, validating data used inputs and preparing the feeder models used in the power flow simulations, is the most time-intensive part of implementing an HCA.[11] Data validation efforts ensure that a utility's databases used in the HCA meet modern data quality standards. More accurate electronic records of the distribution system unlock a variety of benefits. Implementing an HCA often involves centralizing load data previously found in multiple systems into new commercial load forecasting software.[12] This software correct gaps, errors, and abnormalities in the load data. After this process is complete, the data is ready to use in the HCA, as well as for other distribution engineering activities including creating load forecasts for planning and operations.[13] Prior to performing the HCA, similar data validation efforts are necessary for several other utility databases. (See section 14.) Because of the multiple benefits provided by data validation efforts, utilities often assign these costs to their grid modernization programs and not the HCA specifically.[14]

2. STAKEHOLDER ENGAGEMENT PROCESS

KEY DECISION: Should regulators convene a stakeholder engagement process in advance of the utility performing the HCA?

OPTIONS:

- Stakeholder process occurs before regulators determine to procced with an HCA, or occurs before regulators direct the design of the HCA
- Facilitation by independent third party, regulator, or utility

The timing of the stakeholder process—and when key decisions are vetted by regulators—can significantly impact how useful a hosting capacity analysis is to customers.

Figure 1. Regulatory Stakeholder Engagement Strategies

In a stakeholder engagement process, stakeholders and regulators openly discuss the key decisions identified in this paper. These processes can be in advance of regulators directing or guiding the design of the HCA; as a middle step after regulators have already determined to proceed with an HCA; or both (see sidebar: Sample Process). A stakeholder process typically includes workshops where any stakeholder can make proposals and presentations, followed by written comments from stakeholders describing recommendations.

A stakeholder process enables the key decisions about the HCA to be made in a transparent manner, builds common understanding about the intended uses of the HCA, incorporates best practices, and helps users understand the HCA's assumptions and outcomes.

The stakeholder process also informs regulators about the benefits and consequences associated with each key decision about the HCA. Many of the decisions are tied to technical issues that regulators are unlikely to have faced in the past. To aid regulators' understanding, engineers and policy staff from engaged stakeholder groupss can attend workshops to explain and discuss the implications of each decision. For example, engineers and policy staff could identify which options align with existing interconnection screens and study processes, which align with existing distribution planning study processes, and which represent the best practices based on other states' experiences with HCA. Regulatory staff may facilitate workshops, an outside facilitator may be engaged, or the utility may facilitate the discussions. Particularly if a utility facilitates, regulators may want to establish clear expectations about how stakeholder input is to be incorporated into any resulting product to transparently reflect the discussions and avoid perceptions of bias.

SAMPLE PROCESS

1. Initial workshops and party comments
2. Regulators authorizes HCA, makes initial HCA decisions, set implementation phases
3. Utilities publish Phase 1 basic distribution system maps and downloadable tabular data
4. Implementation workshops and party comments
5. Regulators make decisions regarding the analysis and how results should be displayed
6. Utility performs HCA, validates data, and publishes fully functional HCA
7. Regulators tracks results, learn about latest improvements, and evolve update requirements

3. USE CASES

KEY DECISION:
How will regulators and stakeholders use the HCA?

OPTIONS:

- **Interconnection**
  - Guiding site selection and system design
  - Use in the interconnection process's fast track screens
- **Distribution system upgrade planning**
- **Locational value**

Determining how, and for what, the HCA will be used is an important factor to consider when making other key decisions about the design of the HCA, therefore it is often one of the first decisions regulators will want to make. Having a robust discussion about how the HCA will be used will help ensure the necessary functionality is included. This discussion can also help guide decisions about phased rollout (see Section 4). An HCA can be designed with one or more use cases in mind. The most common use cases are summarized below.

For more detailed information on the use cases, see **Optimizing the Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources.**[15]

3.1 INTERCONNECTION

The interconnection use case often includes two parts: guiding site selection and system design, as well as use in the interconnection process's fast track screens.

HCA can be used to guide customers to locations on the distribution grid with sufficient capacity to accommodate a project without negative impacts on the grid or the need for upgrades. It can alleviate interconnection queue backlogs and disputes by identifying which locations will likely result in costly upgrades and delays so that customers may avoid those locations entirely or redesign their project, perhaps with energy storage or a smart inverter, to address the issue identified in the HCA. It may also support identifying locations where a DER could provide a system benefit.

HCA can also identify the months or seasons when constraints occur. For example, if a constraint appears only in a few months of the year or hours of the day, a customer may choose to limit export in those months or hours, avoiding the need for upgrades or downsizing the project.

The key point of the interconnection use case is that customers are given information that shows their options at the outset, before they spend money (and utility time) on a pre-application report and before the utility uses resources processing an interconnection application.

In addition to using HCA to guide siting decisions, the HCA can be used in the actual interconnection process in place of (or in addition to) the typical screening process. Almost all states currently rely on a set of interconnection screens that are built on rules of thumb rather than known conditions at the point of interconnection. A well designed HCA can be used to supplant some screens and thereby provide a more accurate way of identifying whether a project needs further study. See sidebar on p. 24: Replacing Interconnection Screens with HCA.

The end goal of the interconnection use case is for projects to transparently connect to the grid in a quicker and more informed manner.

3.2 DISTRIBUTION SYSTEM UPGRADE PLANNING

For the planning use case, an HCA identifies where constraints on the distribution system exist. This tool can then be used to proactively identify feeders as candidates for upgrades to increase hosting capacity for new load or generation. It can also be used to help incent the siting of DERs at locations with available capacity and a need for additional generation (consistently or during defined periods). Planned upgrades can be modeled to show future hosting capacity, and DER forecasts (both load and generation) can be modeled to show how capacity may grow or constrict under different scenarios.

For example, in Nevada and California, HCA is used as the foundational starting point for assessing grid needs as part of a regular distribution planning process.[16] The HCA could also be combined with forecasts of DER growth to inform decision-making processes such as integrated resource planning or general rate cases. In Nevada, the HCA includes an option that enables users to view a forecast of hosting capacity in future years based on anticipated DER additions and system upgrades.[17]

While there has been general agreement that hosting capacity could be used to help inform planning, this use case is not as well developed as the interconnection use case.

3.3 LOCATIONAL VALUE

DERs will have greater energy, capacity, and benefit to the grid in some locations than others, depending on the characteristics and needs of the feeder. Recognizing that the benefits of DERs may be 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 could 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. When the results of locational benefits analyses are combined with accurate hosting capacity and DER forecasting results, utilities and states could 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). 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. This is the least mature HCA use case.

4. PHASED IMPLEMENTATION

KEY DECISION: Should the HCA implementation occur in a single phase or multiple phases?

OPTIONS:
- Full rollout of HCA at one time
- Phased implementation starting with a map that includes a narrow set of HCA results and includes more features over time
- Phased implementation starting with a map that includes only basic distribution system data, with HCA results to be included later. The following list includes the basic distribution data that stakeholders commonly request utilities publish *(continued on the next page)*:

Basic Distribution System Data for Publication in an Early-Phase Map and Spreadsheet:

SUBSTATION

- Name or identification number
- Voltages
- Substation transformer nameplate rating
- Existing generation (weekly refresh rate)
- Queued generation (weekly refresh rate)
- Total generation (weekly refresh rate)
- Load profile showing 8760 hours, by substation and transformer
- Percentage of residential, commercial, industrial customers
- Currently scheduled upgrades
- Has protection and/or regulation been upgraded for reverse flow (yes/no)
- Number of substation transformers and whether a bus-tie exists
- Known transmission constraints that require study
- Notes (include any other relevant information to help guide interconnection applicants, including electrical restrictions, known constraints, etc.)

FEEDER

- Name or identification number
- Which substation the feeder connects to
- Feeder voltage
- Number of phases
- Which substation transformer the feeder connects to
- Feeder type: radial, network, spot, mesh, etc.
- Feeder length
- Feeder conductor size and impedance
- Service transformer rating
- Service transformer daytime minimum load
- Existing generation (weekly refresh rate)
- Queued generation (weekly refresh rate)
- Total generation (weekly refresh rate)
- Load profile showing 8760 hours
- Percentage of residential, commercial, industrial customers
- Currently scheduled upgrades
- Federal or state jurisdiction
- Known transmission constraints that require study
- Notes (other relevant information to help guide interconnection applicants)

Almost all states phase their HCA rollout in some way because of the time and complexity associated with implementing the first HCA. Some phase the implementation in order to more quickly publish basic distribution system data[18] or to allow more HCA results to be added over time.[19] Basic distribution system data can typically be readily accessed from a utility's geographic information systems (GIS) and asset management database. The basic distribution data is independent of the power flow simulations performed as a part of the HCA and the HCA results themselves. Accordingly, an early Phase 1 map and downloadable files, *e.g.*, tabular spreadsheet and GIS shapefile,* with basic data that could be published before the conclusion of the stakeholder process and before the utility performs the HCA modeling.

Regulators may also opt to phase the implementation of the HCA modeling, adding additional results or features over time. For example, some states have started by just providing HCA results on a yearly basis and then transitioned to providing more frequent updates in later phases.[20] Some started by providing only results for solar, then added analyses for other generation types and load DER (*e.g.*, electric vehicles and storage) in later phases.[21]

To make these decisions, regulators can assess the most immediate needs of users, the additional resources and complexity associated with performing the different types of analyses, and other considerations. The benefits of a phased approach include:

*The shapefile format is used by a wide variety of GIS software, including ArcGIS and the open source QGIS.

Almost all states phase their HCA rollout in some way because of the time and complexity associated with implementing the first HCA.

- Customers have earlier access to information that informs interconnection siting decisions
- Time for stakeholders and regulators to work through the process to make key decisions
- The impetus and opportunity for utilities to validate basic distribution system data before performing the HCA modeling
- A rollout that spreads the time and resources expended over multiple years

HOW CUSTOMERS USE BASIC DISTRIBUTION SYSTEM DATA

After publishing a map and tabular file with basic distribution system data, developers and customers can use the data to help design and site DERs. Here are a few examples of how customers could use this basic distribution system data:

- **Location of Distribution System Lines:** A customer can use the location of distribution system lines to determine what feeder (also called circuit) they are closest to and design the project to be compatible with that feeder's characteristics. If there are multiple potential points of interconnection for a project, a customer can identify the differences in the distribution system at those locations and select the one most suitable for the project.

- **Existing and Queued Generation:** Customers can use the quantity of existing and queued generation on a feeder to make a very rough estimate of the likelihood that a new interconnection request will require study or upgrades. Feeders with a high quantity of existing generation are generally more likely to require study or upgrade. The same is true with queued generation, although there is more uncertainty associated with queued generation because a customer can cancel the project and withdraw it from the queue.

- **Load Profile:** Customers and developers use load profiles to strategically locate DERs or provide the valuable service of reducing peak load hours. For example, a customer seeking to site an electric vehicle charging station would find it very useful to know the peak load on a feeder to understand the magnitude of the proposed new load compared to the existing peak load. In addition, a customer seeking to site a new solar project could use a load profile to avoid expensive distribution system upgrades by designing a system that accommodates daily or seasonal variations in minimum load with voluntary seasonal or hourly export limits.

- **Notes:** Customers often get useful data from notes that engineers add about the known constraints on, or characteristics of, a feeder. For example, the notes field could indicate that recent interconnection studies on the feeder found that voltage issues constrain available hosting capacity, certain equipment was recently installed, or the feeder is abnormally configured.

5. METHODOLOGY

KEY DECISION:

What HCA methodology should be used for power flow simulation?

OPTIONS:

- **Iterative:** The iterative method directly models the addition of new DERs on the distribution grid to identify hosting capacity limitations. A power flow simulation is run iteratively at each node on the distribution system, adding larger DERs until a violation of a power system limitation criteria is identified.
- **Stochastic:** The stochastic method models the addition of new DERs of varying sizes to a feeder at randomly selected locations, then the feeder is evaluated for adverse effects. The results are a hosting capacity range and not specific to a node.
- **Other:** There are ways to combine the above methodologies and there are also other methods for assessing HCA that are not publicly documented.

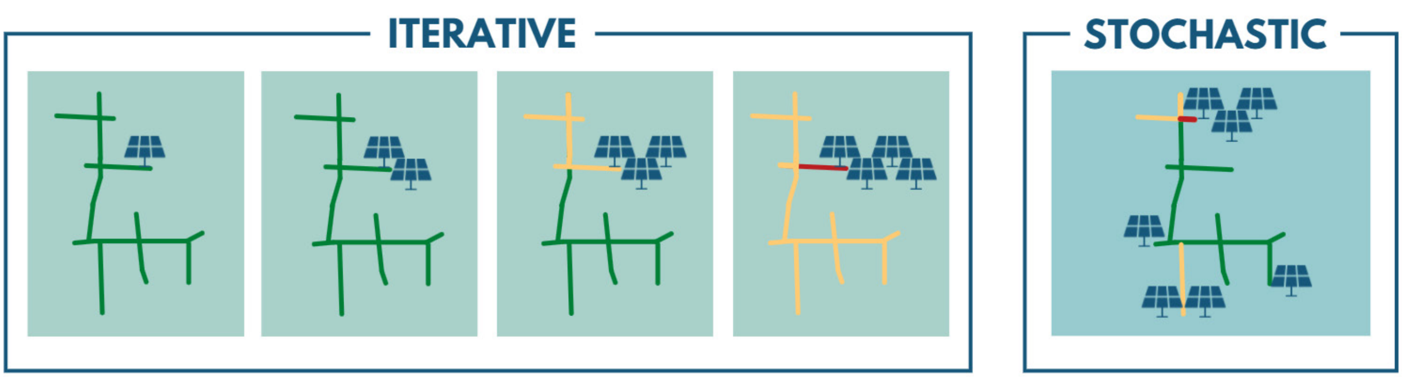


Figure 2. Methodology

One decision closely linked to the use case is the methodology of the power flow simulation. The selected methodology significantly impacts how the HCA results can be used; therefore, regulators may want to ensure that it is compatible with the selected use case(s). For example, because the stochastic method provides a range it may be appropriate for the planning use case, but is likely not precise enough for the interconnection use case.

Accompanying the selection of the methodology is the decision about which software provider will host or run the methodology for the utility. Regulators may not need to be involved in the selection of software, but regulators may want to be aware of how this decision can impact the methodology used and costs. See sidebar: Power Flow Modeling Software Providers. In the initial years of hosting capacity deployment there was little to no research on the different types of methodologies and the differences between the software. California started with a pilot process that provided some comparisons between the methodologies and illustrated that, at least at the time, there were significant differences in the results depending on what method was chosen.[22] As more utilities have begun to deploy HCA and the use cases have become more clearly defined, the methodologies and software have also evolved. Accordingly, the selection of a software provider is not as central of an issue now, but selection of a methodology is still one that warrants careful attention to ensure that the results support the intended use case and that regulators understand how the results were arrived at.

The selected methodology significantly impacts how the HCA results can be used; therefore, regulators may want to ensure that it is compatible with the selected use case(s).

There are also ways to combine these two basic methodologies—iterative and stochastic—and other fundamentally different ways of determining hosting capacity. When commencing discussions about an HCA, regulators may want to invite the utility or software providers to present on the different methodologies and how they may serve the desired use cases to inform the decision about what method to adopt.

POWER FLOW MODELING SOFTWARE PROVIDERS

Utilities use distribution system modeling software to prepare feeder models. Major utilities use distribution system modeling software regularly and typically already own licenses for this software. IREC has most often encountered utilities that use either DNV's Synergi and Eaton's CYME, however others are available.[23]

Following the creation of feeder models, the utility uses the models to perform power flow simulations that calculate the hosting capacity value for each node on the distribution system. Most distribution system modeling software can perform power flow simulations using both the iterative and stochastic methods of HCA. The HCA software module is included in the license for Synergi, and the module is an add-on available for purchase from Eaton for CYME. In addition, some utilities purchase software solely to perform the power flow simulations for hosting capacity analysis, such as the Distribution Resource Integration and Value Estimation (DRIVE) tool developed by the Electric Power Research Institute (EPRI). Xcel Energy reported that purchasing the DRIVE tool from EPRI included both a one-time cost of $250,000 plus $10,000 annually to access EPRI's DRIVE user group.[24] DRIVE cannot create feeder models, therefore to use DRIVE utilities create the feeder models in other software, *e.g.*, Xcel Energy uses Synergi to create its feeder models and DRIVE to perform the power flow simulations.[25]

6. UPDATING THE HCA WHEN SYSTEM CHANGES OCCUR

KEY DECISION: What types of changes should trigger an HCA update, and how frequently should updates occur?

OPTIONS:

Options for thresholds that trigger an HCA update:

1. Aggregate **change in generation** on a feeder exceeds a certain amount—*e.g.*, 100 kW, 250 kW, or 500 kW
2. Aggregate **change in load** on a feeder exceeds a certain amount—*e.g.*, 100 kW, 250 kW, or 500 kW
3. Specific **changes in feeder configuration**, such as the number of voltage regulators or the amount of kVAR (capacitors) on the feeder

Options for the frequency of HCA updates:

Figure 3. Update Frequency Options

HCAs provide a snapshot of the distribution grid's ability to host additional DERs in specific locations at the time the simulation is run. As new DERs come online, and as feeder configurations change, so too does the feeder's ability to host additional load and generation. To accurately reflect current conditions, utilities must update the HCA on those feeders that have changed since the model was last run. Two key decisions will inform how to update the HCA: the thresholds that will trigger an update and the update frequency.

The use case often informs these decisions. For the interconnection use case, the more closely HCA results resemble actual conditions on the feeder, the better the HCA can be used to achieve the desired goal of streamlining project approvals. This is particularly important when using the HCA in the interconnection screening process. In contrast, less frequent updates may be sufficient for the planning use case.

The computational intensity, cost, and time associated with performing the HCA may also factor into these decisions. Utilities typically evaluate the need for cloud computing resources to meet the computation intensity associated with more frequent updates. Moreover, utilities have learned it is not necessary to perform a power flow simulation of the entire distribution grid for each update. Rather, updates can be done on a feeder by feeder basis, with a full system refresh done less frequently. See sidebar: Update Thresholds and Frequency. Because updates are incremental and not all feeders see multiple significant changes a year, a more frequent HCA update cycle does not need to entail performing significantly more work than a less frequent cycle. For example, suppose five feeders meet the threshold for updates in January, a different set of five feeders satisfy the threshold in February, and a different set of five feeders satisfy the threshold in March. The cost and time associated with updating the HCA across these 15 feeders would be similar regardless of whether HCA updates are performed quarterly or monthly.

UPDATE THRESHOLDS AND FREQUENCY

NV Energy compares feeder configuration, load, and generation against the previous month and a well-established baseline.[26] When any one of eight different criteria shown in the table below changes by a certain amount over the baseline or prior year, NV Energy flags the feeder for update.[27]

TABLE 1: NV ENERGY MONTHLY UPDATE TRIGGERS

PARAMETER	MINIMUM VALUE CHANGE	MINIMUM % CHANGE FROM BASELINE	MINIMUM % CHANGE FROM PREVIOUS MONTH
Capacitor kVAR	200 kVAR	20%	4%
Regulator Quantity	1	20%	4%
Feeder Length	5,000 ft.	50%	25%
Feeder Sections	1,000	50%	25%
Existing DER	400 kW	50%	10%
Pending DER	80 kW	10%	10%
Connected kVA	800 kVA	100%	40%
Forecasted Loading	100 amps	100%	20%

Southern California Edison considers the change in the following fourteen different parameters from the previous month.[28]

TABLE 2: SOUTHERN CALIFORNIA EDISON MONTHLY UPDATE TRIGGERS

<table>
<tr><th>PARAMETER</th><th>CHANGE FROM PREVIOUS MONTH</th></tr>
<tr><td>Remote Controlled Switch (RCS)</td><td rowspan="4">Any change in count</td></tr>
<tr><td>Regulator</td></tr>
<tr><td>Recloser</td></tr>
<tr><td>Shunt Capacitor</td></tr>
<tr><td>Recloser Ground Trip</td><td rowspan="6">Any change in sum</td></tr>
<tr><td>Recloser Phase Trip</td></tr>
<tr><td>Regulator Rated kVA</td></tr>
<tr><td>Regulator Current Transformer Rating</td></tr>
<tr><td>Shunt Capacitor kVAR</td></tr>
<tr><td>Breaker Phase & Ground Pickup</td></tr>
<tr><td>Count of Spot Loads</td><td rowspan="2">Count change +/- 20</td></tr>
<tr><td>Count of Generators</td></tr>
<tr><td>Total Load kVA</td><td>Trigger criteria based on circuit voltage class:
<5 kV: +/-37.5
>5 kV and <15 kV: +/-400
>15 kV and <31 kV: +/-500
>31 kV and <100 kV: +/-1000</td></tr>
<tr><td>Total Generation kVA</td><td>Trigger criteria based on circuit voltage class:
<5 kV: +/-30
>5 kV and <15 kV: +/-150
>15 kV and <31 kV: +/-200
>31 kV and <100 kV: +/-500</td></tr>
</table>

As for the frequency of updates, Hawaii updates its maps daily.[29] California and Nevada provide monthly updates.[30] Pepco updates its HCA maps monthly, with plans to move to daily updates in the future.[31] In states with annual updates, stakeholders have complained that the frequency of updates was not sufficient to guide interconnection decisions.[32]

7. NUMBER AND TYPE OF LOAD HOURS FOR WHICH THE ANALYSIS IS PERFORMED

KEY DECISION: Should the HCA show a single value or reflect seasonal and hourly variations in capacity constraints?

OPTIONS:

1. A single value:

a. **Daytime minimum load:** helpful for standalone solar generation siting; a single value representing the lowest load on the feeder during daytime hours

b. **Absolute minimum load:** helpful for non-solar generation or solar-plus-storage siting; a single value representing the lowest load on the feeder at any hour

c. **Peak load:** useful for load resource siting and demand response applications and for generation resources looking to optimize output to serve peaks; a single value representing the highest load on the feeder

2. Monthly minimum and peak load: daytime minimum, absolute minimum, and peak load for each month of the year

3. Hourly profiles

a. **576-hourly profile:** The monthly minimum and peak load that occurs during each of the 24 hours in the day; this profile will include 576 load values (24 hours x 12 months x 2 load values (peak and minimum load))

b. **Full 8,760 hourly profile:** The load in every hour of the year; this profile will include 8,760 load values (24 hours x 365 days)

The HCA can include results for only a single load hour, representing the most restrictive grid conditions of the year, or it can provide seasonal or hourly results to allow developers to design DERs that benefit the grid and avoid temporary capacity constraints.

For example, if the HCA provides monthly daytime minimum load results for solar, it gives customers the flexibility to propose projects that limit export only during the most restrictive months. If a line section could support a 2 MW solar generator for 9 months of the year, but only a 1 MW generator in the 3 remaining months, an HCA with monthly results would allow a customer to build a 2 MW system and agree to limit its output to 1 MW during the 3 months that the lower constraint exists. By limiting seasonal output, the customer can build the system at the desired size while avoiding the need for upgrades to the distribution system. Since capacity constraints typically correspond to periods of high or low energy demand, this can enable DERs to serve peak loads more efficiently. Likewise, monthly HCA results for absolute minimum and peak loads can allow customers to design other DERs (such as electric vehicle chargers or solar-plus-storage projects) to avoid seasonal constraints. HCAs that present hourly profiles, such as those from California and Nevada,[33] give developers maximum flexibility to design systems that limit output during specific times of the day and specific seasons.

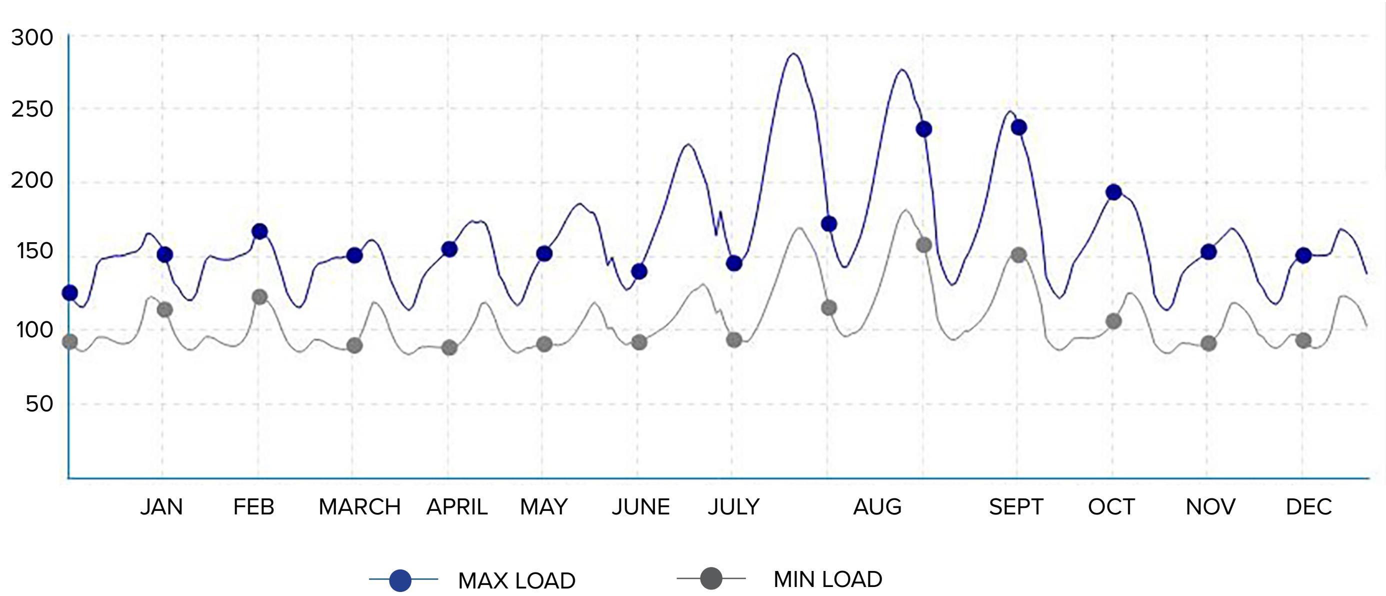


Figure 4. Number and Type of Load Hours

SOURCES OF LOAD DATA

The accuracy of the HCA, and its usefulness in streamlining interconnection processes, depends in large part on the accuracy of the data used as input.[34] HCAs that use actual feeder load data to determine capacity constraints are more likely to help developers design their systems and select optimal interconnection sites without requiring further detailed study. However, there are several potential problems with load data.

Load data can be acquired from various sources, including a customer's smart meter or the feeder's Supervisory Control and Data Acquisition (SCADA) system, each of which may contain missing or inaccurate data. Utilities may not have historical data loaded into the electronic databases or software used to perform HCA, requiring them to resort to estimated feeder loads. If using feeder-level data, then load profiles need to account for the variation between different customer types (*e.g.*, residential, commercial, industrial). Regulators may want to consider the accuracy implications associated with different sources of load data and the use of estimated load data in the HCA. For example, Xcel Energy reported a significant drop in the number of feeders that inaccurately showed no available hosting capacity after the Minnesota Public Utilities Commission ordered the utility to use actual load data recorded from its SCADA system instead of estimated load data in the HCA.[35]

8. ACCOMMODATING NEW DER LOAD AND GENERATION

KEY DECISION: What types of DERs should the HCA address?

OPTIONS

1. **Solar:** The capacity to host additional solar generation, assuming a typical solar generator's output.
2. **Uniform generation:** The capacity to host other types of generation (such as wind, geothermal, energy storage, and solar-plus-storage), assuming a generator outputs a uniform amount 24 hours a day, 365 days of the year. Uniform generation results can be used to determine an hourly operating profile that limits output in certain hours to minimize impacts.
3. **Uniform load:** The capacity to host new load DERs (such as electric vehicles, energy storage, or electric appliances including water heaters, furnaces, dryers, etc.), assuming the uniform use of electricity 24 hours a day, 365 days of the year.

HCAs can be designed to provide hosting capacity information for particular types of DERs, including generating resources and load resources. The HCA uses the same base model of the feeder for both, then adds either new load resources or new generation resources. HCA began with a focus on new solar resources; however, today different types of DERs seek interconnection with the distribution system. Thus, regulators will need to determine what types of resources the HCA will provide results for.

Some provide only solar HCA results (which is essentially the uniform generation results in daylight hours), while others also include uniform generation and uniform load results.[36] The uniform generation and load results are particularly useful for controllable resources (such as energy storage or electric vehicle chargers) that can tailor their charging and discharge schedules based on the constraints identified in the HCA.

Having both a generation and load HCA may be particularly valuable for states looking to use energy storage to both provide energy during periods of peak load, while avoiding over-generation during periods of low load. Moreover, many emissions-free electric vehicles (EVs) and home appliances will add load to the electric grid and HCAs can provide a better understanding of where to place and how to design this new DER load. Having both a load and generation HCA also enables more synergistic planning of DER resources.

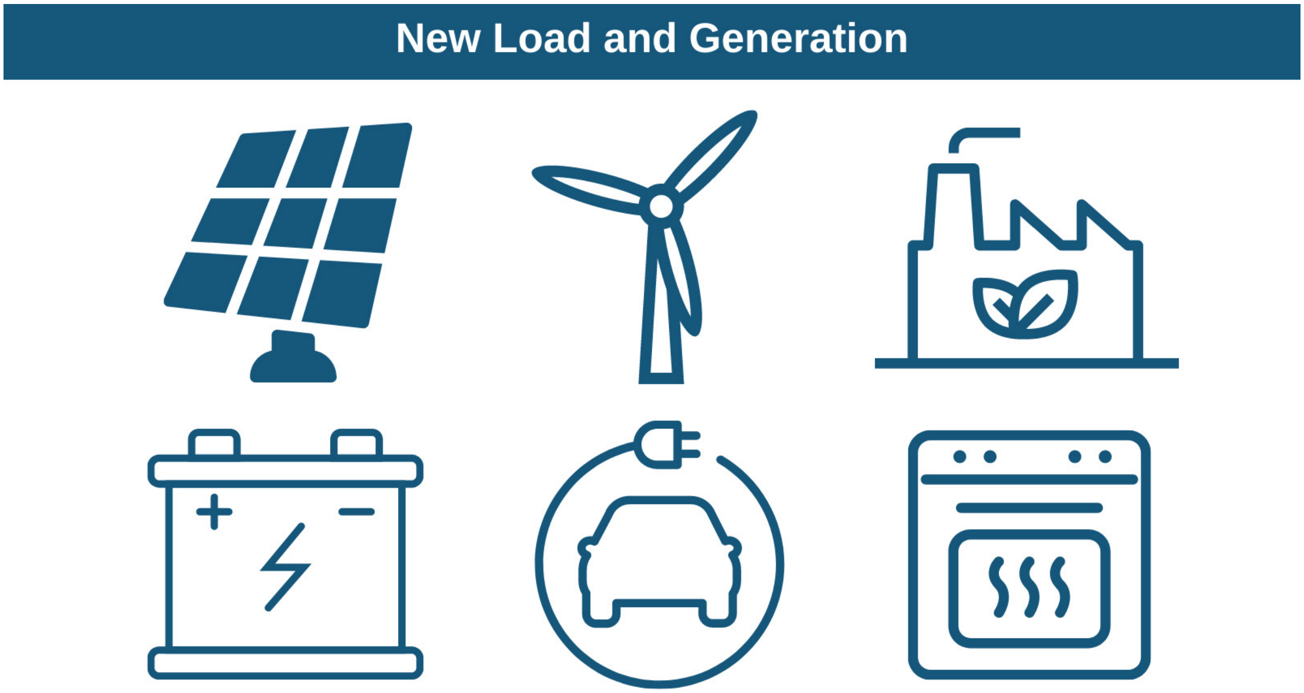


Figure 5. New Load and Generation

HCA LOAD USES

HCA load analyses can provide important insight for regulators, state agencies, and other stakeholders as they review and approve long-term integrated distribution plans and investments, with the aim to integrate new EVs and building electrification in the lowest cost manner for the benefit of all ratepayers. For example, the California Energy Commission (CEC) has been tasked with assessing the infrastructure needed to support 5 million zero emissions vehicles on California roads by 2030.[37] As part of this planning, the CEC uses HCA load data to forecast locational needs and costs of EV charger deployment across the state.[38] The HCA helps the CEC identify locations where the grid can accommodate EV charging stations without incurring costs and delays associated with grid upgrades.[39] A startup looking to implement innovative data analytics techniques could use HCA load data to identify buildings where it could replace existing heating, cooling, and hot water systems with heat pumps and modern, all-electric appliances without the need for grid upgrades.

Finally, distributed energy storage (paired with distributed generation or standalone) costs continue to decline, but the resource remains largely untapped as a backup option to increase grid resilience, further meet onsite load, or participate in markets. HCA load data can play a key role in determining how and where to deploy storage to provide targeted grid services or avoid negative impacts.

9. GRANULARITY OF ANALYSIS AND RESULTS

KEY DECISION: At what granularity should utilities perform HCA and publish results?

OPTIONS:

1. **Nodal-level:** Utilities perform power flow simulations that evaluate each node and then publish results for each line segment of a feeder
2. **Feeder-level:** Utilities perform power flow simulations that evaluate each feeder and then publish results for each feeder
3. **Hybrid:** Utilities perform power flow simulations that evaluate each node and then publish aggregated results at the feeder level

The ability of a feeder to host DERs can vary significantly depending upon the exact location of the DER. For example, generation sited closer to the substation can typically be sized larger than generation far from a substation on the same feeder.* Thus, a key decision for regulators is the level of granularity provided by the HCA results. This decision is most often based on the selected use case.

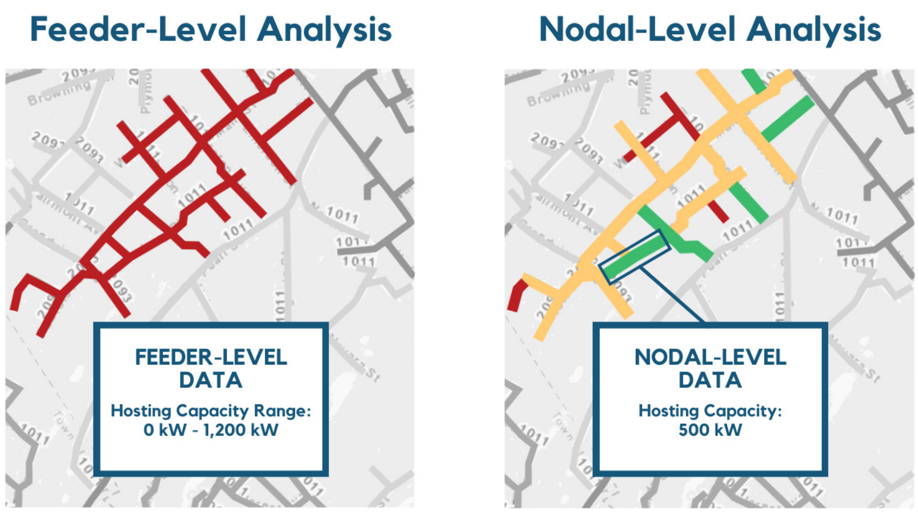


Figure 6. Granularity of Analysis and Results

Feeder-level HCA results typically consist of either a range of values across the feeder or a single value representing the most restrictive conditions on the feeder. Results at the feeder level can inform distribution planning efforts, however feeder-level results are not granular enough to be useful in making interconnection decisions because the hosting capacity of a feeder may vary by multiple megawatts depending on where the DER is located. Feeder-level results may be sufficient for planning purposes where the level of precision for each location is not as necessary. Depending on the methodology and assumptions used, there may be more computational intensity associated with performing a nodal analysis. However, software providers are continuously improving the efficiency of HCA models and utilities typically evaluate the need for cloud computing resources when performing system-wide HCAs. All of the prominent HCA software tools can provide granular nodal-level results.

*Other factors also vary the hosting capacity along a feeder, including a change in thermal ratings and a transition from a three-phase to a single-phase line.

10. LIMITING CRITERIA AND THRESHOLDS

KEY DECISION: Should regulators set or approve the limiting criteria, associated thresholds, and technical assumptions?

OPTIONS FOR LIMITING CRITERIA:

VOLTAGE

- **Primary over-voltage:** Feeder voltage limited to a high nominal specified value
- **Primary under-voltage:** Feeder voltage limited to a low nominal specified value
- **Primary voltage deviation:** Feeder voltage change limited to a specified amount
- **Regulator voltage deviation:** Voltage at a regulating node limited to a specified bandwidth of the regulating device

THERMAL

- **Feeder:** Power flow limited to a percentage of any element normal rating
- **Substation:** Power flow limited to a percentage of the substation normal rating

PROTECTION

- **Additional element fault current:** Increase in fault current limited by a percentage of feeder fault current
- **Sympathetic breaker relay tripping**: Breaker zero sequence fault current limited by a specified amount
- **Breaker relay reduction of reach:** Decrease in breaker fault current limited by a percentage of fault current
- **Reverse power flow:** Power flow through a specified element not to flow towards the substation
- **Unintentional islanding:** Power flow through a specified element not to reduce by more than a percentage of minimum load power flow
- **Ground fault over-voltage (3V0):** Power flow though substation not to be reduced by more than a percentage of minimum load power flow

Operational flexibility: Maintaining ability to reconfigure in the event of a contingency or outage (involves a repeat of some of the already mentioned limiting criteria)

Flicker: Measurement of rapid voltage fluctuations that may cause lights to flicker

While a circuit's hosting capacity is often thought of as a single value, in reality, the power flow simulation takes into account a variety of different limiting (or technical) criteria. Each of these criteria has a different hosting capacity limit. For example, a node may be able to accommodate 500 kW of generation without triggering a violation of a voltage criterion in a certain hour, but only 300 kW before triggering the thermal criterion in that same hour. A line section's hosting capacity is the result provided by the most limiting of the criteria used.

In performing an HCA, the utility determines which limiting criteria to use (there may be some difference in the limiting criteria available from different software providers). For each criterion used, the engineer must enter a threshold which triggers a violation and indicates a limit to the hosting capacity of the line section.

The HCA use case can guide the selection of criteria and thresholds. For example, if, under the distribution planning use case, regulators and stakeholders will use the HCA to identify where to make proactive upgrades to accommodate more DERs, the criteria and thresholds should match the utility's feeder design standards. Similarly, if, under the interconnection use case, regulators and stakeholders will use the HCA to determine if a project will pass certain fast track review screens, the criteria and thresholds should evaluate similar technical concerns as the fast track review screens in the state's interconnection procedures. However, the HCA was originally designed to replace some conservative rule-of-thumb interconnection screens with more precise analyses. See sidebar: Replacing Interconnection Screens with the HCA.

Regulators may want to exercise some oversight over the selection of the criteria and associated thresholds to ensure that they are appropriately (and not overly) restrictive. In addition, similar to how an Integrated Resource Plan typically lists the modeled inputs and assumptions, regulators may want to ensure that the limiting criteria and associated thresholds are publicly available so that users know how the results were developed and what they signify.

REPLACING INTERCONNECTION SCREENS WITH THE HCA

One reason HCAs were originally developed was to improve the interconnection screening process. The goal was to replace or supplement interconnection screens that use a conservative approximation of feeder conditions with a more sophisticated power flow simulation of the actual conditions on the feeder. The HCA is capable of providing a more accurate assessment of impacts than is currently used in several of the more commonly failed screens in the fast track and supplemental review process.

For example, the California Public Utilities Commission authorized the use of HCA results (or Integration Capacity Analysis, as the HCA is called in California) instead of the 15% screen.[40] The 15% screen evaluates if the total generation on the feeder exceeds 15% of a line section's peak load. The 15% screen was designed as a conservative rule-of-thumb based on generic feeder assumptions to approximate when the increased penetration of DERs on a feeder could trigger voltage, thermal, or protection problems. In contrast, the HCA actually examines if the project will result in any specific voltage, thermal, and protection problems based on the historic load at that precise node rather than using a heuristic that approximates problems based on a generic feeder. As a result, in certain circumstances new DERs can interconnect safely using the fast track process even when the project would have failed the legacy 15% screen, and in some cases it may flag an issue where the more generic screen failed to.

11. PUBLIC ACCESS TO HCA DATA

KEY DECISION: In what form should utilities provide HCA data to customers, and what is the range of data they should provide?

OPTIONS:

Options for providing access to HCA data:

1. Application Programming Interface (API)
2. Downloadable tabular data, e.g., spreadsheet
3. Online maps
4. Geographic Information System (GIS) shapefiles

Range of data provided:

1. Basic distribution system data listed in Section 3 above
2. Summary of HCA results
3. Results provided at the same granularity level as they are produced, *e.g.*, number of hours and nodal-level
4. HCA results with detailed technical criteria violations

Once the HCA is completed by the utility, the results must then be made accessible to the intended users. There are a wide variety of users who consume HCA data, including government officials, developers, researchers, policy advocates, and other stakeholders. Regulators may need to consider how to provide HCA data that meets different users' needs.

Sophisticated parties like large developers, government agencies, and researchers have the capability to use APIs to program their own applications to access HCA data. APIs allow computer programmers to design their own queries and user interfaces to access data. This enables entities to integrate the HCA with their internal tools for project siting and also gives them the ability to best utilize the data in a way that aligns with their needs. On the other hand, other stakeholders (*e.g.*, small developers or nonprofit policy advocates) may not have as sophisticated of capabilities or may not use the data frequently enough to justify the investment of time and skill necessary to use APIs.

Online maps are useful for anyone who wants to see the spatial distribution of hosting capacity across the grid. These maps often include pop-up boxes for viewing more detailed HCA data at the feeder or line segment level. See Figure 8. Regulators may also want to consider whether HCA maps should also have bulk search, filter, and sort capabilities. APIs provide sophisticated users programmatic access to large amounts of data. But enabling search, filter, and sort capabilities directly on HCA maps can allow less sophisticated users to use the maps and efficiently search a utility's entire service area. GIS shapefiles are useful for incorporating data into a customer's own GIS maps.

Stakeholders can also use detailed HCA results, called technical criteria violations. (See Section 10 for a description of the technical criteria.) Providing HCA technical criteria violations gives customers the information necessary to estimate the magnitude of potential system upgrades. For example, customers can often address voltage issues by installing a smart inverter at a low cost, avoiding the need for costly distribution system upgrades. Conversely, violations of thermal criteria are not typically resolved without a system upgrade or change in the project size or export amount. Stakeholders typically download technical criteria violation data in tabular form or access it through APIs.

As discussed in Section 7, HCA can be performed using only the maximum peak and minimum load for a year, or can be performed for multiple hours and seasons. As discussed in Section 9, HCA can be performed on the nodal or feeder level. When the HCA is performed on a more granular basis, the results can be provided to the users in that format so that they can understand the limits throughout the hours of the day, or on the specific node of the feeder.

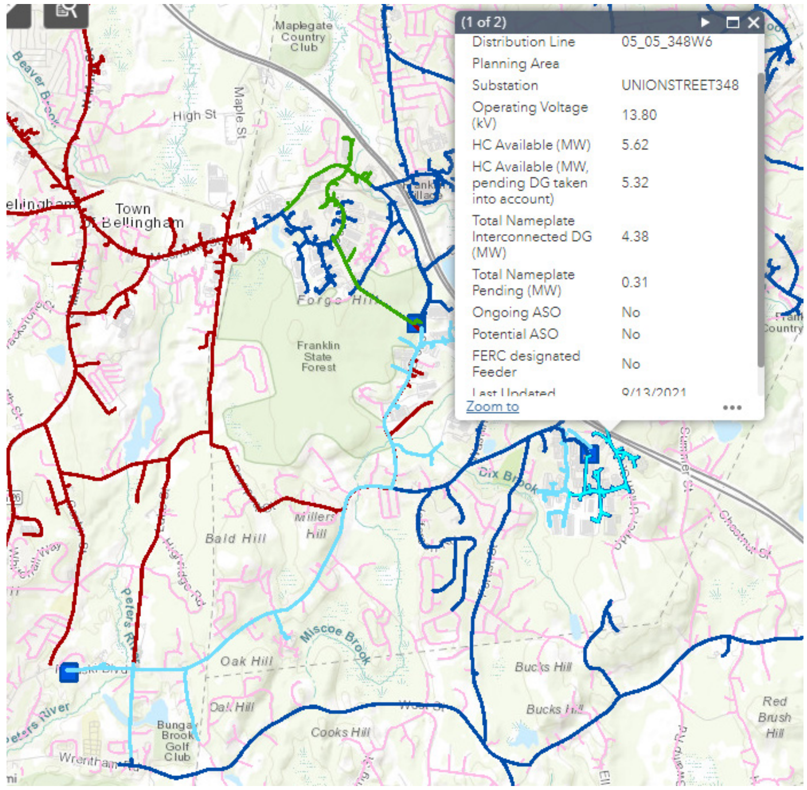


Figure 7. Online Map with Pop-Up Boxes | *Source: National Grid (MA)*

See Figure 8 for an example of technical criteria results provided for each node on an hourly basis for each month.

1	Circuit Name	Node ID	Month	Hour	Load Profile Type	Uniform Generation (kW)	Solar PV (kW)	Thermal (kW)	SSV (kW)	Voltage Fluctuation (kW)	Protection (kW)
21	EDWIN	51008697	6	22	MIN	7784.1	31136.4	9626.2	12625	7784.1	20000
22	EDWIN	51008697	6	22	MAX	7547.8	30191.2	9490.4	14334	7547.8	20000
23	EDWIN	51008697	6	23	MIN	7764.3	31057.2	9610.7	12933	7764.3	20000
24	EDWIN	51008697	6	23	MAX	7546.2	30184.8	9465	14808	7546.2	20000
25	EDWIN	51008697	7	0	MAX	5798.3	23193.2	9724	5798.3	8062.9	20000
26	EDWIN	51008697	7	0	MIN	7888	31552	9684	13602	7888	20000
27	EDWIN	51008697	7	1	MIN	7899.7	31598.8	9685.8	13304	7899.7	20000
28	EDWIN	51008697	7	1	MAX	5655.4	22621.6	9720.8	5655.4	8096.3	20000
29	EDWIN	51008697	7	2	MAX	7867.9	31471.6	9683.9	12496	7867.9	20000

Figure 8. HCA Criteria Results | *Source: Southern California Edison*

12. REDACTION OF DATA TO PROTECT CUSTOMER PRIVACY

KEY DECISION: What amount of regulatory oversight should be given to data redaction and what data should be redacted to protect customer privacy?

OPTIONS:

1. **No oversight:** the utility determines redaction criteria at its discretion without regulatory oversight
2. **Redaction according to established policy:** regulators establish a policy to protect customer privacy, and utilities redact data only as allowed under that policy
3. **Redaction only when expressly granted:** utilities must publish all data unless a regulatory order expressly grants an exception

An individual customer's energy usage patterns are typically considered private and should not be disclosed. Since the HCA relies on customer load data as one of its inputs, and often provides users with the load curve for a feeder, regulators will want to consider how to ensure that private customer data is not shared without customer consent.

When publishing load profiles, regulators may evaluate if an existing policy applies, if a new policy is needed, or whether they will leave this issue to the utility's discretion. Load profiles are generally aggregated at the feeder level, which typically does not allow the identification of an individual customer's energy use pattern. To avoid the uncommon circumstance where feeder-level data could be used to identify a single customer's energy usage, many regulators adopt the "15/15 rule" to govern the redaction of load profiles.[41] The 15/15 rule requires aggregated data to include a minimum of 15 customers, with no single customer exceeding 15% of the aggregated energy consumption. Under this rule, any aggregated load data that does not meet this standard is redacted to protect customer privacy. Some states have adopted other policies for customer data and some have yet to address this issue.

A customer's load typically cannot be derived from HCA results, with the exception of certain implementations of the Operational Flexibility limiting criterion. (See Section 10 for a description of Operational Flexibility and other limiting criteria. See Section 11 for a discussion of the publication of limiting criteria violations.) Regulators that authorize the use and publication of the Operational Flexibility limiting criterion may want to evaluate if it would be feasible for someone to figure out a specific customer's load from that value.

Since load data is an integral part of understanding the ability of a circuit to host DERs, this decision can be particularly important as over-redaction could essentially eliminate some of the most useful information provided by the HCA.

13. HCA DATA SECURITY

KEY DECISION: Should HCA maps and data be published publicly or restricted in some manner to protect grid security and reliability?

OPTIONS FOR PUBLISHING HCA DATA INCLUDE:

1. **Open access:** HCA data is published online and available to anyone.
2. **Authenticated access:** Utilities implement standard authentication and authorization access controls for data published online. This can be as simple as setting up usernames and passwords for stakeholders to access data, or it can involve more robust authentication controls, such as two-factor authentication.
3. **Disclosure under NDA:** HCA data is available only upon request, and disclosed only under a Non-Disclosure Agreement (NDA). This practice typically precludes developers, researchers, regulators, and others from citing the data in public filings or sharing the data with third-party collaborators, consultants, or customers.

Along with considering what information can be published while protecting customer privacy, regulators can consider whether grid security (both cyber and physical) may be impaired by publishing HCA maps and data.

Some utilities have raised concerns about publishing the location of distribution lines, load data, or results for specific critical facilities.[42] There is a lack of consensus on whether publication of HCA data poses a grid security risk, what the exact risk is, and its magnitude relative to the benefits of making grid information more transparent. If such concerns are raised, regulators will need to evaluate the risks and determine their applicability to the data in question.[43] If warranted, regulators may consider restricting access to certain pieces of data.

The arguments about grid security vary, but essentially boil down to whether the HCA data could be used by a potential bad actor to target attacks on the distribution system. For example, by helping them locate lines that feed critical facilities, see how the system is interconnected, or time an attack to coincide with peak load. Counterarguments include the fact that much, if not all, of the locational data can be found via other sources (Google Maps, driving down the street, and private grid mapping software services); the fact that equivalent data on the higher-value transmission system is publicly published by the federal government itself;* and that data alone is insufficient to carry out an attack and may not meaningfully increase the risk of a successful attack.[44]

If regulators determine the risks are not insignificant or outweigh the benefits, then they may restrict access to the data in question.

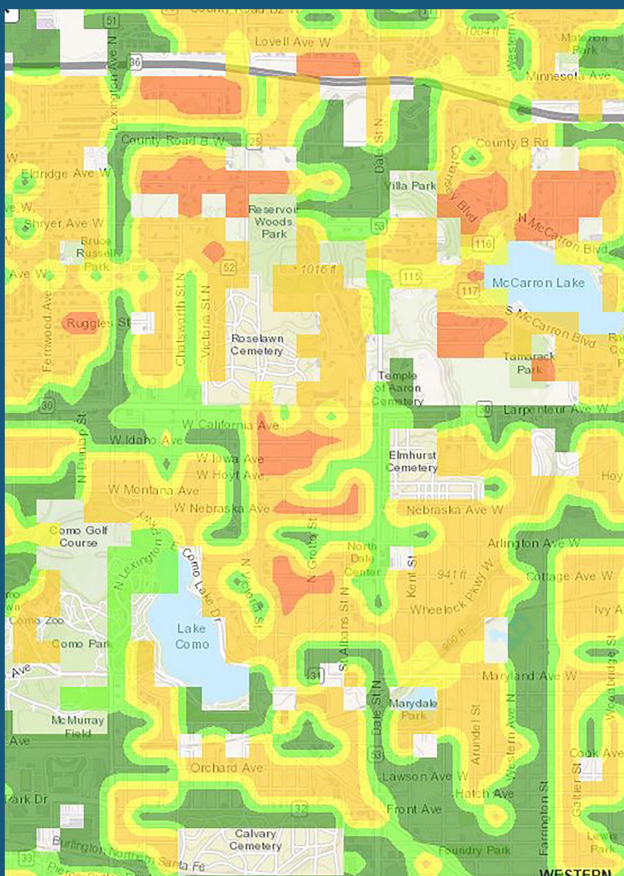
At this time, most utilities provide HCA data

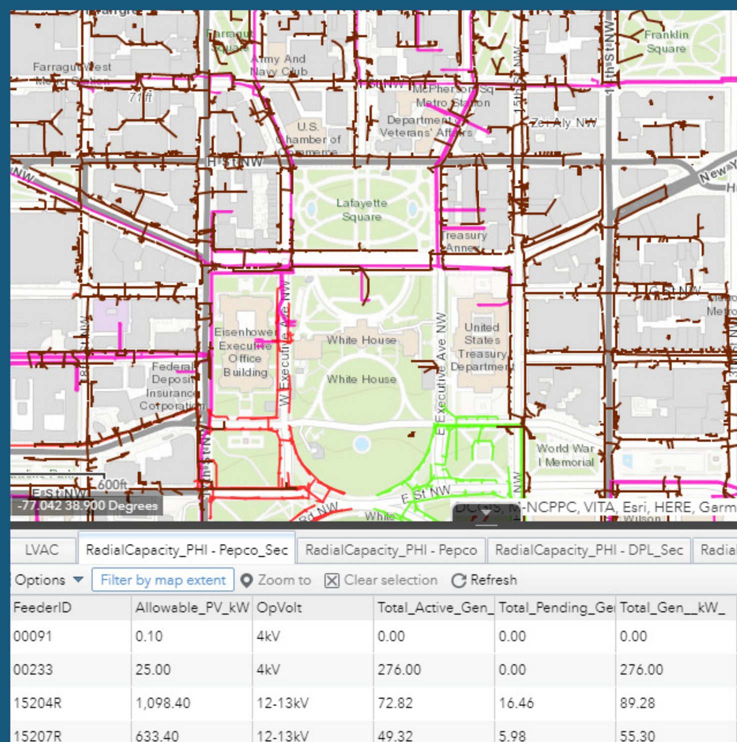
*Dept. of Homeland Security, Homeland Infrastructure Foundation Level Data—Electric Power Transmission Lines, https://hifld-geoplatform.opendata.arcgis.com/maps/edit?content=geoplatform%3A%3Aelectric-power-transmission-lines (accessed Apr. 8, 2021); Dep't of Homeland Sec., Homeland Infrastructure Foundation Level Data—Electric Substations, https://hifld-geoplatform.opendata.arcgis.com/maps/edit?content=geoplatform%3A%3Aelectric-substations (accessed Apr. 8, 2021).

on websites via open access or authenticated access.[45] Some utilities have sought to restrict access to all or some HCA data by either not making it available under any circumstances or by requiring a Non-Disclosure Agreement (NDA).[46] NDAs can be burdensome to obtain and comply with and limit the ability of stakeholders to use the information for development purposes and in regulatory proceedings,[47] so regulators will need to weigh the pros and cons of these restrictions. At this time, no regulator has required an NDA to access HCA data.

LOCATION OF DISTRIBUTION SYSTEM LINES

There is also variation in terms of how data is displayed on an HCA map, even if the map is open to the public. Some HCA maps blur the exact location of distribution lines, while others show the precise location of the lines. See Figures 9 and 10.





Left: **Figure 9.** HCA Map with Blurred Distribition Lines from Xcel Energy's HCA | *Source: Excel Energy, Minnesota*

Above: **Figure 10.** HCA Map Showing Precise Distribution Line Location | *Source: Pepco, Washington, DC*

Maps that obfuscate the precise location of distribution lines are less useful for the interconnection use case because they do not allow developers to determine which locations are serviced by lines that have lower hosting capacity. See Figure 9. In contrast, other maps such as Pepco's in Washington, DC shown in Figure 10 clearly indicate which distribution lines serve which locations. For example, if the White House is looking to add a solar generation, the green colored feeder on the southeast side of the White House complex shows more available capacity than the magenta and red lines on the north and west sides. Pepco's HCA map is available via open access. See sidebar on page 5: Publicly Available HCA Data.

14. DATA VALIDATION

KEY DECISION: What level of data validation should be required and should the process be transparent?

OPTIONS:

- Utility performs data validation independently
- Regulators and stakeholders review and provide feedback on a data validation plan

Figure 11. Data Validation Report

Ensuring that the data used as inputs to the HCA are ready for use in advanced power flow simulations is essential to ensuring the published HCA results are accurate. Cleaning up the data input into the HCA, including utilities' distribution system asset database, load database, and GIS database, is the most time-intensive part of developing an HCA.[48] For example, databases may not include the manufacturer, model number, or characteristics of equipment installed. Even if the electronic database includes this information, it may not note the current configuration of the equipment's settings. In other cases, this information may not be available, or the only reliable copy is in hard copy.[49] Validating data extracted from these databases and using it to build working feeder models can be a significant undertaking for utilities that have not modernized their distribution system engineering practices.

Ensuring that the data used as inputs to the HCA are ready for use in advanced power flow simulations is essential to ensuring the published HCA results are accurate.

Utilities can perform data validation independently or regulators can oversee these efforts, for example by requiring a utility to submit a data validation plan. If a utility has completed a grid modernization program by investing significant time and effort into modernizing and validating the accuracy of its distribution system asset management database, load database, and GIS database, then less oversight may be necessary. However, many utilities have not validated their data to be accurate enough to support the modern power flow simulations used in the HCA. See sidebar: California's Rocky HCA Rollout. Accordingly, regulators can provide transparency into the data validation process by reviewing and requiring improvements to data validation plans. For example, regulators could require submission of a draft data validation plan, accept feedback from stakeholders on the draft, and then require the submission of an improved data validation plan with periodic reporting on its implementation.[50]

IREC is working with the National Renewable Energy Laboratory to develop a set of recommendations for HCA data validation plans. A report describing these recommendations will be available on IREC's HCA resources **webpage**[51] in late 2021.

CALIFORNIA'S ROCKY HCA ROLLOUT

In January 2019, each of the California utilities published their first, much anticipated, system-wide Integration Capacity Analysis (ICA) results. (In California, HCA is called ICA.) Surprisingly, Pacific Gas and Electric's (PG&E's) first ICA showed that approximately 80% of PG&E's feeders had little or no hosting capacity for new solar available, and all three utilities' ICAs showed 60-70% of their distribution systems with little to no hosting capacity for new load.

While it is broadly known that PG&E has relatively high solar penetration, it was highly unlikely that the vast majority of the system had no remaining capacity for new solar projects of any size. Similarly, it would be surprising if 60-70% of California's grid could not support new distributed loads. These results did not reflect the reality experienced by customers interconnecting projects and were met with immediate frustration and suspicion that the results were inaccurate and had not been validated.

Discussions among stakeholders and regulators led to the conclusion that the results were erroneous. As a result, PG&E implemented a concerted data validation effort that took about 15 months to produce validated results for solar generation.[52] In 2021, over two years after the initial load ICA results were published, those results remain suspect and have yet to be validated.[53] As a result, regulators decided to more closely scrutinize utilities' data validation efforts. The California Public Utilities Commission required each utility to file a data validation plan, invited stakeholders to comment on the plans, and then hired an independent technical expert to review the plans and suggest improvements.[54]

Similarly, in other states with early rollouts, including Minnesota and New York, stakeholders did not trust the initial HCA results due to perceived inaccuracies.[55] While California required utilities to file data validation plans and improve those plans only after stakeholders disclosed significant problems with the HCA, regulators in other jurisdictions have the opportunity to begin oversight of data validation earlier in the HCA process.

15. HCA USER GUIDE

KEY DECISION: What information should be included in the HCA user guide?

OPTIONS:

- How to access and use the online map
- How to access and use the downloadable data
- How to access and use the API
- Explanation of how and when the HCA is updated
- Explanation of the technical criteria and associated thresholds
- Explanation of data redaction practices

Publishing user guides helps customers access HCA data and understand the analyses that produced the HCA data. Not all utilities publish user guides. Those that do may provide updates to user guides when inputs or assumptions to the analysis change, new data is included, or functionality of the HCA changes.

Regulators may want to require publication of a user guide along with the HCA and may consider requiring that the guide be updated when features are added or the HCA process changes.

16. CONCLUSION

Hosting capacity analyses can function as a bridge to span information gaps between regulators, developers, customers, and utilities, enabling more efficient and effective grid solutions for the benefit of utilities, customers, and developers. By making the key decisions discussed in this report, regulators can ensure that they, and all other stakeholders, have a clear understanding of the meaning and quality of the HCA results. Making these decisions clearly upfront can be beneficial in order to avoid the need to "fix" the HCA down the road. However, as with most technology and software, HCAs will also likely need updating in the future as utility data improves, DER technologies and their capabilities advance, and the use cases for the HCA evolve.

After the initial deployment, regulators can implement a process to track the HCA's performance and the experience of HCA users. The results of this tracking can help inform future needs and changes.

IREC hopes that this guide can serve as a useful roadmap for regulatory proceedings by helping regulators understand the importance and consequences of these key decisions.

ENDNOTES

1. CA Pub. Util. Comm., Dkt. 14-08-013, Distribution Resources Plans; CO Pub. Util. Comm., Dkt. 19M-0670E, Distribution System Planning; MD Pub. Service Comm., Dkt. RM68, Small Generator Facility Interconnection Standards; NY Pub. Service Comm., Dkt. 14-M-0101, Reforming the Energy Vision; NY Pub. Service Comm., Dkt. 16-M-0411, Distributed System Implementation Plans; MA Dpt. of Pub. Util., Dkt. 19-55, Distributed Generation Interconnection; MA Dpt. of Pub. Util., Dkt. 20-75, Distributed Energy Resource Planning and Recovery of Costs; NV Pub. Util. Comm., Dkt. 17-08022, Rulemaking to Implement Senate Bill 146 (2017); MN Pub. Util. Comm., Dkt. E999/CI-15-556, Investigation into Grid Modernization; MN Pub. Util. Comm., Dkt. E002/M-15-962, Xcel Energy Biennial Report on Distribution Grid Modernization; MN Pub. Util. Comm., Dkt. E002/M-17-777, Xcel Energy 2017 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E002/CI-18-251, Xcel Energy Distribution System Planning; MN Pub. Util. Comm., Dkt. E002/M-18-684, Xcel Energy 2018 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E002/M-19-685, Xcel Energy 2019 Hosting Capacity Study; MN Pub. Util. Comm., Dkt. E999/CI-20-800, Grid And Customer Security Issues Related to Public Display or Access to Electric Distribution Grid Data; MN Pub. Util. Comm., Dkt. E002/M-20-812, Xcel Energy 2020 Hosting Capacity Analysis; 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); IREC, *Optimizing the Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources* (December 2017); IREC and Nat. Renewable Energy Laboratory, *Data Validation for Hosting Capacity Analysis* (forthcoming).
2. https://ltmdrpep.sce.com/drpep/
3. https://coned.maps.arcgis.com/apps/MapSeries/index.html?appid= 8cf1195eedcb4992852c806f3384d62c
4. https://mn.my.xcelenergy.com/s/renewable/developers/interconnection (if prompted to select a state, click on Minnesota, then click Hosting Capacity Map under "Before Interconnecting, and accept the disclaimer to load the map.)
5. https://www.dominionenergy.com/projects-and-facilities/electric-projects/energy-grid-transformation/hosting-capacity-tool
6. https://www.pepco.com/SmartEnergy/MyGreenPowerConnection/Pages/HostingCapacityMap.aspx
7. https://irecusa.org/our-work/hosting-capacity-analysis/
8. https://irecusa.org/our-work/hosting-capacity-analysis/
9. For example, the cost of Southern California Edison's analysis is included in its grid modernization budget, but not individually identified. CA Pub. Util. Comm., Dkt. A.19-08-013, Southern California Edison 2021 General Rate Case, Exhibit No. SCE-02, Vol. 4, Part 1, Grid Modernization, Grid Technology, and Energy Storage (Aug. 30, 2019).
10. VA State Corp. Comm., Dkt. PUR-2019-00154, Testimony of Robert Wright (RSW) on behalf of VA Electric and Power Co. (d/b/a Dominion), Schedule 1, at p. 2 (Sept. 30, 2019); MN Pub. Util. Comm., Dkt. E002/M19-685, Comments of Interstate Renewable Energy Council on Xcel's 2019 HCA, at pp. 10-12 (Dec. 30, 2019) (citing Xcel Energy's Response to IREC Information Request No. 7.B D); CA Pub. Util. Comm., Dkt. R.14-08-013, Pacific Gas & Electric's Integration Capacity Analysis Implementation

Update (May 7, 2020).

11. *See*, *e.g*., NV Pub. Util. Comm., Dkt. 19-04003, Exhibit D, NV Energy 2019 Distributed Resources Plan, at p. 19 (April 1, 2019).
12. When performing its first HCA, Southern California Edison developed a custom tool to centralize and cleanse its load profiles. However, the custom tool did not provide adequate quality control for its load data, so SCE is in the process of transitioning to the Grid Analytics Tool, a commercially supported software tool. CA Pub. Util. Comm., Southern California Edison Advice Letter No. 4508-E, Improved Integration Capacity Analysis Data Validation Plan, at p. 4 (May 28, 2021).
13. *Id.* LoadSEER, a commercially available program used by Pacific Gas & Electric and other utilities, can cleanse load profiles and provide load forecasts. See Pacific Gas & Electric Advice Letter No. 6212-E, Attachment 1, Integration Capacity Analysis Process and Data Validation Plan (May 28, 2021).
14. *See, e.g.,* MN Pub. Util. Comm., Dkt. E002/M-20-812, Xcel Energy 2020 Hosting Capacity Analysis, Attachment F, at p. 5 (Nov. 2, 2020) ("Because the foundational data improvements would benefit other Company planning and operational processes . . . all customers would share in the costs"); Southern California Edison 2021 General Rate Case, Exhibit No. SCE-02, Vol. 4, Part 1, Grid Modernization, Grid Technology, and Energy Storage.
15. https://irecusa.org/resources/optimizing-the-grid-regulators-guide-to-hosting-capacity-analyses/
16. *See, e.g.*, NV Energy 2021 Distributed Resources Plan, at p. 34.
17. NV Pub. Util. Comm., Dkt. 21-06001, NV Energy Integrated Resource Plan, Vol. 13, Narrative Distributed Resources Plan and Technical Appendix (NV Energy 2021 DRP) at p. 196 (June 1, 2021).
18. California's first published maps, called PVRAM, included "selected electric distribution lines, substations, and transmission lines . . . paired with general electric system information. *See, e.g.*, Pacific Gas and Electric, Distribution Resource Planning Data Portal, https://www.pge.com/en_US/for-our-business-partners/distribution-resource-planning/distribution-resource-planning-data-portal.page?ctx=large-business (accessed Aug. 6, 2021).
19. New York has published HCA results for solar since October 2017, and began publishing HCA for load in 2021. Joint Utilities of New York, *Hosting Capacity Stakeholder Webinar*, at p. 7 (May 20, 2020), https://jointutilitiesofny.org/utility-specific-pages/hosting-capacity/; NY Pub. Service Comm., Dkt. 18-E-0138, Order Establishing Electric Vehicle Infrastructure Make-Ready Program and Other Programs, at p. 119 (July 16, 2020) ("utilities shall publish load serving capacity maps for EV charging by no later than December 31, 2020").
20. Xcel Energy 2020 Hosting Capacity Analysis, at p. 19 ("Based on what we heard from stakeholders, we intend to increase the frequency of the HCA to a quarterly cadence from its current annual cadence starting in Q3 2021.").
21. New York has published HCA results for solar since October 2017, and began publishing HCA for load in 2021. Joint Utilities of New York, *Hosting Capacity Stakeholder Webinar*, at p. 7 (May 20, 2020), https://jointutilitiesofny.org/utility-specific-pages/hosting-capacity/; NY Pub. Service Comm., Dkt. 18-E-0138, Order Establishing Electric Vehicle Infrastructure Make-Ready Program and Other Programs, at p. 119 (July 16, 2020) ("utilities shall publish load serving capacity maps for EV charging by no later than December 31, 2020").
22. *Optimizing the Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources,* (https://irecusa.org/resources/optimizing-the-grid-regulators-guide-to-hosting-capacity-analyses/) at pp. 19-20.
23. Pacific Gas & Electric and Southern California Edison use CYME, while Xcel Energy, NV Energy, and San Diego Gas & Electric use Synergi. Pepco uses Electrical Distribution Design's Distributed

Engineering Workstation's Integrated Systems Model (EDD's DEW/ISM).

24. MN Pub. Util. Comm., Dkt. E002/M019-685, Comments of Interstate Renewable Energy Council on Xcel's 2019 HCA, at pp. 10-12 (Dec. 30, 2019) (citing Xcel Energy's Response to IREC Information Request No. 7.B D).
25. Xcel Energy 2020 Hosting Capacity Analysis, Attachment A, at pp. 10-11.
26. NV Energy 2021 DRP at pp. 46-47.
27. NV Energy 2021 DRP at pp. 46-47.
28. CA Pub. Util. Comm., Southern California Edison Advice Letter No. 4508-E, Improved Integration Capacity Analysis Data Validation Plan, at p. 5 (May 28, 2021).
29. Hawaiian Electric, *Locational Value Maps*, https://www.hawaiianelectric.com/clean-energy-hawaii/integration-tools-and-resources/locational-value-maps (accessed July 2, 2021).
30. CA Pub. Util. Comm., Dkt. R.14-08-013, Decision No. 17-09-026, Decision on Track 1 Demonstration Projects A (Integration Capacity Analysis) and B (Locational Net Benefits Analysis), at p. 11 (Oct. 6, 2017), https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M196/K747/196747754.PDF; NV Energy 2021 DRP at 46.
31. Pepco Holdings, *Hosting Capacity—Lessons Learned*, at pp. 24-25.
32. In the past, Minnesota and New York updated HCAs annually, but after receiving complaints they moved to a more frequent update cycle. See, *e.g.*, MN Pub. Util. Comm., Dkt. E002/M-18-684, Fresh Energy's Comments on Xcel's 2018 Hosting Capacity Study, at pp. 16 (Developer stating that the HCA "is not updated in real time and therefore cannot be relied on to show up-to-the minute verification of DG capacity."); Xcel Energy 2020 Hosting Capacity Analysis, at p. 19 ("Based on what we heard from stakeholders, we intend to increase the frequency of the HCA to a quarterly cadence from its current annual cadence starting in Q3 2021."); Joint Utilities of New York, *Hosting Capacity Stakeholder Webinar,* at pp. 22, 28 (May 20, 2020), https://jointutilitiesofny.org/utility-specific-pages/hosting-capacity/.
33. *See* Southern California Edison, Integration Capacity Analysis User Guide, at p. 14 (Dec. 10, 2020), https://ltmdrpep.sce.com/drpep/downloads/ICAUserGuide.pdf; NV Energy, Distributed Resources Plan Web Portal User Guide, at p. 11 (June 24, 2021), https://drp.nvenergy.com/.
34. *See, e.g.*, CA Pub. Util. Comm., Dkt. R.14-08-013, Quanta Technology, SCE Integration Capacity Analysis Data Validation Plan Assessment, at p. 3-5 (June 24, 2021).
35. Xcel Energy 2020 Hosting Capacity Analysis, Attachment A, at p. 23 ("The number of feeders with zero maximum hosting capacity decreased by seven from the 2019 analysis, and this was likely the result of using more actual daytime minimum load data for feeders with SCADA in the 2020 analysis.").
36. *See* Xcel Energy 2020 Hosting Capacity Analysis, Attachment A, at p. 15, pp. 19-21 (using daytime minimum loading to calculate HCA for solar); Southern California Edison, Integration Capacity Analysis User Guide, at p. 9 ("SCE produced and made available the 576 hourly ICA values using a technology agnostic uniform generation and uniform load approach. This approach generates ICA values that are independent of the type of DER technology").
37. CA Pub. Util. Comm., Dkt. R.14-08-013, Interstate Renewable Energy Council, Inc.'s Proposals for Refinements of the Load Integration Capacity Analysis (May 28, 2021), Attachment 5, Micah Wofford, California Energy Comm., EVSE Deployment and Grid Evaluation (EDGE) Tool, at p. 3 (CEC Apr. 28, 2021 Presentation).
38. CEC Apr. 28, 2021 Presentation, at p. 5. In California, HCA is called Integrated Capacity Analysis.
39. CEC Apr. 28, 2021 Presentation at p. 4.

40. CA Pub. Util. Comm., Dkt. R.17-07-007, Interconnection of Distributed Energy Resources and Improvements to Rule 21, Decision 20-09-035, Decision Adopting Recommendations from Working Groups Two, Three, and Subgroup (Sept. 30, 2020).
41. *See*, *e.g.*, 4 Code of Colorado Regulations 723-3-3033(b) (defining the 15/15 Rule); CA Pub. Util. Comm., Dkt. R.08-12-009, Decision 14-05-016, Adopting Rules to Provide Access to Energy Usage and Usage-Related Data While Protecting Privacy of Personal Data, at pp. 26-27 (May 5, 2014) (adopting the 15/15 standard "in order to ensure that the released data is sufficiently aggregated to prevent the identification of [customer load data] on individuals"); *see also* MN Pub. Util. Comm., Dkt. E,G-999/CI-12-1344, Order Governing Disclosure of Customer Energy Use Data to Third Parties, Requiring Filing of Privacy Policies and Cost Data, and Soliciting Comment, at pp. 7-8 (Jan. 19, 2017) (requiring utilities to establish defined practices to protect the anonymity of customer energy use data (CEUD) before releasing such data to third parties); Xcel Energy, Dkt. E,G-999/CI-12-1344, Compliance Filing—CEUD Aggregation and Release Policies, Privacy Policies of Rate-Regulated Energy Utilities, at pp. 4-6 (Feb. 10, 2017) (selecting the 15/15 rule as the appropriate level of aggregation to protect CEUD).
42. *See, e.g.*, CA Pub. Util. Comm., Dkt. 14-08-013, Administrative Law Judge's Ruling Resolving Confidentiality Claims Raised by Pacific Gas & Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company as to Distribution System Planning Data Ordered by Decision (D.) 17-09-026 and D.18-12-004 (Dec. 17, 2018) (Dec. 17, 2018 CPUC Data Redaction Order).
43. Dec. 17, 2018 CPUC Data Redaction Order, at pp. 8-14.
44. *See* MN Pub. Util. Comm., Dkts. E002/M-19-685 and E999/CI-20-800, Comments of the Interstate Renewable Energy Council, Inc. on Grid and Customer Security Issues Related to Public Display or Access to Electronic Distribution Grid Data, at pp. 9-18 (Apr. 30, 2021) (IREC Apr. 30, 2021 MN Grid Security Comments).
45. *See, e.g.*, Dec. 17, 2018 CPUC Data Redaction Order.
46. *See, e.g.*, CA Pub. Util. Comm., Dkt. 08-08-009, Joint Petition of Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company for Modification of D.10-12-048 and Resolution E-4414 to Protect the Physical Security and Cybersecurity of Electric Distribution and Transmission Facilities (Dec. 10, 2018); MN Pub. Util. Comm., Dkts. E002/M-19-685 and E999/CI-20-800, Xcel Energy Comments—Response to Notice: Distribution Grid and Customer Security (Jan. 29, 2021).
47. *See* IREC Apr. 30, 2021 MN Grid Security Comments, at pp. 22-29.
48. NV Energy 2019 Distributed Resources Plan, at p. 19.
49. *See, e.g.,* Xcel Energy 2020 HCA, Attachment A, at p. 14 (Most feeders "were constructed more than 30 years ago, and we do not have good historical information regarding their conductor spacing.").
50. *See, e.g.*, CA Pub. Util. Comm., Dkt. R.14-08-013, Administrative Law Judge's Ruling on Joint Parties' Motion for an Order Requiring Refinements to the Integration Capacity Analysis, at pp. 4-6 (Jan. 27, 2021) (CPUC ICA Refinements Order) (according to CPUC rules, stakeholders may comments on advice letters).
51. https://irecusa.org/our-work/hosting-capacity-analysis/
52. PG&E implemented GridUnity's Network Model Management software beginning in Q1 2019 and reported that its maps included verified and published results on May 7, 2020. CA Pub. Util. Comm., Dkt. R.14-08-013, Pacific Gas & Electric's Integration Capacity Analysis Implementation Update, at p. 1 (May 7, 2020).
53. *See* CPUC ICA Refinements Order, at pp. 4-14.
54. *See* CPUC ICA Refinements Order at pp. 4-6 (according to CPUC rules, stakeholders may comment on advice letters).
55. *See, e.g.*, Fresh Energy's Comments on Xcel's 2018 Hosting Capacity Study.

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ATTACHMENT 2

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769.	Rulemaking 14-08-013 (Filed August 14, 2014)
And Related Matters.	A.15-07-002 A.15-07-003 A.15-07-006

(NOT CONSOLIDATED)

In the Matter of the Application of PacifiCorp (U901E) Setting Forth its Distribution Resource Plan Pursuant to Public Utilities Code Section 769.	A.15-07-005 (Filed July 1, 2015)
And Related Matters.	A.15-07-007 A.15-07-008

PACIFIC GAS AND ELECTRIC COMPANY'S (U 39 E) ICA IMPLEMENTATION UPDATE

CHRISTOPHER J. WARNER

Pacific Gas and Electric Company
77 Beale Street, B30A
San Francisco, CA 94105
Telephone: (415) 973-6695
Facsimile: (415) 973-5520
E-Mail: Christopher.Warner@pge.com

Attorney for
PACIFIC GAS AND ELECTRIC COMPANY

Dated: May 8, 2020

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769.	Rulemaking 14-08-013 (Filed August 14, 2014)
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PACIFIC GAS AND ELECTRIC COMPANY'S (U 39 E)
ICA IMPLEMENTATION UPDATE

Pursuant to D.17-09-026, Pacific Gas and Electric Company ("PG&E") provides this Integration Capacity Analysis ("ICA") implementation update to the California Public Utilities Commission ("Commission"), outlining steps that PG&E has taken to complete a system refresh of all valid circuits, as part of the effort to operationalize the Integrated Capacity Analysis ("ICA") map and to better incorporate quality control into the ICA process. The implementation update is attached as an appendix to this pleading.

Respectfully Submitted,

CHRISTOPHER J. WARNER

By: */s/ Christopher J. Warner*
CHRISTOPHER J. WARNER

Pacific Gas and Electric Company
77 Beale Street, B30A
San Francisco, CA 94105
Telephone: (415) 973-6695
Facsimile: (415) 973-5520
E-Mail: Christopher.Warner@pge.com

Attorney for
PACIFIC GAS AND ELECTRIC COMPANY

Dated: May 8, 2020

APPENDIX

PG&E'S INTEGRATION CAPACITY ANALYSIS (ICA) IMPLEMENTATION UPDATE

MAY 7, 2020

Background

In December 2018, PG&E posted completed integration capacity analysis (ICA) results, as directed in D.17-09-026. This was the first time PG&E had completed a system-wide iterative ICA. PG&E filed a Completion Report on December 28th, 2018 that summarized the initial ICA.[1] Upon further examination of the initial results (which frequently showed low or no integration capacity), PG&E determined that a new systematic approach to a system refresh would likely improve the quality and comprehensiveness of results.

Summary of System Refresh

Beginning in 2019, PG&E worked with a third-party vendor, GridUnity, to operationalize ICA and incorporate intelligent quality control into the ICA process. GridUnity's Grid Model Management (GMM) software solution uses a combination of automated engineering rules and manage-by-exception business process flows that enable PG&E to systematically address data issues before initiating ICA for each circuit. Figure 1 provides an illustration of how ICA is at the center of the process, but is enabled by four preliminary steps—Model Intake, Sanity Check, Peak Load Allocation, and Hourly Load Allocation.[2] In addition to the project goals above, PG&E's and GridUnity's work on ICA and the GMM quality control process has resulted in 1) expansion of GridUnity's GMM capabilities, 2) improvements to PG&E's forecasting software, 3) improvements to PG&E's distribution power flow software and ICA algorithm, and 4) improvements to PG&E's Electric Distribution GIS.

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[1] PG&E's ICA Completion Report Pursuant to Ordering Paragraph 9 of D.17-09-026, R.14-08-013, December 18, 2018.

[2] GridUnity's Grid Model Management (GMM) involves four steps. 1) Model Intake ingests PG&E's distribution model and automatically performs routine model-handling updates to prepare a circuit specifically for ICA. 2) Sanity Check performs situation-based model corrections, automates existing manual processes, and flags to engineers any corrections that cannot be addressed through the processing. 3) Peak Load Allocation checks for modeling errors identified after a peak load flow is performed. 4) Hourly Load Allocation performs time- and power flow-dependent steps for all 576 hours.

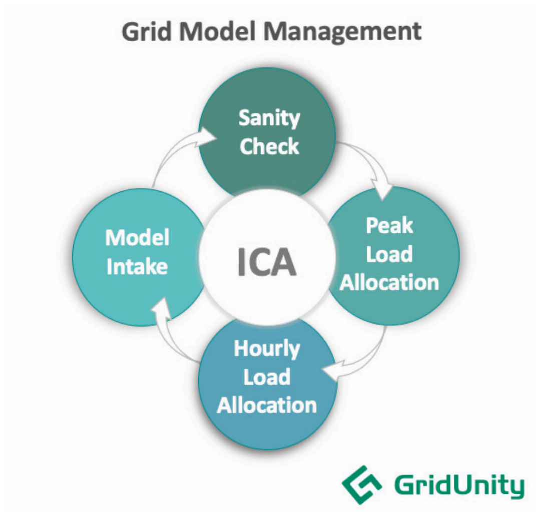

Figure 1 - GridUnity's Grid Model Management Software

Summary of Results

In order to operationalize ICA studies and better incorporate quality control into the ICA study process, PG&E re-analyzed all valid circuits, performing a system refresh using the GMM solution. As of April 2020, PG&E completed the refresh, and is now reporting increases in the posted integration capacity.

Figure 2 below provides a system-level illustration of how the reported integration capacity[3] has increased following the implementation of the new data quality improvements. The figure shows a histogram of the distribution of line sections by their reported integration capacity. The results from before system refresh (as of December 2018) are shown in orange, with results after system refresh (April 2020) shown in blue. As shown on the left of the figure, 85% of the line sections on PG&E's distribution system had reported no available integration capacity before the system refresh. After the system refresh, only 45% of the line sections have reported no integration capacity. The right of the figure shows the trend of increasing integration capacity.

3 The integration capacity value shown in these figures is "Uniform Gen with OpFlex" as shown on the ICA maps, one of the five posted ICA values. The other ICA values had increases generally consistent with those shown for the "Uniform Gen with OpFlex".

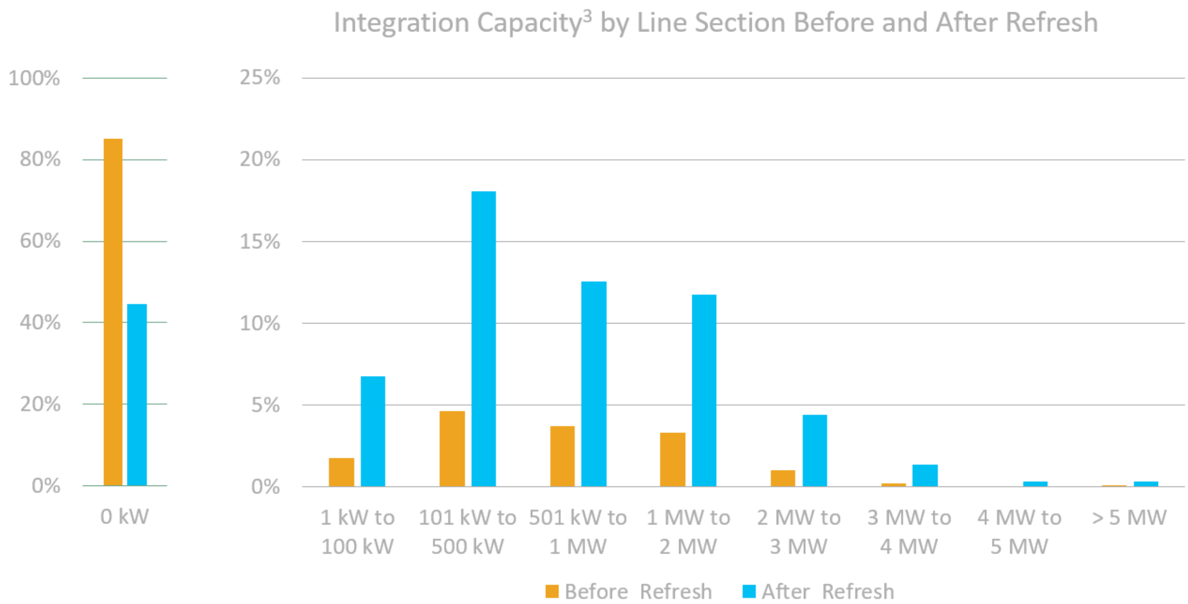

Figure 2 – Distribution of Line Section Results by Integration Capacity

In addition to reducing the number of line sections reporting no integration capacity, the reported integration capacity of line sections increased across the entire system. The process has resulted in the average reported integration capacity on each line section increasing by nearly 400%. Before the system refresh, the average reported line section integration capacity was 126 kW. After system refresh, the average reported line section integration capacity increased to 500 kW. The trend of increasing integration capacity is summarized in **Figure 3**.

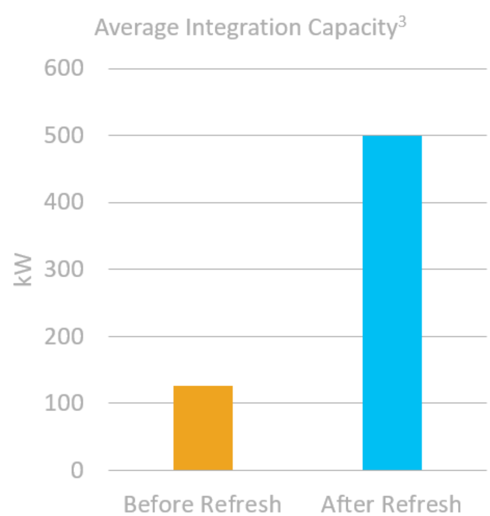

Figure 3 - System Average of Line Section Integration Capacity

Posting of ICA Results on Distribution Resource Planning (DRP) Portal

PG&E has analyzed all valid circuits with GridUnity and the results are now available on PG&E's DRP Portal. Using data-based study triggers, the GMM system will continue to automatically analyze circuits on a monthly basis, with updated results to be published as they become available.

Updated ICA Implementation Costs

Table 1 shows an update on the ICA implementation costs. In 2018, PG&E spent $1,290k on the initial implementation of ICA. In 2019 and 2020, PG&E spent $3,240k and $806k, respectively, working with GridUnity to perform the system refresh, operationalizing ICA and better incorporating quality control into the ICA process. In addition, this investment has resulted in the automation of future studies based on system changes such as new interconnections and distribution system changes. Going forward, PG&E anticipates spending $2,500k annually for ongoing administration and monthly updates.

Table 1 - Historical and Forecasted ICA Implementation Costs

	2018 ($1,000)	2019 ($1000)	2020 ($1000)	2021 ($1000)	Total ($1000)
Initial Implementation	$1,290	$0	$0	$0	$1,290
System Refresh	$0	$3,240	$806	$0	$4,046
Ongoing Administration and Monthly Updates	$0	$0	$2,000	$2,500	$4,500
Total	$1,290	$3,240	$2,806	$2,500	