Overview of Distribution Planning Efforts

Grid Modernization: Distribution Planning Workshop
Minnesota Public Utilities Commission
Oct. 24, 2016

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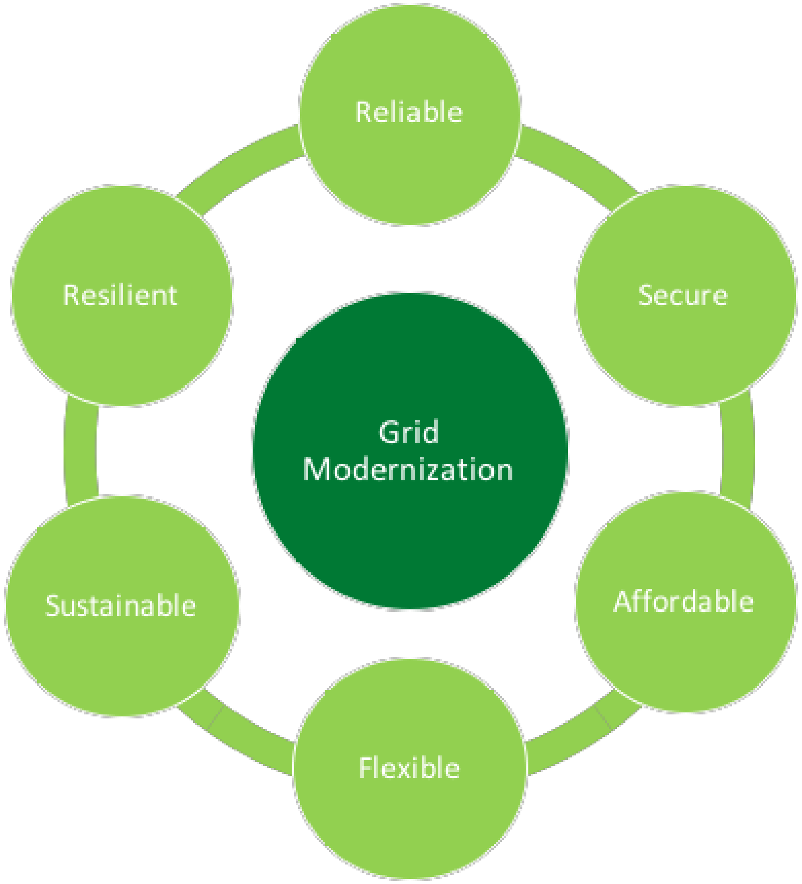
In this presentation

- Grid modernization visions and initiatives - DOE, MN
- MN context for distribution planning
- What other states are doing – leading or starting
- Drivers and benefits of improved distribution planning
- Considerations for establishing a regulatory process for distribution planning
- Possible places to start
  - Including some integration of planning activities — T, D and IRP
- Berkeley Lab resources – assistance, education, reports
- Additional slides – DOE institutional support under grid modernization initiative, more on LBNL's DPV report

DOE’s grid modernization vision

A modern grid must have:*

- greater resilience to hazards of all types
- improved reliability for everyday operations
- enhanced security from an increasing and evolving number of threats
- additional affordability to maintain our economic prosperity
- superior flexibility to respond to variability and uncertainty
- increased sustainability through additional clean energy and energy-efficient resources



*Adapted from U.S. Department of Energy’s Grid Modernization Multi-Year Program Plan (MYPP): http://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf

DOE's grid modernization vision - 2

The future grid will solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation. It will provide a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It will deliver resilient, reliable, flexible, secure, sustainable, and affordable electricity to consumers where they want it, when they want it, how they want it.

Enhance the Security of the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

DOE's grid modernization initiative

- An aggressive five-year grid modernization strategy
  - Alignment of the existing base activities among DOE Offices
  - An integrated Multi-Year Program Plan (MYPP)
  - New activities to fill major gaps in existing base
  - Laboratory consortium with core scientific abilities and regional outreach
- Scope
  - Developing **new architectural concepts, tools and technologies** that measure, analyze, predict, protect and control the grid of the future
  - **Enabling the institutional conditions that allow for more rapid development and widespread adoption of these tools and technologies**
- Grid Modernization Lab Consortium
  - Collaboration among 14 DOE national labs and regional networks that will help develop and implement the MYPP
  - Includes support for PUCs and utilities on distribution planning planning
  - See "Additional Slides" for institutional support projects. Full project list: http://energy.gov/under-secretary-science-and-energy/doe-grid-modernization-laboratory-consortium-gmlc-awards

MN PUC context: 2016 staff report

- Defined grid modernization - *A modernized grid assures continued safe, reliable, and resilient utility network operations, and enables Minnesota to meet its energy policy goals, including the integration of variable renewable electricity sources and distributed energy resources. An integrated, modern grid provides for greater system efficiency and greater utilization of grid assets, enables the development of new products and services, provides customers with necessary information and tools to enable their energy choices, and supports a standards-based and interoperable utility network.*
- 3 questions for inquiry, focused on distribution planning
  - Are we planning for and investing in the distribution system that we will need in the future?
  - Are the planning processes aligned to ensure future reliability, efficient use of resources, maximize customer benefits and successful implementation of public policy?
  - What commission actions would support improved alignment of planning for and investment in the distribution system?
- 3-phase approach: Phase 2 is “prioritize potential action items”

MN PUC context - 2

- Grid modernization drivers include "aging infrastructure, rapid technological advances and cost declines, changing customer demands, and emerging public policies."
- "These changes will continue with or without Commission action. Aging infrastructure will need to be replaced, [DERs] will expand as costs fall, advances will be made in distribution system technology, and customer demands will continue to evolve."
- Threshold question: "how can forward looking planning targeted at the distribution system level, in coordination with other planning (IRP, transmission, etc), be effectively and appropriately accomplished in order to protect and promote the public interest"?
- A "more directed and coordinated approach to grid modernization is warranted," recognizing separate but related proceedings
- MN "Distribution Grid Plans" could include scenario planning and hosting capacity analyses, grid data, actions on PV smart inverters and more

MN PUC context – 3
Principles for Grid Modernization

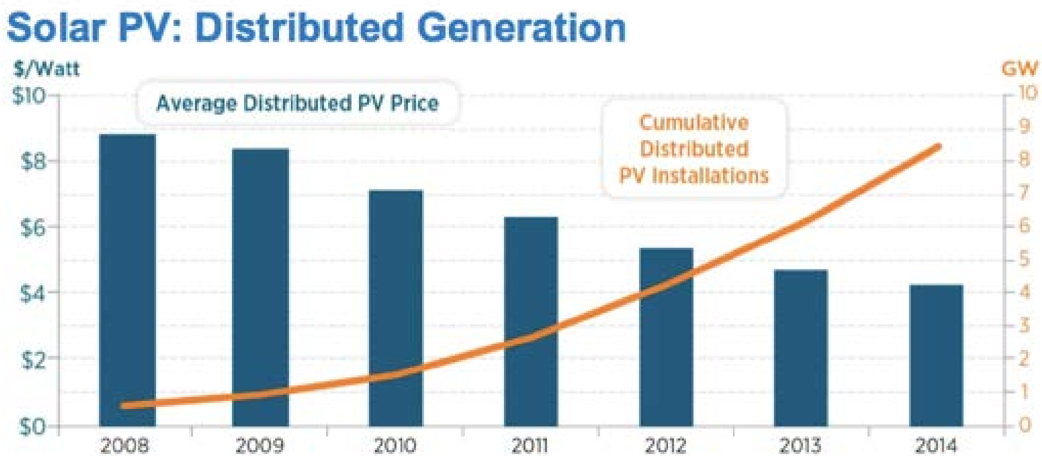
- Maintain and enhance the safety, security, reliability, and resilience of the electricity grid, at fair and reasonable costs, consistent with the state's energy policies
- Enable greater customer engagement, empowerment, and options for energy services
- Move toward the creation of efficient, cost-effective, accessible grid platforms for new products, new services, and opportunities for adoption of new distributed technologies
- Ensure optimized utilization of electricity grid assets and resources to minimize total system costs
- Facilitate comprehensive, coordinated, transparent, integrated distribution system planning

MN PUC context – 4
<u>Some</u> MN requirements re: distribution planning

- ”Each entity subject to this section that is operating under a multiyear rate plan [Xcel] ... shall conduct a distribution study to identify interconnection points on its distribution system for small-scale distributed generation resources and shall identify necessary distribution upgrades to support the continued development of distributed generation resources, and shall include the study in its report....” (Minn. Stat. § 216B.2425, subd. 8.)
- Xcel to identify “investments that it considers necessary to modernize the ... distribution system by enhancing reliability ... and by increasing energy conservation opportunities by facilitating communication between the utility and its customers through the use of two-way meters, control technologies, energy storage and microgrids, technologies to enable demand response, and other innovative technologies” (subd. 2(e))
- Xcel to complete a distribution study by 12/1/16 including initial hosting capacity analysis of each feeder for small-scale DG [≤1 MW] and potential distribution upgrades necessary to support expected DG additions, including those in the company’s IRP filings and active in its community solar garden process (Docket No. E-002/M-15-962)
- When considering a Large Energy Facility—high-voltage transmission line or generating facility—utilities must evaluate “possible alternatives for satisfying the energy demand or transmission needs including but not limited to potential for increased efficiency … load-management programs, and distributed generation.” (Minn. Stat. § 216B.243, Subd. 3(6))
- Cogeneration and Small Power Production statute (Minn. Stat. § 216B.164)

Drivers for states of improved distribution planning

- More DERs due to:
  - Cost reductions
  - Public policies
  - Third-party providers
  - Consumer expectations for control over energy costs and sources



DOE, *Revolution Now*

- Resiliency and reliability (see LBNL's value of service reliability report*)
- More data and better tools to analyze data
- Aging grid infrastructure and proposals for grid investments
- Need for greater grid flexibility with high levels of renewables
- Interest in distribution efficiency improvements (CVR/VVO)
- Pilots demonstrating cases where alternatives to traditional distribution solutions provide net benefits to customers

*In "Additional Slides"

Benefits for states of improved distribution planning

- Makes transparent utility distribution system investments before showing up individually in rider or rate case
- Provides opportunities for meaningful PUC and stakeholder engagement
- Considers uncertainties under a range of possible futures
- Considers all solutions for least cost/risk
- Motivates utility to choose least cost/risk solutions
- Enables consumers and third parties to participate in providing grid services

Other states advancing distribution planning

- NY – Reforming the Energy Vision
  - Utilities filing Distribution System Implementation Plans with stakeholder engagement

  - Expansion of non-wires alternatives (NWAs) — e.g., Brooklyn and Queens Demand Management project ($200M) enabled $1.2B deferral of traditional network upgrades in (41 MW customer-side, 11 MW utility-side)
  - Hosting capacity analysis in stages
  - RFPs for capacity displacement services in near term
  - Auction-based process longer term

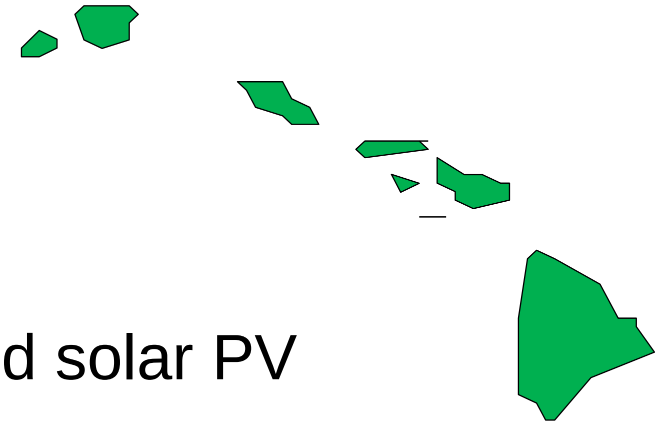
Other states advancing distribution planning - 2

- CA

  - AB 327 and PUC order on distribution planning
  - Distribution Resource Plans (proposals 7/1/15)
    - *Locational Net Benefits Analysis* - Specify net benefits DERs can provide at any given location, using E3's Distributed Resource Avoided Cost Calculator as framework for system-level values and PUC-required, location-specific methods for avoided T&D costs
    - *Integration Capacity Analysis* – "Streamlined" hosting capacity analysis to identify how much generation can be installed on a line section w/o distribution upgrades. 9 functional requirements for demos
  - Integrated DERs proceeding proposes utility shareholder incentive for deployment of cost-effective DERs that displace or defer a utility expenditure (through all-source request for offers)
  - SB 350 - 50% RPS and doubling energy efficiency by 2030, ZEVs, establishing IRP requirements for utilities
  - Energy storage mandate (AB 2514)

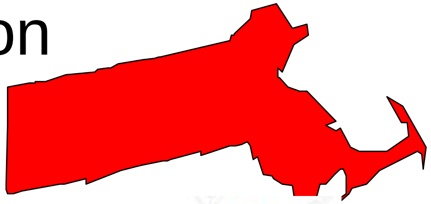
Other states advancing distribution planning - 3

- HI
  - Clean Energy Initiative
  - 100% RPS by 2045
  - High penetration levels for distributed solar PV
  - Isolated island grids
  - Investigations into DERs including procurement
  - Exploring demand response including time-varying pricing, EV charging and community solar
  - PUC inclinations on future of utilities
  - RFP for study to evaluate alternative utility and regulatory models including independent DSOs

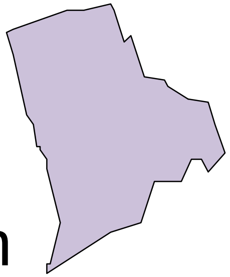


Other states advancing distribution planning - 4

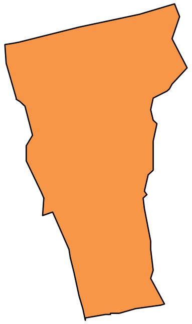
- MA – Requirements for each electric distribution company to develop/implement a 10-year grid modernization plan (plans filed 8/2015)



- DC – Modernizing the Energy Delivery System, staff report and roadmap forthcoming



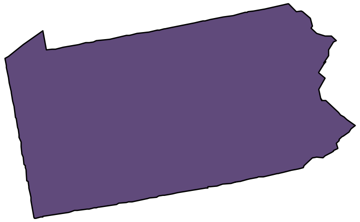
- RI – Systems Integration Vision, including identifying ways to promote more cost-effective, comprehensive NWA distribution planning, System Reliability Procurement law



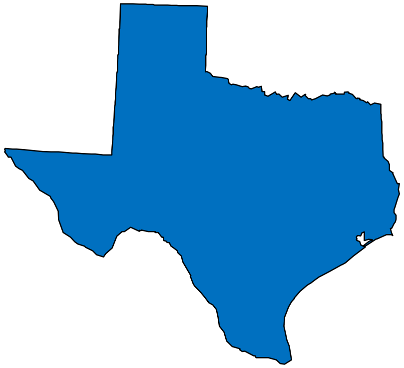
- VT – State law obligates the utility or other transmission provider to undertake NWA analysis as part of the transmission planning process

Examples of what additional states are doing in the area of distribution system planning and markets

- PA – Distribution reliability code directs PSC to regulate distribution inspection & maintenance plans, requires utilities to report quarterly on worst-performing circuits and propose investments recovered through a Distribution System Improvement Charge and make annual compliance filings (see 2015 PA reliability report)



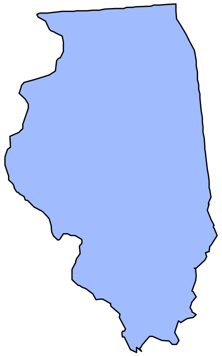
- FL – Storm hardening and undergrounding requirements (Duke storm hardening plan)
- TX - Aggregation and participation of DERs in wholesale markets (ERCOT DER whitepaper, DREAM TF report)



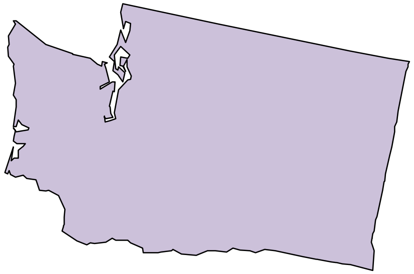
Examples of what additional states are doing - 2

- OH – Distribution system reliability code, distribution circuit performance codes and annual reliability compliance filings

- IL – Utilities file annual reliability reports, ICC assesses utility report ≤3 years, Energy Infrastructure Modernization Act authorized investment plans for grid hardening and smart meters



- WA – New rulemaking to consider changes in IRP methods, including consideration of distribution-level resources (e.g., DG and storage); distribution system modeling; EV impacts, changes in end uses and DG; smart grid reporting (with sunset of current reporting requirements)



Some considerations for establishing a regulatory process for distribution planning

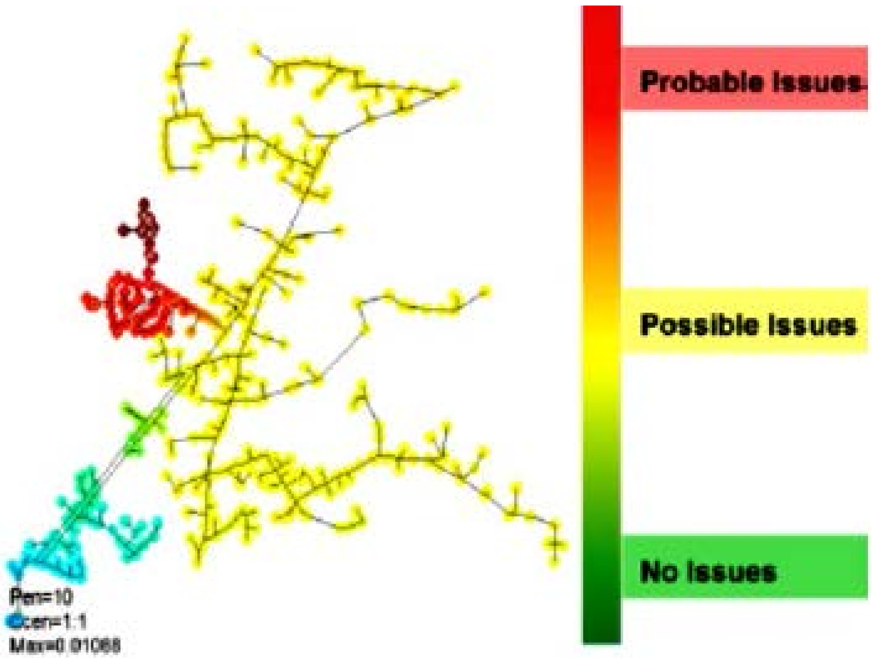
- Statutory requirements and regulatory precedents
- Priorities, phasing and related proceedings
- What's worked elsewhere, tailored to MN
- Recognize differences across utilities
- Regulatory clarity for grid investments with flexibility built-in
- Quick wins, early benefits for consumers
- Long-term, cohesive view to achieve PUC's goals
- Pilots vs. full-scale approaches (and rate impacts)
- Focus of planning for distribution vs. T vs. bulk power system
- Vast majority of new generation today connected to D system
- Utility distribution investments are large
  - $200M for MN IOUs in 2014 (MN PUC staff 2016 report)
  - $20.8B nationally among EEI members in 2013 (EEI survey)

Possible places to start

- *Take early integration steps* - Consistency in inputs (assumptions, forecasts), scenarios and modeling methods — updated in time — across distribution planning, integrated resource planning and transmission planning
- *Account for all resources* – Consider energy efficiency, demand response (including direct load control, smart Tstats and time-varying pricing), distributed generation and energy storage, alongside traditional distribution solutions
- *Specify DER attributes* – In order to meet identified needs
- *Analyze multiple possible futures* – DERs plus other scenario drivers
- *Consider CVR/VVO* in distribution plans (and in IRPs)

Possible places to start - 2

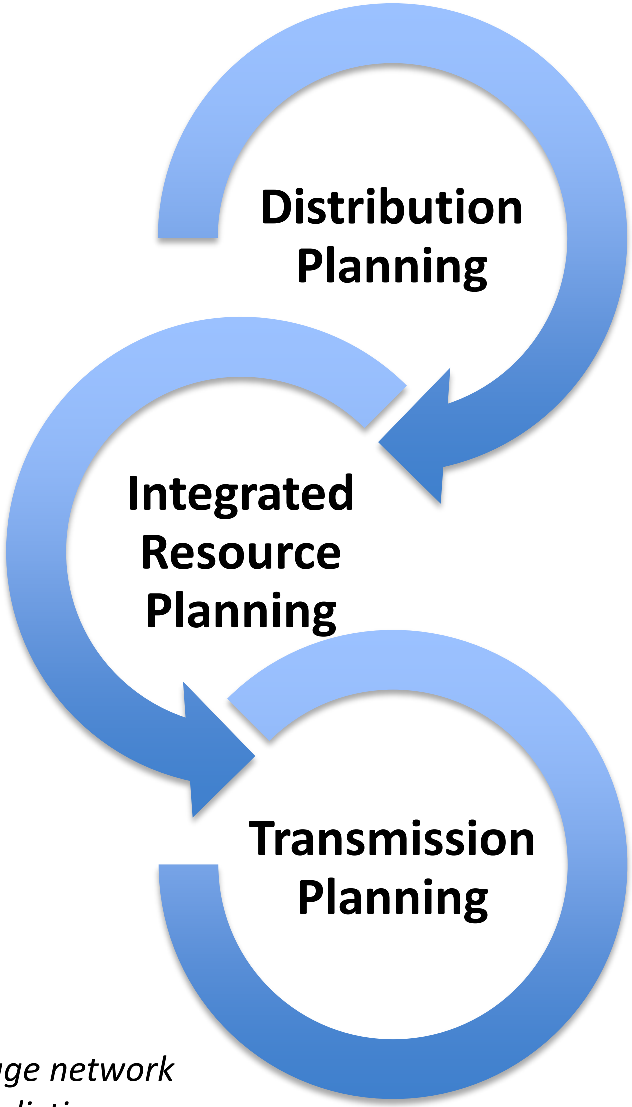
- *Phase in hosting capacity analysis* – To facilitate DG integration and indicate better or more difficult locations
- *Pilot evaluation of locational impacts* – Identify where DERs might offer greatest benefits



- *Integration of new utility systems* – If/when ADMS, AMI and other new systems are implemented, specify in advance how they will be used in distribution planning and lock in early consumer benefits
- *Test new sourcing and pricing methods* – e.g., competitive solicitations, tariffs, programs
- *Training for staff* – e.g., DOE-funded courses starting next summer

Integration of planning activities

- While *distribution planning* is focused on assessing needed physical and operational changes to local grid, can support DER growth and optimal use for net benefits for customers
- While *integrated resource planning* is focused on identifying future investments to meet bulk power system reliability and public policy objectives at a reasonable cost, can consider scenarios for adoption of customer-hosted DERs at the distribution level and impacts on the need for, and timing, of utility investments
- While *transmission planning* is focused on identifying future transmission expansion needs and options for meeting those needs, can begin anticipating operational challenges at T-D interface* and solutions



**Boundary between wholesale & retail markets; between meshed high-voltage network & radial, lower-voltage feeders; and between federal & state regulatory jurisdiction*

Berkeley Lab Resources on Distribution System Planning

- Technical assistance for PUCs, forthcoming guide for states, and education/training courses for PUCs
  - LBNL with partners NREL and PNNL, funded by DOE Office of Electricity Delivery and Energy Reliability and Office of Energy Efficiency and Renewable Energy
- *Planning for a Distributed Disruption: Innovative Practices for Incorporating Distributed Solar into Utility Planning*
  - By Andrew Mills, et al., funded by DOE Office of Energy Efficiency and Renewable Energy – Solar Energy Technologies Program
- Future Electric Utility Regulation report series (**feur.lbl.gov**):
  - *Distribution Systems in a High DER Future: Planning, Market Design, Operation and Oversight* by Paul De Martini (Cal Tech) and Lorenzo Kristov (CAISO)
  - *The Future of Electricity Resource Planning* by Fredrich Kahrl (E3), Andrew Mills (LBNL), Luke Lavin, Nancy Ryan and Arne Olsen (E3)
  - Funded by DOE Office of Electricity Delivery and Energy Reliability – Electricity Policy Technical Assistance Program and Office of Energy Efficiency and Renewable Energy

FUTURE ELECTRIC
Utility Regulation

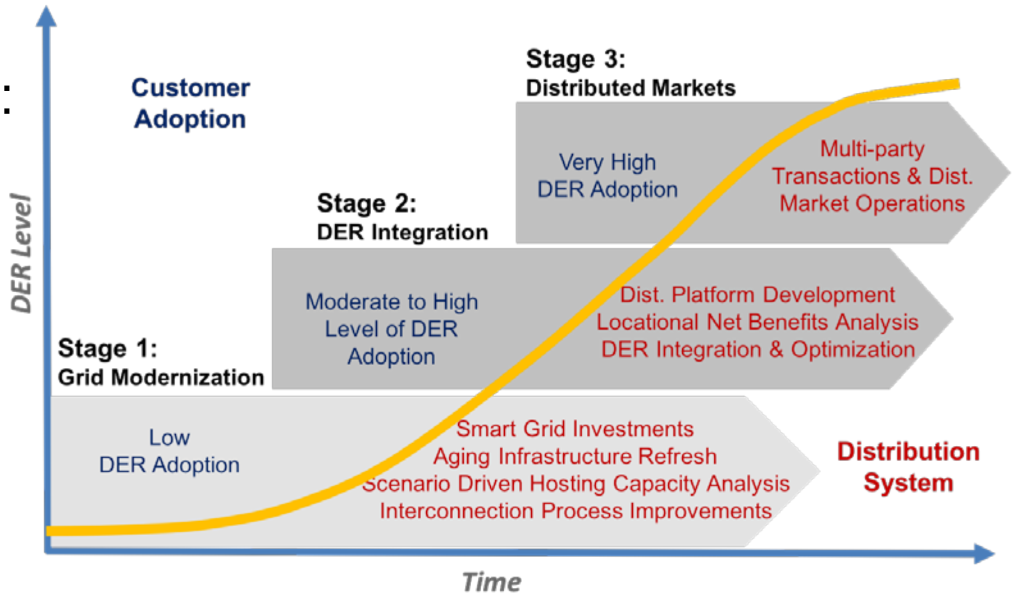
Berkeley Lab Resources – Report #1:
Innovative Practices in Distribution Planning for Solar PV

- **Forecasting:** Include distributed PV in forecast of peak load for distribution planning. Use hosting capacity analysis to identify needs for proactive distribution investments. Use customer-adoption modeling for DPV forecasts.
- **Robustness:** Develop scenario-specific plans. Use differences in plans to identify "trigger events" that will result in changes to plan.
- **DPV as a Resource:** Fully characterize DPV as an option for meeting distribution system needs.
- **Location of DPV:** Forecast location of DPV to improve estimates of distribution system impact and location-specific value. Use propensity to adopt based on household/customer characteristics.
- **Impacts to distribution system:** Use hosting capacity analysis to identify needs for proactive distribution investments.
- **Avoided Losses:** Account for time-varying loss rates.
- **Changes with penetration:** Identify costs and benefits for different tranches of DPV, including for charging electric vehicles when solar output is high.

From *Planning for a Distributed Disruption: Innovative Practices for Incorporating Distributed Solar into Utility Planning* by Andrew Mills *et al.*, Berkeley Lab and NREL, August 2016. See "Additional Slides."

Berkeley Lab Resources – Report #2
Distribution Systems in a High DER Future

- Diverse end-use devices & owners/operators will change:
  - Net end-use load shapes, peak demands, total energy
  - Direction of energy flows
  - Variability and predictability of net loads and grid conditions
  - kWh volumes and revenues



- Traditional passive one-way delivery from central power plants to end-use customers inadequate
- Distribution utilities will need new approaches for system operation, grid planning, interconnection procedures, and coordination with transmission system & wholesale markets
- Focus on what's needed to provide reliable, safe operation of distribution system & T-D interface and to integrate DER expansion

From *Distribution Systems in a High DER Future: Planning, Market Design, Operation and Oversight* by Paul De Martini and Lorenzo Kristov, Future Electric Utility Regulation series, Berkeley Lab, October 2015, **feur.lbl.gov**

Distribution Systems in a High DER Future (report #2 cont.)
Stage One: Grid Modernization

- Low adoption of DERs
- Some new planning studies useful if DER expansion is anticipated
  - Scenario-based, probabilistic planning studies
    - Scenarios capture range of DER growth over planning horizon
    - Probabilistic methods model DER behavior impacts on grid
  - Enhanced interconnection studies & processes
  - Hosting capacity = maximum DER penetration consistent with reliable & safe grid operation (per feeder from T-D substation)
  - Locational net value of DER
    - Operating or capital expense reduction, locational benefits
  - Integrated T & D planning
    - Iterative approach where results of one are inputs to the other

From *Distribution Systems in a High DER Future: Planning, Market Design, Operation and Oversight* by Paul De Martini and Lorenzo Kristov, Future Electric Utility Regulation series, Berkeley Lab, October 2015, **feur.lbl.gov**

Berkeley Lab Resources – Report #3
Distributed Generation: Emerging Issues in IRP

- DG can have significant impact on system operations, need for and timing of investments in conventional generation and T&D infrastructure
- Utilities have limited direct control over adoption
- That said, utilities:
  - Do have some ability to target DG adoption
  - Can plan for DG uncertainty

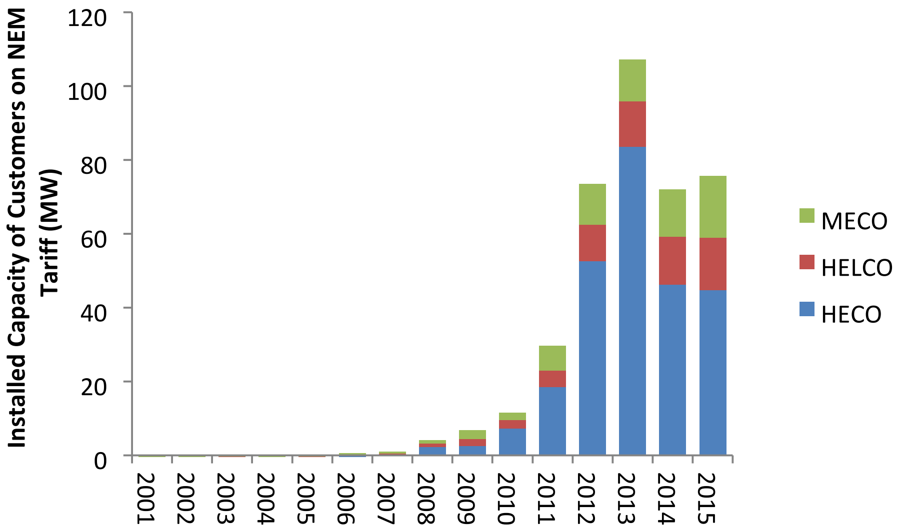


Figure shows net energy metering installations in MECO, HELCO, HECO (Hawaii) from 2001 to 2015. In five years customers install 246 MW, 54 MW and 58 MW, respectively, of NEM DG (22%, 29%, 30% of 2013 system peak).

From *The Future of Electricity Resource Planning by* Fredrich Kahrl (E3), Andrew Mills (LBNL), Luke Lavin, Nancy Ryan and Arne Olsen (E3), Berkeley Lab, September 2016: **feur.lbl.gov**

Distributed Generation: Evolving IRP Practices (report #3 cont.)

- Key areas:
  - How utilities are modeling DG adoption and its impact on bulk power system planning variables
  - How utilities are valuing DG in resource plans
  - How utilities and regulators are comprehensively assessing DG impacts, beyond traditional resource planning

From *The Future of Electricity Resource Planning,* Berkeley Lab

Emerging Best Practices

- Generating DG forecasts using models of customer adoption behavior
- Assessing locational value of DG, incorporating distribution deferral values in DG evaluation
- Making use of “triggers” and “signposts” to revisit plans if adoption is significantly different than anticipated

For examples, see CECONY, NSP, PacifiCorp, TVA plans; SCE DRPs

Additional Slides

Value to Customers of Service Reliability

- LBNL est. interruption costs by customer class, duration, timing, region
- Based on 34 datasets from 10 utilities from 1989 to 2012 using nearly identical interruption cost or willingness-to-pay/accept methods
- Can be used to prioritize distribution reliability projects

Table ES-1: Estimated Interruption Cost per Event, Average kW and Unserved kWh (U.S.2013$) by Duration and Customer Class

Interruption Cost	Interruption Duration					
	Momentary	30 Minutes	1 Hour	4 Hours	8 Hours	16 Hours
Medium and Large C&I (Over 50,000 Annual kWh)						
Cost per Event	$12,952	$15,241	$17,804	$39,458	$84,083	$165,482
Cost per Average kW	$15.9	$18.7	$21.8	$48.4	$103.2	$203.0
Cost per Unserved kWh	$190.7	$37.4	$21.8	$12.1	$12.9	$12.7
Small C&I (Under 50,000 Annual kWh)						
Cost per Event	$412	$520	$647	$1,880	$4,690	$9,055
Cost per Average kW	$187.9	$237.0	$295.0	$857.1	$2,138.1	$4,128.3
Cost per Unserved kWh	$2,254.6	$474.1	$295.0	$214.3	$267.3	$258.0
Residential						
Cost per Event	$3.9	$4.5	$5.1	$9.5	$17.2	$32.4
Cost per Average kW	$2.6	$2.9	$3.3	$6.2	$11.3	$21.2
Cost per Unserved kWh	$30.9	$5.9	$3.3	$1.6	$1.4	$1.3

Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States, by Michael J. Sullivan, Josh Schellenberg and Marshall Blundell, Nexant, Inc., prepared for Berkeley Lab, January 2015: https://emp.lbl.gov/publications/updated-value-service-reliability

DOE GMLC institutional support activities

Four main institutional support activities under DOE's Multi-year Program Plan:

1. Provide technical assistance to states and tribal governments
2. Support regional planning and reliability organizations
3. Develop methods and resources for assessing grid modernization: Emerging technologies, valuation and markets
4. Conduct research on future electric utility regulations

Each activity has specific goals and target achievements to be completed by 2020.

6 GMLC institutional support projects

Regional Projects

- New York: Technical Support to the Reforming Energy Vision (REV) Initiative
- California: Distributed Energy Resources (DER) Siting and Optimization Tool to enable large scale deployment of DER

Foundational Projects

- Foundational Analysis: Metrics
- Grid Services and Technologies Valuation Framework
- Future Electric Utility Regulation
- Distribution System Planning: Decision Support Tools

1.1 Foundational Analysis for GMLC Establishment of a Framework of Metrics

Goals:

To develop a comprehensive framework of metrics and supporting data collection, processing, analysis and reporting, along with underlying data, *tools*, methods and *systems* to assess the evolving state of the grid and the impact that specific grid modernization investments are expected to achieve and actually deliver

The six "ilities:"

- *Reliability*
- *Resilience*
- *Flexibility*
- *Sustainability*
- *Affordability*
- *Security*

Tasks:

1. Establish initial metrics/baseline
2. Refine/implement
3. Multi-dimensional analysis
4. Stakeholder engagement

1.2.4 Grid Services and Technologies Valuation Framework

Goals:

- Provide a widely accepted, well-tested framework for evaluating the collection of value streams (net benefits) that can be provided by different grid-related services and technologies

Tasks:

1. Stakeholder Advisory Group and communications
2. Listing and definition of services, technologies, values, and beneficiaries
3. Review methodologies for gaps and commonalities
4. Develop full framework
5. Conduct table-top and pilot demonstrations

1.3.22 Technical Support to the New York State Reforming the Energy Vision (REV) Initiative

Goals:

- Continue and expand DOE support to the New York Reforming the Energy Vision initiative in the form of TA to New York Public Service Commission and New York State Energy Research and Development Authority (NYSERDA)

Tasks:

1. Project Coordination and Oversight
2. Needs Assessment
3. Deliver Technical Assistance
4. Assessment of Distribution Planning Methods
5. Evaluation of REV Demonstration Projects
6. Analysis of Implementation Models
7. Support to New York Prize (microgrid competition)

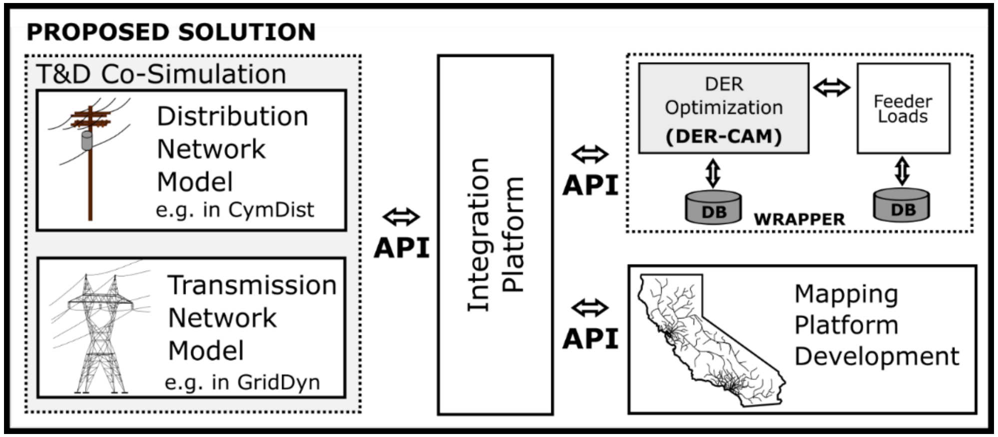
1.3.5 DER Siting and Optimization Tool to enable large scale deployment of DER in California

Goals:

- Deliver an online, open-access integrated distributed resource planning tool to promote DER penetration taking into account system-wide impacts

Tasks:

1. Develop CA T&D co-simulation models and data visualization
2. Find meaningful behind-the-meter DER adoption patterns and DER operational strategies
3. Identify favorable DER and microgrid sites considering policy incentives and DER grid services
4. Consider network constraints for DER location
5. Evaluate and mitigate impacts of DER in bulk electric system



1.4.25 Distribution System Decision Support Tool

Goal:

- A widely accepted process for advanced electric distribution planning (EDP)

Tasks:

1. Conduct outreach and workshops on EDP processes and gaps
2. Provide education for state regulators and utilities on EDP
3. Develop a formal approach to review grid components and systems and identify and modify tools for utilities for next-generation EDP processes
4. Provide technical assistance to utilities (modeling tools and best practices, leveraging NRECA and APPA) and state regulators
5. Develop lessons learned toolkit (models, resources, best practices)

Participants:

- NREL (lead – Mike Coddington), LBNL (Lisa Schwartz), PNNL (Juliet Homer)

1.4.29 Future Electric Utility Regulation

Goals:

- States will have improved capability to consider alternative regulatory and ratemaking approaches to enable grid modernization investments, including financial incentives for utilities and impacts on consumers and markets
- Approaches will better tie utility earnings to consumer value, economic efficiency, pollution reduction and other public policy goals

Tasks:

1. Use improved financial analysis tools to help states make better-informed decisions
2. Provide direct technical assistance to state public utility commissions considering incremental changes to cost of service regulation (e.g., decoupling or rate design changes) or more fundamental changes (e.g., performance-based regulation)
3. Continue Future Electric Utility Regulation series of reports

Participants:

- LBNL (lead – Lisa Schwartz), NREL (Lori Bird), PNNL, SNL, LANL, NETL

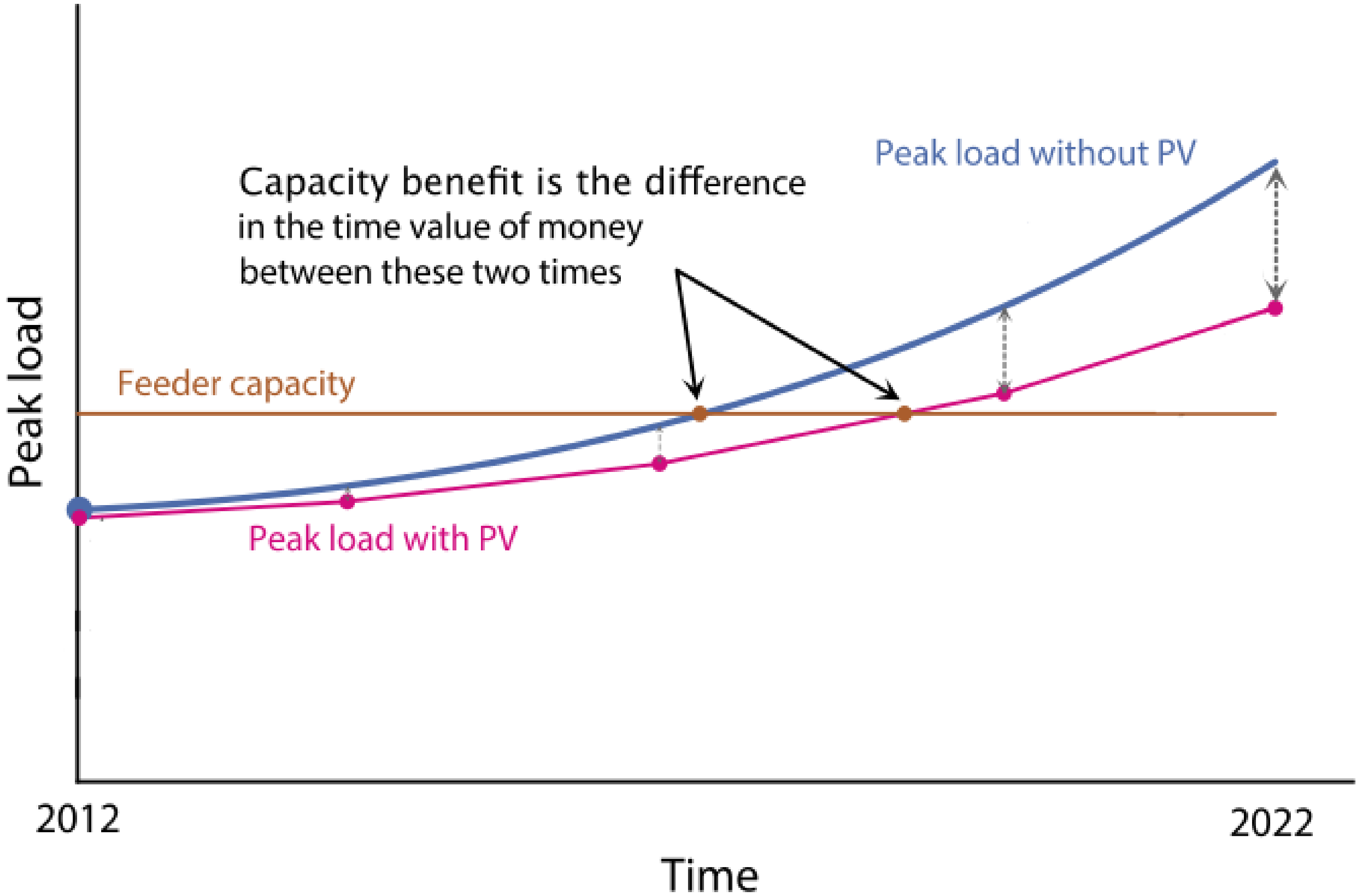
Distribution System Plans Reviewed for LBNL Study: Innovative Practices in Distribution Planning for Solar PV

Entity	Plan
California: PG&E	2015 Distribution Resources Plan
CA: Southern California Edison (SCE)	2015 Distribution Resources Plan
CA: San Diego Gas and Electric (SDG&E)	2015 Distribution Resources Plan
Hawaii: HECO	2014 Distributed Generation Interconnection Plan
Massachusetts: National Grid	2015 Grid Modernization Plan
New York: NY Department of Public Service	2015 Distributed System Implementation Plan Guidance

Planning for a Distributed Disruption: Innovative Practices for Incorporating Distributed Solar into Utility Planning by Andrew Mills, Galen Barbose, Joachim Seel, Changgui Dong, Trieu Mai, Ben Sigrin, Jarett Zuboy, Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory, August 2016: https://emp.lbl.gov/publications/planning-for-a-distributed-disruption

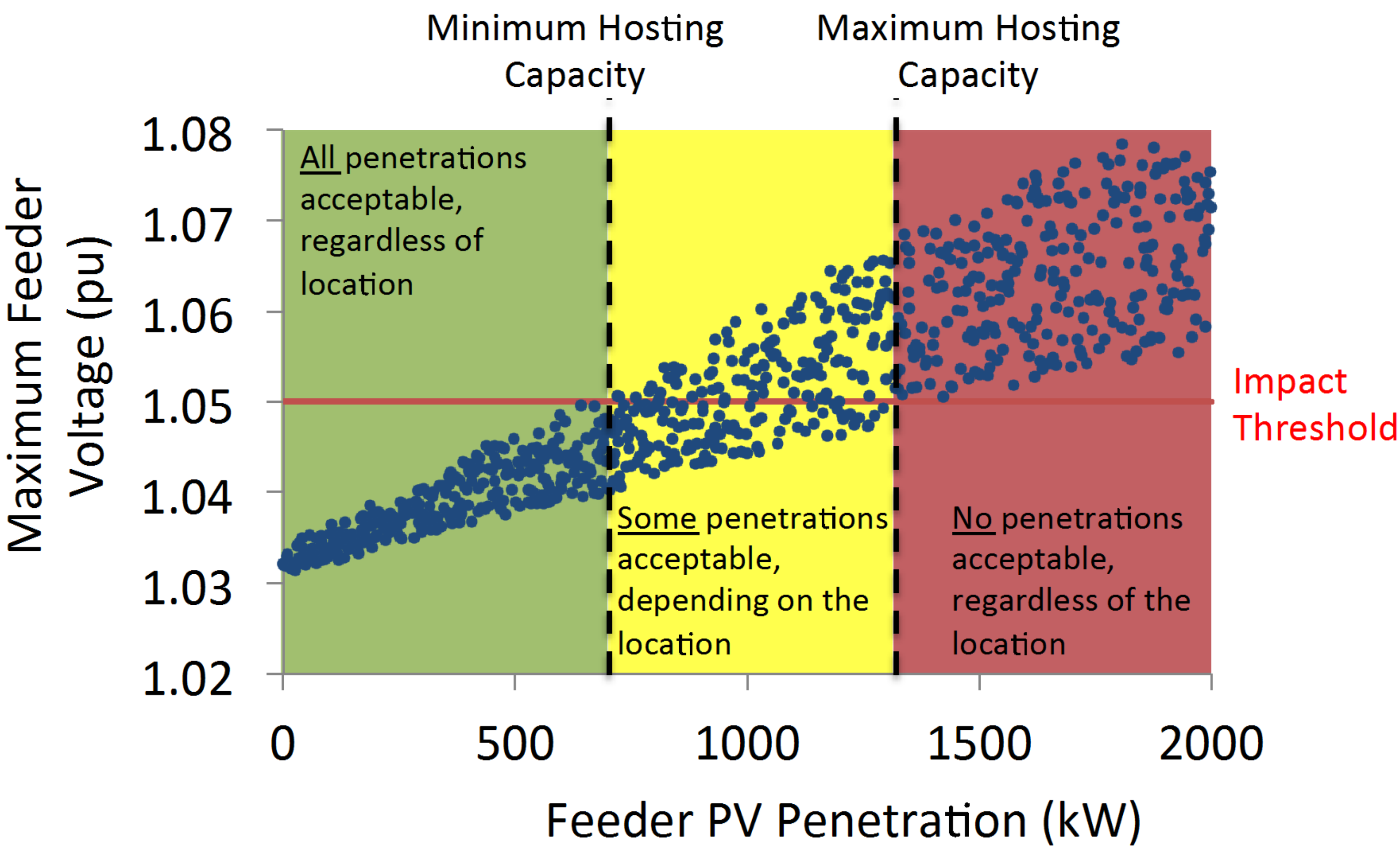
The study also reviewed integrated resource plans and transmission plans.

Impact of DPV on T&D Investments: Potential Deferral Value



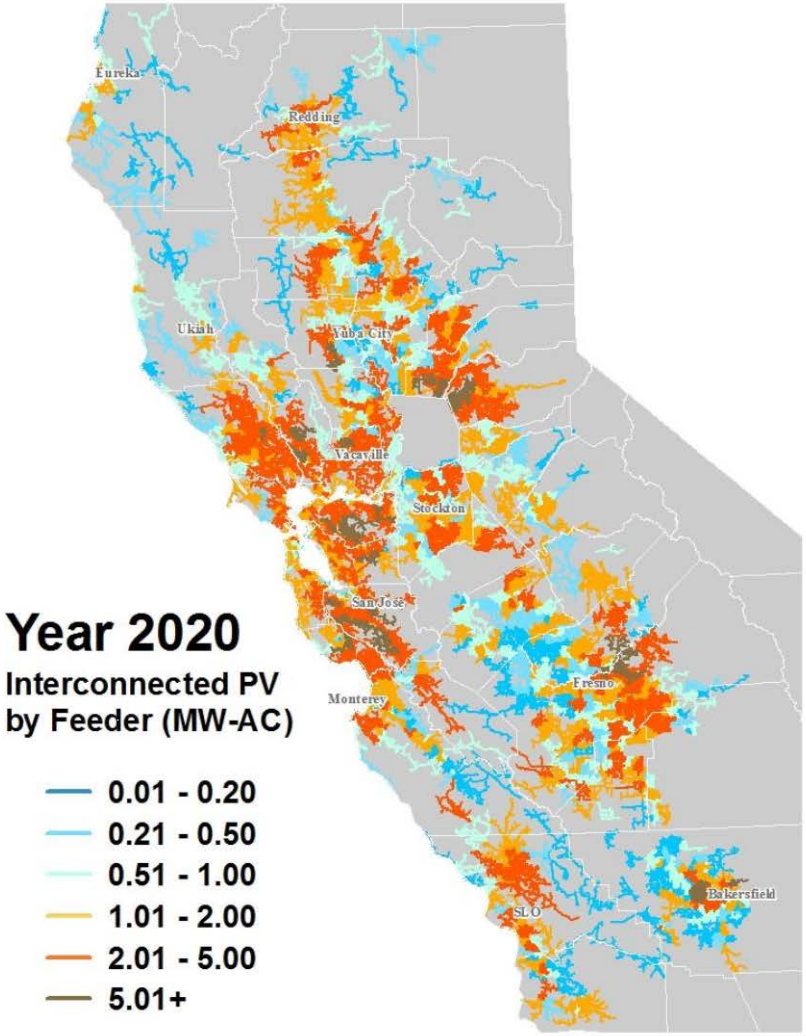
Source: Adapted by LBNL from Cohen, M.A., P.A. Kauzmann, and D.S. Callaway. 2016. "Effects of Distributed PV Generation on California's Distribution System, Part 2: Economic Analysis." Solar Energy, Special Issue: Progress in Solar Energy, 128(April): 139–152. doi:10.1016/j.solener.2016.01.004.

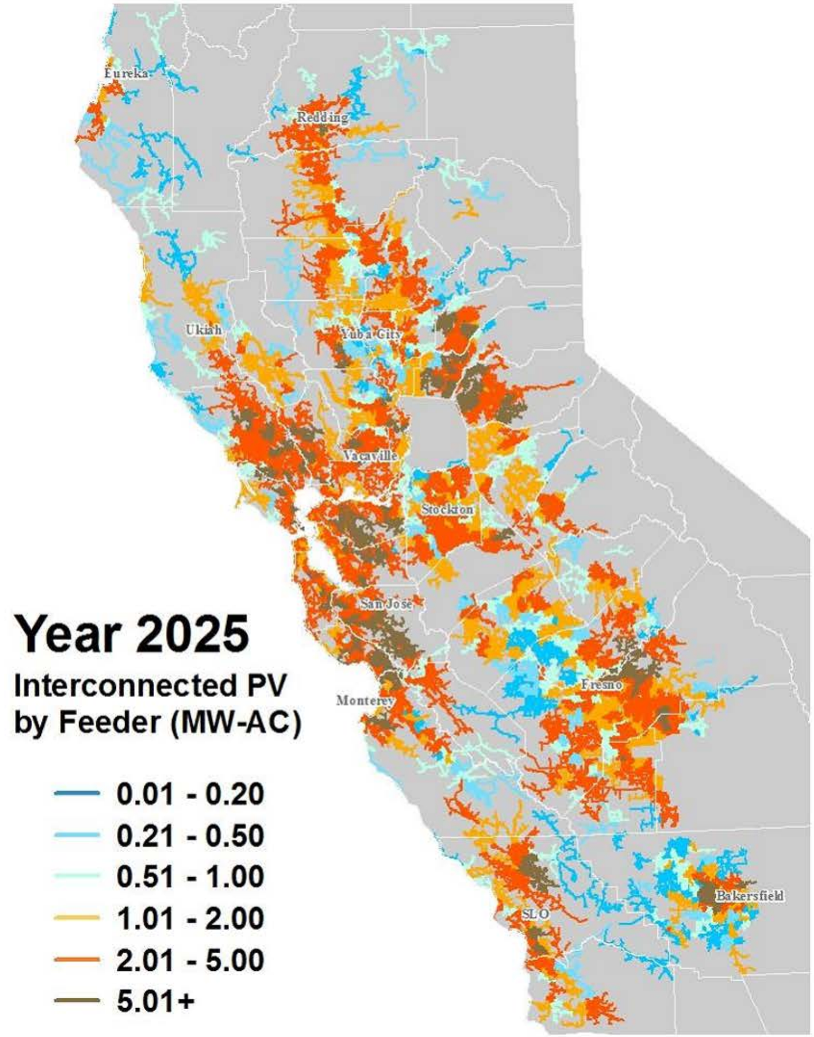
Impact of DPV on T&D Investments: Hosting Capacity Analysis



Source: Adapted by LBNL from EPRI, 2015. Distribution Feeder Hosting Capacity: What Matters When Planning for DER? http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004777

Predicting the Location of DPV Adoption

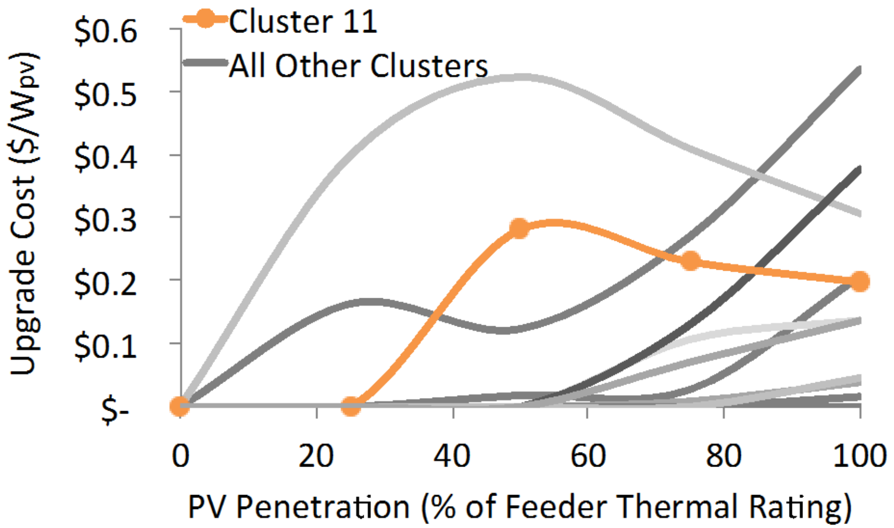




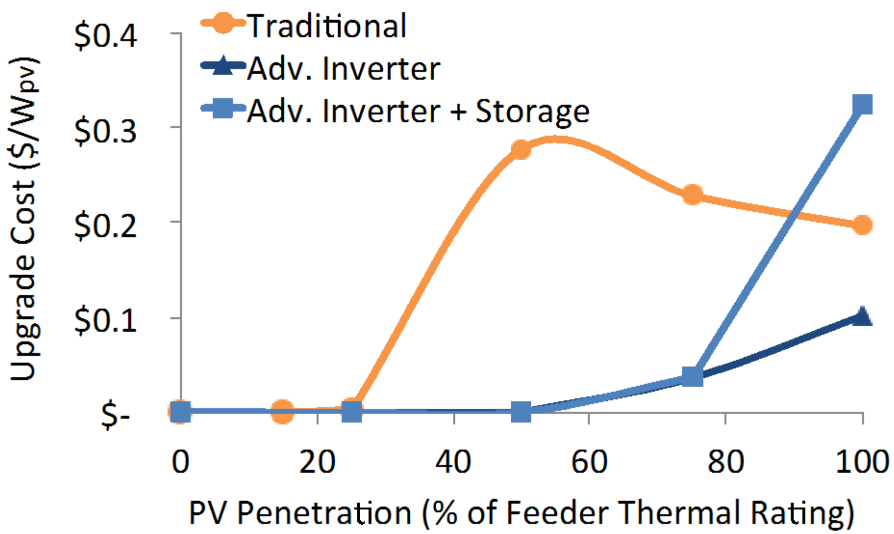
Source: PG&E 2015 Distribution Resources Plan

Impact of DPV on T&D Investments: Proactive Planning for DPV

Costs to Increase the Hosting Capacity of Fourteen Representative Feeders with Traditional Grid Upgrades



Costs to Increase the Hosting Capacity of Cluster 11 Comparing Traditional Grid Upgrades to Emerging Options



Source: Adapted by LBNL from Navigant Consulting, Inc. 2016. Virginia Solar Pathways Project: Study 1 - Distributed Solar Generation Integration and Best Practices Review. Dominion Virginia Power.

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