Determining Utility System Value of Demand Flexibility From Grid-interactive Efficient Buildings

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April 6, 2020

This presentation was supported by the U.S. Department of Energy's Building Technologies Office under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

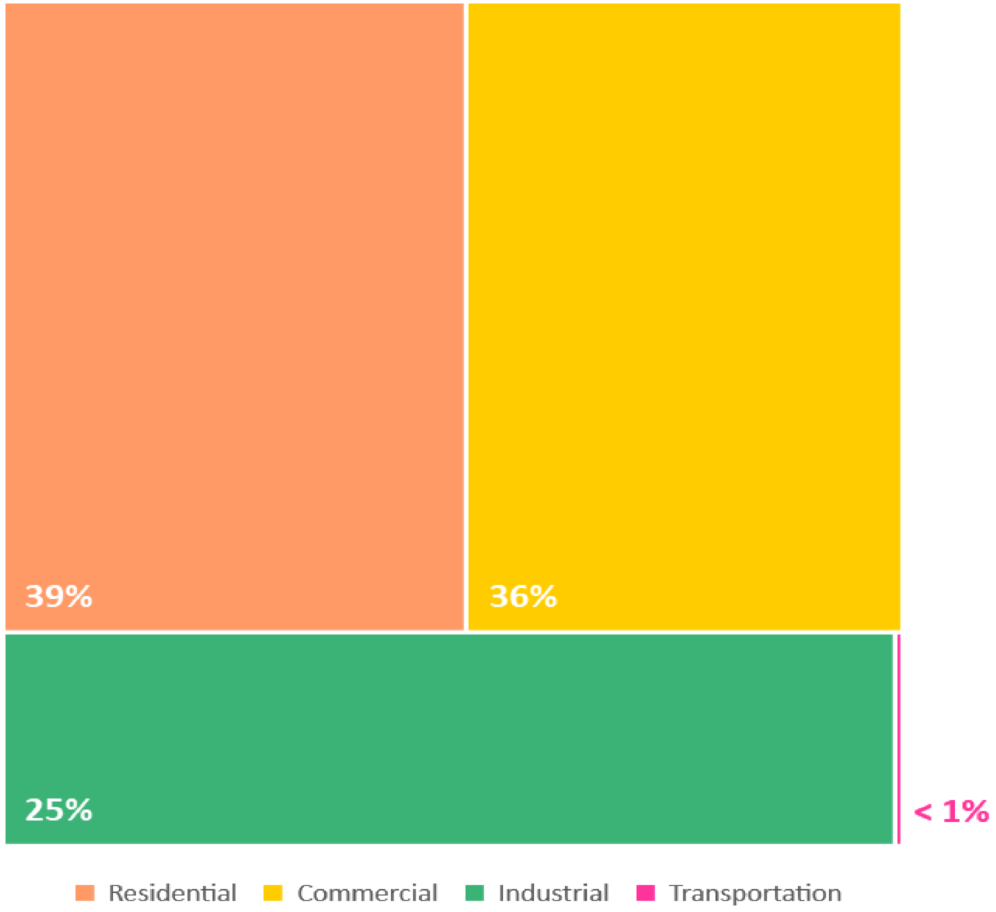
Introduction

- The State and Local Energy Efficiency Action (SEE Action) Network offers resources, discussion forums, and technical assistance to state and local decision makers as they provide low-cost, reliable energy to their communities through energy efficiency.

- Forthcoming SEE Action reports on Grid-interactive Efficient Buildings
  - **Introduction for State and Local Governments:** Describes grid-interactive efficient buildings in the context of state and local government interests; highlights trends, challenges, and opportunities for demand flexibility; provides an overview of valuation and performance assessments for demand flexibility; and outlines actions that state and local governments can take, in concert with utilities, regional grid operators, and building owners, to advance demand flexibility.
  - **Determining Utility System Value of Demand Flexibility from Grid-Interactive Efficient Buildings:** Describes how current methods and practices that establish value to the electric utility system of investments in energy efficiency and other distributed energy resources (DERs) can be enhanced to determine the value of grid services provided by demand flexibility **— focus of this webinar**
  - **Issues and Considerations for Advancing Performance Assessments of Demand Flexibility from Grid-interactive Efficient Buildings:** Summarizes current practices and opportunities to encourage robust and cost-effective assessments of demand flexibility performance and improve planning and implementation based on verified performance

Electricity Use by U.S. Buildings

- Buildings account for 75 percent of electricity consumption and in some regions up to 80 percent of peak demand.
- With many adjustable loads, buildings also represent the largest source of demand flexibility.



Data source: U.S. Energy Information Administration (EIA), Monthly Energy Review. June 2019, Table 7.6

Grid-interactive Efficient Buildings and Demand Flexibility

Grid-interactive Efficient Building	An energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences in a continuous and integrated way	Demand Flexibility*	Capability of DERs to adjust a building's load profile across different timescales

DERs – Resources sited close to customers that can provide all or some of their immediate power needs and/or can be used by the utility system to either reduce demand or provide supply to satisfy the energy, capacity, or ancillary service needs of the grid

Smart technologies for energy management - Advanced controls, sensors, models, and analytics used to manage DERs. Grid-interactive efficient buildings are characterized by their use of these technologies.

**Also called "energy flexibility" or "load flexibility"*

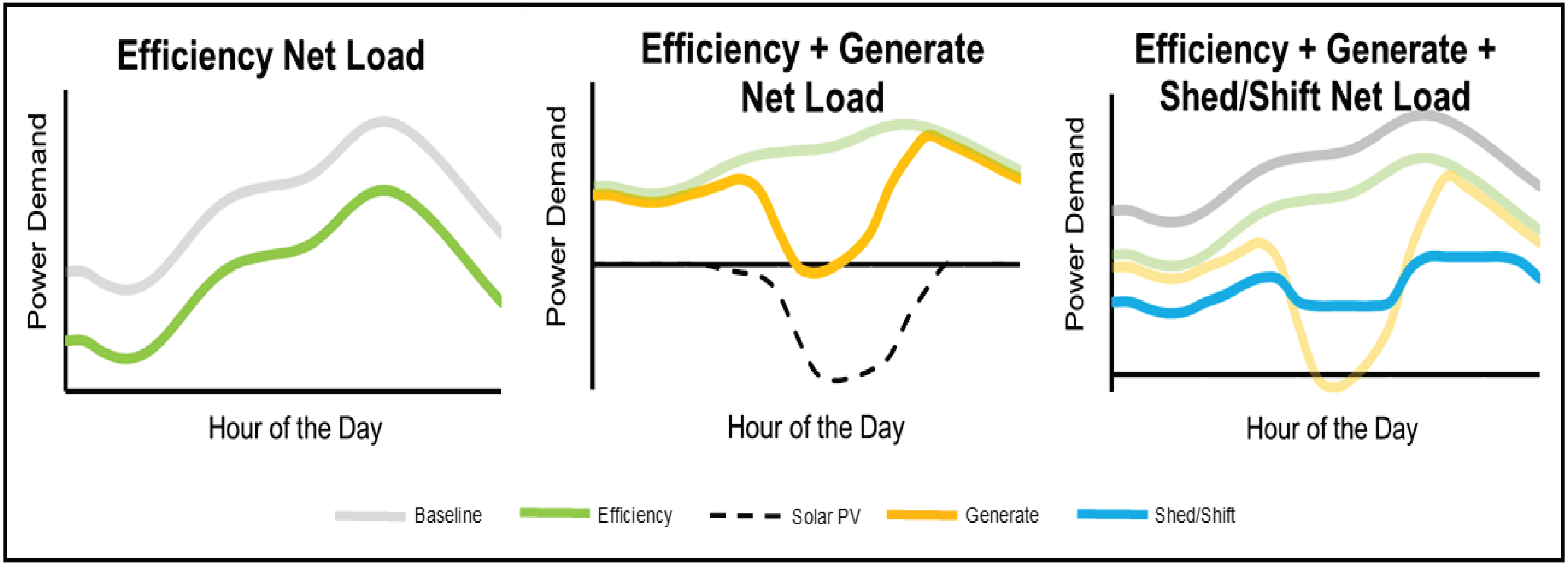
Source: Neukomm et al. 2019. *Grid-interactive Efficient Buildings Technical Report Series: Overview of Research Challenges and Gaps*. Also see example building in Extra Slides. More information here.

Demand-side Management Strategies to Manage Building Loads

- *Energy efficiency:* Ongoing reduction in energy use while providing the same or improved level of building function
- Demand flexibility:
  - *Load shed*: Ability to reduce electricity use for a short time period and typically on short notice.
  - *Load shift*: Ability to change the timing of electricity use. In some situations, a shift may lead to changing the amount of electricity that is consumed.
  - *Modulate*: Ability to balance power supply/demand or reactive power draw/supply autonomously (within seconds to subseconds) in response to a signal from the grid operator during the dispatch period
  - *Generate*: Ability to generate electricity for onsite consumption and even dispatch electricity to the grid in response to a signal from the grid

Source: Neukomm et al. 2019

Daily Average Load Profiles for Grid-interactive Efficient Building



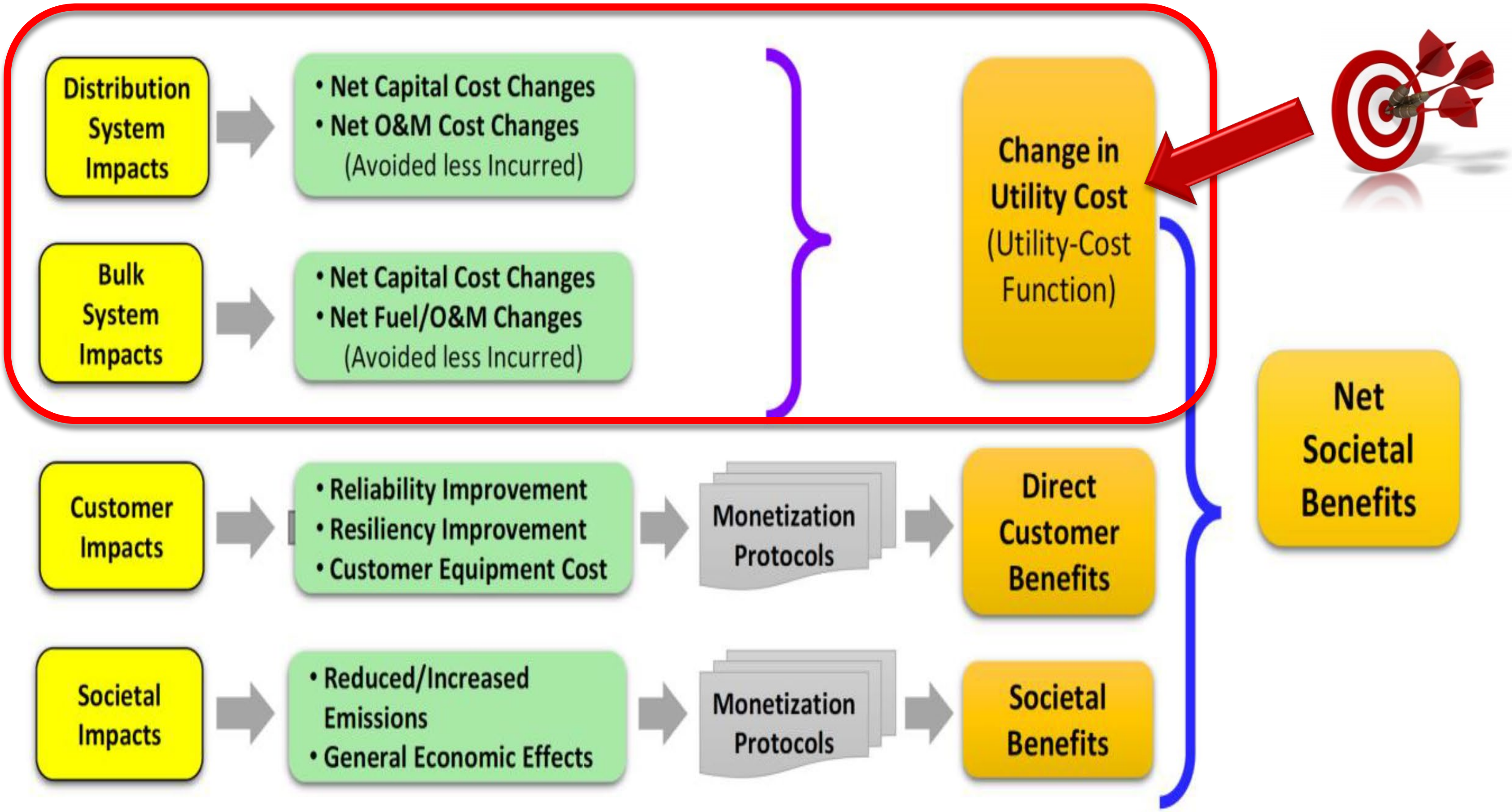
Source: Neukomm et al. 2019

Left: *Energy efficiency alone pushes down the load curve.*
Middle: *Energy efficiency plus distributed generation (in this case, solar PV) reduce overall energy use, but the building's peak load coincides with utility peaks.*
Right: *Adding load shedding and shifting flattens the building load profile, providing the greatest support to the grid.*

Forthcoming Report on Demand Flexibility Valuation

- Focuses on methods and practices for determining the *economic value* of demand flexibility to *electric utility systems*
  - This value provides the basic information needed to design programs, market rules, and rates that align the economic interest of utility customers with building owners and occupants.
  - Jurisdictions can use utility system benefits and costs as the *foundation* of their economic analysis, but align their primary cost-effectiveness metric with *all applicable policy objectives*, which may include *non-utility system* impacts.
- Provides guidance to state and local policy makers, public utility commissions, state energy offices, utilities, state utility consumer representatives, and other stakeholders on how to improve consistency and robustness of economic valuation of demand flexibility to electric utility systems

Scope of Valuation = Electric Utility System



Grid-interactive efficient buildings with demand flexibility can provide grid services that:

- *reduce generation costs*, and/or
- *reduce delivery (transmission and distribution) costs*

Graphic: EPRI. 2015. *The Integrated Grid: A Benefit-Cost Framework*

Demand Flexibility's Value to Grid Depends on Controls

- Mr. McGuire: I want to say one word to you. Just one word.
- Benjamin: Yes, sir.
- Mr. McGuire: Are you listening?
- Benjamin: Yes, I am.
- Mr. McGuire: ~~***Plastics***~~.

Controls

The list of DERs for which economic values need to be established is limited to those that rely on ***<u>controls</u>***.

Planning Challenges (1)

Limited analytical capacity

- Declining costs and increasing levels of storage and other DERs provide opportunities for utilities to incorporate demand flexibility into grid planning, operations, and investment decisions alongside other options for meeting electricity system needs.
- To do so, utilities need to be able to evaluate multiple resource portfolio options in an organized, holistic, and technology-neutral manner and normalize solution evaluation across generation, distribution, and transmission systems.

Planning Challenges (2)

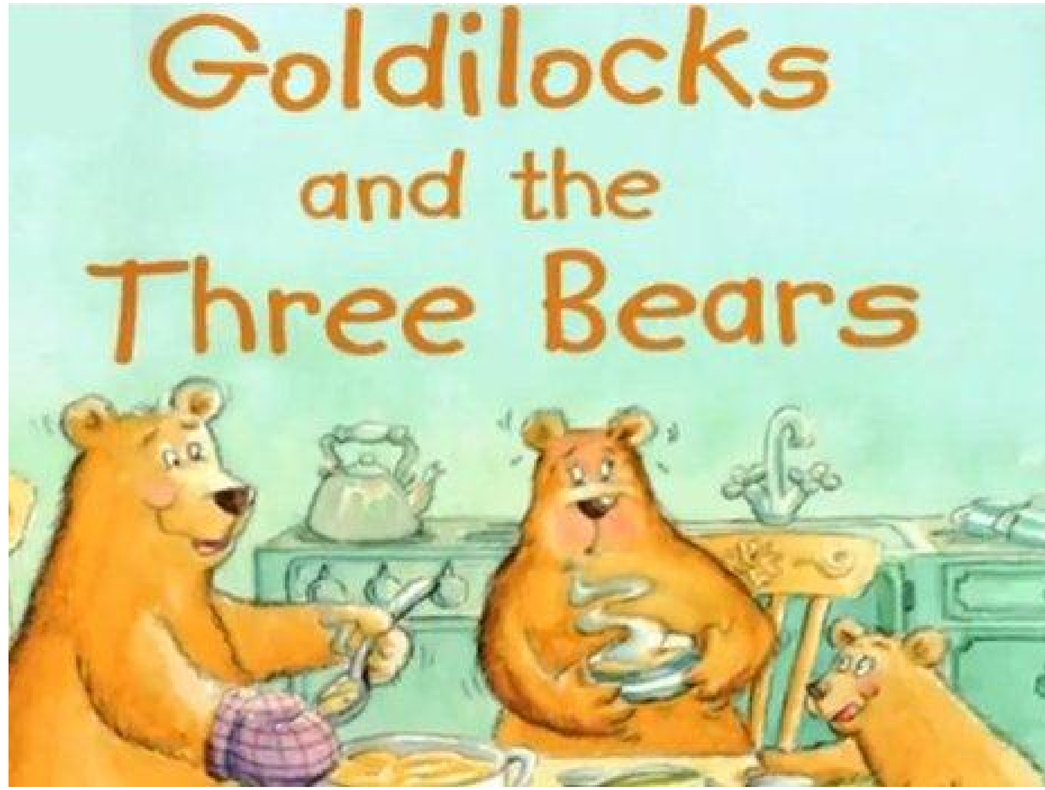
Lack of parity in cost-effectiveness analysis in planning

- For most utilities, economic valuation of DERs as utility system resources generally is not equivalent to such valuation for utility-scale generation resources and traditional transmission and distribution system solutions.
- This lack of parity in cost-effectiveness analysis limits the selection of demand flexibility for achieving state energy goals including reliability, resilience, security, and affordability.

Current Methods and Gaps for Resource Options Analysis and Valuation

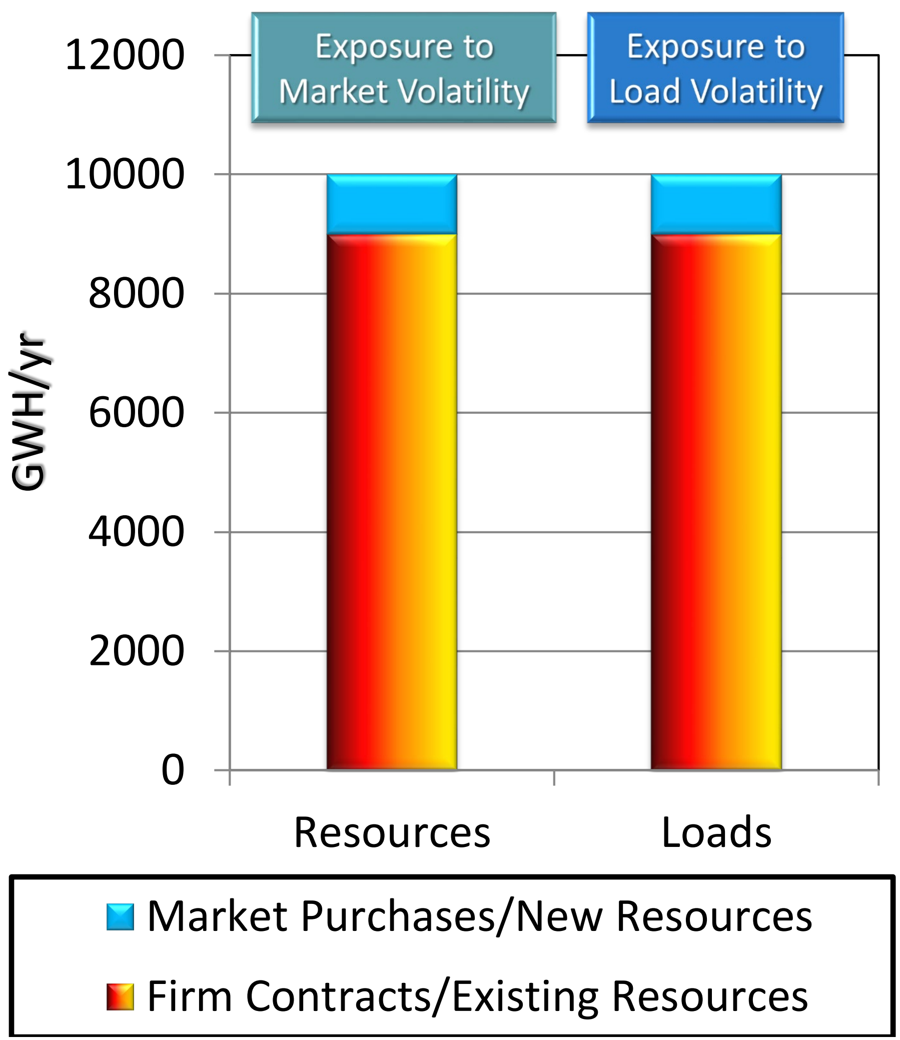
The Resource Options Analysis Problem

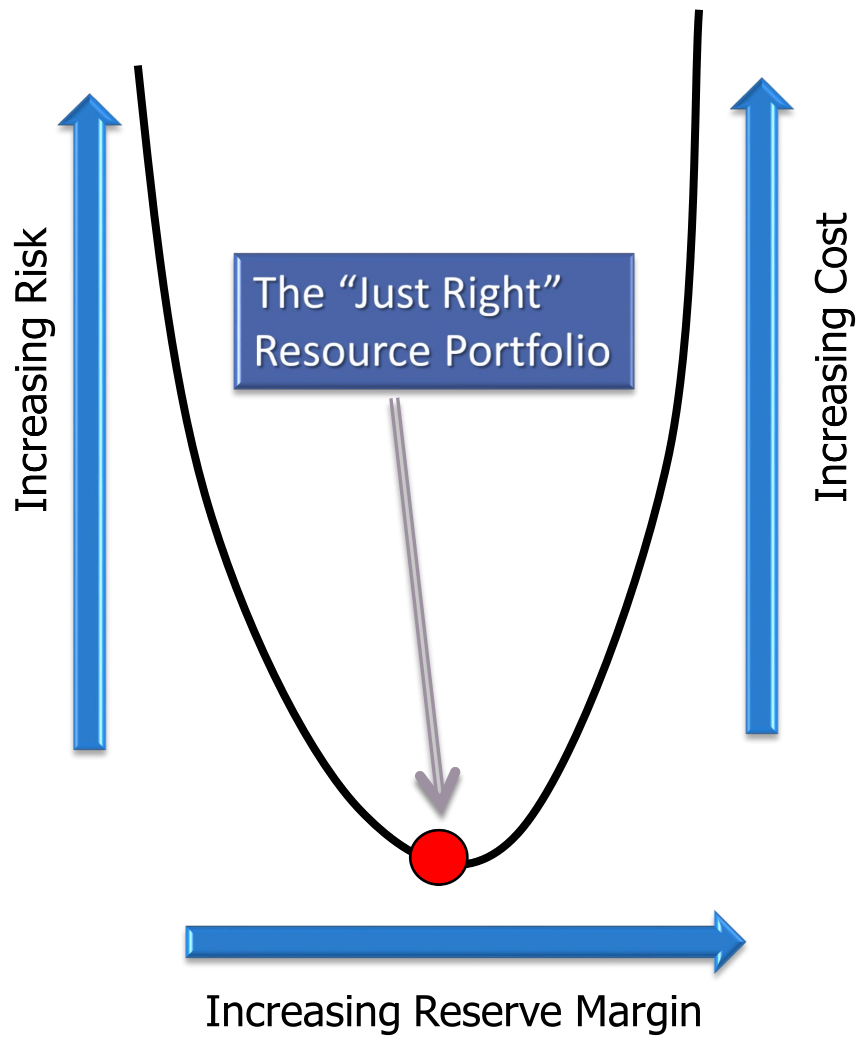
- Don’t have too many resources
- Don’t have too few resources
- Have “just the right amount” of resources*



**The “right amount” means not only the quantity developed, but the timing of their development and the mix (type) of resources required to provide energy, capacity, flexibility, and other ancillary services for system reliability, including risk management and resilience.*

Solving the "Goldilocks' Problem" Requires Analysis Comparing Cost and Risk of Alternative Resource Options





Primary Methods of Resource Options Analysis for DERs

- **System capacity expansion and market models***
  - *Most prevalent practice* – Reducing the growth rate of energy and/or peak demand in load forecasts input into the model, then let it optimize the type, amount, and schedule of new conventional resources (generation, transmission or distribution)
  - *Less prevalent practice* - Directly competing DERs with conventional resources in the model to determine DERs' impact on existing system loads, load growth, and load shape—and thus dispatch of existing resources—and the type, amount, and timing of conventional resource development
- **Competitive bidding processes/auctions:*** Use "market mechanisms" to select new DERs, currently limited to energy efficiency (EE) and demand response (DR)
- **Proxy resources:** Use the cost of a resource that provides grid services (e.g., a new natural gas-fired simple-cycle combustion turbine to provide peaking capacity) to establish the cost-effectiveness of DERs (i.e., determine the amount to develop) that provide these same grid services
- **Administrative/public policy determinations**: Use legislative or regulatory processes to establish development goals (e.g., Renewable Portfolio Standards and Energy Efficiency Resource Standards)

**Also used for utility scale resource options analysis*

Gaps and Limitations of Current Methods: Restructured Markets

- Not all DERs are eligible to participate in markets.
- Not all utility system DER benefits are reflected in the bulk power system. Not captured:
  - Locational value of avoided/deferred T&D capacity
  - Value of distribution system losses
  - Value of resilience
- "Long-term" resource value is not recognized in some markets.
  - For example, PJM limits compensation for EE and DR to four years, regardless of measure life, assuming that the impact of these resources will be embedded in its econometric forecast after that period.

Gaps and Limitations of Current Methods: Utilities in Vertically Integrated States

- Not all utilities (or state requirements) include all system benefits of DERs.
  - e.g., some include time-varying, locational, risk mitigation, and resilience value, while others do not
- Not all utilities (or state requirements) consistently quantify system benefits of DERs.
  - e.g., some use marginal distribution system losses to "gross up" impacts to generation and transmission system, while others use average system losses, and the accuracy of load shape data (if used) varies widely
- Resource options analysis often fails to account for the potential interaction *between* DERs (e.g., impact of EE on DR potential, impact of storage on distributed generation).
- Typical resource optimization modeling embeds DER impacts in the load forecast, so it fails to capture potential DER interactions with existing and future resources.
- Commercially available capacity expansion models have limited capability to model DERs as resource options (except perhaps DR and battery storage).

Example Gaps and Limitations

- Not accounting for *all substantial utility system impacts*
- Not using *accurate load shapes* to determine time-varying value
- Not accounting for *distribution and transmission system capacity impacts*
- Not accounting for variations in *interactions between DERs*
- Not accounting for variations in *interactions between DERs and existing and future utility system resources*
- Failing to *quantify risk mitigation and resilience* value of DERs

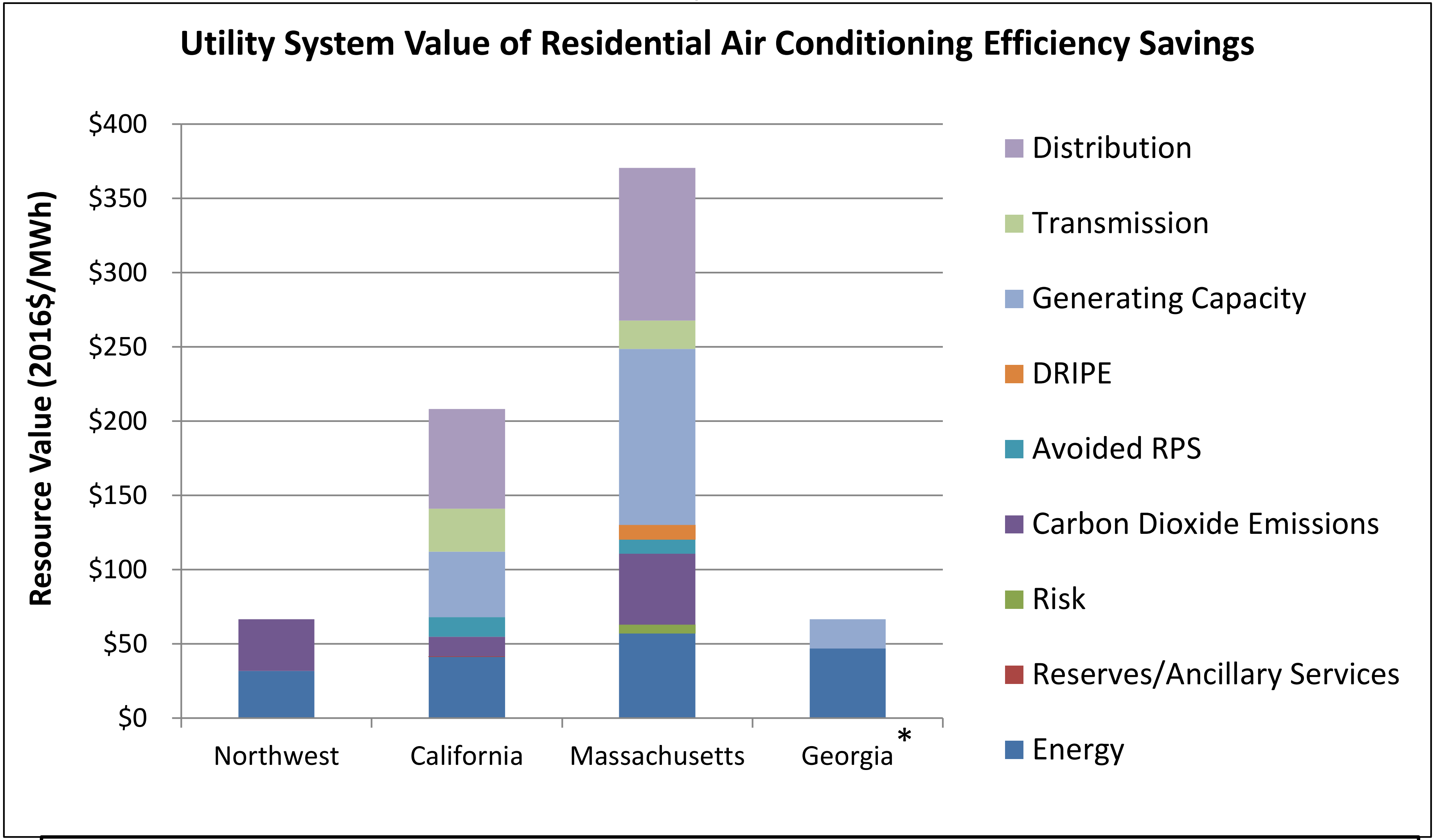
Not all states require utilities to account for all electricity system benefits of DERs.

Value Category	Value Stream	State																					
		AZ	AK	CA	CO	HI	ME	MD	MA	MI	MN	MS	MT	NC	NJ	NY	NV	PA	SC	TN	TX	UT	VT
Generation	Avoided Energy																						
	Avoided Fuel Hedge																						
	Avoided Capacity & Reserves																						
	Avoided Ancillary Services																						
	Avoided Renewable Procurement																						
	Market Price Reduction																						
Transmission	Avoided or Deferred Transmission Investment																						
	Avoided Transmission Losses																						
	Avoided Transmission O&M																						
Distribution	Avoided or Deferred Distribution Investment																						
	Avoided Distribution Losses																						
	Avoided Distribution O&M																						
	Avoided or Net Avoided Reliability Costs																						
	Avioded or Net Avoided Resiliency Costs																						
Environmental/Society	Monetized Environmental/Health																						
	Social Environmental																						
	Security Enhancement/Risk																						
	Societal (Economy/Jobs)																						

Locational value of DER studies from states, utilities, consultancies, and stakeholders

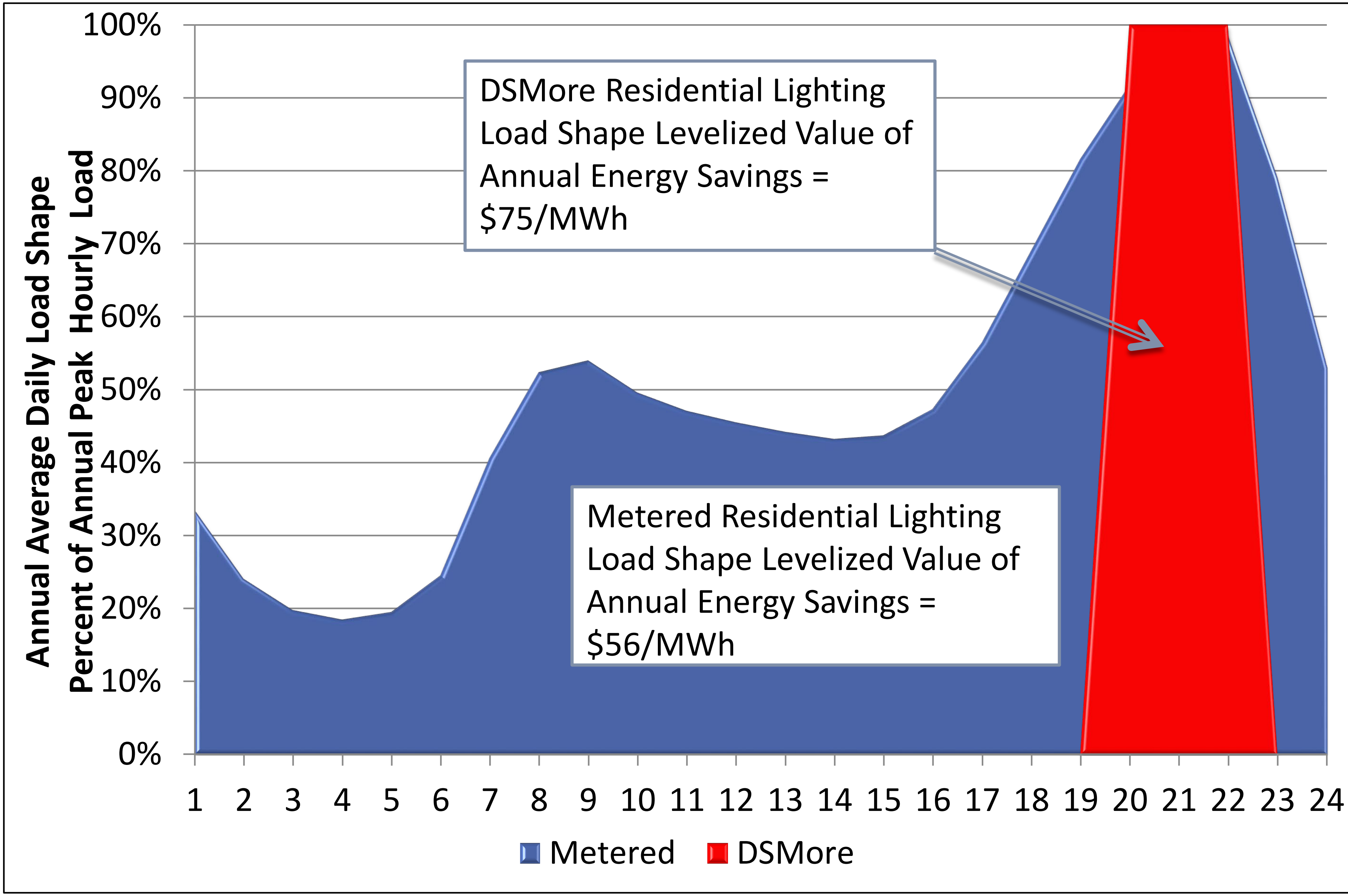
Source: Adapted by Natalie Mims Frick from Shenot et al. 2019 and DOE 2018.

Not accounting for all substantial utility system impacts undervalues demand flexibility.

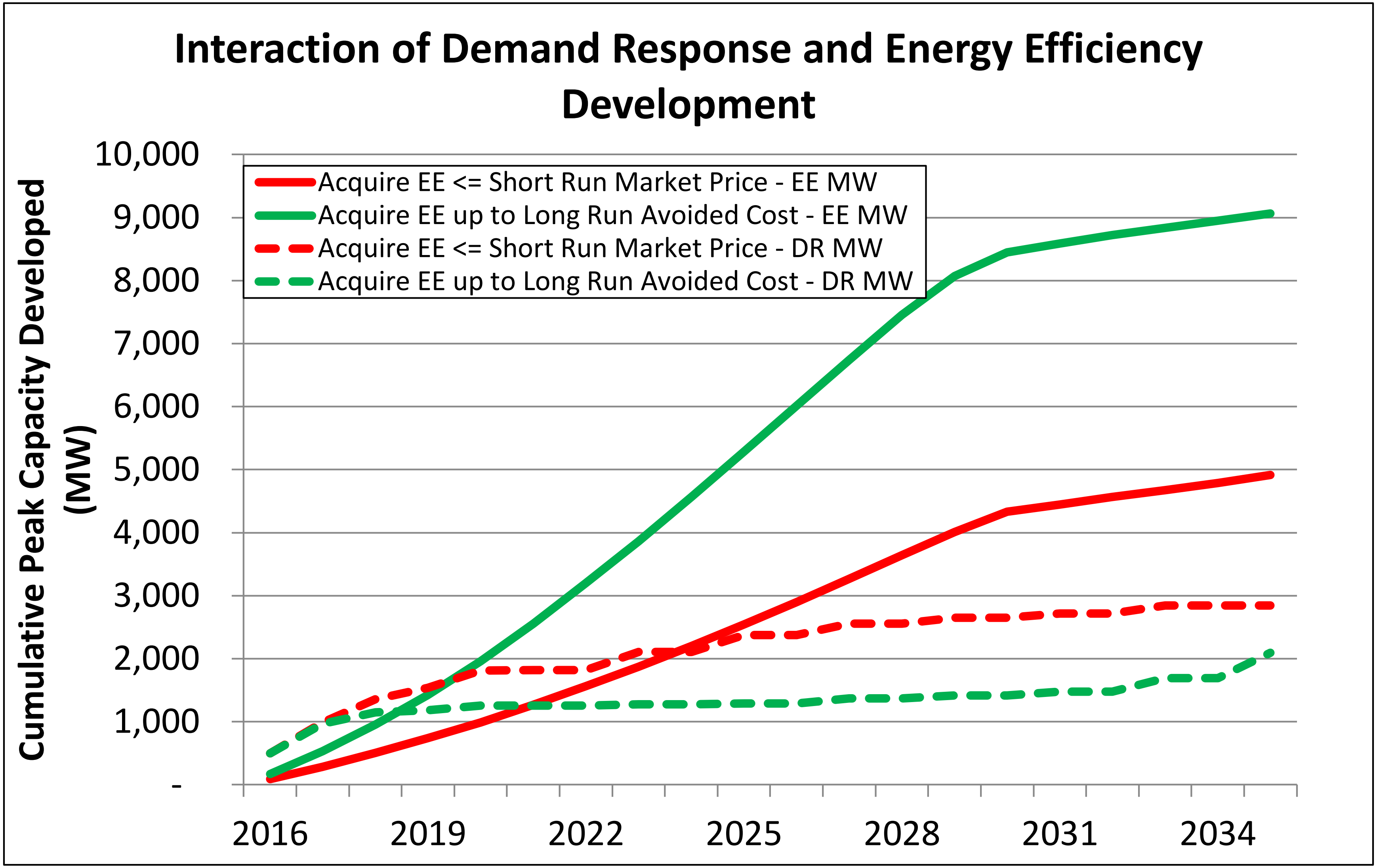


* In Georgia, where publicly available data did not include avoided transmission and distribution system values, the time-varying value of efficiency appears much lower for all measures evaluated. Avoided transmission and distribution costs are included in Georgia Power's energy efficiency evaluations, but are not a part of the publicly available PURPA avoided cost filing.

Using inaccurate load shapes impacts evaluation of DERs as resource options — both energy and peak impacts.

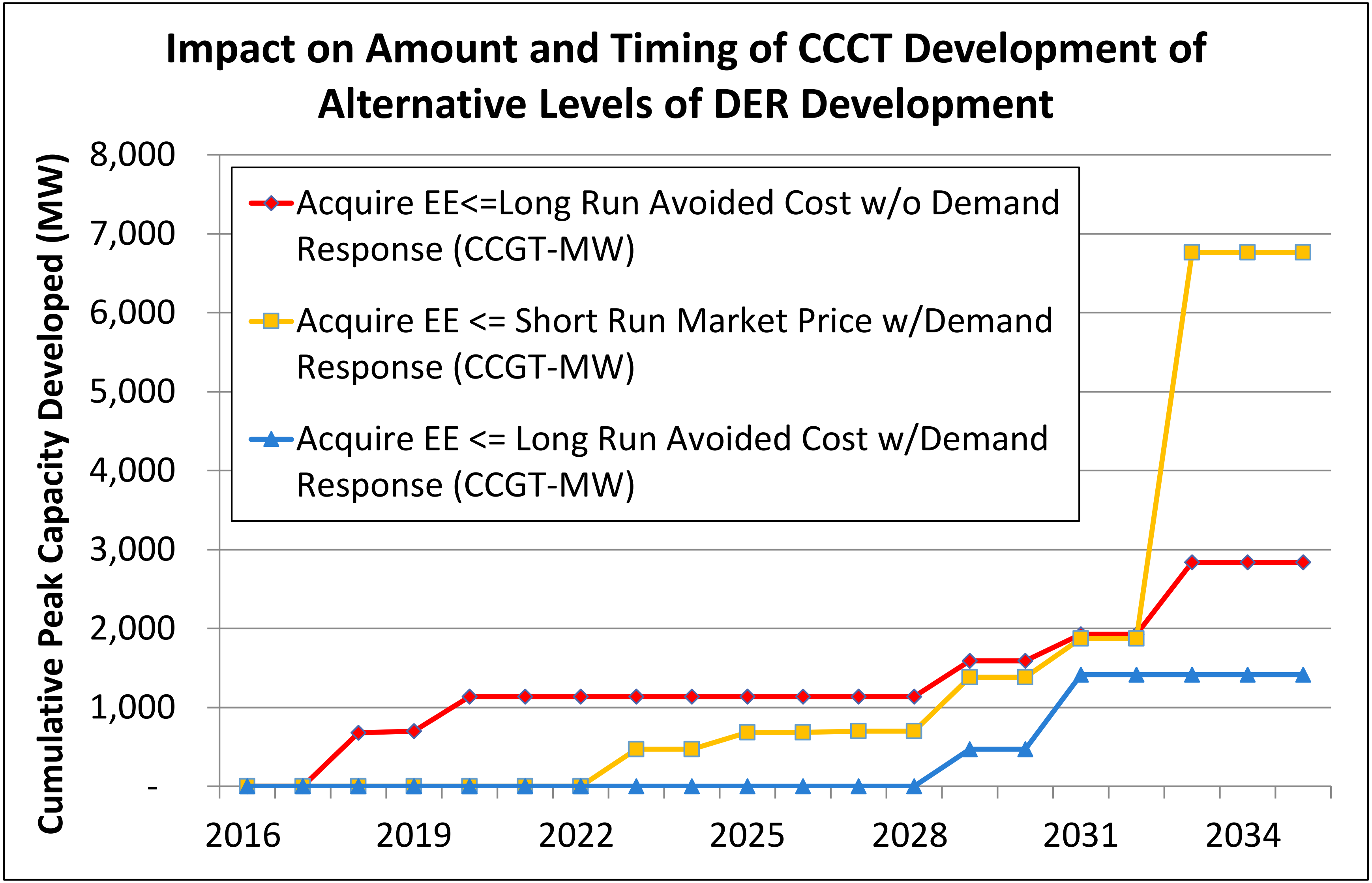


Failing to analyze the potential interactions *between* DERs may result in selection of higher cost resource strategies.



Source: Northwest Power and Conservation Council, 7th Power Plan

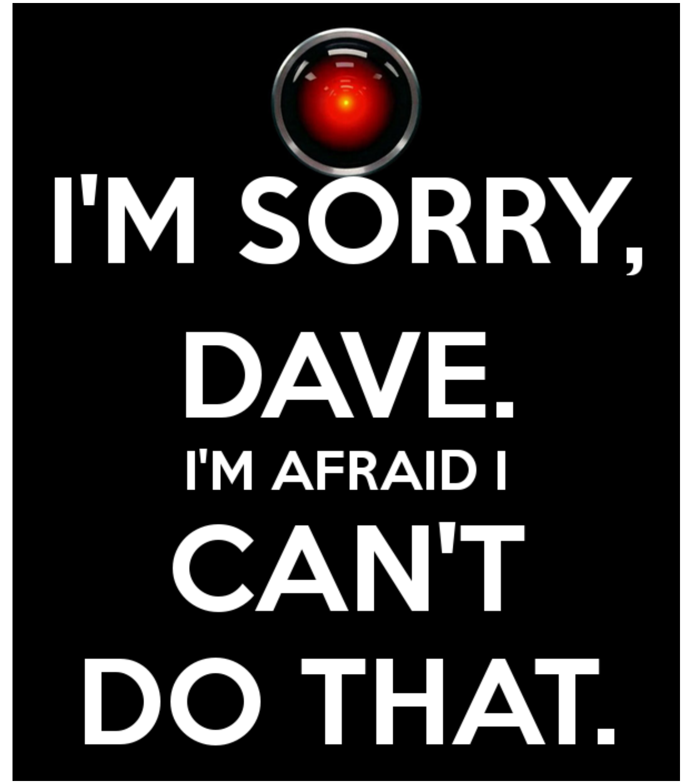
Failing to analyze the potential interaction between DERs and the existing and future utility system may result in less than optimal resource strategies.



Source: Northwest Power and Conservation Council, 7th Power Plan

Most capacity expansion models are not designed to conduct risk analysis.

- Market equilibrium models generally optimize capacity expansion for a single future.
  - They assume control of not only all "known knowns," but also the "known unknowns" and the "unknown unknowns."
- Sensitivity studies are often used to inform risk analysis, but only compare optimizations created for *single* futures.



These models systematically understate risk, and therefore the value of risk mitigation and resilience.

Treating DERs as Resource Options in Capacity Expansion Modeling

It can be done, but it is non-trivial.

- Most commercially available capacity expansion models can model DERs as resource options.
- These models require users to define the specific resource characteristics such as cost, quantity, lead times, and load shapes.
- Modeling of DERs as resource options requires many user-defined inputs, an experienced modeler, potentially multiple model runs, and post-processing of model output.

Ways to Improve Valuation of Demand Flexibility That Enhance Its Consideration in Resource Options Analysis and Decision-making

Primary Factors Impacting Value of Demand Flexibility

- There is no single economic value of demand flexibility for utility systems.
- The value of a single “unit” (e.g., kW, kWh) of grid service provided by demand flexibility is a function of:
  - the *timing* of the impact (temporal load profile),
  - the *location* in the interconnected grid,
  - the *grid services* provided,
  - the *expected service life* (persistence) of the impact, and
  - the *avoided cost of the least-expensive resource alternative* providing comparable grid service.
- Demand flexibility valuation methods and practices should account for these variations.

Value = Avoided Cost

- Traditionally, the economic value of energy efficiency, demand response, and other DERs has been determined using the "avoided cost" of conventional resources that provide the identical utility system service.

- The underlying economic principle of this approach is that the *value* of a resource can be estimated using the *cost of acquiring the next least expensive alternative resource* that provides comparable services (i.e., the *avoided cost* of that resource).

Primary Valuation Task

- The primary task required to determine the value of demand flexibility based on avoided cost is to *identify the alternative (i.e., "avoided") resource* and *establish its cost*.

- Methods used to establish avoided cost vary widely across the United States due to differences in:*
  - electricity market structure
  - available resource options and their costs
  - state energy policies and regulatory context

*See "Market Structure Influences Value of Demand Flexibility," "Resource Availability and Cost Vary Across U.S.," and "State Energy Policies and Regulatory Context" in Extra Slides.

Enhanced Valuation Methods - Seven Considerations*

1. Account for *all electric utility system economic impacts* resulting from demand flexibility
2. Account for variations in value based on *when* demand flexibility occurs
3. Account for the *impact of distribution system* savings on transmission and generation system value
4. Account for variations in value specific *locations* on the grid
5. Account for variations in value due to *interactions between DERs* providing demand flexibility
6. Account for benefits across the *full expected useful lives* (EULs) of the resources
7. Account for variations in value due to *interactions between DERs and other system resources*

*See summary implementation guidance and resources in Extra Slides.

Account for all electric utility system economic impacts resulting from demand flexibility

- The goal is to treat demand flexibility on a par with supply-side options so that *all grid impacts*, *costs, and benefits* to the utility system can be quantified and monetized.

- The objective of this enhancement is to include *all substantive and reasonably quantifiable generation and T&D system impacts.*

Not all utility system benefits provided by demand flexibility are of equal value

T&D Capacity
Resilience
Reserves
Ancillary Services
Losses
Generating Capacity
Energy
Risk
DRIPE
RPS Compliance
Credit Collection
Reliability
Environmental Compliance

So, start with the “Big Ones”

Account for variations in value based on when demand flexibility occurs

- The value of DERs that can adjust load is fundamentally dependent on the timing of their impacts.

- The impact of demand flexibility must be addressed on a more *granular time scale*.
  - The economic value of grid services that demand flexibility provides varies from sub-hourly to daily, monthly, and seasonally as well as across future years and across utility systems.

See "Example: Time-Sensitive Value of Energy Efficiency Measures" in Extra Slides.

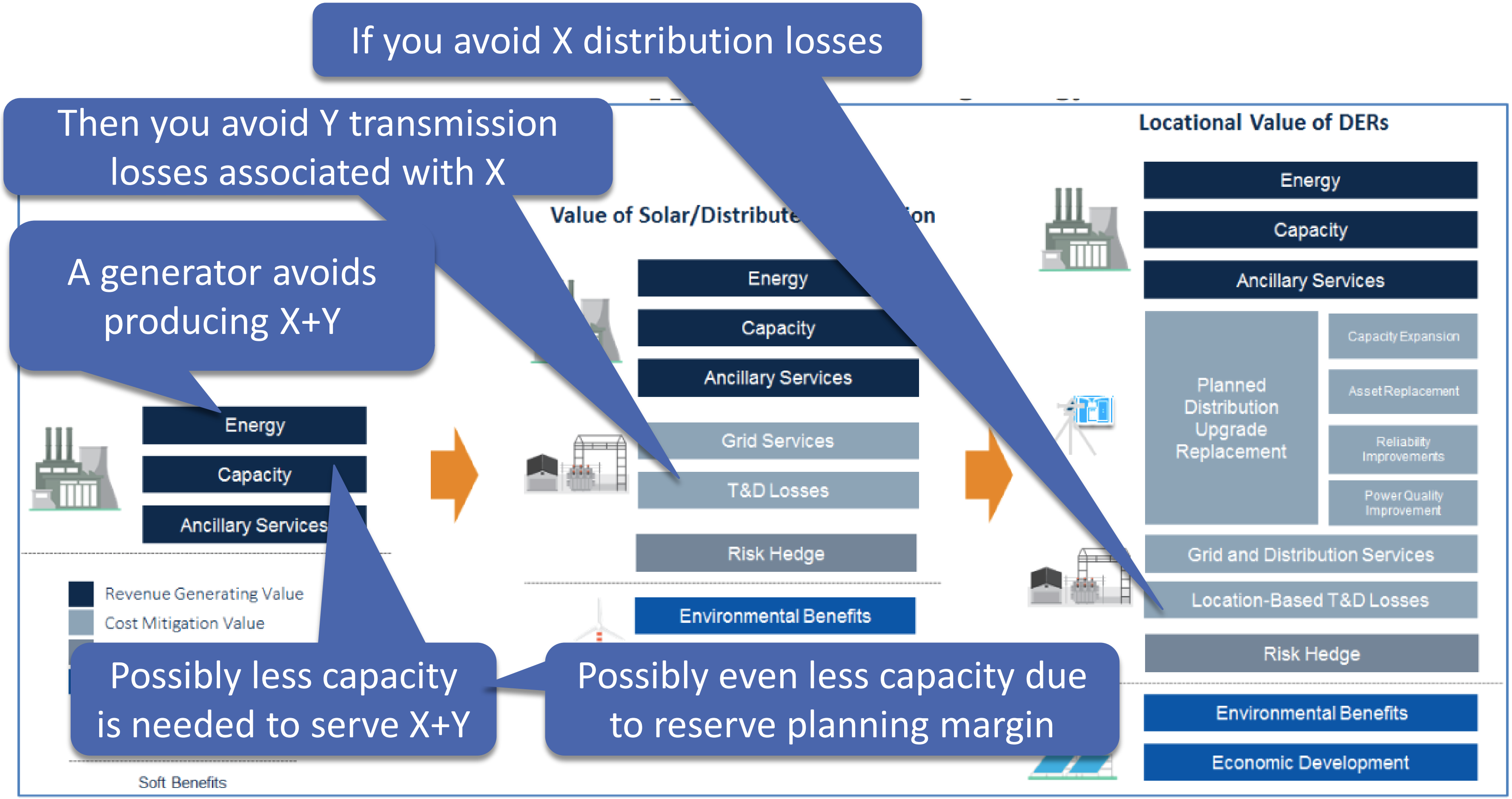
Account for the impact of distribution system savings on transmission and generation system value

- Demand flexibility can be used to avoid *distribution system losses* when they are highest, resulting in reduced transmission system losses and avoided generator capacity needs (including the planning reserve margin).

- *Locational impacts* on the distribution system and their associated economic value should be modeled and *calculated first.* Results can be used to adjust inputs to the analysis of transmission and generation system values.

Ohm's Law:
Volts = I (Amps) x (R)esistance (Ohms)
Power Law:
Watts = Volts x Amps
Therefore:
Watts = Amps x Ohms x Ohms or (I^2R)

Value Streams Have Ripple Effects



Ben Kellison, "Unlocking the Locational Value of DER 2016: Technology Strategies, Opportunities, and Markets," January 2016,

Calculate the localized impacts first

See "Three Enhancements to Distribution System Planning" in Extra Slides.

Account for variations in value at specific grid locations

- The locational value of demand flexibility is highly dependent on where grid services resulting from demand flexibility occur on the interconnected grid (i.e., T&D systems).
- Particular attention must be given to this issue in regions with centrally-organized organized wholesale markets, where prices for capacity do not reflect distribution system locational benefits.
  - *Using only wholesale energy or capacity market prices to represent the value of demand flexibility undervalues it. These methods do not account for other utility system benefits, particularly those that rely on locational value.*

See "Locational value of demand flexibility may account for significant economic value" and "Account for variations in value due to interactions between DERs providing demand flexibility" in Extra Slides.

Account for variations in value due to interactions between DERs providing demand flexibility

- Analysis should first capture major interactions between pairs of DERs
  - Interactions can be estimated assuming that deployment of DERs does not impact the existing or future electric grid sufficiently to alter avoided cost.
- Higher levels of DERs increases the need to address *interactions of DERs* with one another and with the electric grid. It is unlikely that their collective and cumulative impacts are simply additive, and they ***may*** alter avoided cost.
  - *Widespread deployment of demand flexibility for grid services will change grid operations and infrastructure development, altering avoided resource costs.*

Account for benefits across full expected useful resources lives

- Expected useful lives (EULs), determined independently of policy or program decisions regarding the length of time compensation is offered for the grid services they provide, should be used in calculating the economic value of DERs providing demand flexibility.
- Demand flexibility that defers or avoids capital expenditures, ongoing fuel costs, or O&M costs throughout their EULs need to be valued (and perhaps compensated) differently than resources that only reduce near-term fuel costs or O&M costs, as well as demand flexibility that is forecast to have variable and uncertain impacts through time.

Program Implications

- Some DERs with demand flexibility *will likely exhibit variation in measure/resource grid impacts* over their lifetimes because:
  - their "dispatch," while controlled by a grid operator, also will be dictated by the response of building owners and occupants, or
  - by design, the technology they employ is intended to adjust impacts through time (e.g., learning thermostats and similar Artificial Intelligence learning controls)
- Uncertainty regarding EULs for demand flexibility may be best addressed through program designs that rely more on "pay for performance" mechanisms rather than one-time, upfront payments.

Account for variations in value due to interactions between DERs and other system resources

- System expansion models used to estimate avoided costs should include all resources so the model can select them for development when determining impact of widespread deployment of demand flexibility.
- Significant scale is typically necessary to alter the dispatch of existing resources and/or the type, timing, and amount of conventional generating resources sufficiently to materially affect avoided costs.

Applicability of Enhanced Valuation Methods to Distribution, Generation, and Transmission Planning Analyses

Enhanced valuation methods to account for:	Distribution System Planning			Generation Planning		Transmission Planning	
	Hosting Capacity (for distributed generation capacity)	Energy Analysis (loss estimation)	Thermal Capacity (peak capacity)	Capacity Expansion Modeling	Market-Based Mechanisms	Capacity Expansion Modeling	Congestion Pricing Analysis
1. All electric utility system economic impacts resulting from demand flexibility	●	●	●	●	●	●	●
2. Variations in value based on when demand flexibility occurs	●	●	●	●	●	●	●
3. Impact of distribution system savings on transmission and generation system value	◔	●	◑	◑	◑	◑	◑
4. Variations in value at specific locations on the grid	●	●	◔	◔	◔	●	●
5. Variations in value due to interactions between DERs providing demand flexibility	●	◕	●	◕	◕	◕	◕
6. Benefits across the full expected useful lives of the resources	◑	◑	●	◑	◑	●	●
7. Variations in value due to interactions between DERs and other system resources	◕	◑	●	●	●	●	●

● most applicable, ◔ least applicable

Technical Assistance Opportunity

- With support from DOE's Office of Electricity, and in collaboration with DOE's Buildings Technologies Office, SEE Action, NARUC and NASEO, LBNL is offering technical assistance to states to apply enhanced valuation methods in their jurisdictions

- A call or webinar will be announced in the coming weeks to learn more about the opportunity and share your needs to help shape it

- In the meantime, as you reflect on today's presentation and have thoughts on how technical assistance in this area could help you, please contact Lisa Schwartz

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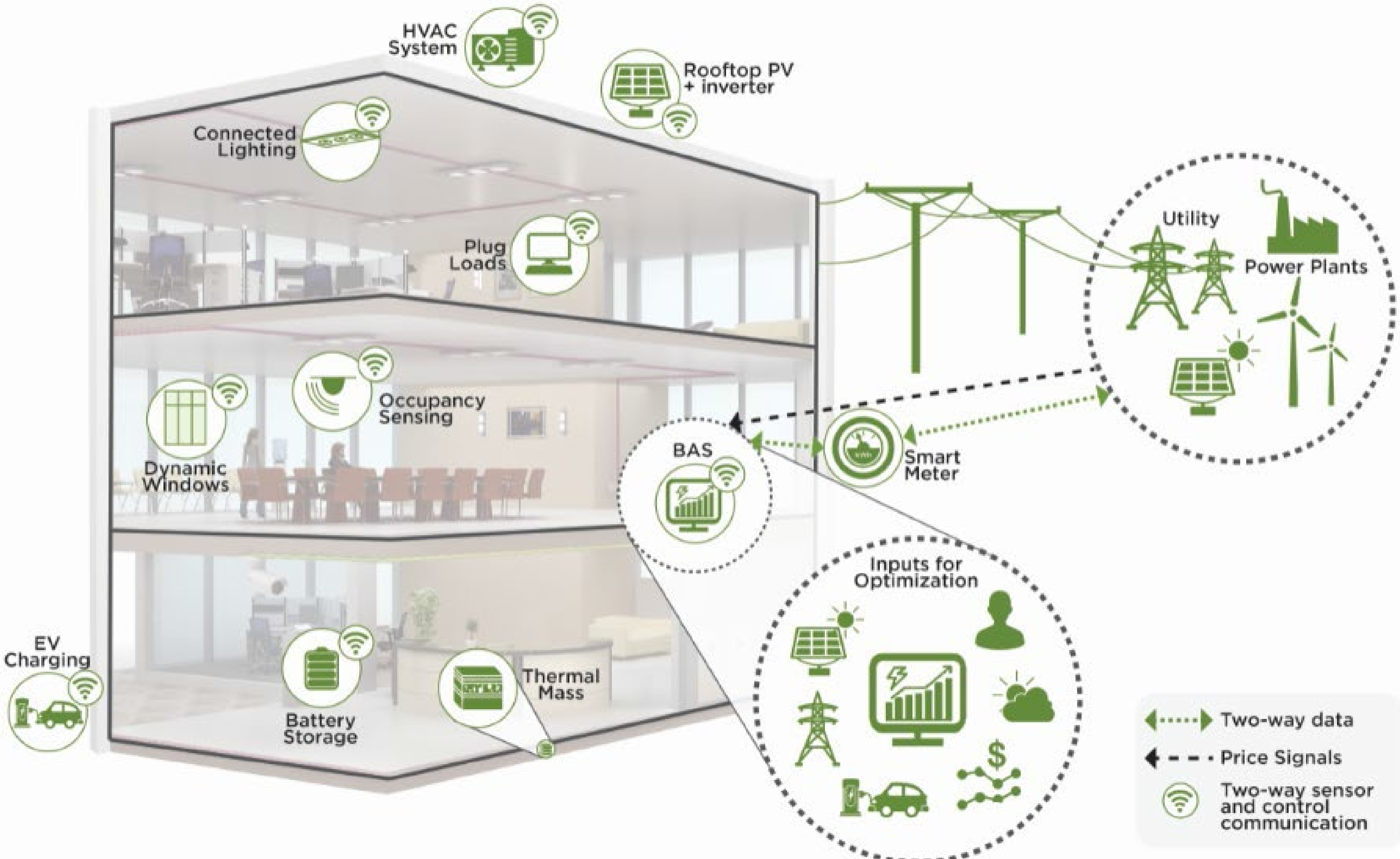
EXTRA SLIDES

Example Grid-interactive Efficient Commercial Building



Source: Neukomm et al. 2019

Summary of Valuation Enhancements and Implementation Guidance (1)

Valuation Enhancement	Guidance
1. Account for all electric utility system economic impacts resulting from demand flexibility	Prioritize enhancements for analyses used to derive the value of primary utility system benefits.
2. Account for variations in value based on when demand flexibility occurs	Develop and use hourly forecasts of avoided energy and capacity costs in combination with publicly available load shape data for DERs to value demand flexibility.
3. Account for the impact of distribution system savings on transmission and generation system value	Model and calculate distribution system-level impacts (i.e., locational impacts and associated economic value) first so that results can be used to adjust inputs to analysis of bulk transmission and generation system values.

Summary of Valuation Enhancements and Implementation Guidance (2)

Valuation Enhancement	Guidance
4. Account for variations in value at specific locations on the grid	Initiate a distribution system planning process that includes: (1) hosting capacity analysis to estimate generating DER capacity limits and identifies demand flexibility that can mitigate limits, (2) thermal limit analysis to estimate locational value of non-wires solutions, (3) energy analysis to quantify marginal distribution system losses, and (4) systemwide analysis of the avoided cost of deferred distribution capacity expansion.
5. Account for variations in value due to interactions between DERs providing demand flexibility	Start accounting for interactions between DERs. Basic analysis can assume that deployment of multiple types of DERs does not impact the existing or future electric grid in a way that alters avoided costs. Such basic analysis does not require the use of system capacity expansion models.

Summary of Valuation Enhancements and Implementation Guidance (3)

Valuation Enhancement	Guidance
6. Account for benefits across the full expected lives of the resources	As a first step, use the EUL of DERs providing demand flexibility to calculate their economic value. However, because demand flexibility is largely based on controls, the dispatch of which is determined by the combined impact of grid operators and owner/occupant responses, EULs may be more a function of rate and program design, compared to EULs for traditional energy efficiency measures. Uncertainty regarding EULs for demand flexibility may be best addressed through program design.
7. Account for variations in value due to interactions between DERs and other system resources	Use distribution, transmission and generation capacity expansion modeling, supplemented as necessary with other methods described in section 4 of this report, to determine the impact of widespread deployment of demand flexibility for grid services. Implementing this enhancement will require customization of commercially available capacity expansion models.

Implementation Resources (1)

Valuation Enhancement`	Implementation Resources
1. Account for all electric utility system economic impacts resulting from demand flexibility	• National Efficiency Screening Project, *National Standard Practice Manual* • EPRI, *The Integrated Grid - A Benefit-Cost Framework* • EPA, *Assessing the Multiple Benefits of Clean Energy – Resources for States* (particularly Section 3.2.4)
2. Account for the time-sensitive economic value of demand flexibility	• Berkeley Lab reports discuss data and methods required to capture temporal value of energy efficiency including *Time-Varying Value of Electric Energy Efficiency* and *Time-Varying Value of Energy Efficiency in Michigan*. More resources at https://emp.lbl.gov/projects/time-value-efficiency. • Smart Electric Power Alliance, *Beyond the Meter: Addressing the Locational Valuation Challenge for Distributed Energy Resources*
3**. Account for the impact of distribution system-level savings on transmission and generation system value**	• PNNL, *Electric Distribution System Planning with DERs – Tools and Methods (forthcoming)* • Smart Electric Power Alliance, *Beyond the Meter: Addressing the Locational Valuation Challenge for Distributed Energy Resources*

Implementation Resources (2)

Valuation Enhancement	Implementation Resources
4. Account for the locational economic value of demand flexibility	• Smart Electric Power Alliance, *Beyond the Meter: Addressing the Locational Valuation Challenge for Distributed Energy Resources* • *Benefit-Cost Analysis Handbook* developed for New York's REV process • California's Locational Net Benefits Analysis Tool (and user's guide) • ConEd's *Benefit Cost Analysis Handbook* recognizes DER benefits for avoided distribution capacity infrastructure and provides methods to quantify location-specific marginal costs that the system defers or avoids by opting for non-wires solutions.
5. Account for interactions between DERs providing demand flexibility	• Frick et al., Berkeley Lab, *A Framework for Integrated Analysis of Distributed Energy Resources: Guide for States* EPRI, *The Integrated Grid - A Benefit-Cost Framework*
6. Account for potential variations in the timing and/or amount of the electric grid service provided by demand flexibility over the expected lives of the DERs	• EPRI, *The Integrated Grid - A Benefit-Cost Framework*
7. Account for interactions between DERs providing demand flexibility and existing and potential conventional grid resources supplying comparable services	• Berkeley Lab, *A Framework for Integrated Analysis of Distributed Energy Resources: Guide for States* • EPRI, *The Integrated Grid - A Benefit-Cost Framework*

Market Structure Influences Value of Demand Flexibility

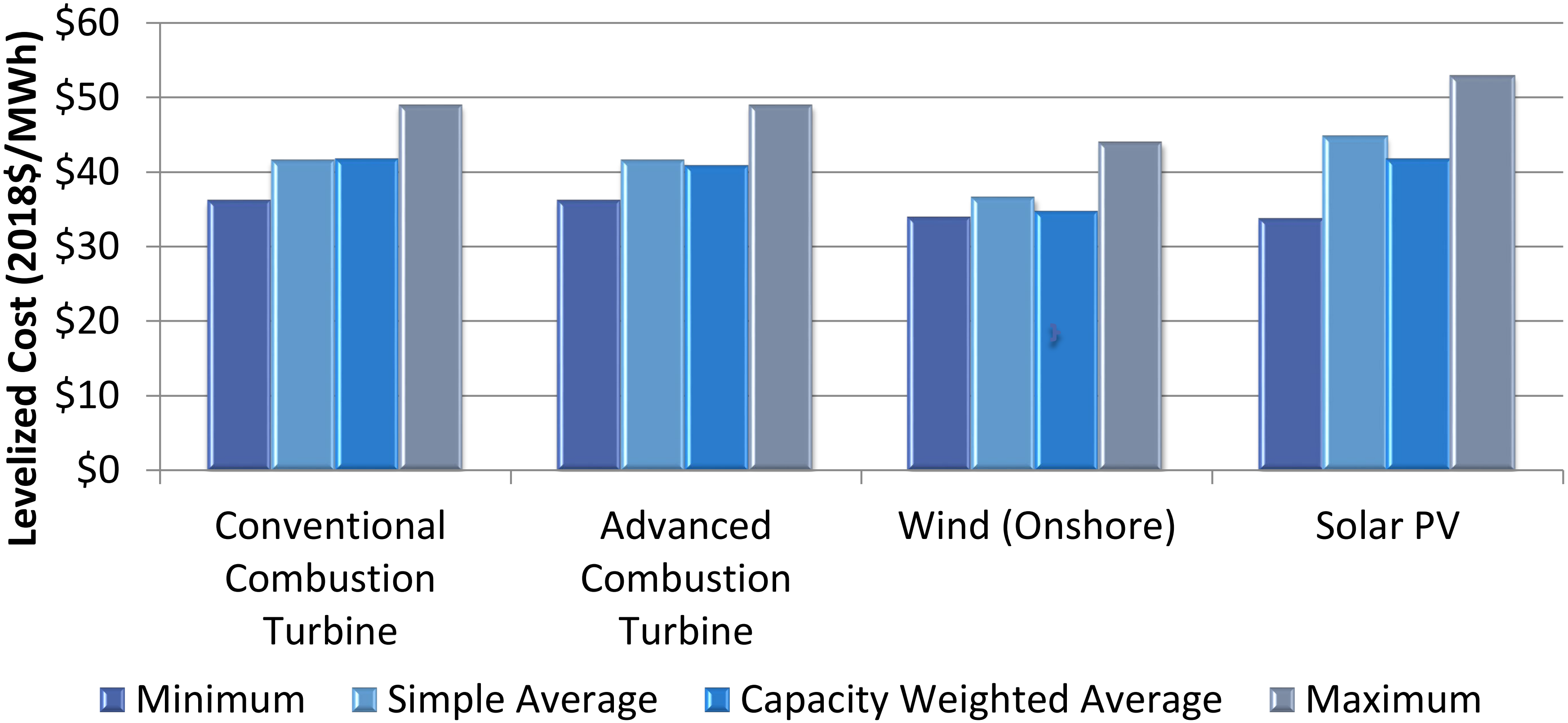
Organized Markets

- Value established by market
- Only values "products" traded in market:
  - Capacity
  - Energy
  - Reserves (spinning and balancing)
  - Volt/Var support
- Gaps/Challenges
  - Locational value of avoided/deferred T&D capacity not captured
  - Value of resilience
  - Value of increased hosting capacity
  - Recognition of "long-term" resource value in some markets

"Dis-organized" Markets

- Value established through regulatory/planning processes (e.g., PURPA filings, IRPs)
- Value depends on scope of state "cost-effectiveness" test
- Gaps/Challenges
  - Not all states include all utility system benefits of demand flexibility or quantify them in a consistent manner (e.g., not all states use time-dependent valuation).
  - Methods to quantify and monetize the locational value of demand flexibility are "under construction."
  - Integrated analysis of the impacts of demand flexibility is complex, and thus rarely done.

Resource Availability and Cost Vary Across U.S.



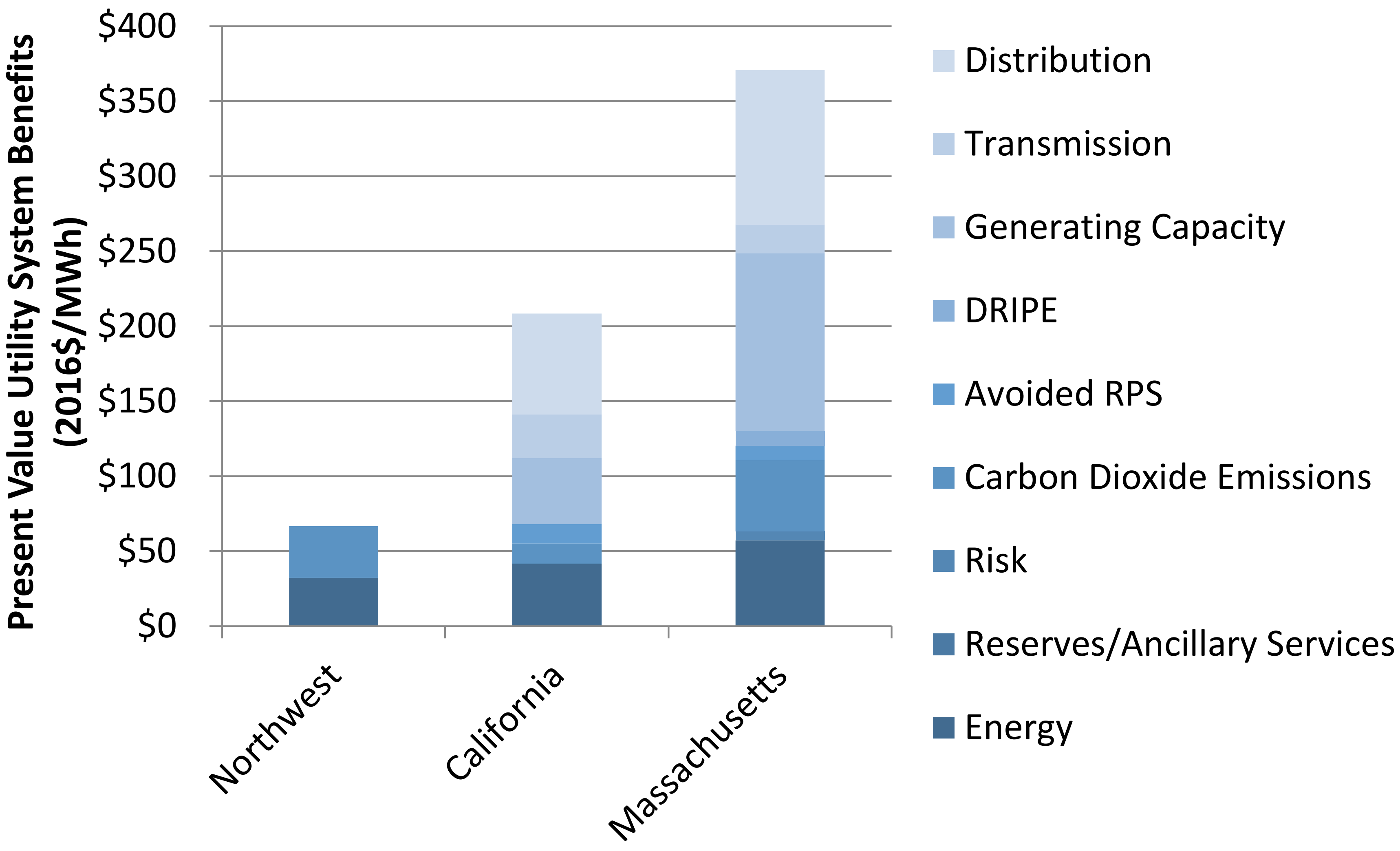
Regional variation in levelized avoided cost of electricity for new generation resources entering service in 2021.

Source: U.S. Energy Information Administration, Annual Energy Outlook 2019

State Energy Policies and Regulatory Context

- State policies directly or indirectly influence which of the utility system benefits of demand flexibility to include in determinations of its economic value by:
  - Establishing costs and benefits to be included in a utility's (or third-party program administrator's) cost-effectiveness tests
  - Prescribing a specific methodology for determining avoided cost
- State resource standards also directly impact avoided costs—for example:
  - Wind resource development to satisfy a state renewable energy standard might *lower the avoided cost of energy* (kWh), but have little impact on the avoided cost of new peaking capacity (KW).
  - Energy efficiency development to satisfy a state's energy efficiency resource standard might *lower the avoided cost of energy (kWh) as well as peaking capacity (kW)* by reducing the near-term need for new generation or transmission peaking capacity.

Example: Time-Sensitive Value of Energy Efficiency Measures for Residential Air-Conditioning by Region/State



Source: Mims et al. 2017. *Time-varying value of electric energy efficiency*

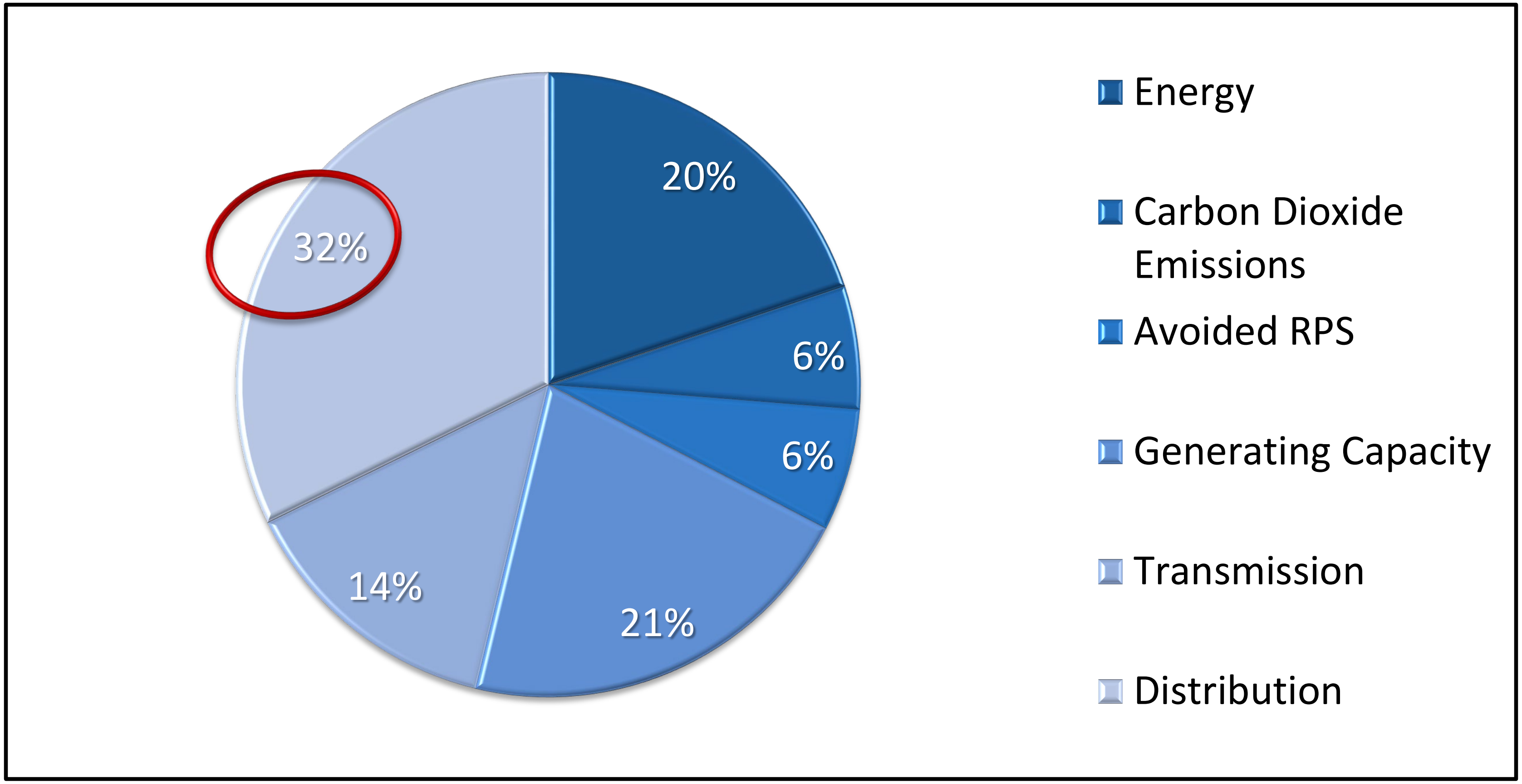
Three Enhancements to Distribution System Planning

- **Hosting capacity analysis** – Estimates maximum generating capacity of DERs that can be accommodated on individual feeders without adversely impacting power quality or reliability or requiring significant distribution system upgrades

- **Energy analysis** - Quantifies the magnitude of marginal distribution system losses (i.e., I^2R)

- **Thermal capacity (limit) analysis** - Identifies potential locational value from deferral of distribution asset investments from demand flexibility deployment

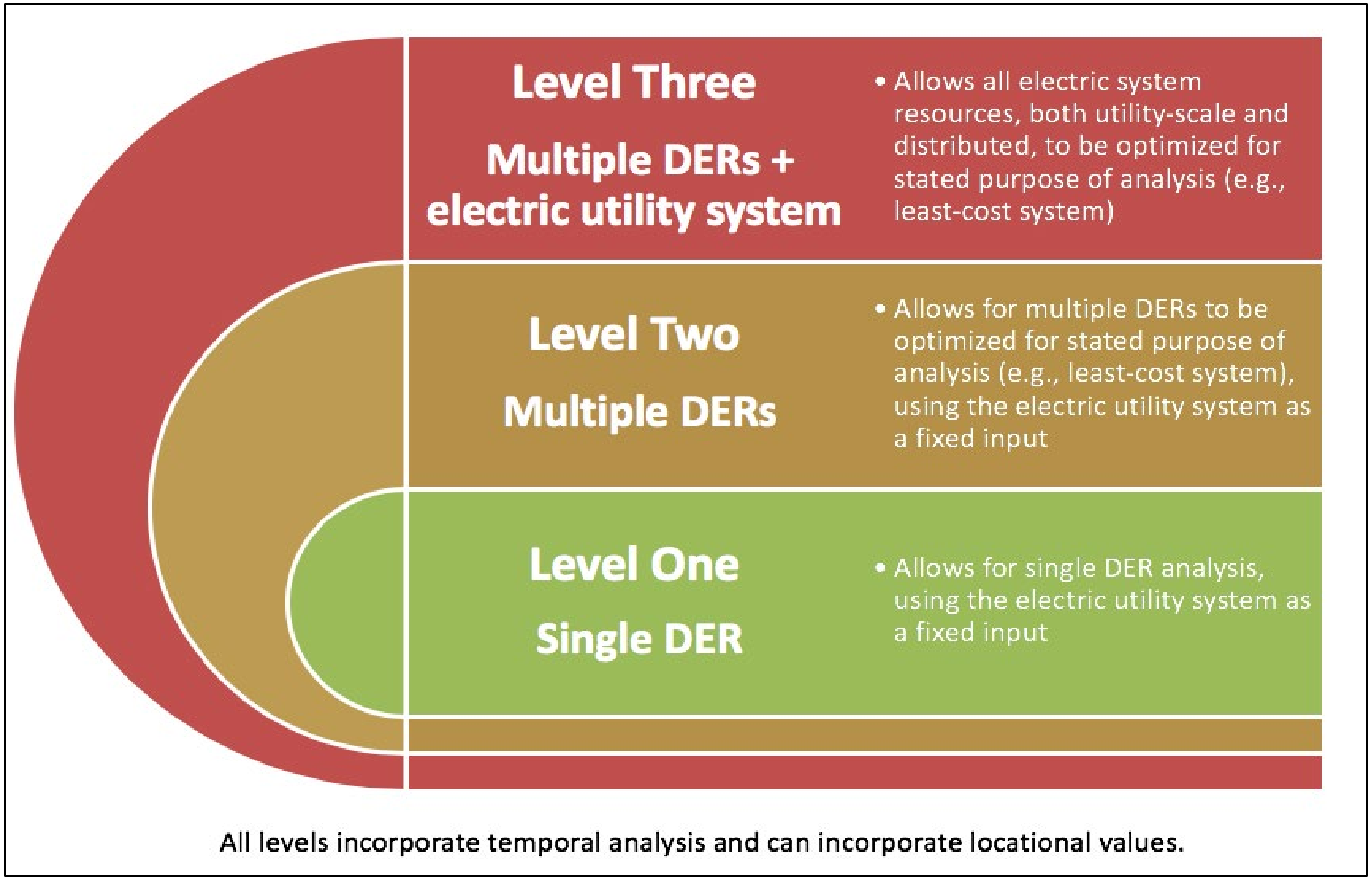
Locational value of demand flexibility may account for significant economic value.



Example - Relative Contribution to Total Utility System Value for Energy and Capacity Savings From Residential Air-Conditioning Efficiency Measures in California

Source: Mims et al. 2017. *Time-varying value of electric energy efficiency*

Framework for Addressing Interactions Between DERs



Source: Mims Frick et al. 2018. *A Framework for Integrated Analysis of Distributed Energy Resources: Guide for States*