The Integrated Grid

Understanding the Benefits and Costs of Distributed Energy Resources

Ben Kaun
Sr. Project Manager

DEDI DER Workshop

4-15-15

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Goals for Today

- Introduce Distributed Energy Resources (DER) and Technical Considerations
- Introduce EPRI Integrated Grid Benefit-Cost Framework
- Evolving Regulatory Frameworks – New York and California

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Introduction to Distributed Energy Resources

Definitions, Issues, and Examples

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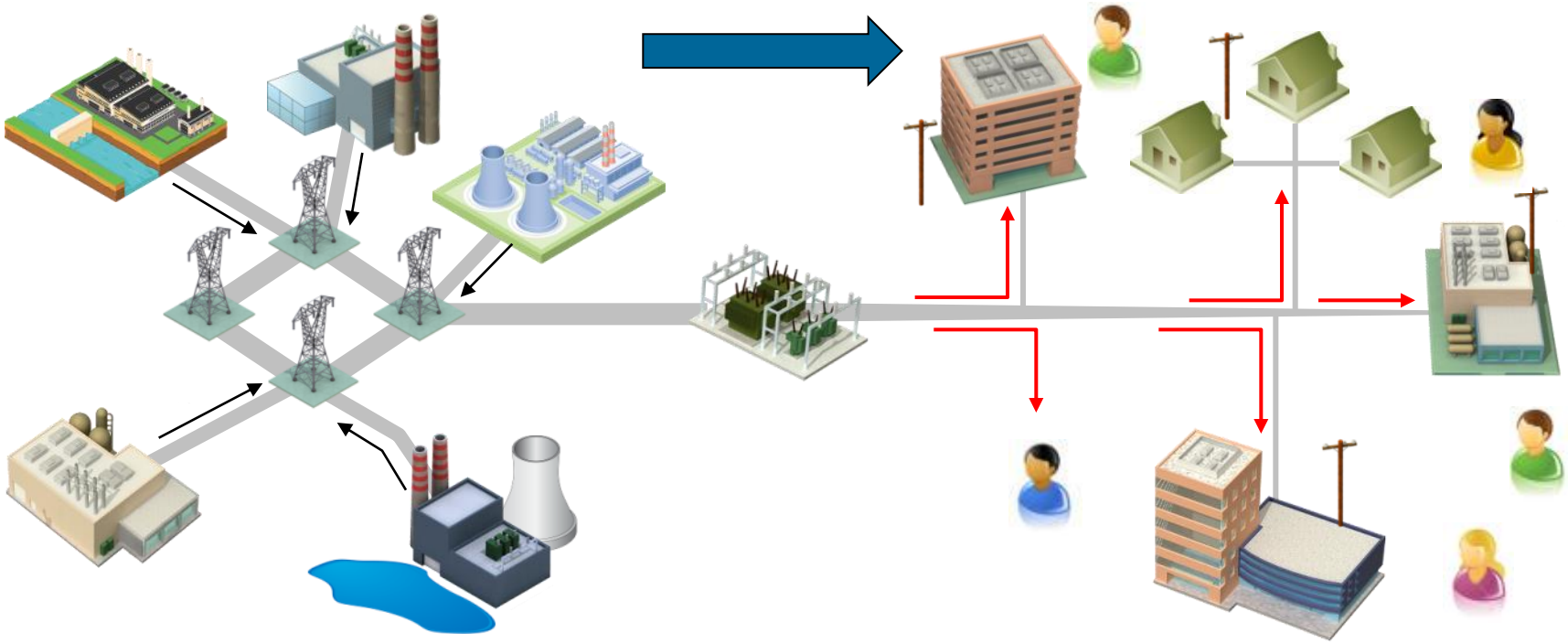
Today's Power System – Power Flows from Centralized Generation to Distributed Loads



Generation **Delivery** **Customer**

Planning and Operations of Generation, Transmission, Distribution, and Customers are Mostly Independent

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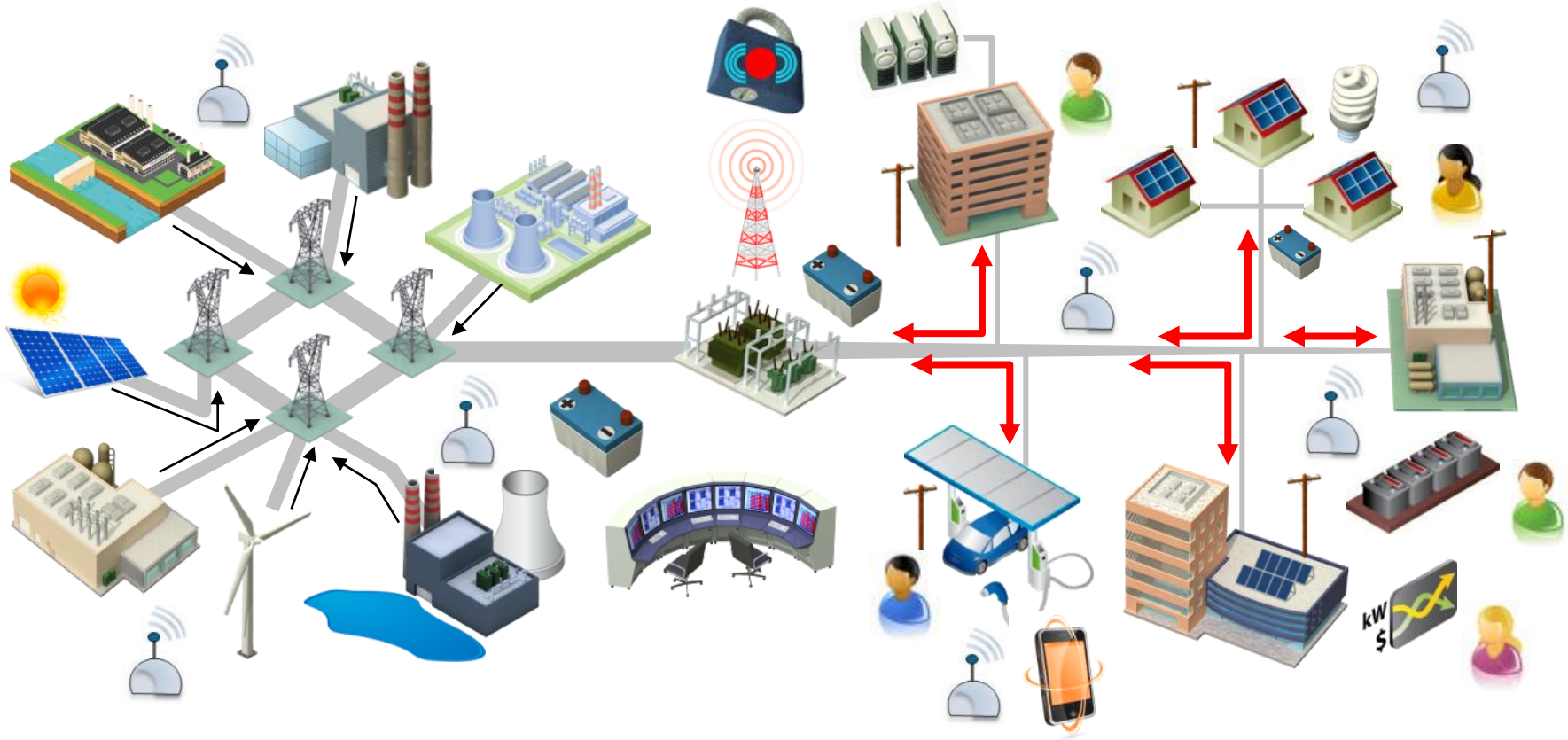
Transformation of the Power System – New Resources, Communication, and Control at all Levels



New Opportunities and Challenges Require Integrated Approaches with New Methods, Tools, and Collaborations

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Definition: What is a Distributed Energy Resource?

- Connected to the Distribution system (< 69 kV voltage level)
- And…
  - Generates electricity
    - Or…
  - Stores electricity
    - Or…
  - Involves load changes in response to signals

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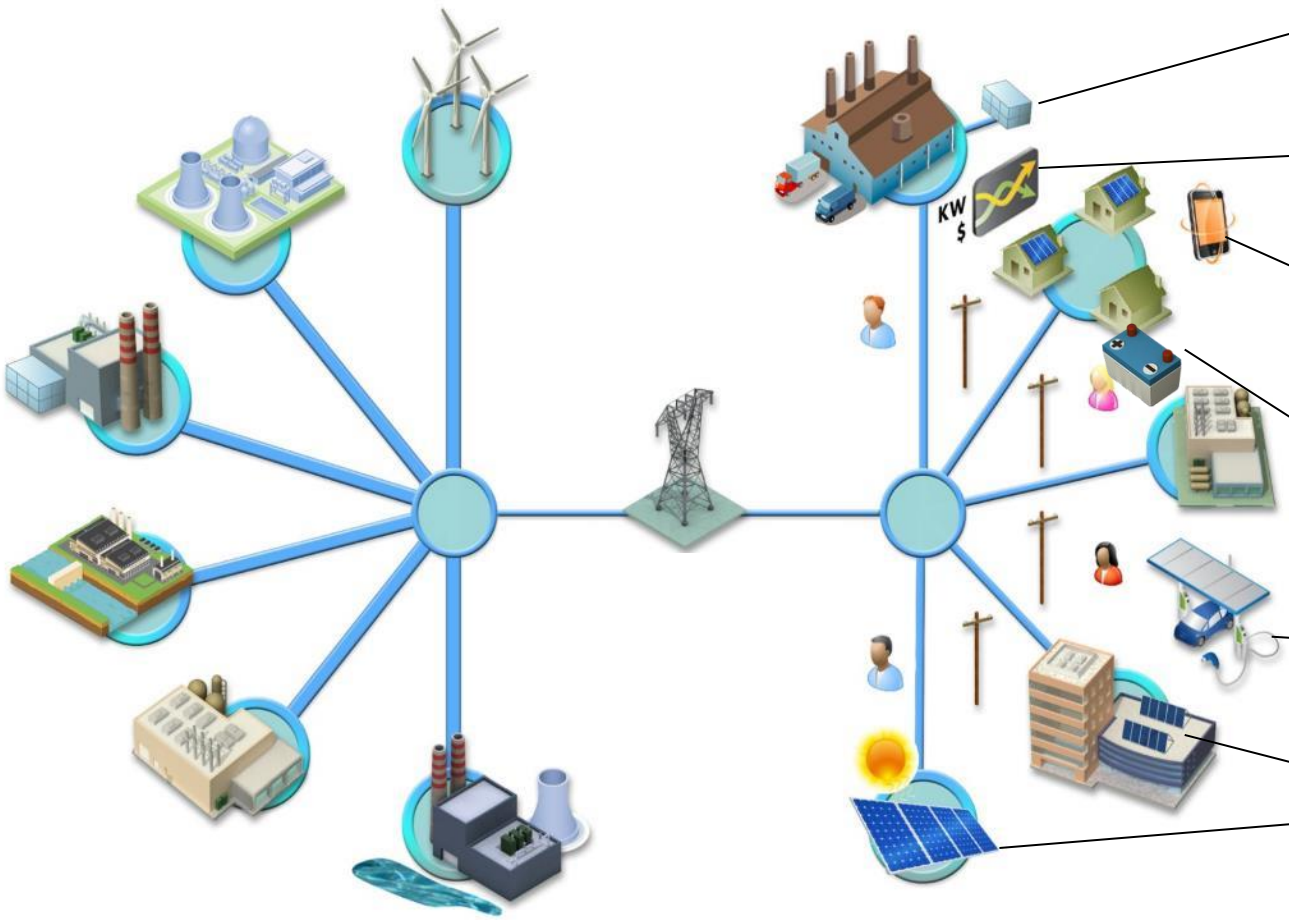
Some Examples of Distributed Energy Resources - May be Deployed by Customer, Utility, or 3rd Party



Combined Heat and Power / DG

Demand Response

Building Energy Management

Energy Storage

Electric Vehicles / Smart Charging

Distributed Solar

Distributed Energy Resources (DER)

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EPRI Integrated Grid Initiative

Benefit-Cost Framework and Next Steps

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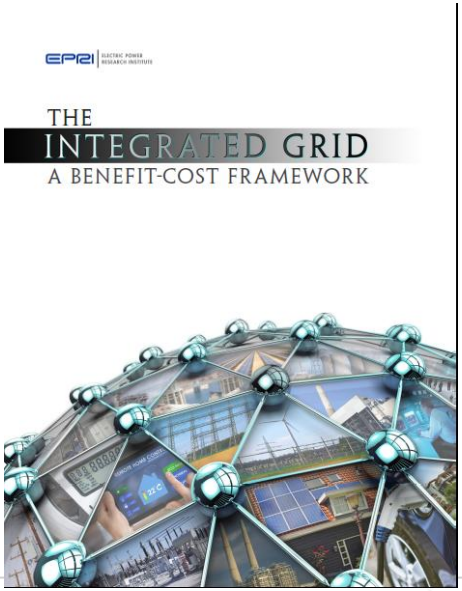
EPRI's Integrated Grid Initiative

An integrated grid that optimizes the power system while providing safe, reliable, affordable, and environmentally responsible electricity will require global collaboration in the following four key areas:

- Interconnection Rules and Communications Technologies and Standards
- Assessment and Deployment of Advanced Distribution and Reliability Technologies
- Strategies for Integrating Distributed Energy Resources (DER) with Grid Planning and Operation
- Enabling Policy and Regulation

http://integratedgrid.epri.com



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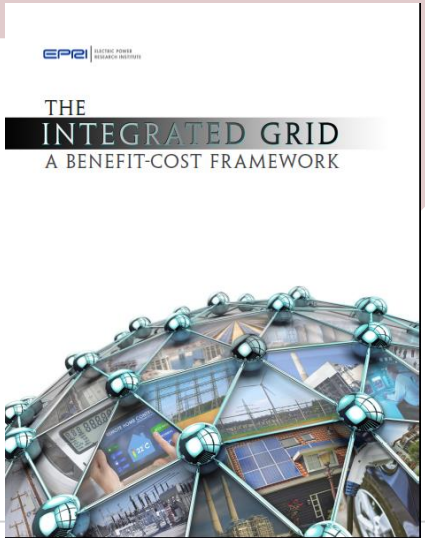
Timeline of EPRI's Integrated Grid Effort

Phase I
Concept Paper
Feb 2014

Phase 2
Benefit/Cost Framework
Feb 2015

Phase 3
Pilot Deployments
2015 -



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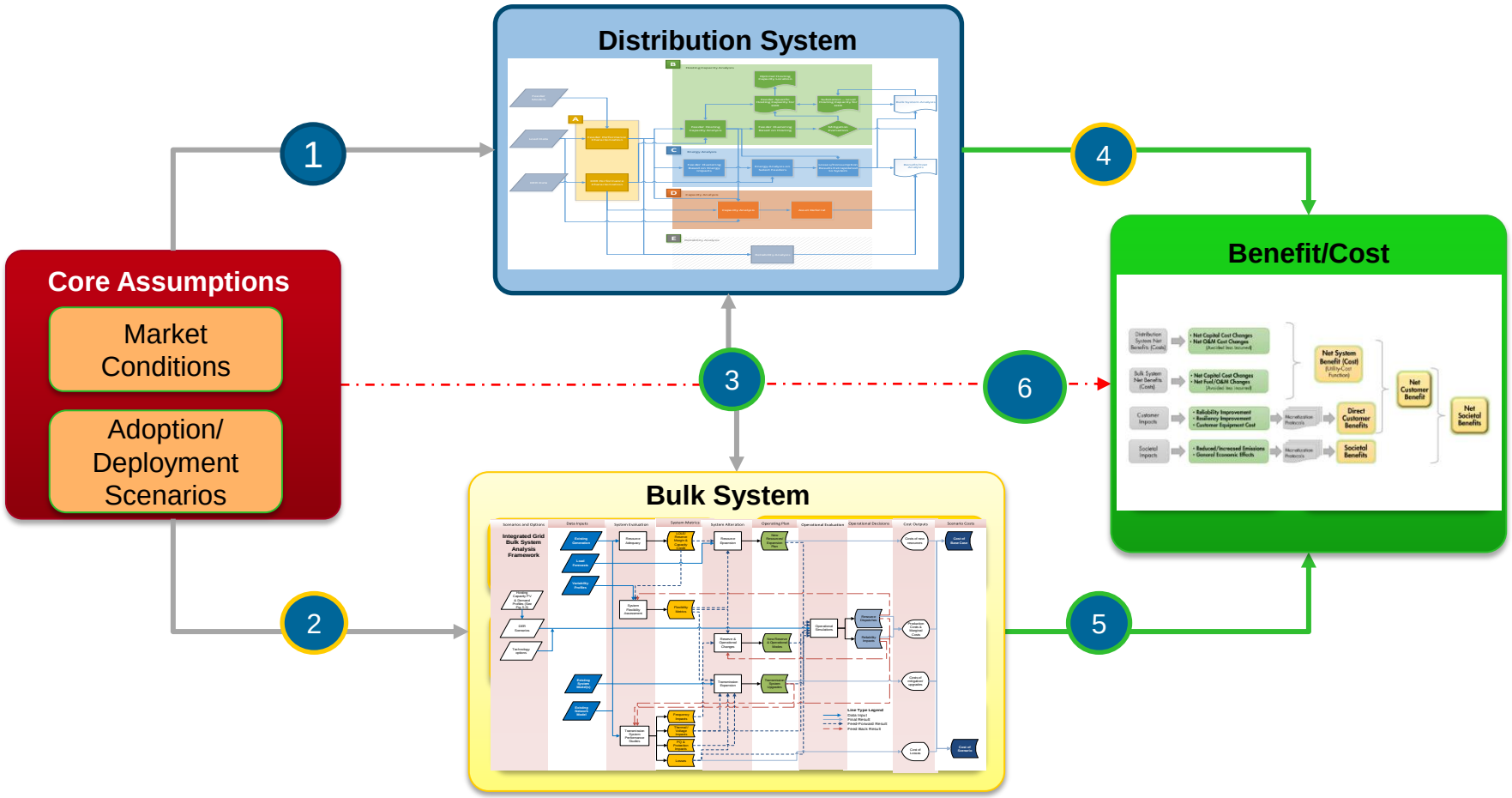
Integrated Grid Benefit-Cost Framework Overview



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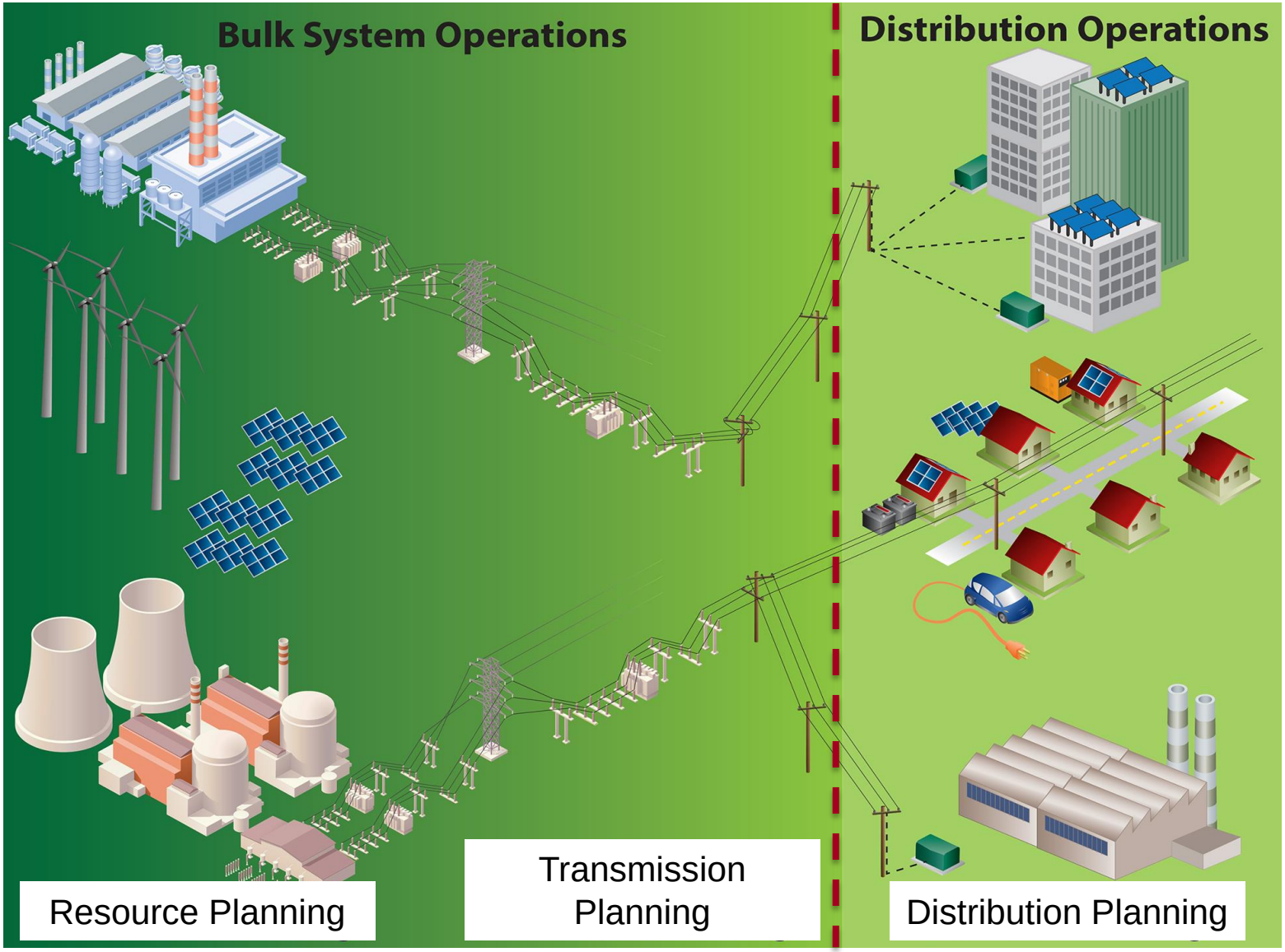
Crossing Traditional System Divisions



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Vision for Effective Methods to Incorporate DER in Planning and Operations

Granular	• Capture location-specific system responses
Repeatable	• Approach can be replicated at all sites
Scalable	• Practical for full service area deployment
Transparent	• Clear and open methods for analysis
Proven	• Validated and benchmarked with real data and review
Available	• Facilitate the transition to commercial-ready products

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Impact of DER – Two Sides of the Same Coin

Increasing Penetration Level

POSSIBLE BENEFITS	DOMAIN	POSSIBLE COSTS
Energy, Capacity & Ancillary Support	Generation	Additional Capacity & Ancillary Service Need
Voltage & Frequency Support	Transmission	Voltage & Frequency Instability
T&D Avoided Capacity	Substation	Reverse Power Flow Transmission Congestion
Loss Reduction	Feeder	Increased Losses Equipment Wear
Local Reliability	Customer	Voltage Variation

Increasing Penetration Level

Benefits and Costs will Depend on Location, Technology, Control, and System Conditions

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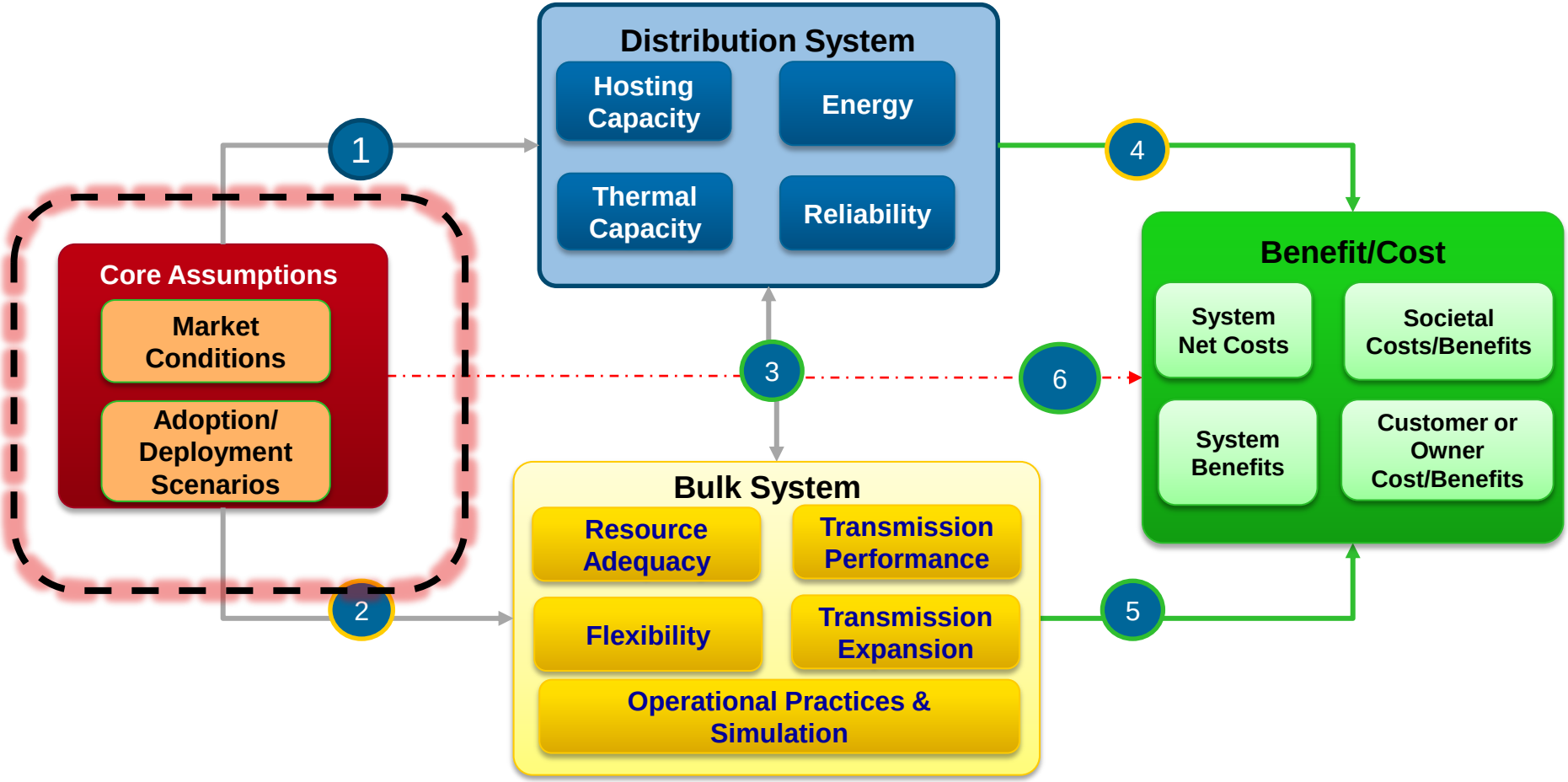
Overview of Integrated Grid Benefit-Cost Framework



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Step 1: Getting off on the Right Foot with Appropriate Scoping

Research Questions

- Value of Solar?
- Where to Place Storage?
- Good sites for Community Solar?
- Smart Inverter Cost/Benefit?
- Value of DR Program?

Core Assumptions

- Study Timeframe
- Compliance Criteria
- Existing Resource Mix
- Growth Scenarios
- DER Cost & Performance

Clarify the Key Questions and Foundational Assumptions before Proceeding to Analysis

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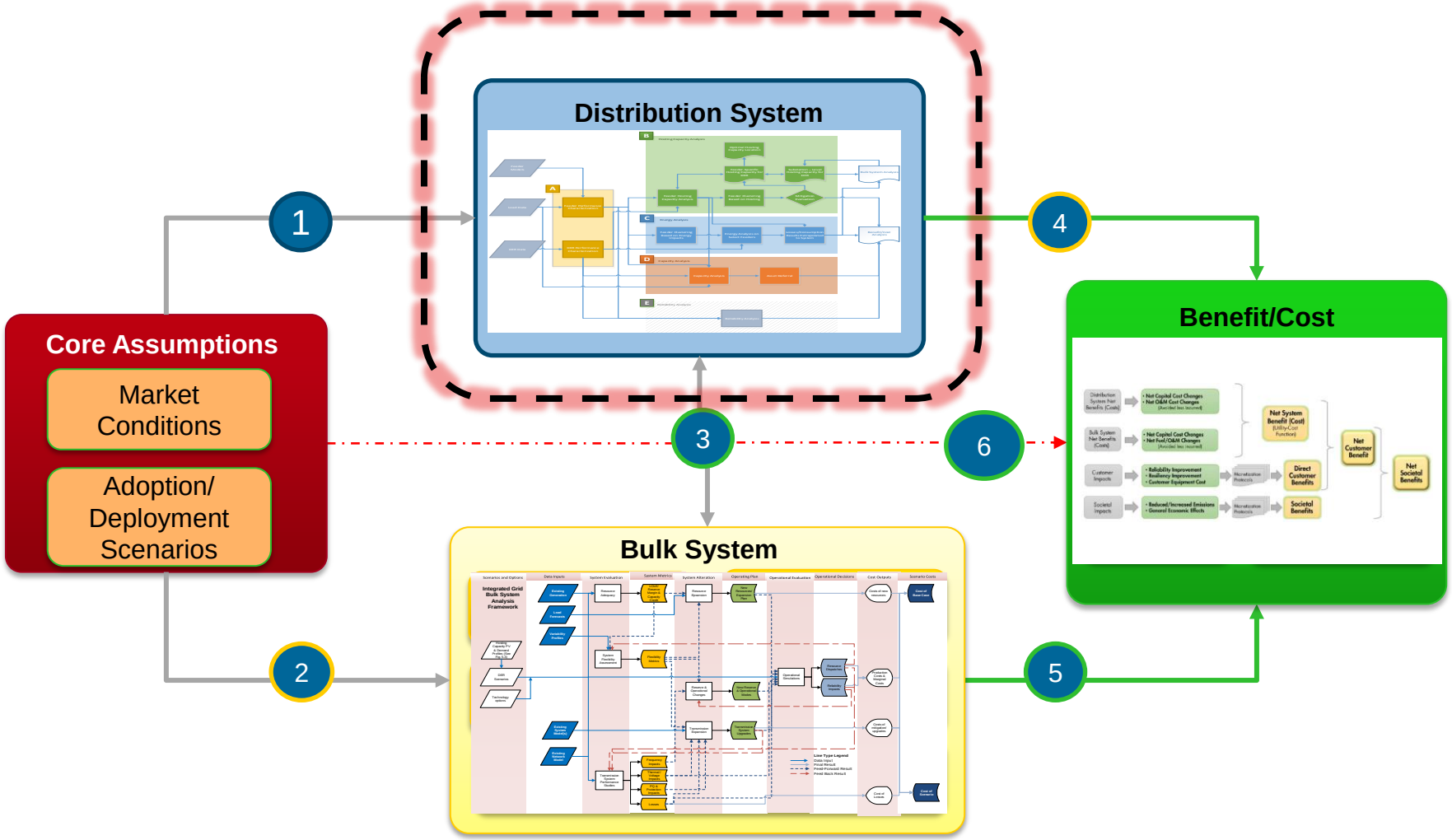
Integrated Grid Framework: Distribution Impacts



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Distribution Systems are Unique and Large in Scale

Distribution Feeders are Unique

- Designed to reliably serve ALL customers in least-cost manner
- Evolve around customer needs
- Feeder design impacts reliability, costs, and benefits of DER

Distribution Systems are Vast

Typical Distribution Utility	Number
Service Territory	1
Planning area	1's - 10's
Substations	10's - 100's
Feeders	100's -1000's
Service Transformers	1000s - 1,000,000's
Customers	100,000's - 1,000,000's

Decreasing visibility

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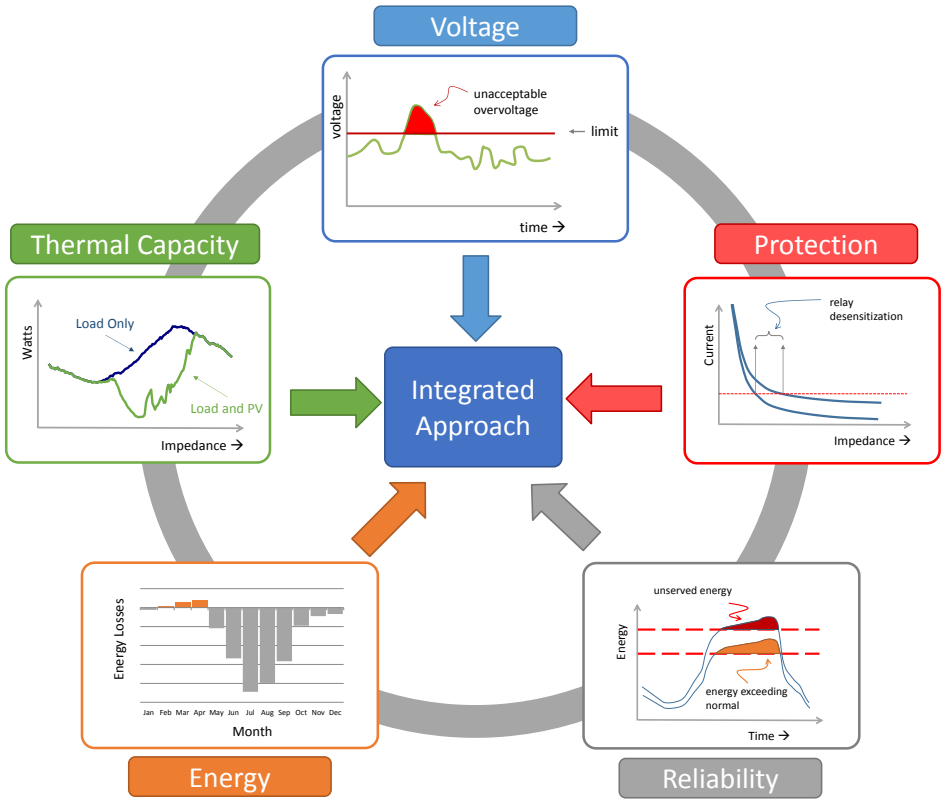
Primary Planning Objectives and Dimensions of Distribution Assessment for DER

- **Objective 1: Meet Compliance Criteria at Minimal Cost**
  - Avoid driving new capital upgrades with DER
  - Maintain voltage, protection, thermal capacity,and reliability standards
- **Objective 2: Proactively Consider DER for Cost Reduction and Reliability Enhancment**
  - Defer or avoid planned capital upgrades
  - Improve system efficiency
  - Enhanced power quality, reliability, and resiliency



Components for determining optimal type and location of DER

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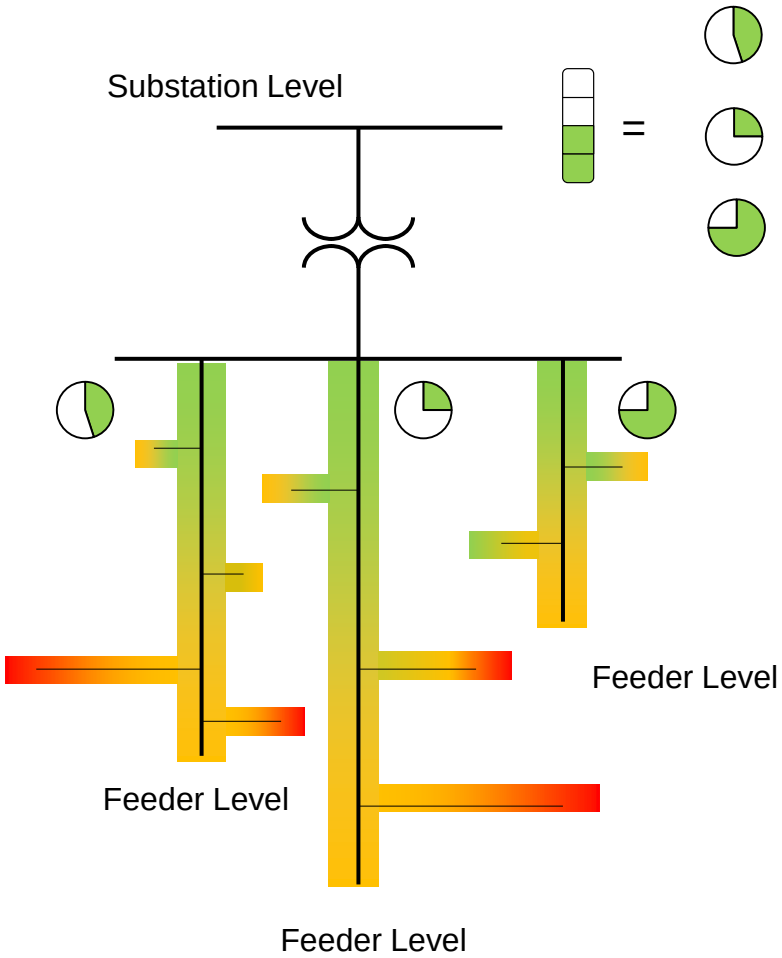
EPRI Approach to Distribution Planning with DER

- Leverage deep insights and findings from rigorous analysis (OpenDSS)
- Streamlined utility implementation
  - Utilize current utility planning tools and data
  - Evaluate each feeder individually
  - Apply throughout entire system (1000's of feeders) in automated fashion
  - Consider "feeder-level" response with results that can be aggregated up to substation level
- **EPRI is working to generalize findings of detailed analysis and implementing new capabilities in commercial planning tools (e.g. CYME, Synergee, etc.)**



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EPRI Approach to Distribution Planning with DER

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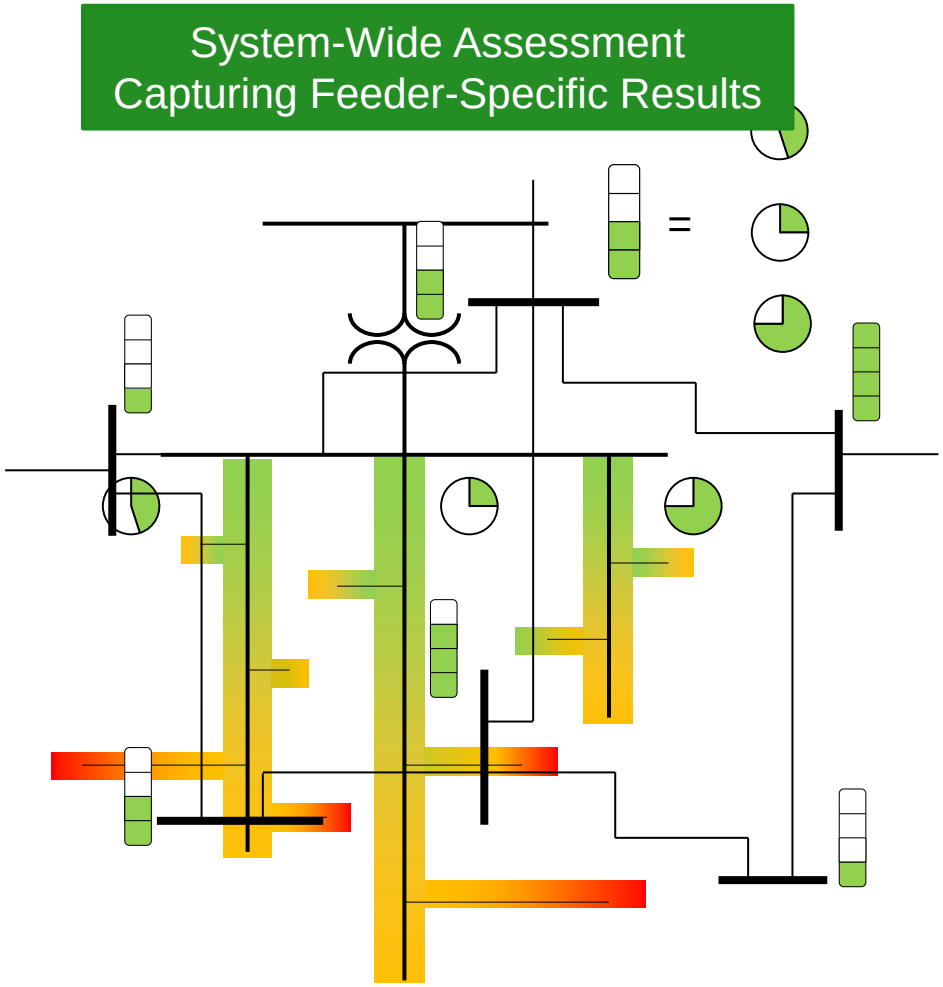

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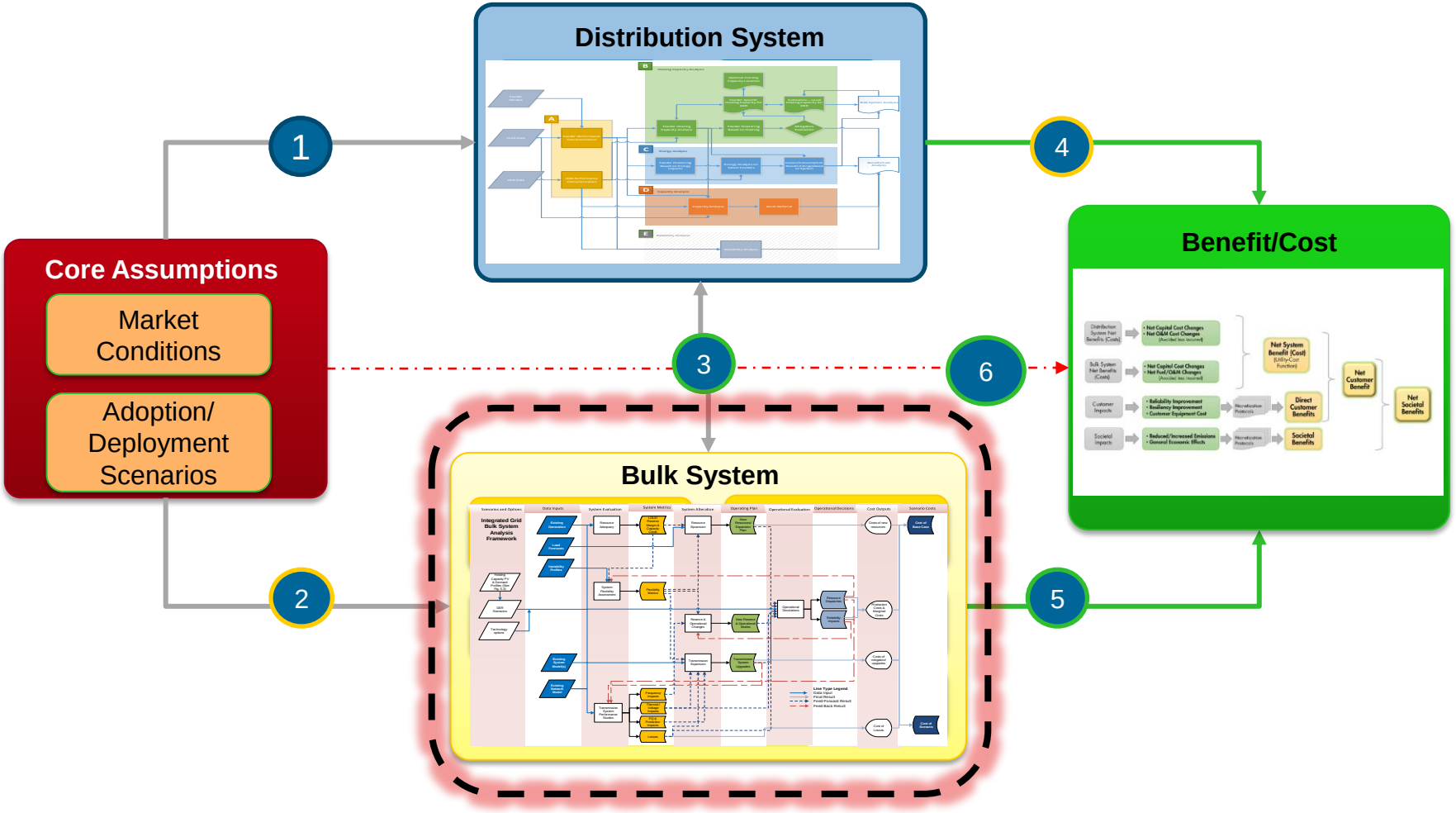
Integrated Grid Framework: Bulk System / Transmission Impacts



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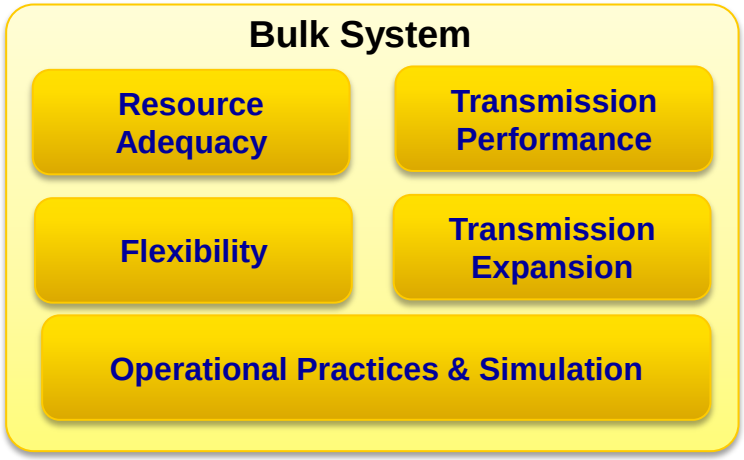
Bulk System (Transmission) Impacts



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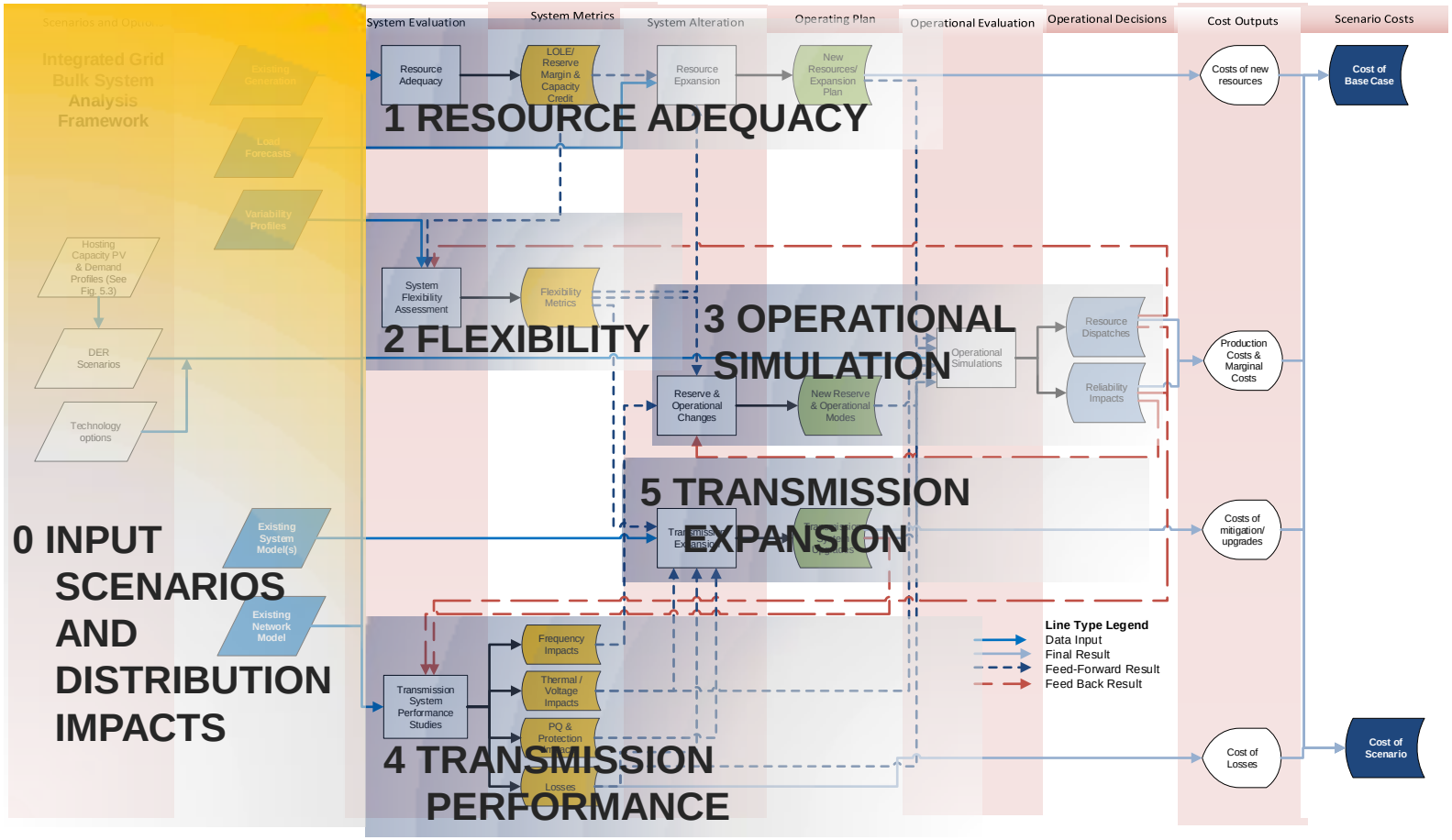
Integrated Grid: Bulk System Analysis Overview



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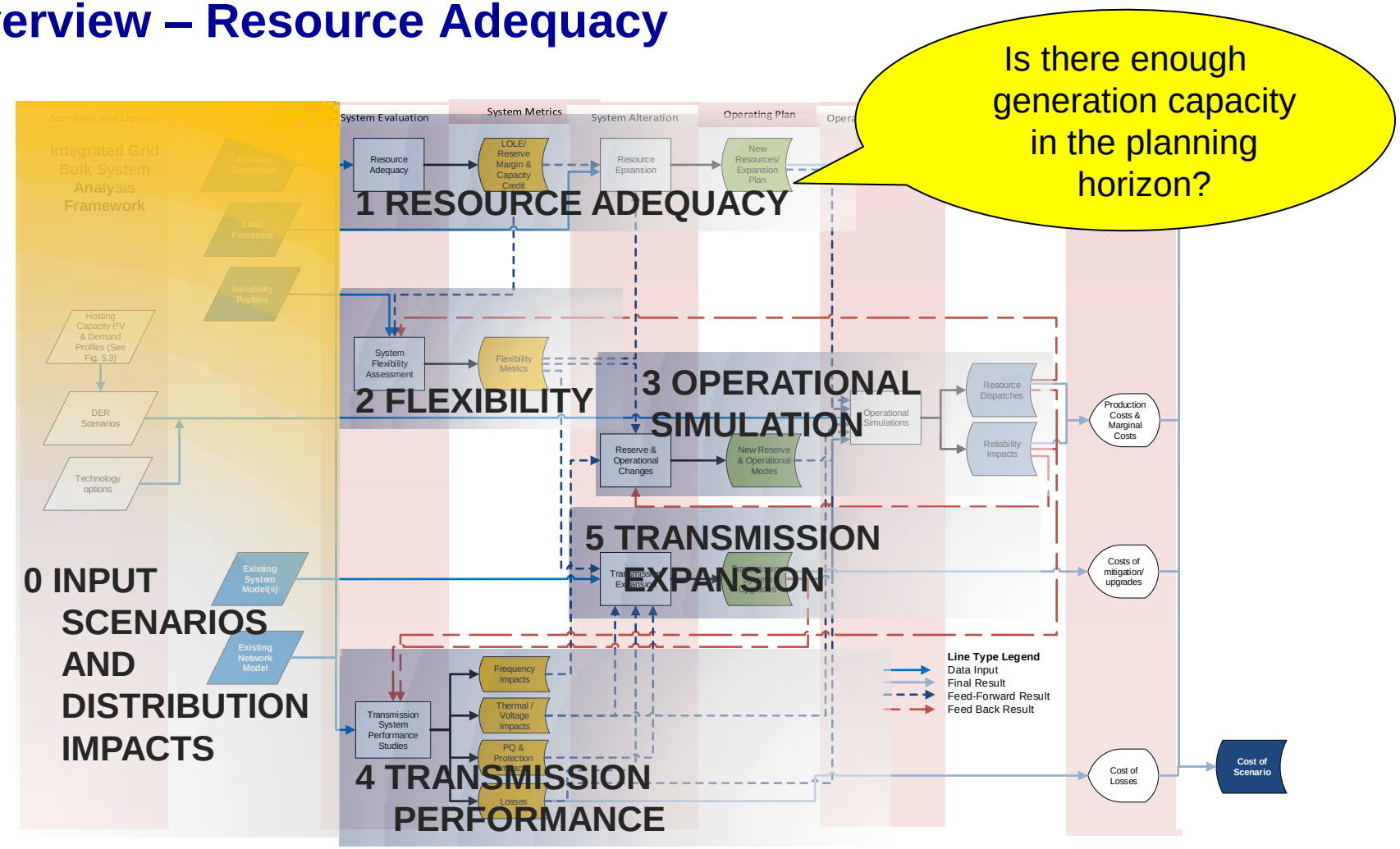
Integrated Grid: Bulk System Analysis Overview – Resource Adequacy



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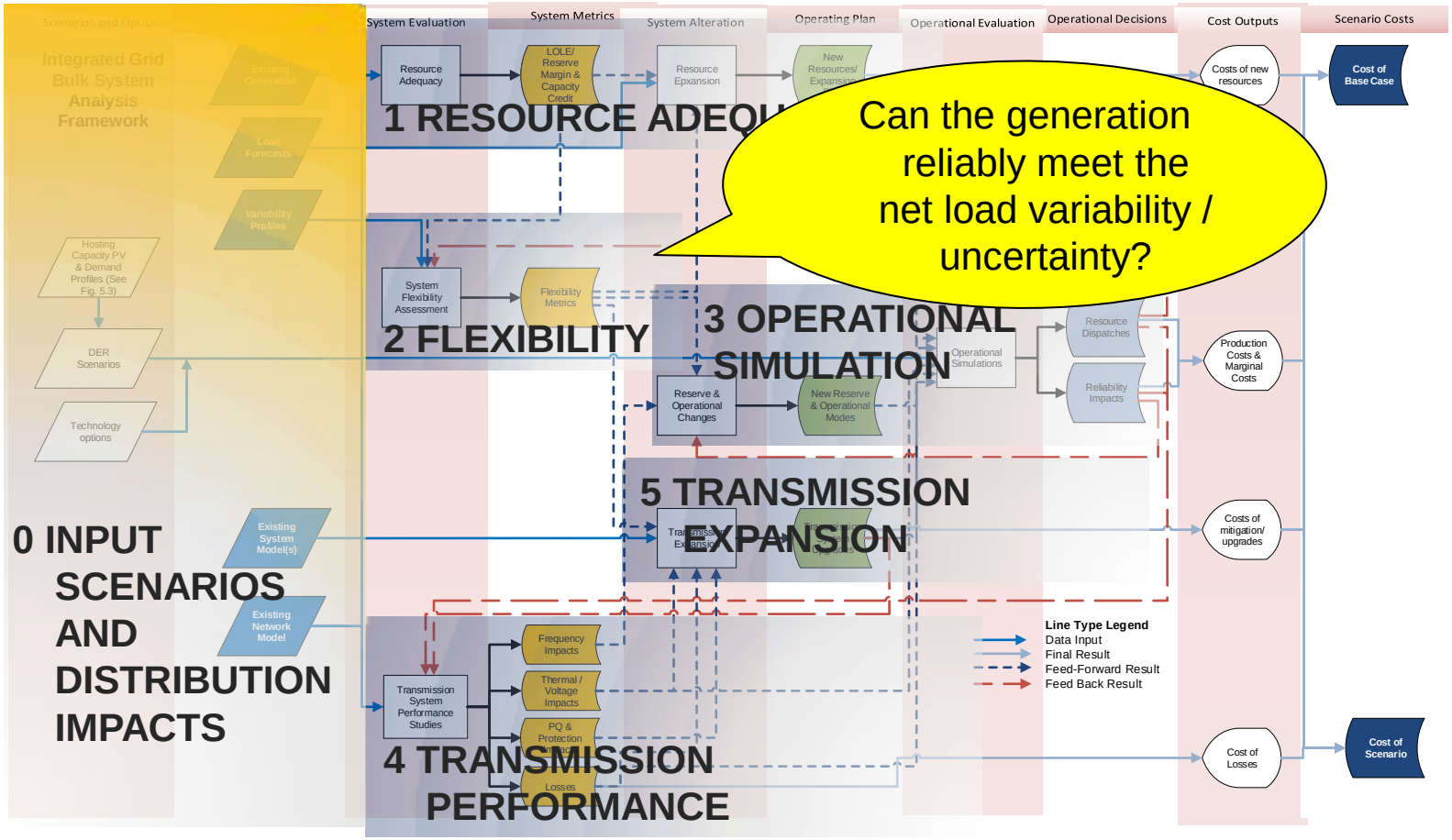
Integrated Grid: Bulk System Analysis Overview - Flexibility



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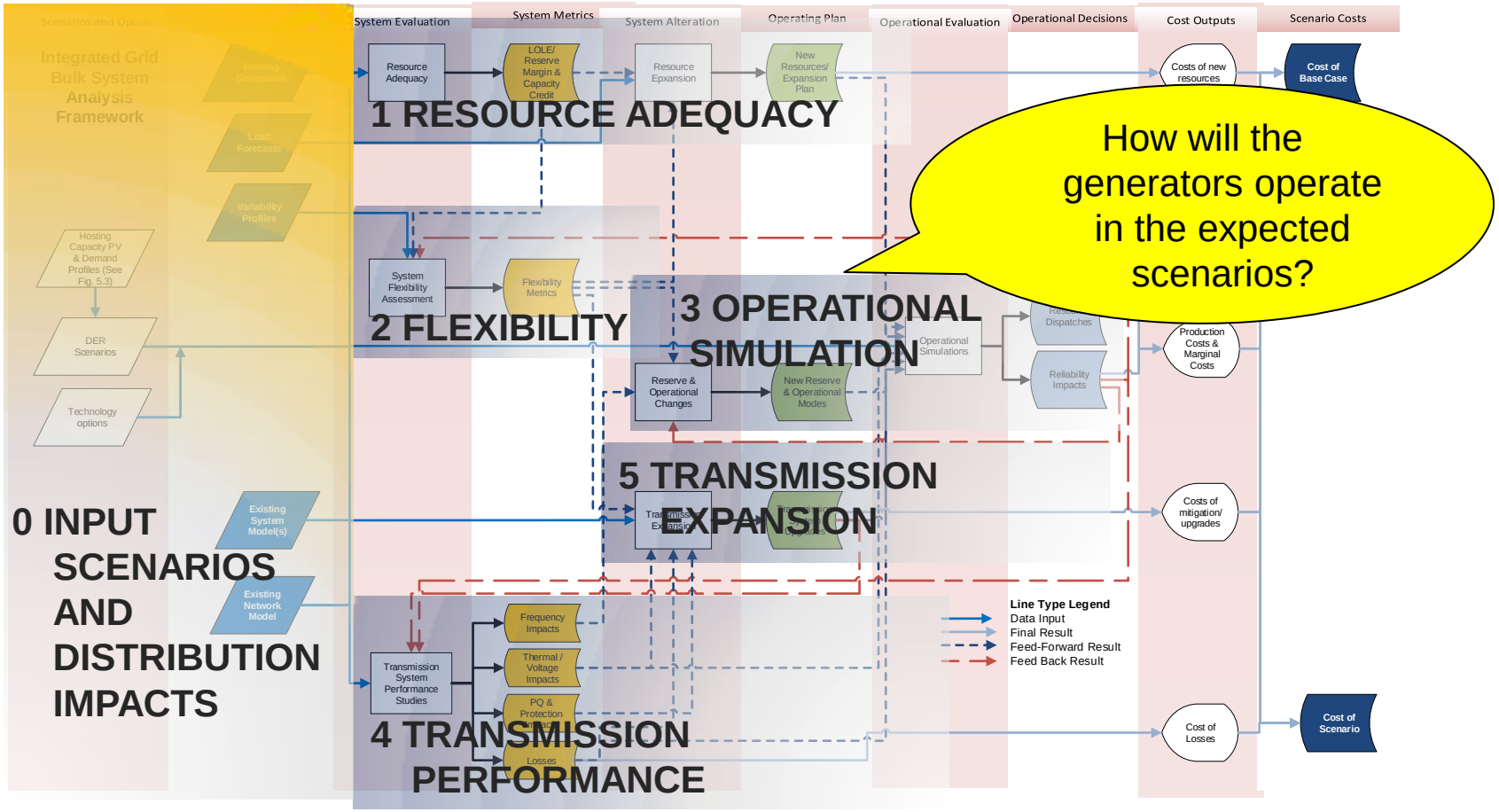
Integrated Grid: Bulk System Analysis Overview – Operational Simulation



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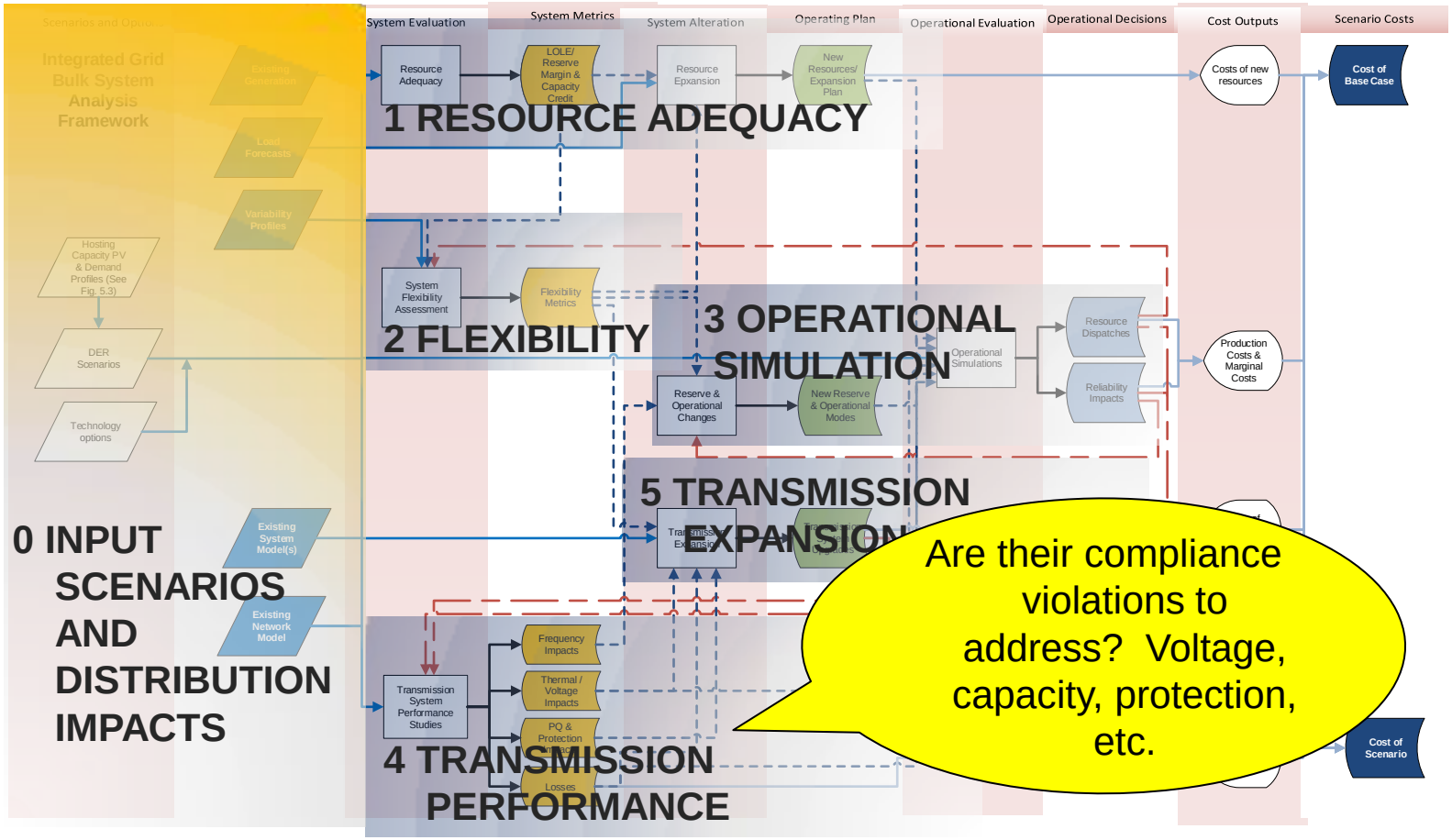
Integrated Grid: Bulk System Analysis Overview – Transmission Performance



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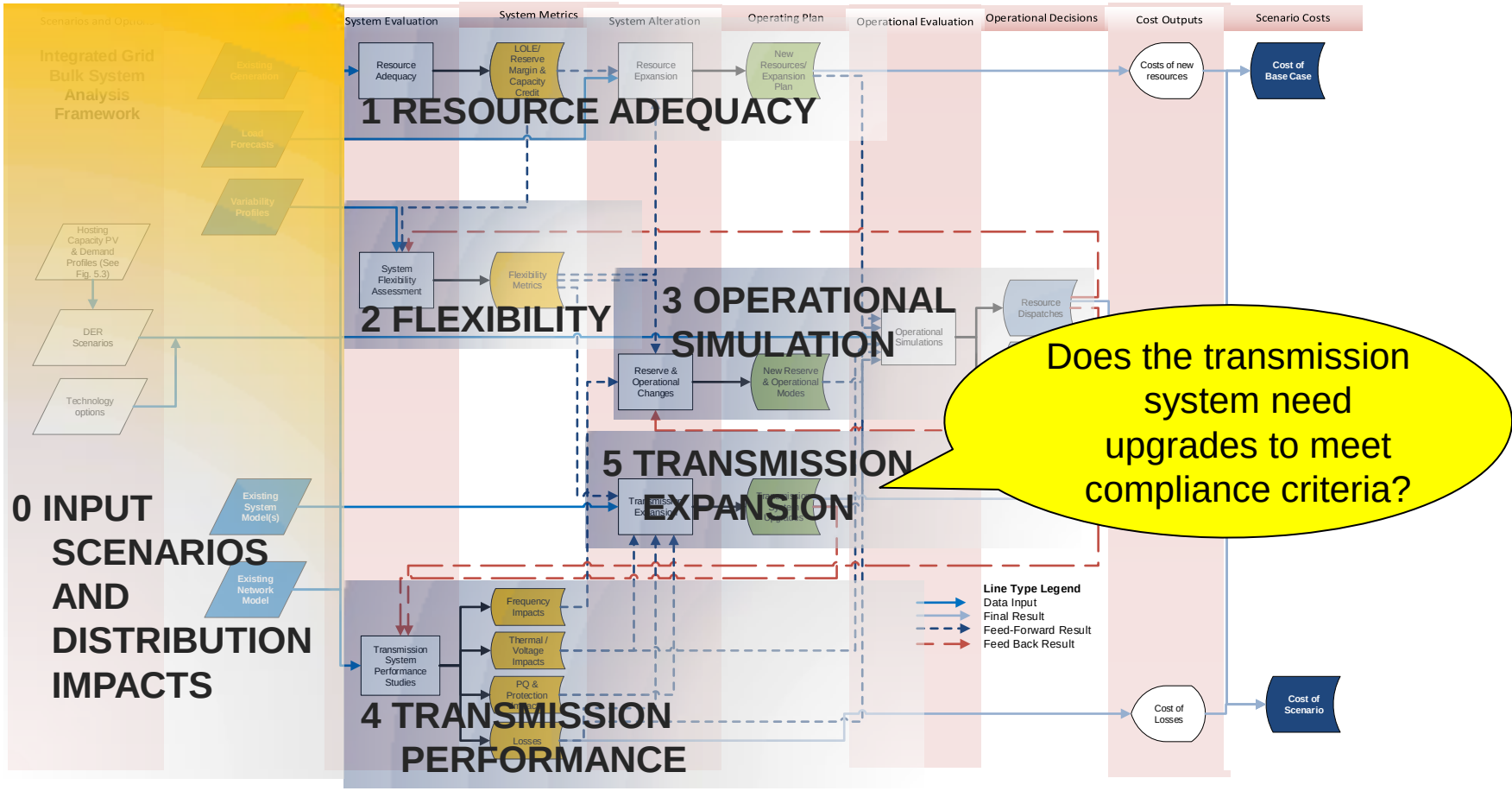
Integrated Grid: Bulk System Analysis Overview – Transmission Expansion



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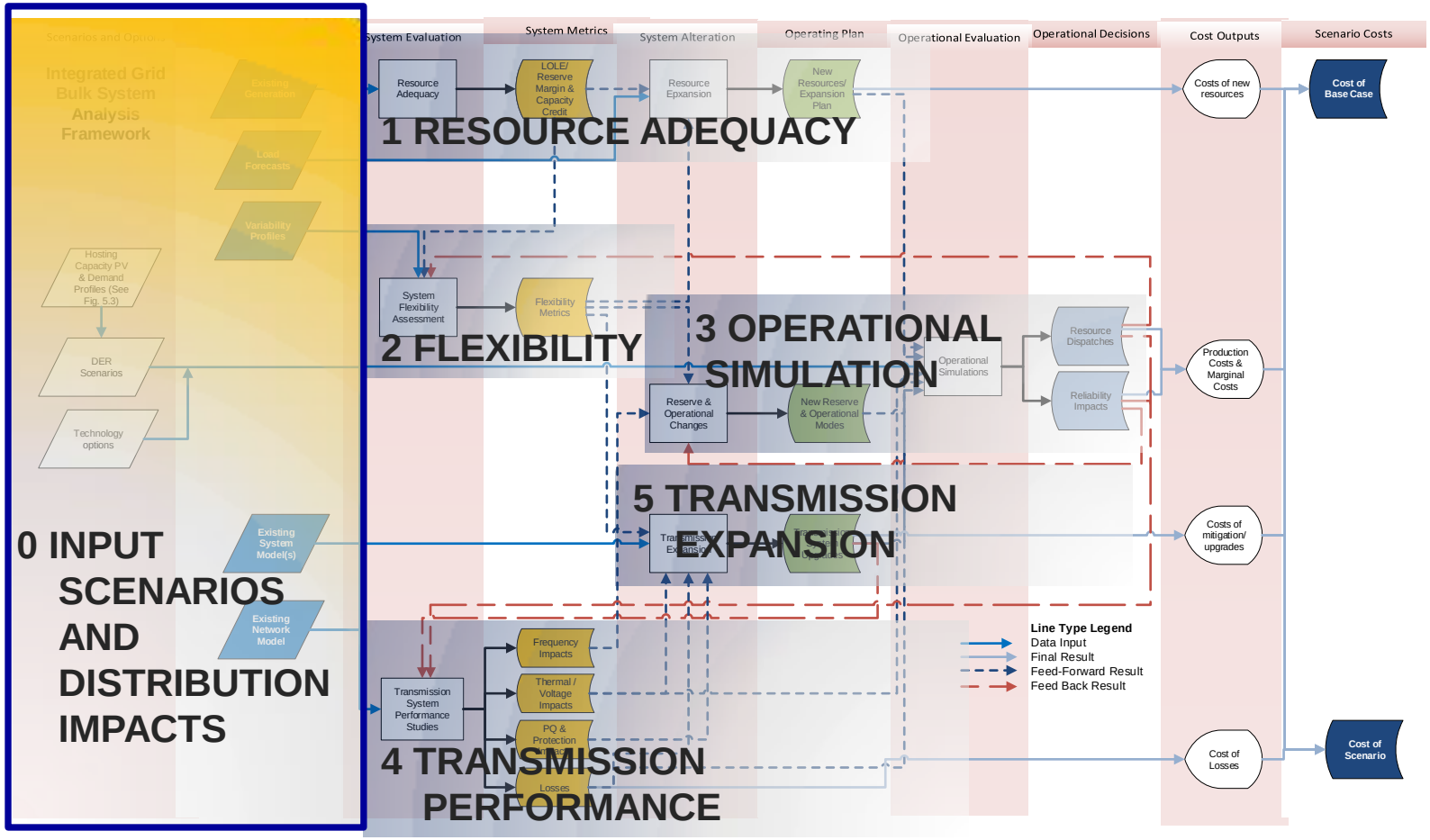
Integrated Grid: Bulk System Analysis
Transmission and Generation are Already Somewhat Integrated



However, there are new considerations with monitoring and control of large numbers of distributed resources

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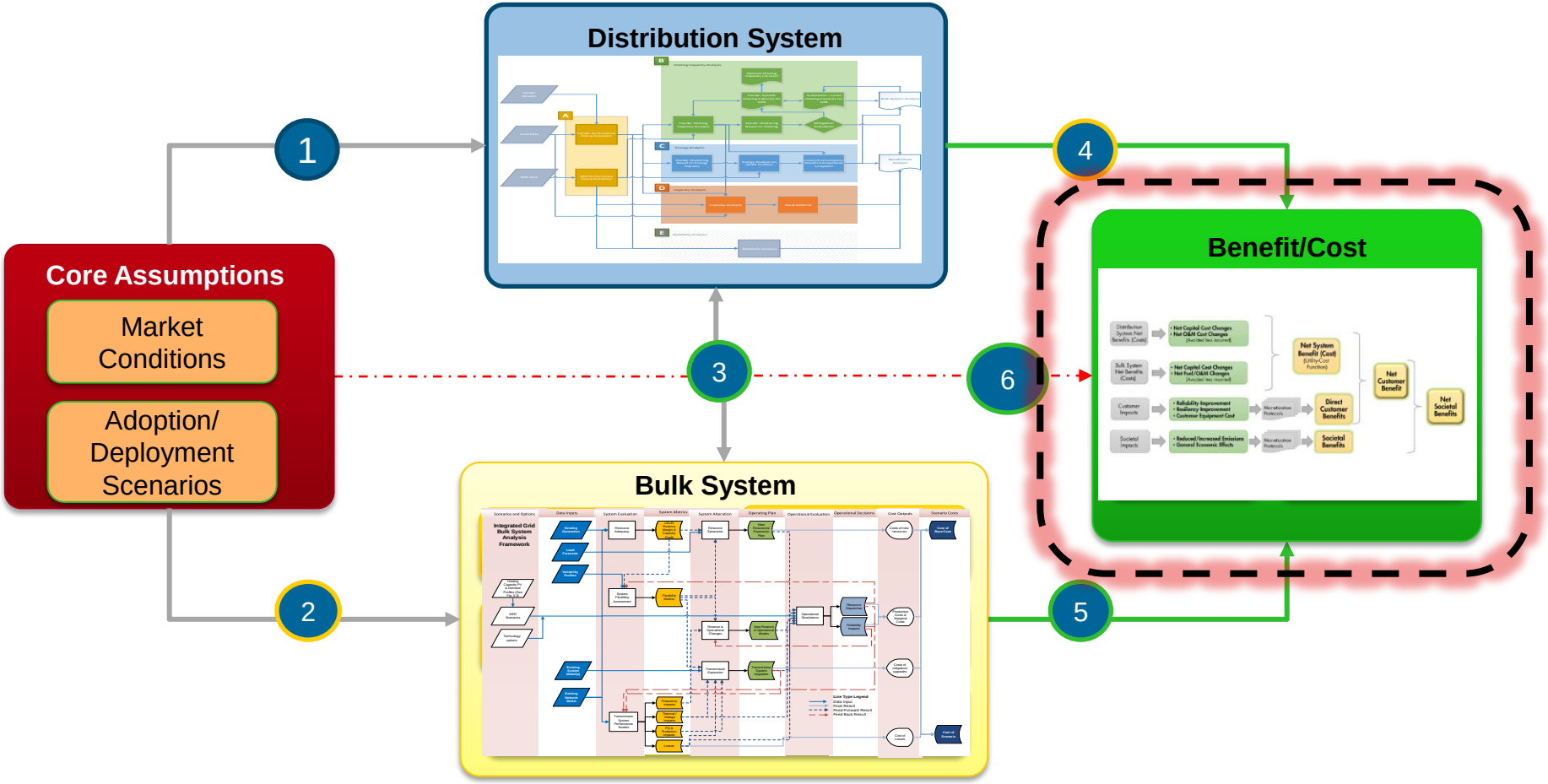
Integrated Grid Framework: Benefits and Costs



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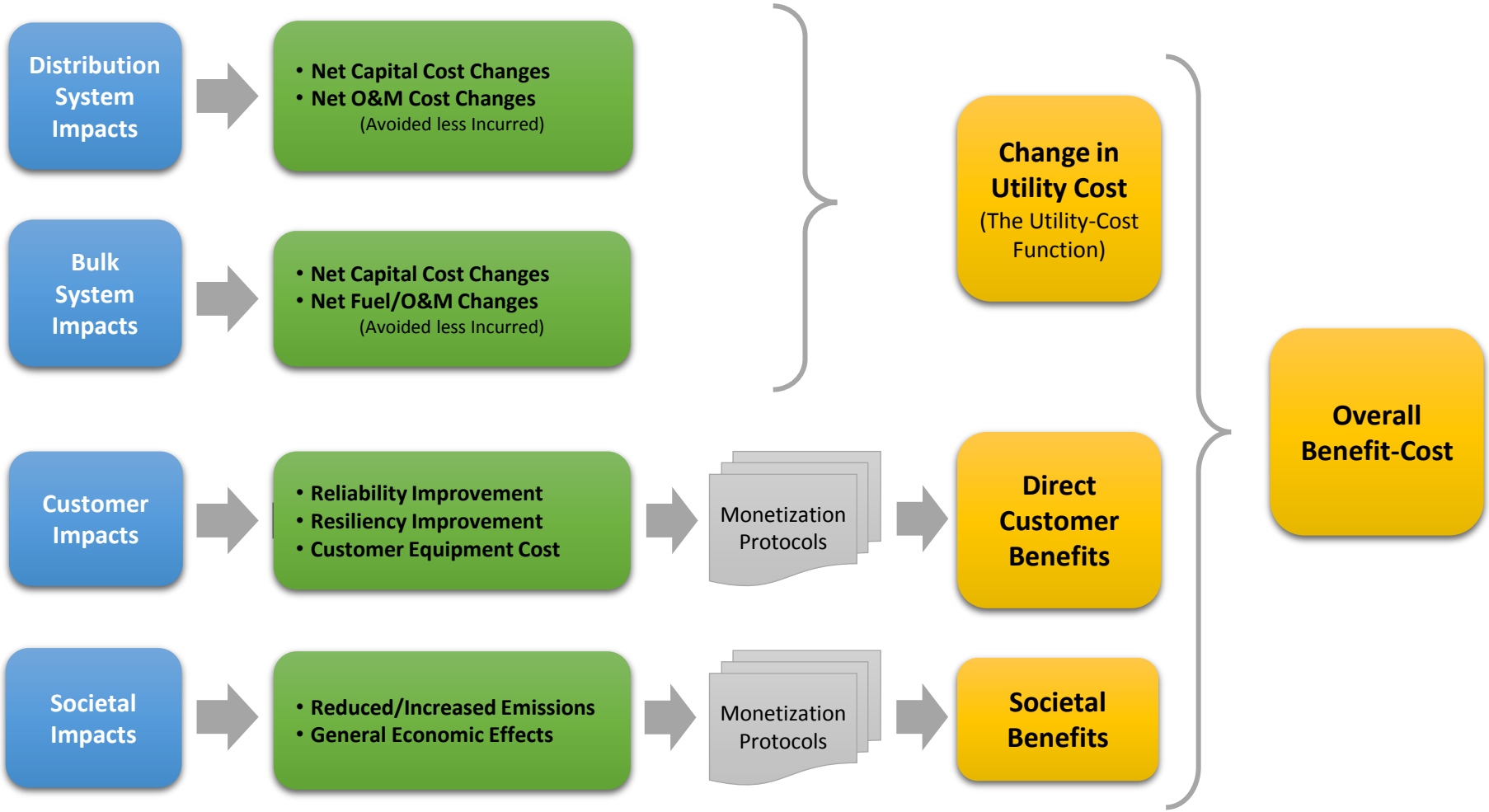
Overview of Benefit-Cost Categories



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Testing and Advancing the Integrated Grid Framework – Pilot Projects Covering Broad Technological Scope

- Utility Scale Solar
- Utility Scale Solar with Energy Storage
- Distributed Energy Storage
- Microgrids
- Electric Vehicle Charging Infrastructure
- Customer-Side Technologies

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Value From Collaborative Pilots

Better understanding of operational values, performance issues and economic benefits of an integrated approach

Broad data sets and shared lessons learned

Provides rigorous testing platform for system evolution

- Traditional approaches and conventional controls vs. advanced forecasting and advanced controls
- Impacts and resultant changes to dispatch and operational practices

Tests and advances framework toward a consistent, repeatable, transparent methodology and tool set

- Supports ability to make most prudent system investments going forward

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Evolving Regulatory Frameworks

Examples from New York and California

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New York Public Service Commission
Reforming the Energy Vision (REV) – Policy Goals

- Enhanced customer knowledge and tools
- Market animation and leverage of ratepayer contributions
- System wide efficiency
- System reliability and resiliency
- Fuel and resource diversity
- Reduction of carbon

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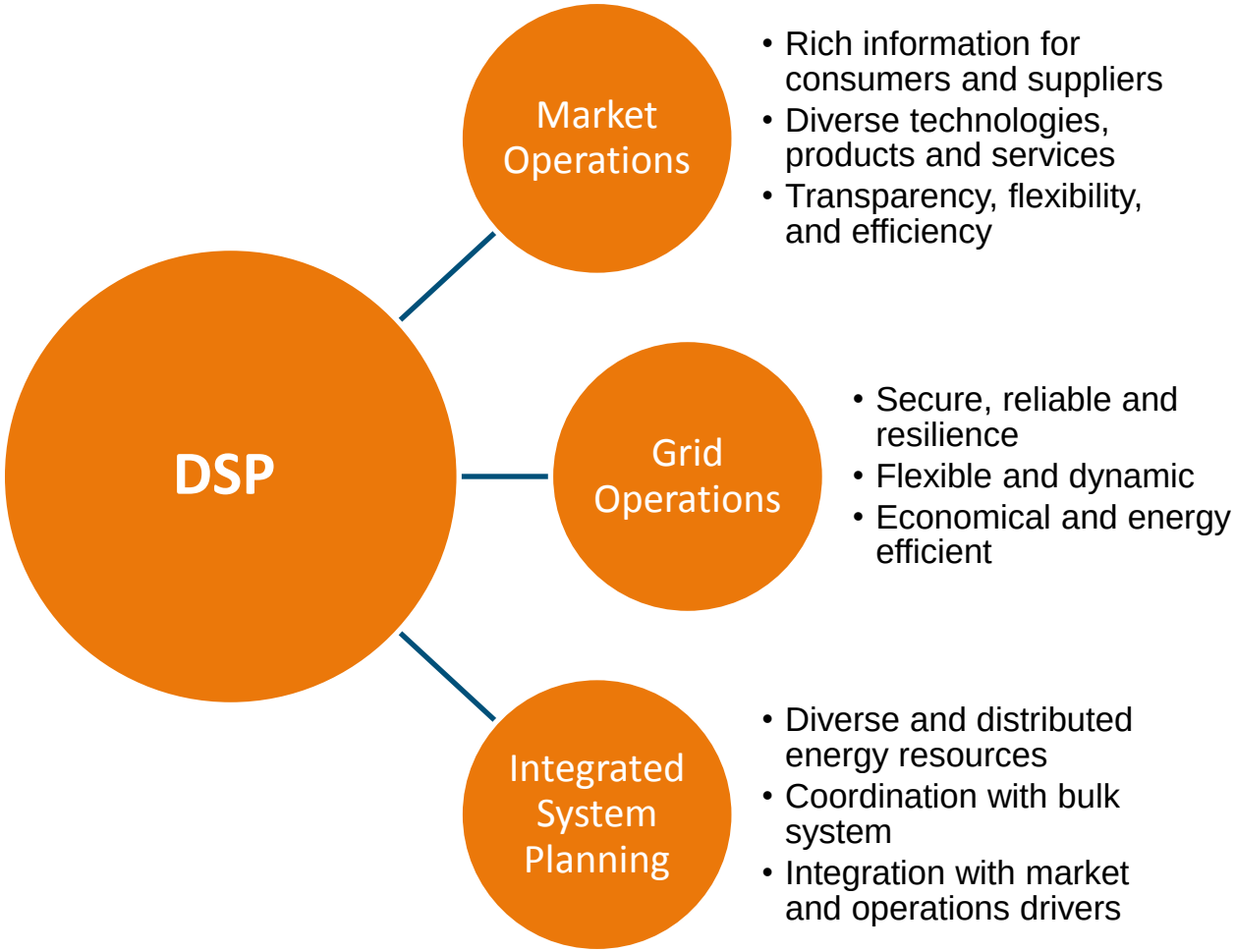
New York PSC Order
Developing a Distribution System Platform (DSP)



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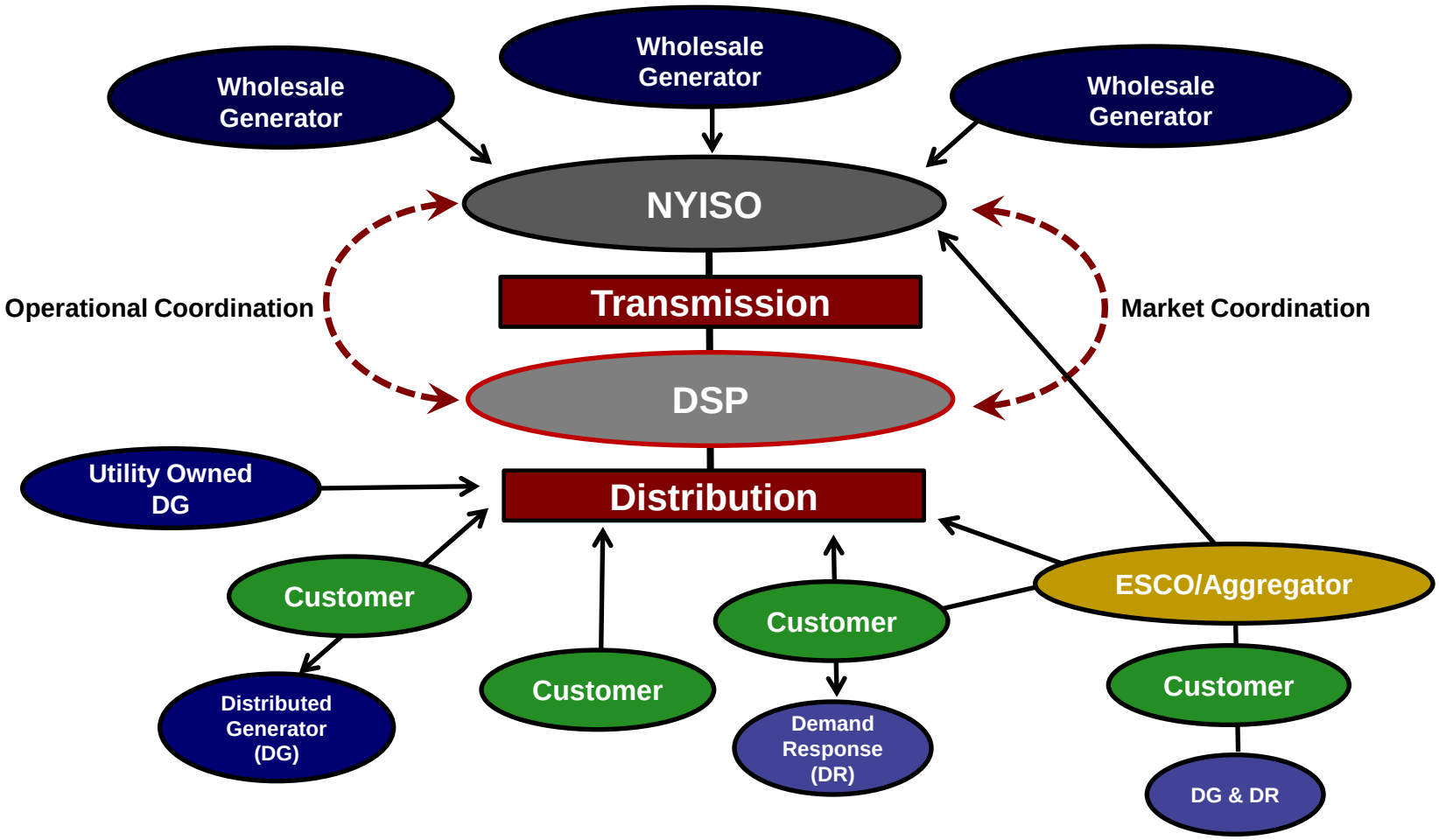
Framework for the Distributed System Platform (DSP)



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Overview of California's Distributed Resources Plan Proceeding

- Began with passage of California Assembly Bill (AB 327)
- CPUC currently holding a proceeding to determine the role of customer DER in utility distribution planning (**R.14-08-013)**
- California IOU's are ordered to provide plans by July 1, 2015 to "identify optimal locations for the deployment of distributed resources."
- Unlike New York, no specific order for retail markets has been made

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Review Vision for Effective Methods to Incorporate DER in Planning and Operations

Granular	• Capture location-specific system responses
Repeatable	• Approach can be replicated at all sites
Scalable	• Practical for full service area deployment
Transparent	• Clear and open methods for analysis
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Valuation of DER: Energy and Capacity

Andrew Mills

Lawrence Berkeley National Laboratory

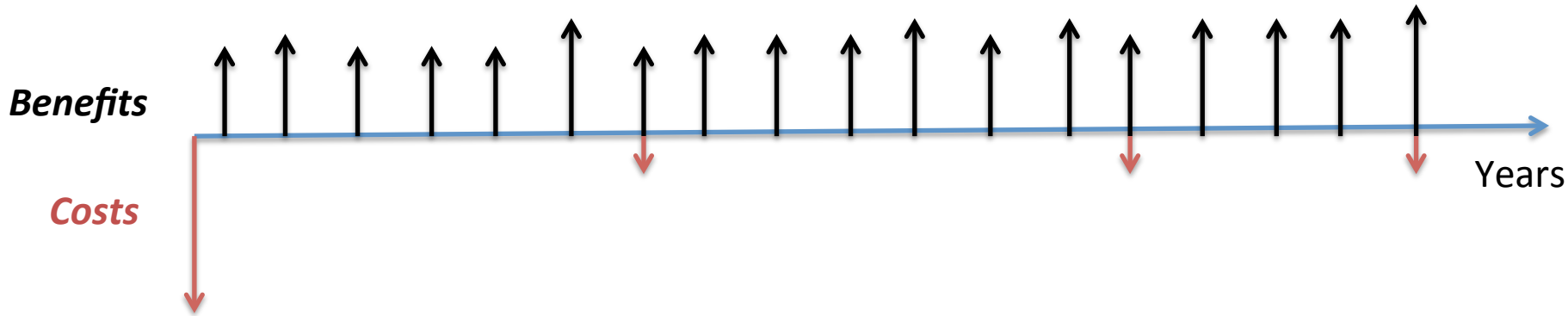
Kentucky's Distributed Energy Resources Workshop

April 15, 2015

Presentation overview

- Definitions
- Energy Value
  - Methods to calculate energy value
  - Fundamental Issues:
    - Developing profiles, identifying marginal units, projecting fuel prices and uncertainty
- Capacity Value
  - Methods to calculate capacity value
  - Fundamental Issues:
    - Developing profiles, identifying periods of high risk, translating to economic terms
- Overlap with other value categories
  - Separating energy value from capacity value and integration costs
  - Accounting for compliance cost impacts
  - Wholesale price reduction effects

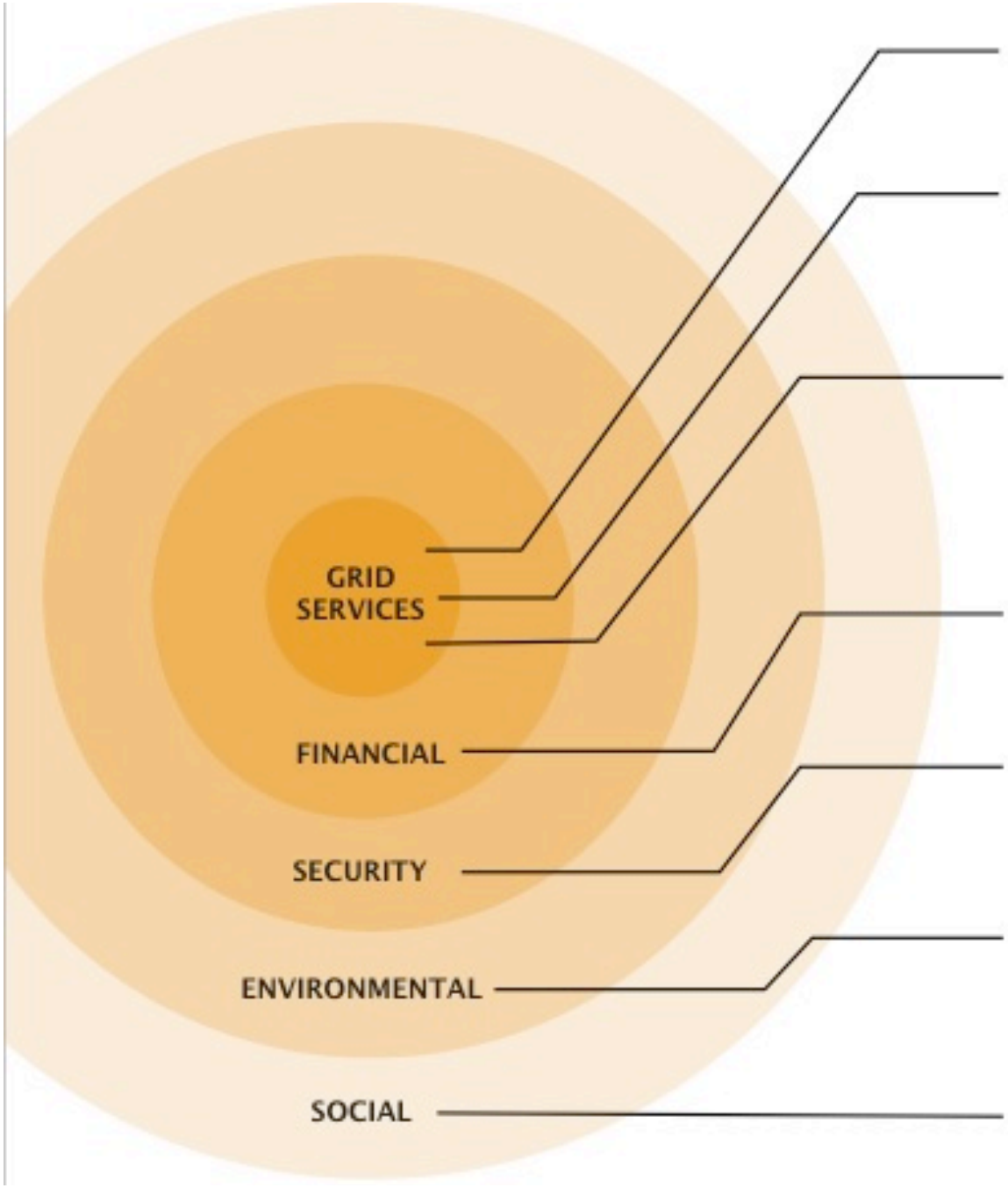
What do I mean by valuation of DER?



- Often refers to the benefits side of a cost-benefit analysis: How much would you be willing to pay to get a stream of future benefits?
- In many cases, valuation is synonymous with the concept of the "avoided costs" of DER
- PURPA provides helpful definitions:

"Avoided costs" means incremental costs to an electric utility of electric energy or capacity or both which, if not for the purchase from the qualifying facility, the utility would generate itself or purchase from another source.

Value categories from RMI review of PV benefit and cost studies



ENERGY
- energy
- energy losses

CAPACITY
- generation capacity
- transmission & distribution capacity
- DPV installed capacity

GRID SUPPORT SERVICES
- reactive supply & voltage control
- regulation & frequency response
- energy & generator imbalance
- synchronized & supplemental operating reserves
- scheduling, forecasting, and system control & dispatch

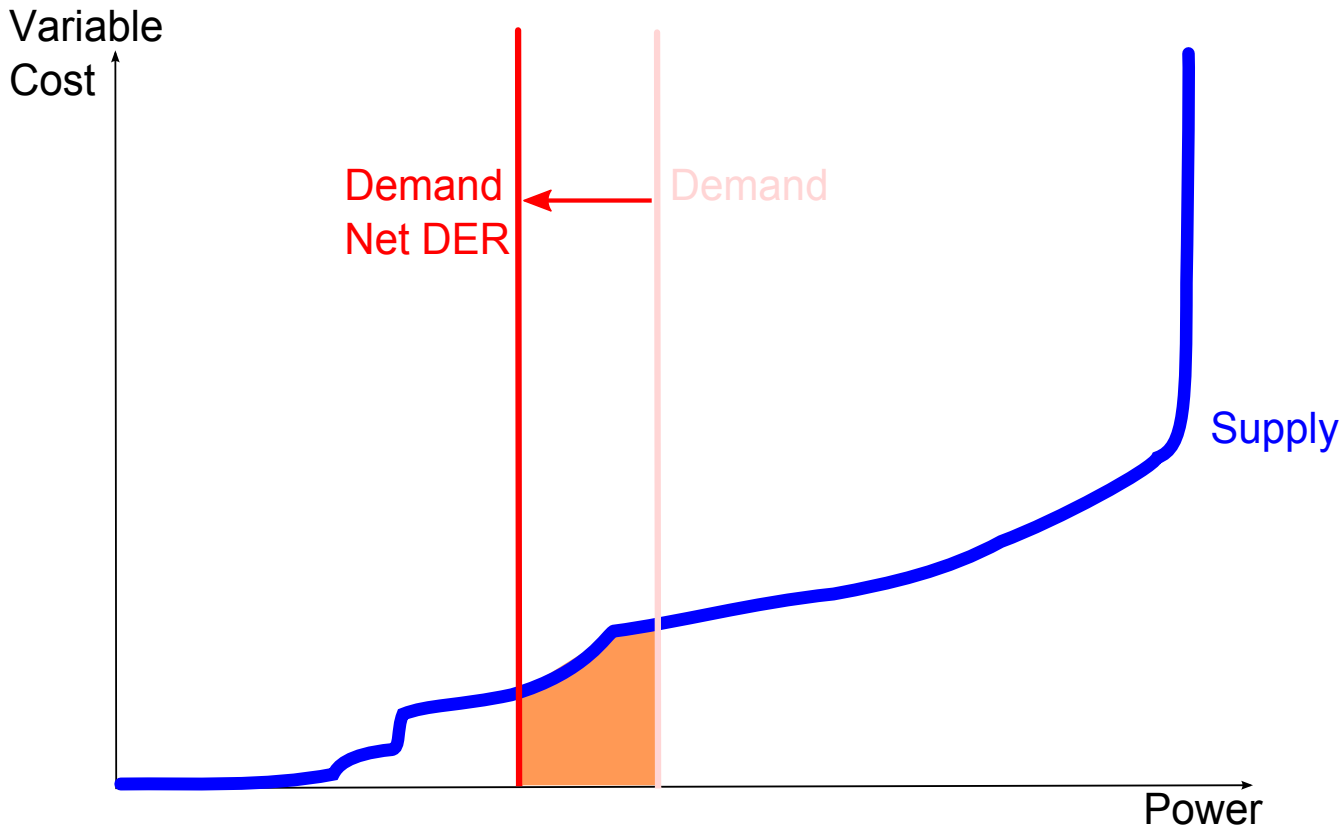
FINANCIAL RISK
- fuel price hedge
- market price response

SECURITY RISK
- reliability & resilience

ENVIRONMENTAL
- carbon emissions
- criteria air pollutants (SOx, NOx, PM10)
- water
- land

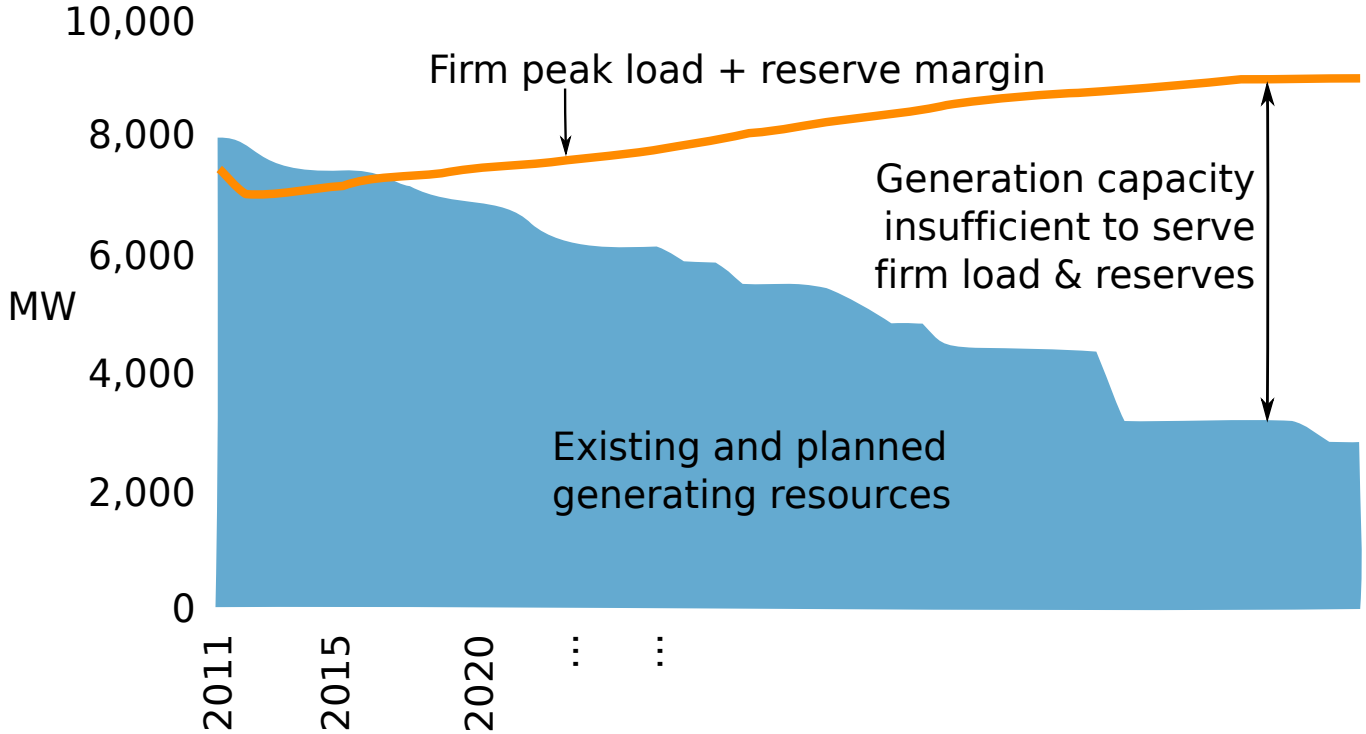
SOCIAL
- Economic development (jobs and tax revenues)

Understanding energy value



- Power systems are generally dispatched to minimize variable costs
- Dispatch plants up to the point that demand is met (marginal unit)
- Addition of DER reduces generation, which reduces variable costs
- With large DER share, increasingly lower cost units are displaced
- Complications: (1) some DERs shift electricity use (DR), or increase it (storage, EVs); (2) power system constraints can lead to curtailment

Understanding capacity value

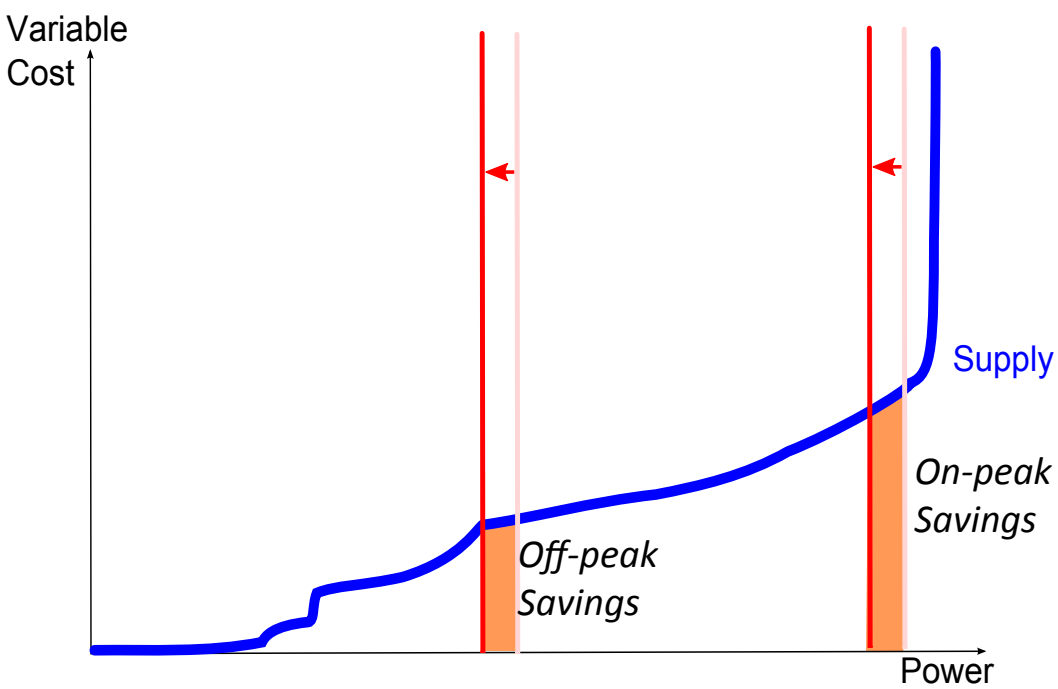


- Power systems require sufficient generation capacity to reliably meet demand
- New capacity is added as load grows, old units retire, or contracts expire
- DER contributes to adequacy, reducing the need to build other units
- With large DER share, incremental contribution to adequacy can decline
- Complications: (1) Standard methods are not well suited to energy-limited resources (e.g. storage, EVs) (2) Deliverability is important consideration for DER

Methods to calculate energy value

Three main questions / steps:

1. When is DER generating (or charging)?
2. What generation is displaced (or used) during those times (i.e. what is the marginal unit)?
   - Can all DER generation be used or is there a need for some curtailment?
3. What are the variable costs of the displaced generators?



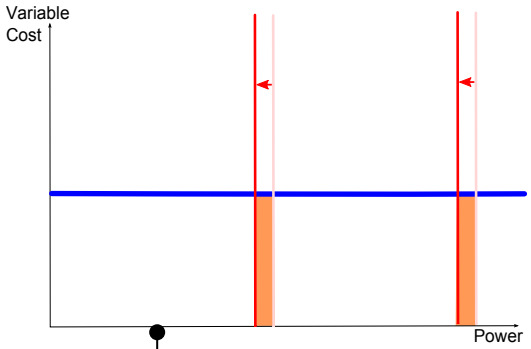
Energy Value of DPV from RMI Study:

Step #1: When is DER generating (or charging)?

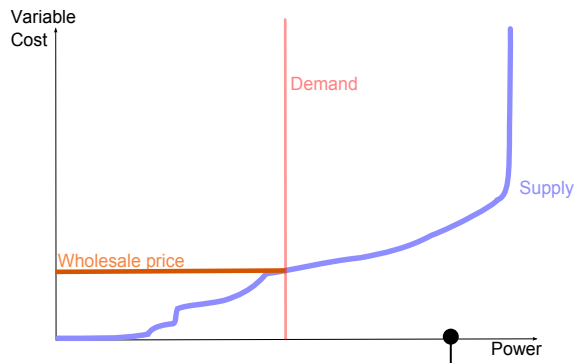
- Solar PV or distributed wind
  - Relatively straightforward to use historical meteorological data with location, type, size, and orientation of DER
- Demand response
  - Programs often designed to reduce demand during peak times
  - Does customer time-shift energy consumption (e.g. pre-cooling)? Is there a rebound (increase in energy post-event)?
- Electric vehicles
  - Customer preferences & infrastructure will dictate charging needs/availability
- Customer-sited storage
  - Is storage dispatched based on local retail rates?
  - Or is it dispatched based on local T&D needs?
  - Or is it dispatched based on bulk power system needs?
- Combined heat and power (CHP)
  - What processes drive dispatch of CHP units? Is it building/district heating? Industrial process? Do bulk power system needs impact dispatch?

Step #2: What generation is displaced (or used) and at what heat rate?

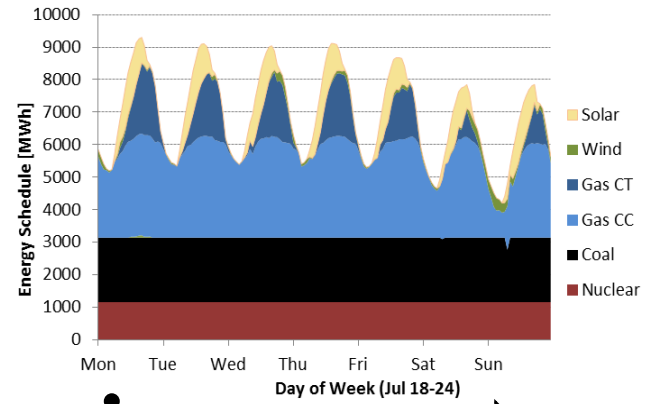
One type of unit always on the margin



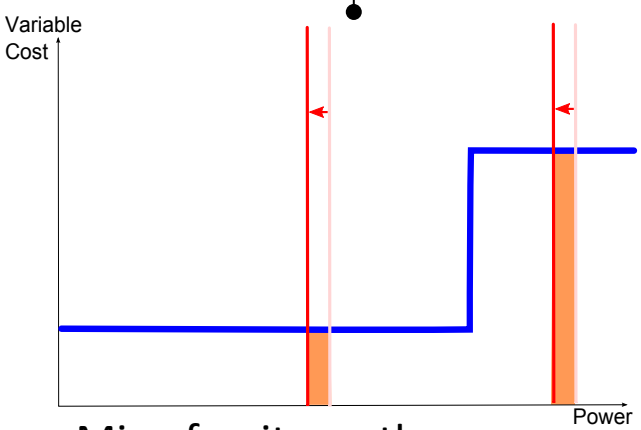
Historical marginal plant: wholesale prices, system lambdas, econometric methods



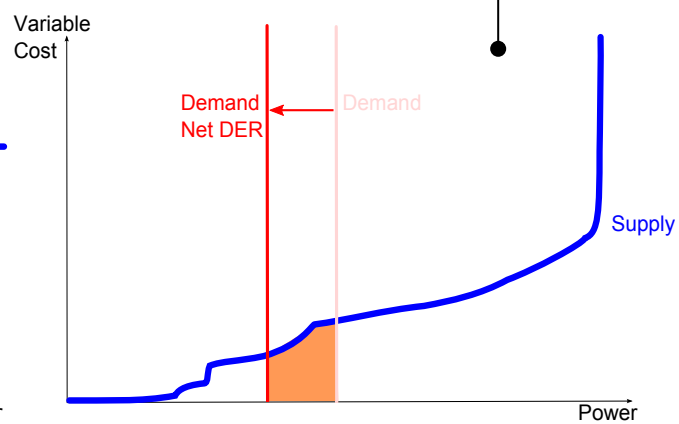
Production cost model: *static generation mix*



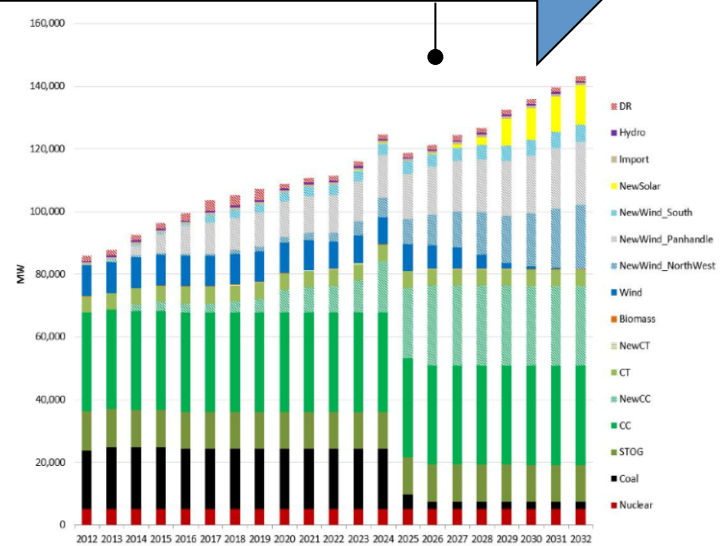
Increasing complexity of analysis



Mix of units on the margin, e.g. off-peak CCGT, on-peak CT



Simple merit-order dispatch



Production cost model: *dynamic generation mix*

Step #2b: Can all DER generation be used or is there a need for some curtailment?

- When the system is constrained, DER may need to be curtailed rather than displacing generation
  - Curtailed DER does not reduce variable costs
- Curtailment mostly occurs with low load and high shares of DER generation, and is magnified by:
  - Congestion: transmission and distribution constraints
  - Inflexibility in conventional generation: high startup and shut-down costs, long start times or minimum run times, high minimum generation levels for reliability or environmental reasons (e.g. minimum river flows for hydro)
- Only some of the previous methods can endogenously estimate curtailment needs

Step #3: What are the variable costs of marginal units?

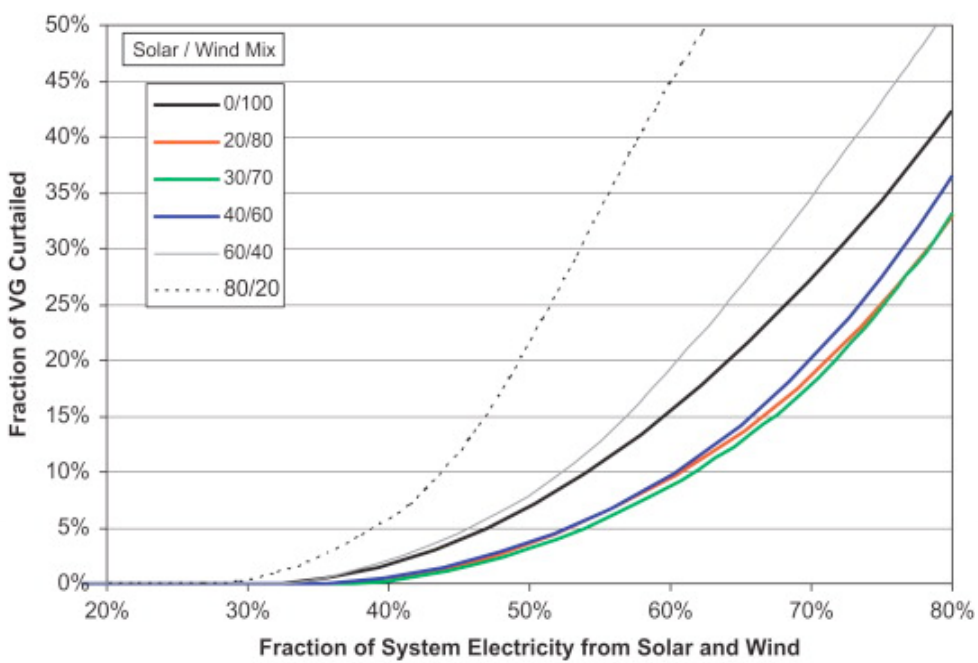
- Variable O&M costs are relatively small: can use data from EIA or others
- Fuel costs are large source of uncertainty and variation in estimates of energy value
- Estimates of energy value need to project variable costs over life of DER
- NYMEX futures and EIA AEO are common sources of fuel price forecasts

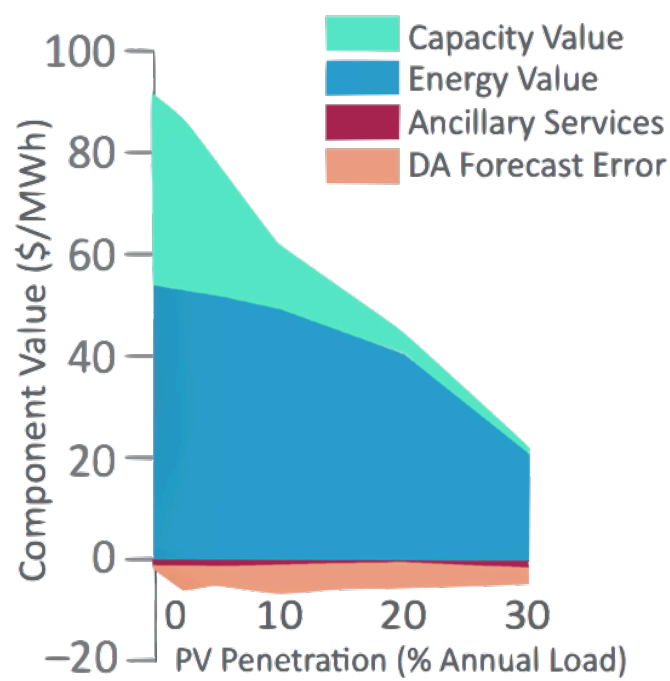
Fundamental Issue #1: DER output profiles

- Not a lot of experience and data for certain types of DERs
  - Solar and wind are among the most straight-forward
  - DR, electric vehicles, storage, CHP all more complicated
- Different assumptions for dispatch/availability can be both justifiable and lead to quite different results
  - e.g. different energy value if you assume storage will be dispatched to reduce customer peak demand charge vs. to minimize system costs
- Dispatch of DER can depend on penetration of other DER
  - e.g. storage dispatch to minimize system costs will be different with low PV vs. with high PV
- Only some of the methods for identifying marginal units can account for different / complicated DER profiles
  - Particularly important for net energy consuming technologies (e.g. storage, electric vehicles), and for DERs that can be dispatched

Fundamental Issue #2: Change in marginal units (& curtailment) with time, DER penetration, or footprint of analysis

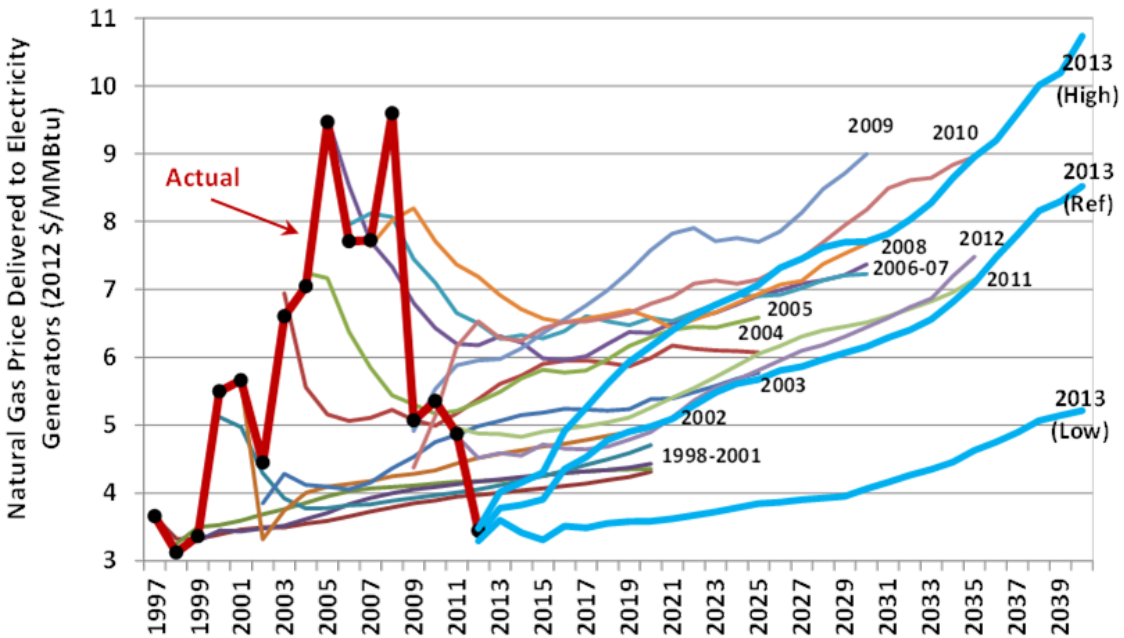
- Which units are on the margin depends on time, DER penetration, and interactions with neighboring regions; also affects curtailment
- Only some methods for estimating which units are displaced endogenously account for these changes, otherwise adjustments need to be made 'manually'
- Changes in marginal unit and curtailment with DER penetration can be important factors at high penetration, but have often been ignored in studies thus far





Fundamental Issue #3: Fuel cost projections and uncertainty

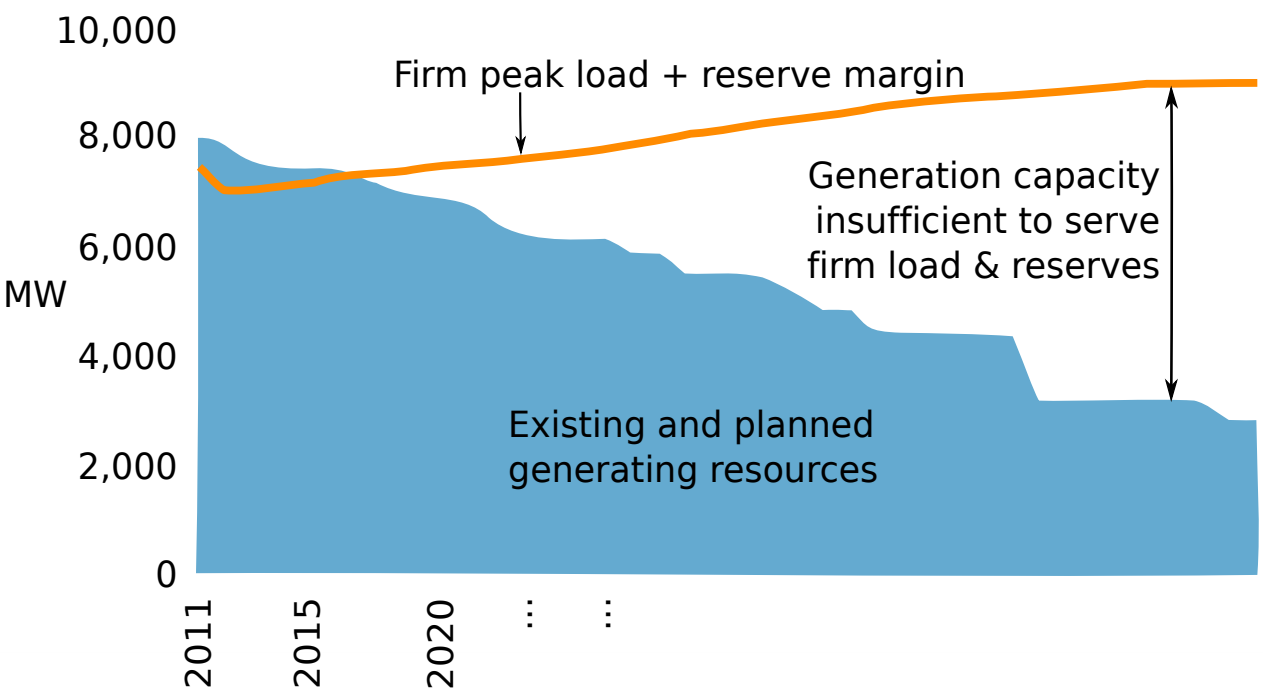
- Future fuel costs are uncertain – how is this addressed?
- Fuel costs vary by location and season – will these differences be the same in the future or do they reflect temporary constraints?
- Lack of fuel costs for some DERs implies overall exposure to fuel price volatility will be decreased (risk "hedge" value)
  - Is this a social benefit? Or does it only inure to the participant? How can it be calculated?



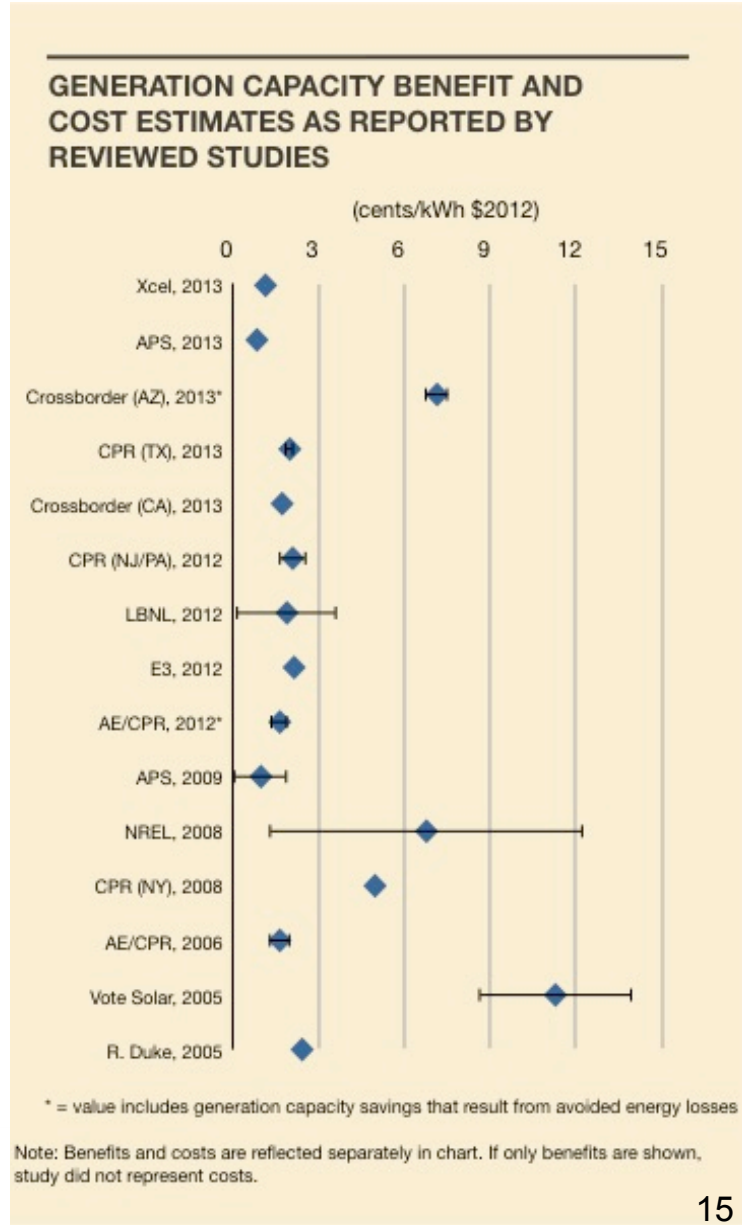
Methods to calculate capacity value

Two main questions / steps:

1. How much does DER contribute toward adequacy (i.e. what is the *capacity credit* of DER)?
2. How do you translate that contribution to a monetary value (i.e. what is the capacity value)?

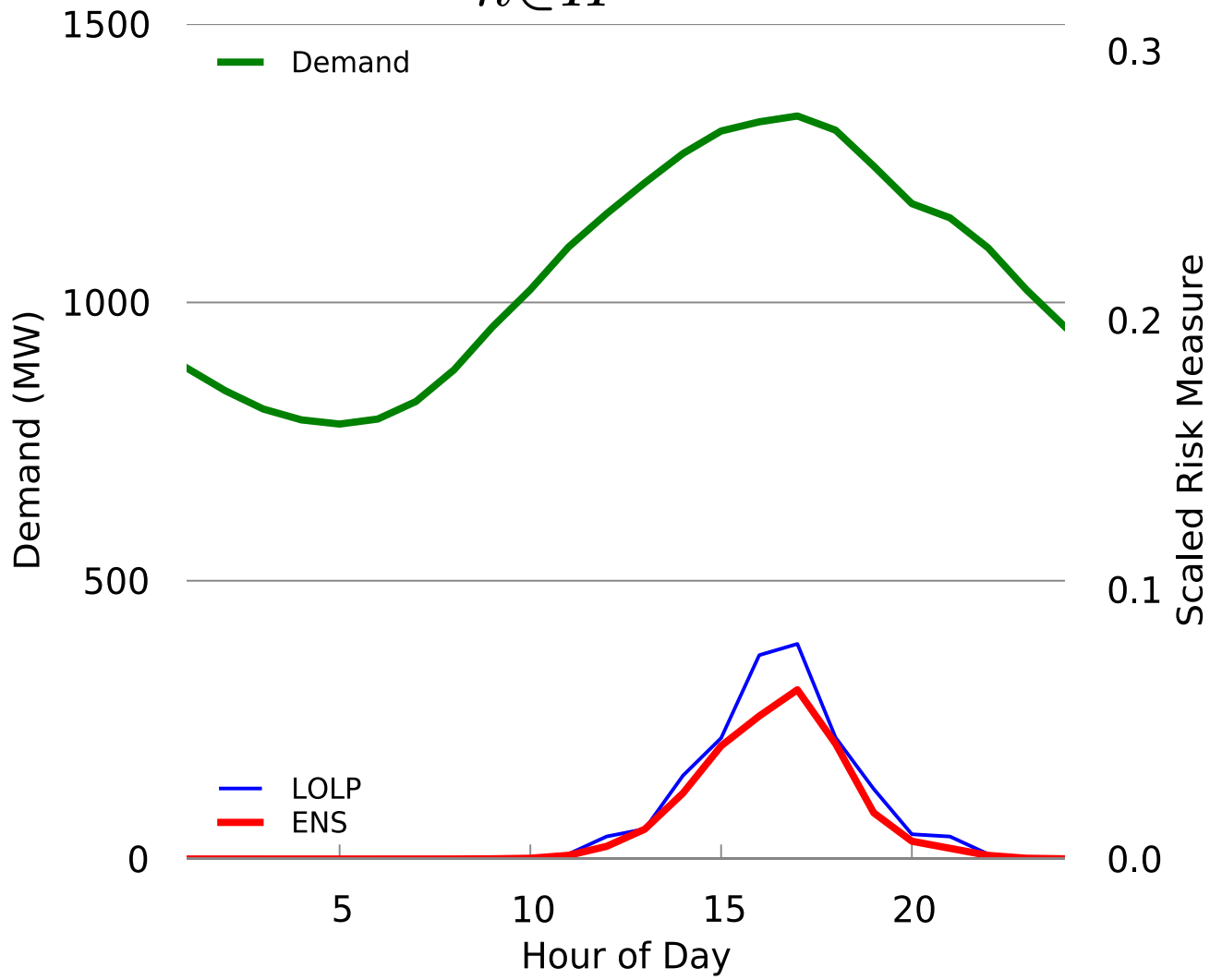


Capacity Value of DPV from RMI Study:

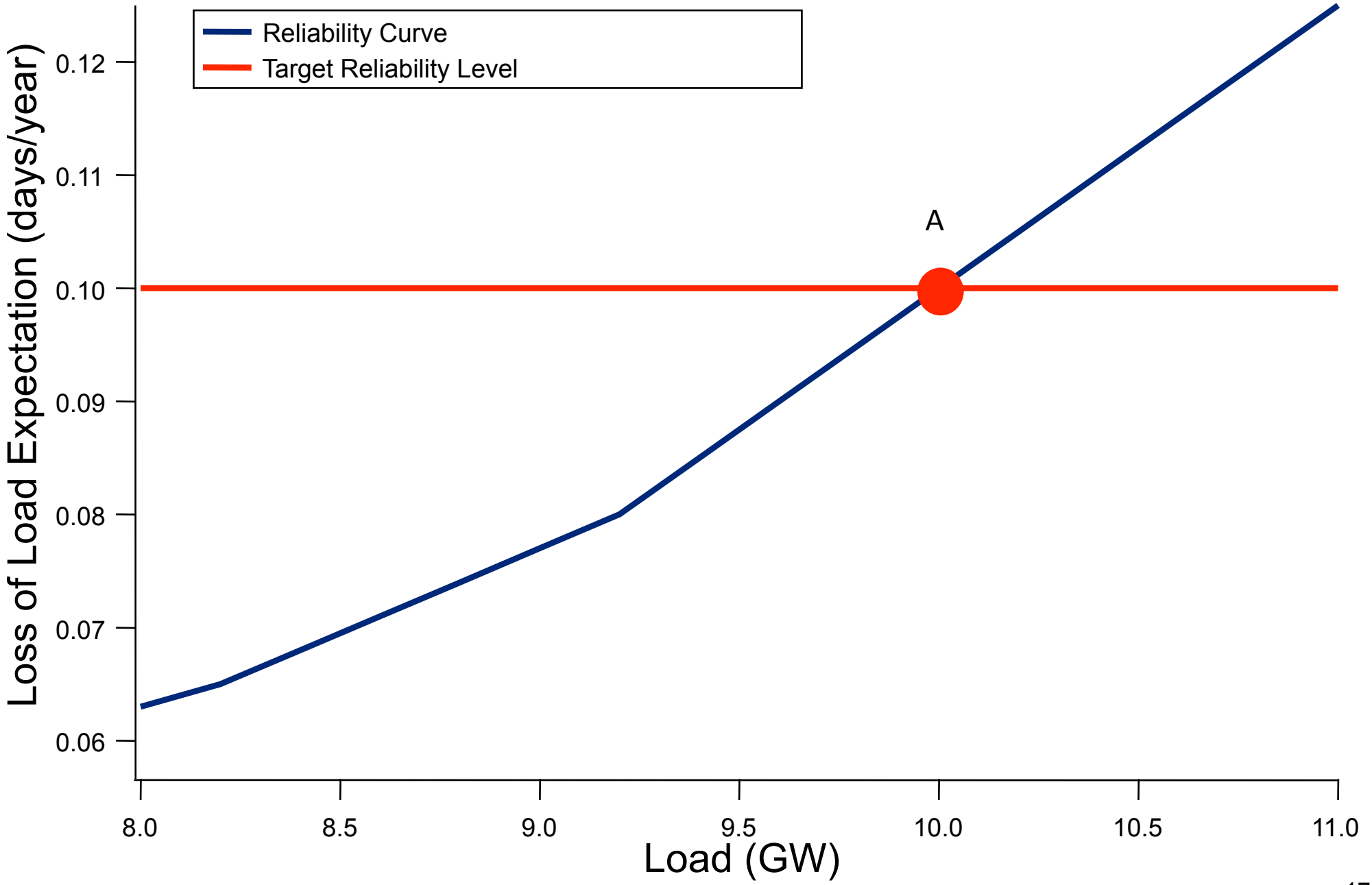


Resource adequacy maintains risk of unmet demand below a target level

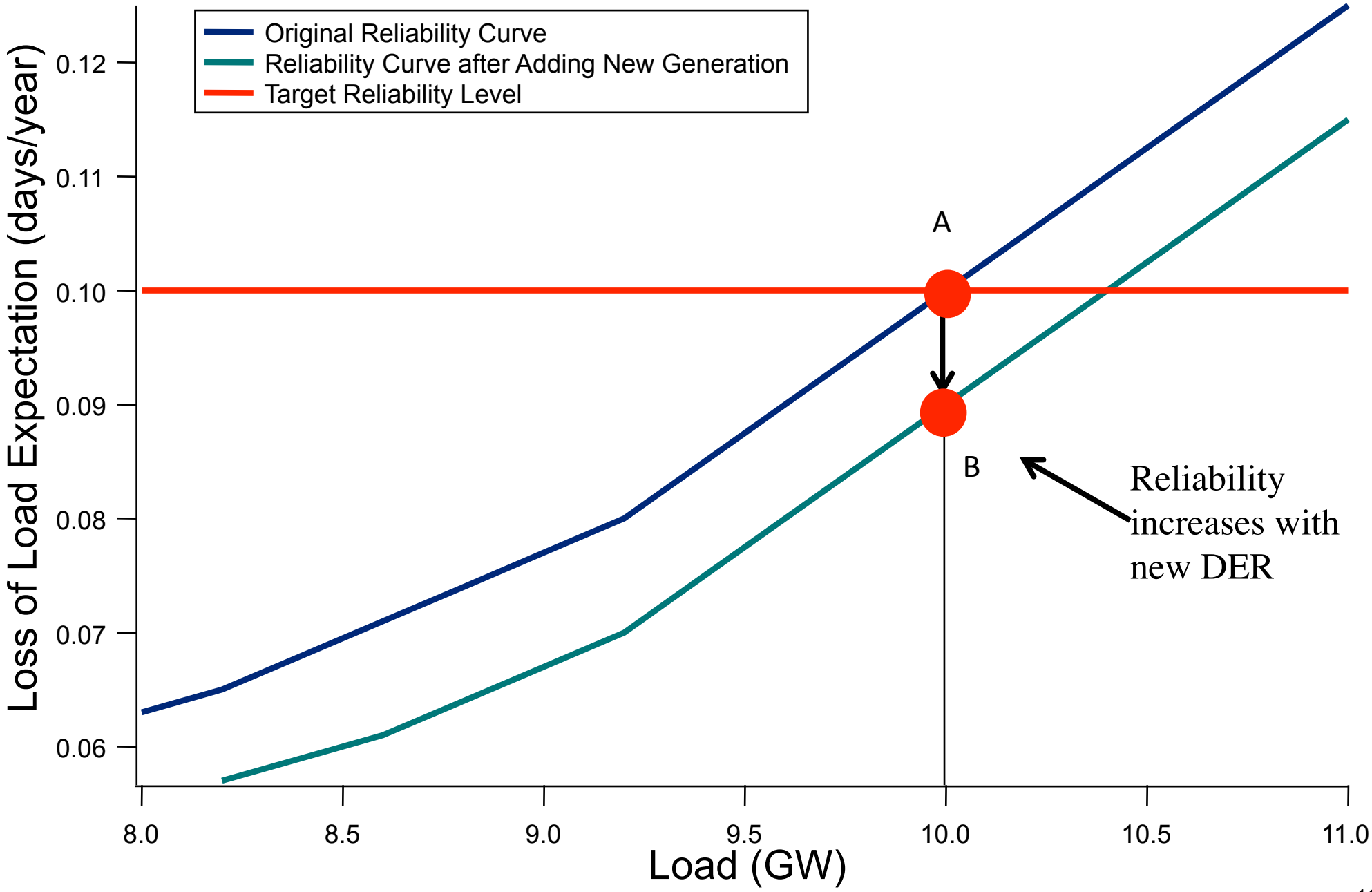
$$LOLE = \sum_{h \in H} P(D_h > G_h)$$



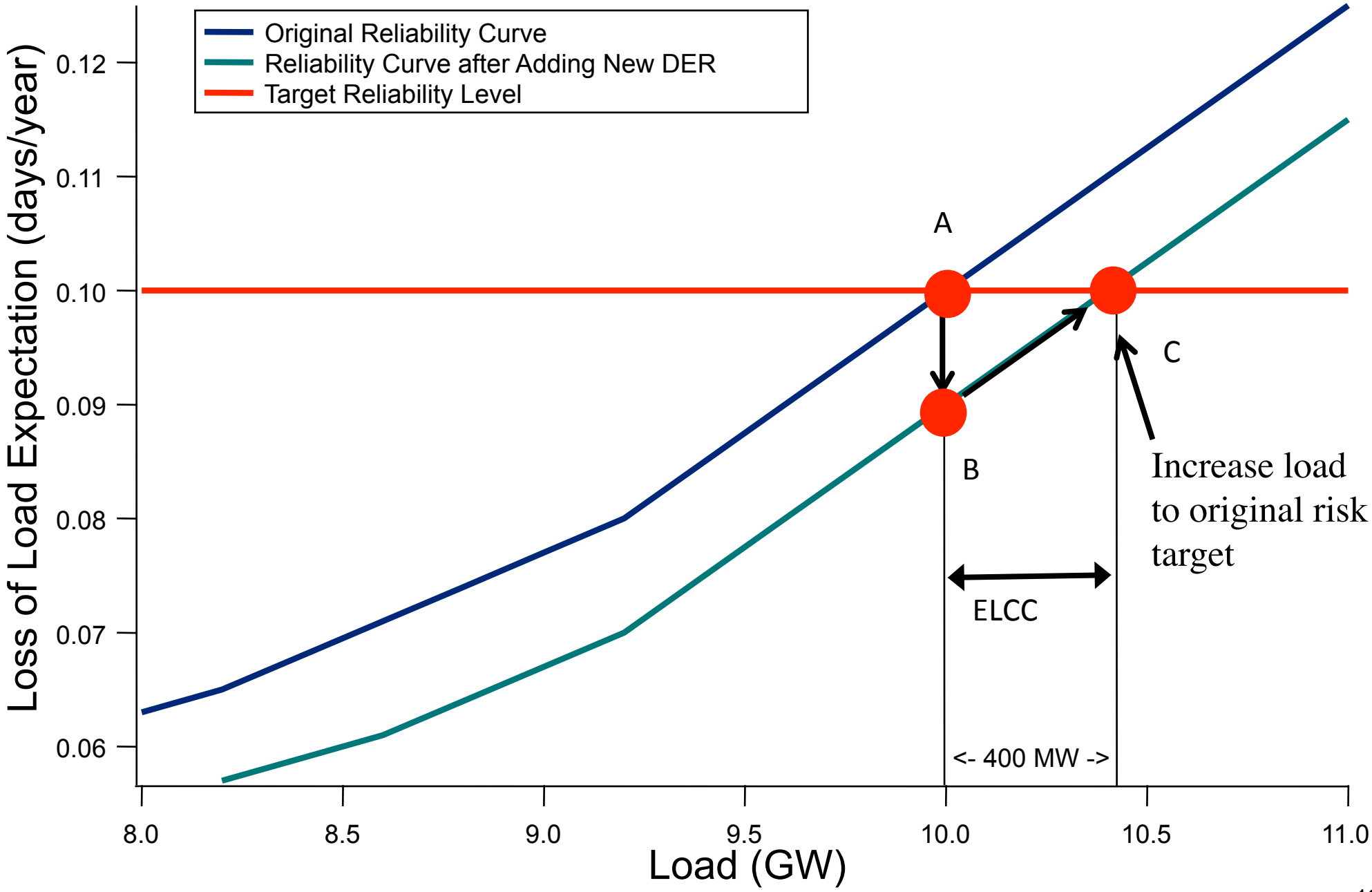
Reliability assessment: How reliable is the system for different levels of peak load?



Addition of DER lowers risk (LOLE) and increases reliability



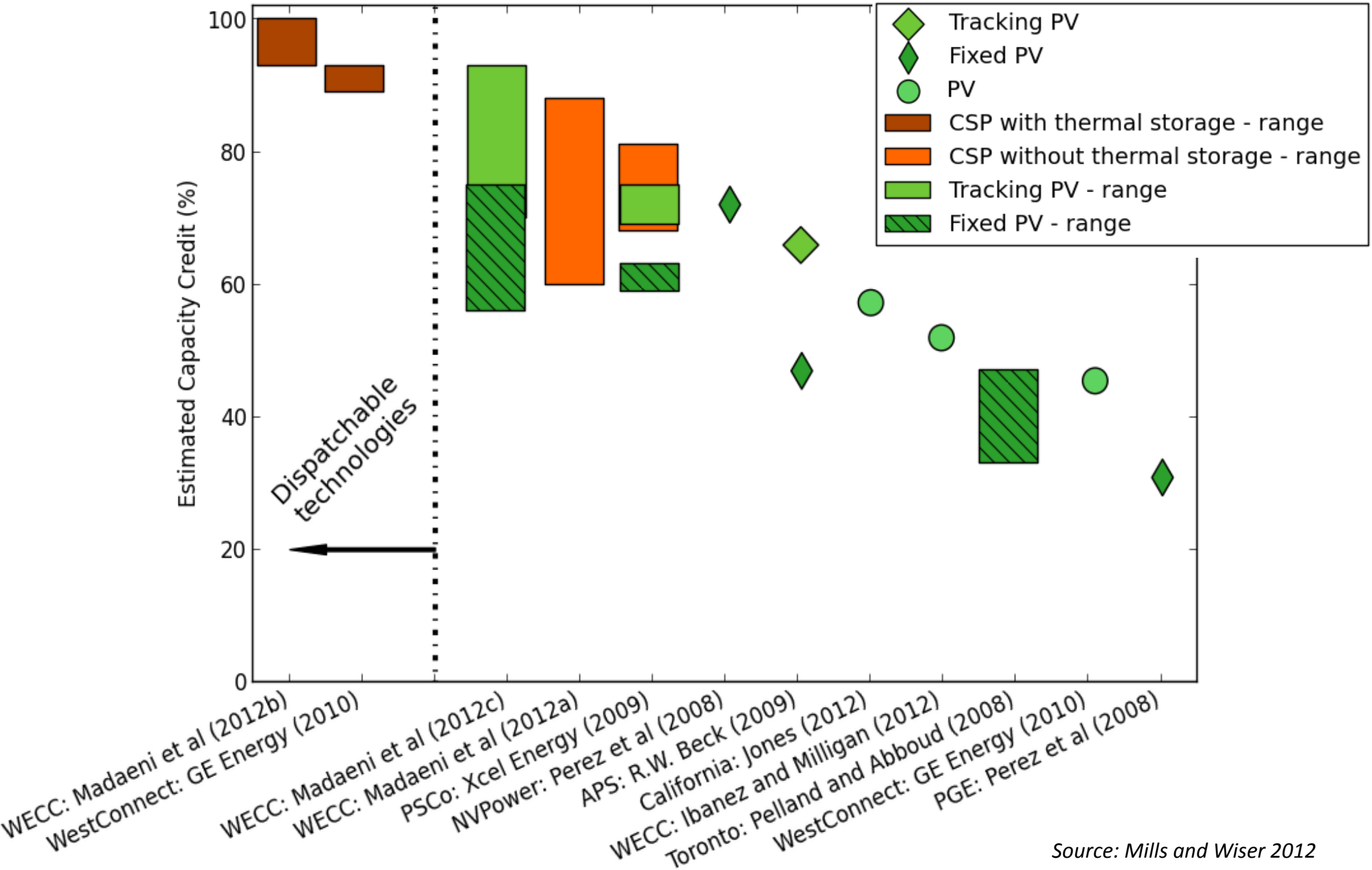
Effective Load Carrying Capability (ELCC): Increase in load to return to target level of reliability with DER



Reliability (ELCC) based approach

- How does ELCC work? Holds the system at constant annual risk level with/without the generator of interest (wind, solar, etc.)
- Utilizes reliability/production simulation model
  - Hourly loads
  - Generator characteristics
  - DER generation pattern (hourly for >= 1 year) time-synchronized with load
  - Calculates hourly LOLP (loss of load probability)
- The hourly LOLP calculation finds high-risk hours: risk can be caused by
  - Peak loads
  - Unit unavailability (planned maintenance)
  - Interchange and hydro schedules/availability
- Most hours/days have LOLP=0 so are discarded: only high-risk/peak hours remain in the calculation of ELCC
- Conventional units ELCC is function of FOR (forced outage rate)

Estimates of capacity credits for PV



Source: Mills and Wiser 2012

Methods to calculate capacity credit

Name	Description	Tools Required
Capacity factor approximation using net load	Examines output during periods of highest net demand	Spreadsheet
Capacity factor approximation using loss of load probability (LOLP)	Examines output during periods of highest LOLP	Spreadsheet
Effective load-carrying capacity (ELCC) approximation (Garver's Method)	Calculates an approximate ELCC using LOLPs in each period	Spreadsheet
Full Effective load-carrying capacity (ELCC) calculation	Performs full ELCC calculation using iterative LOLPs in each period	Dedicated tool

Capacity factor approximation methods

Basic Method:

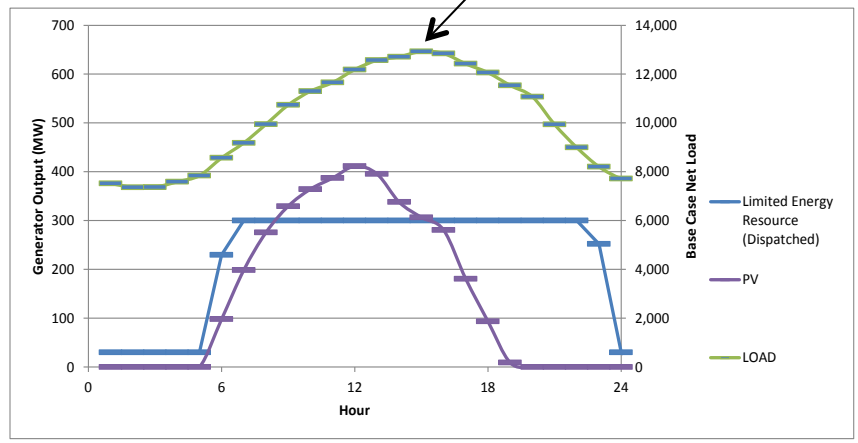
- Examine generator output/ capacity factor during periods of high net load or periods of highest risk
- Choice of peak period (top 100 hours, top 1% etc) can significantly influence results

Pros/Cons

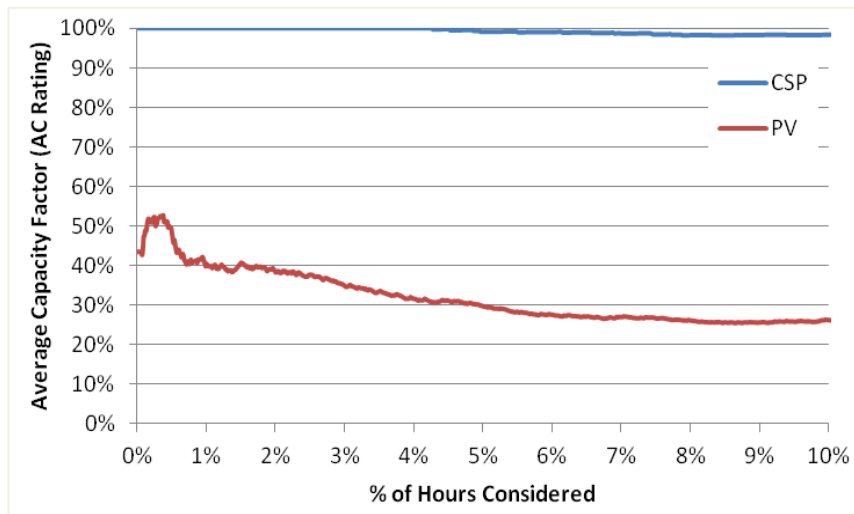
- Very easy, useful for rough estimates
- Requirements are only load, DER profiles and a spreadsheet
- Still somewhat common although decreasingly so…

Simple Example

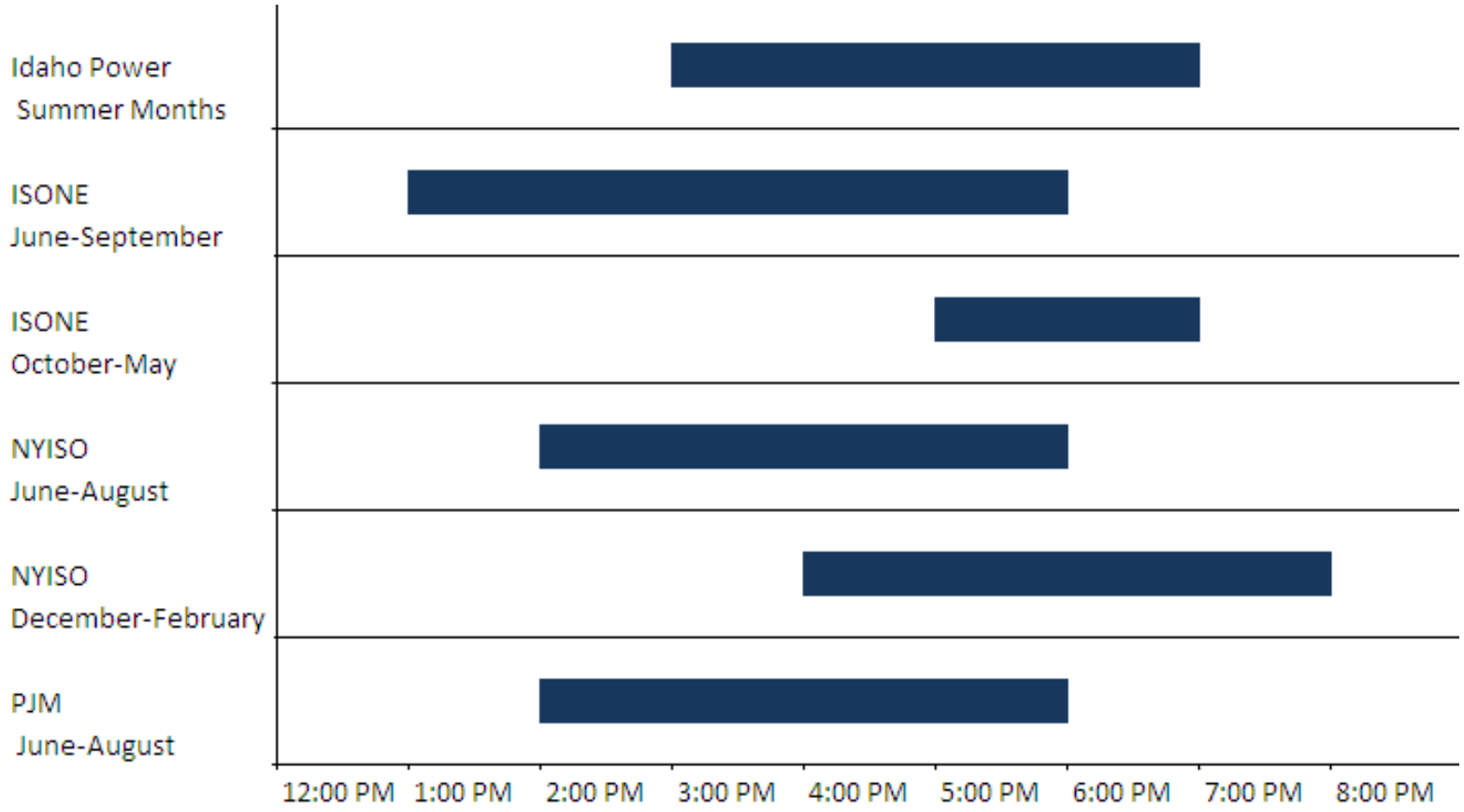
Peak Hour on this day



But period examined is important



Examples of peak periods used in capacity factor approximation methods in the United States

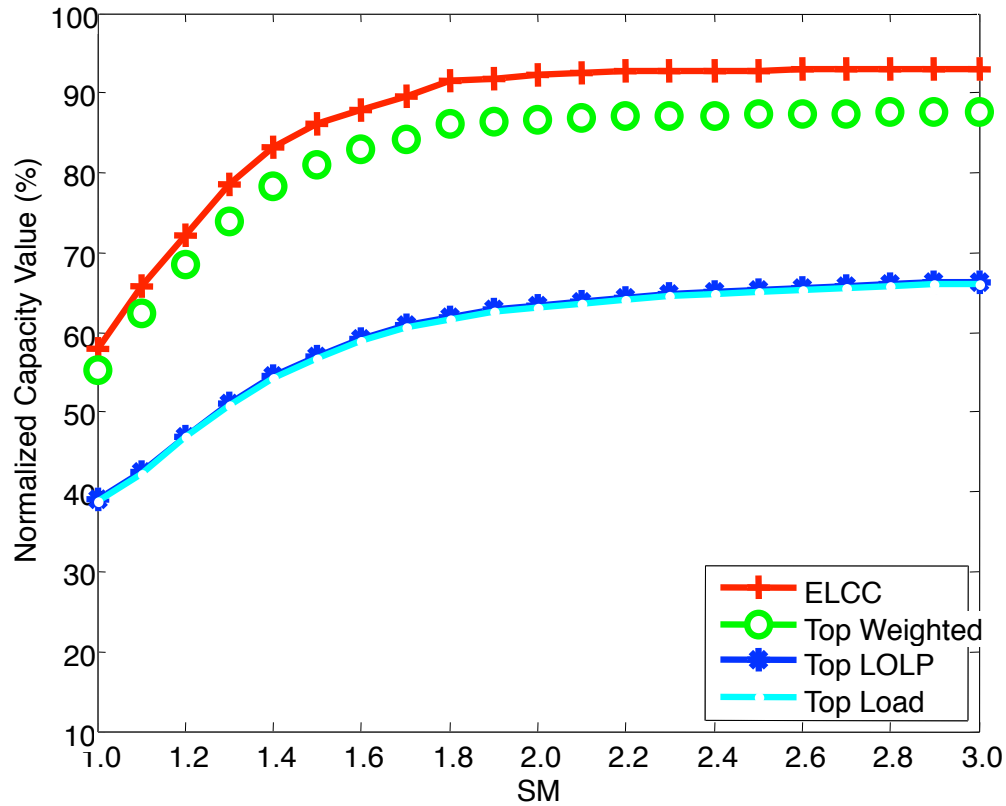


Rogers and Porter (2012), "Summary of Time Period-Based and Other Approximation Methods for Determining the Capacity Value of Wind and Solar in the United States." NREL Subcontract report. Available at http://www.nrel.gov/docs/fy12osti/54338.pdf

Capacity factor approximation methods may not fully measure contribution to resource adequacy

- DER generation-load relationship is only part of the equation
- Capacity factor, even during peak periods, won't capture annual risk profile
- Improvement is to use CF during period of high risk (high LOLP periods)
- All CF based approaches are inherently limited

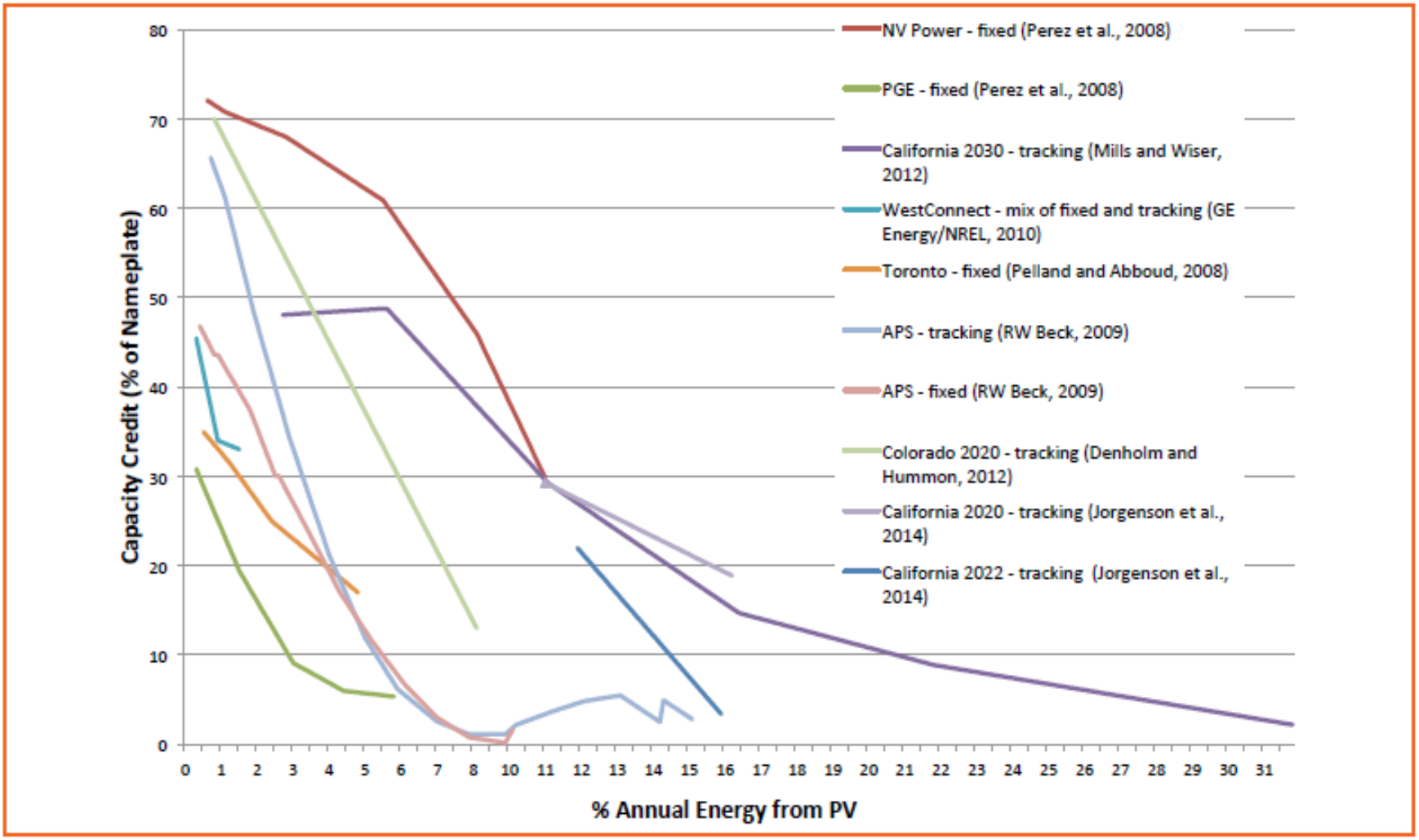
Comparison of Capacity Factor Methods for CSP with Increasing Levels of Storage



Step #2: Translating capacity credit to monetary value

Name	Description	Tools Required
Simple avoided generator (CT)	Assumes DG avoids construction of a new CT	None
Weighted avoided generator	Assumes DG avoids a mix of generators based on avoided fuel	None
Capacity market value	Uses cost of capacity in restructured markets	None
Screening curve	Uses system load and generation data to estimate avoided generation mix based on capacity factor	Spreadsheet
Complete valuation of DER versus alternative technologies	Estimates the type or mix of generators avoided in subsequent years using a capacity-expansion model	Detailed capacity-expansion model

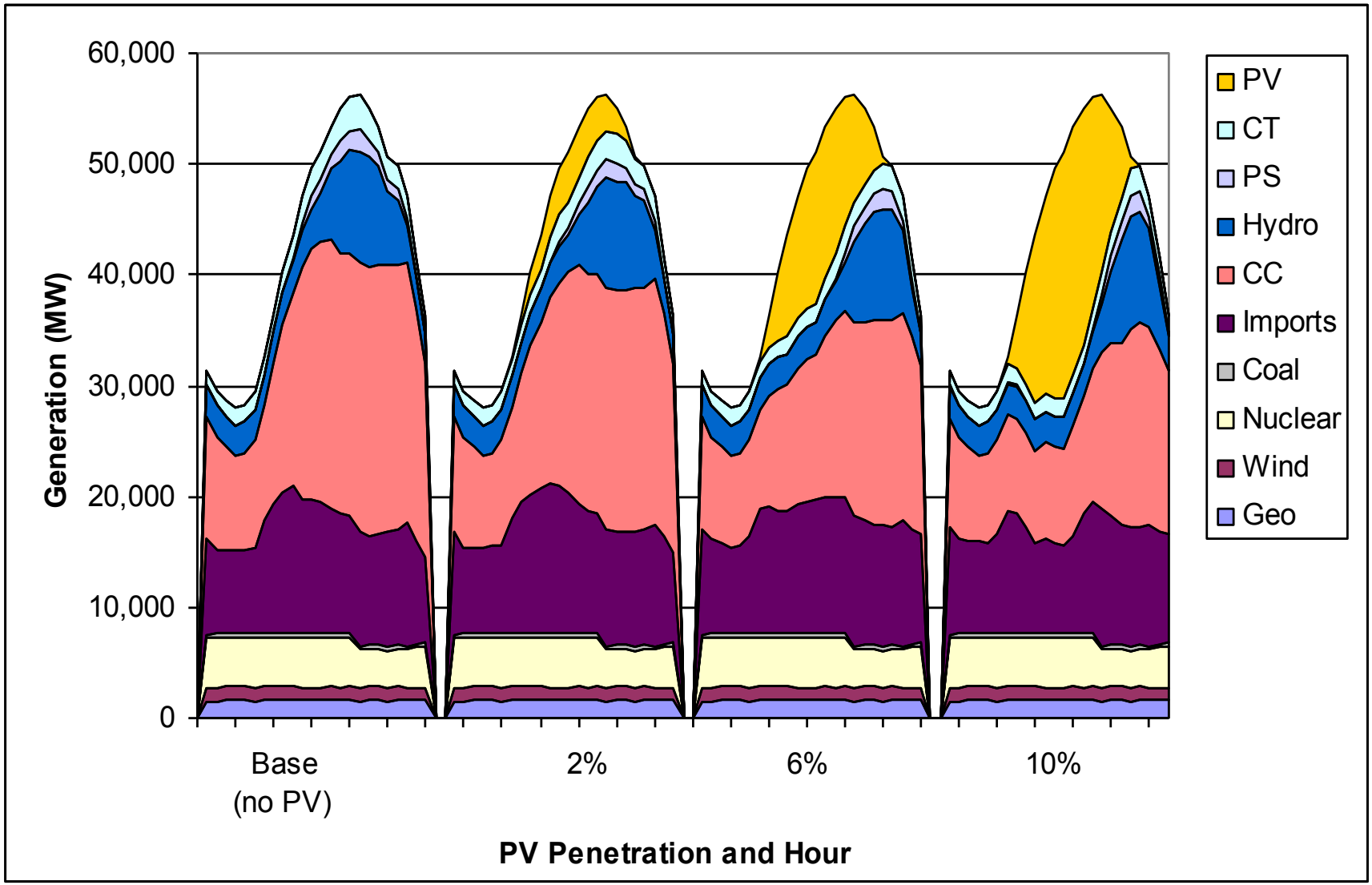
Capacity value depends on level of penetration



Source: Mills and Wiser (2012); adapted with additional results in Helman (2014).

Most studies indicate that by 10% energy penetration capacity credit and capacity value of DG PV is very low

Potential interactions between DERs



Here PV narrows the peak, which could ease the ability of demand response, hydro, storage, etc. to provide capacity. But it also shifts the timing of the peak into the early evening.

Additional issues for capacity value

- Fundamental relationship between weather and solar/ wind profiles means need for multiple years of data/ analysis
- Transmission – capacity sharing would impact DER capacity value
- As penetration of DERs increases, could see interactions between technologies.
- ELCC addresses the issue of sufficient planning reserves—is there a need for a flexibility assessment?
  - Consider ramping needs over relevant time scales
  - Contribution of various sources of flexibility (including DER control)
  - Probabilistic assessment of system ramping capability (effective ramping capability)

Overlap Issue #1: Separating energy value from capacity value and integration costs

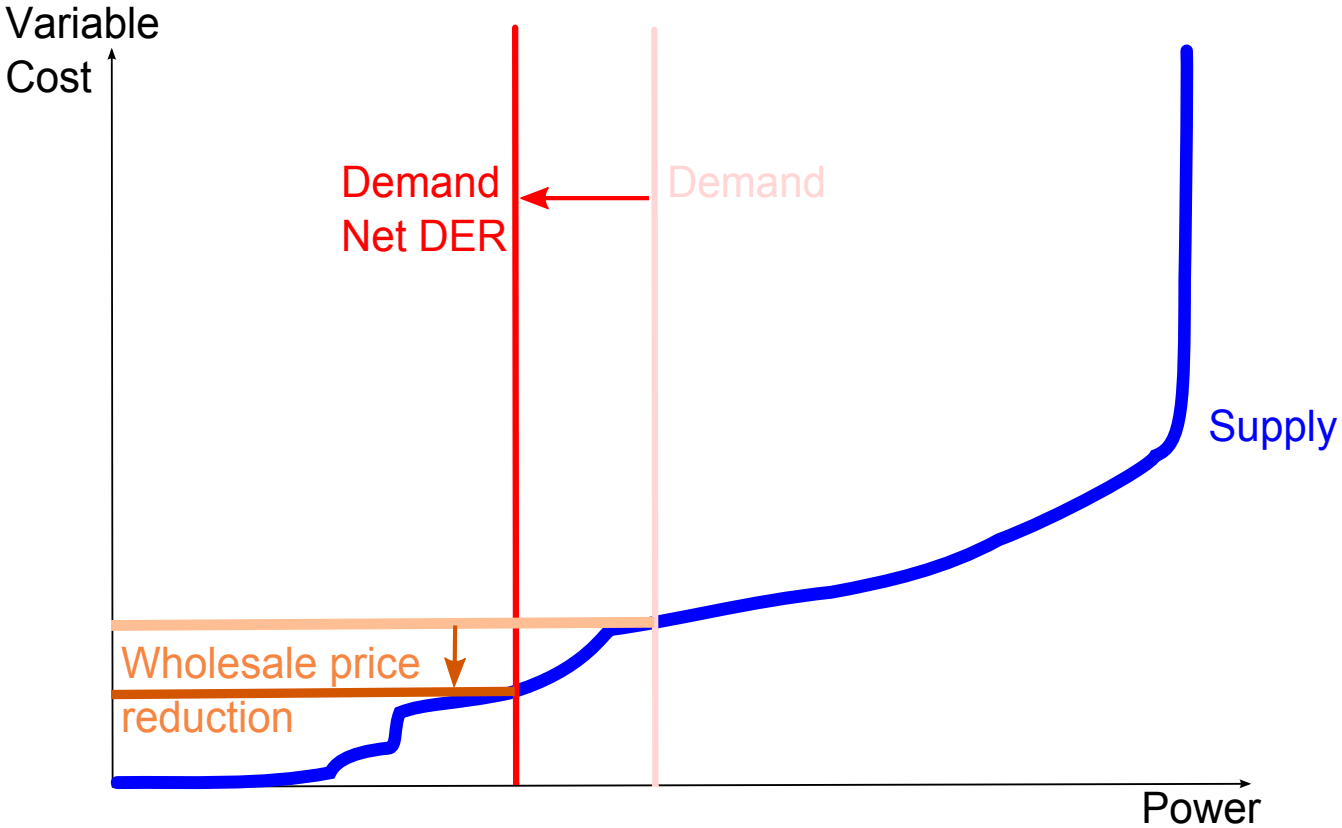
- When wholesale prices are used to estimate energy value, one needs to be careful not to "double count" capacity value
  - Wholesale prices can sometimes exceed variable costs of generators (scarcity prices)
  - High prices in the energy market may reduce capacity market prices
- To some degree wholesale prices and production cost models embed costs associated with "integration"
  - Part-load heat rates and startup costs are often included in production cost models
  - Wholesale prices may reflect opportunity costs related to shutdown or ramping
  - Again this requires careful consideration of what costs and benefits are included and in what category

Overlap Issue #2: Accounting for compliance cost savings

- Wholesale prices, system lambdas, and production cost models may already include costs associated with criteria pollutants (e.g. NOx or SOx permit prices)
  - Be careful not to double count with social costs, but also recognize that permit prices may not reflect true social cost
- RPS compliance cost savings
  - DERs can sometimes reduce retail sales, which reduces absolute amount of renewable energy needed to meet RPS based on fraction of retail sales
  - Some DERs may also produce RECs that count toward RPS compliance, thereby offsetting alternative REC purchases
- GHG compliance cost savings
  - Some DERs may help meet current or future GHG goals or regulations
- These values can be considered part of energy value, can be considered part of social costs and benefits, or might be considered separately altogether

Overlap Issue #3: Wholesale electricity price reduction ("merit-order") effects

- Addition of DER can lower wholesale energy and capacity prices
- Clear benefit to consumers that purchase power in wholesale markets, but…
  - Is this a social benefit or just a transfer from producers to consumers?
  - How long does this effect persist? Is it permanent or temporary?



Summary of Key Points

- Steps to address energy and capacity value:
  - When is DER generating (or charging)?
  - What generation is displaced (or used) during those times?
    - Does any of the DER need to be curtailed instead of used to displace generation?
  - What are the variable costs of those generators?
  - What is the capacity credit of DER?
  - What is the cost of capacity?
- Fundamental issues in answering these questions:
  - Developing profiles for DER resources
  - Dependence of marginal units and curtailment on time, DER penetration, and footprint of analysis
  - Fuel cost projections and uncertainty
  - Capacity credit is not a static number
- Overlap with other categories
  - Separating energy value from capacity value and integration costs
  - Accounting for compliance cost savings
  - Wholesale price reduction effects

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Download all of the original presentations from the U.S. DOE workshop on valuing DER:

http://energy.gov/oe/downloads/estimating-benefits-and-costs-distributed-energy-technologies-workshop-agenda-and

Energy Storage for the Electric Grid

State of Energy Storage and Assessment of Value

Ben Kaun
Sr. Project Manager

DEDI DER Workshop
4-15-15

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Goals for Presentation

- Provide an overview on the development of grid-connected energy storage and its drivers

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Overview of Energy Storage

Roles, Key Issues, and Drivers

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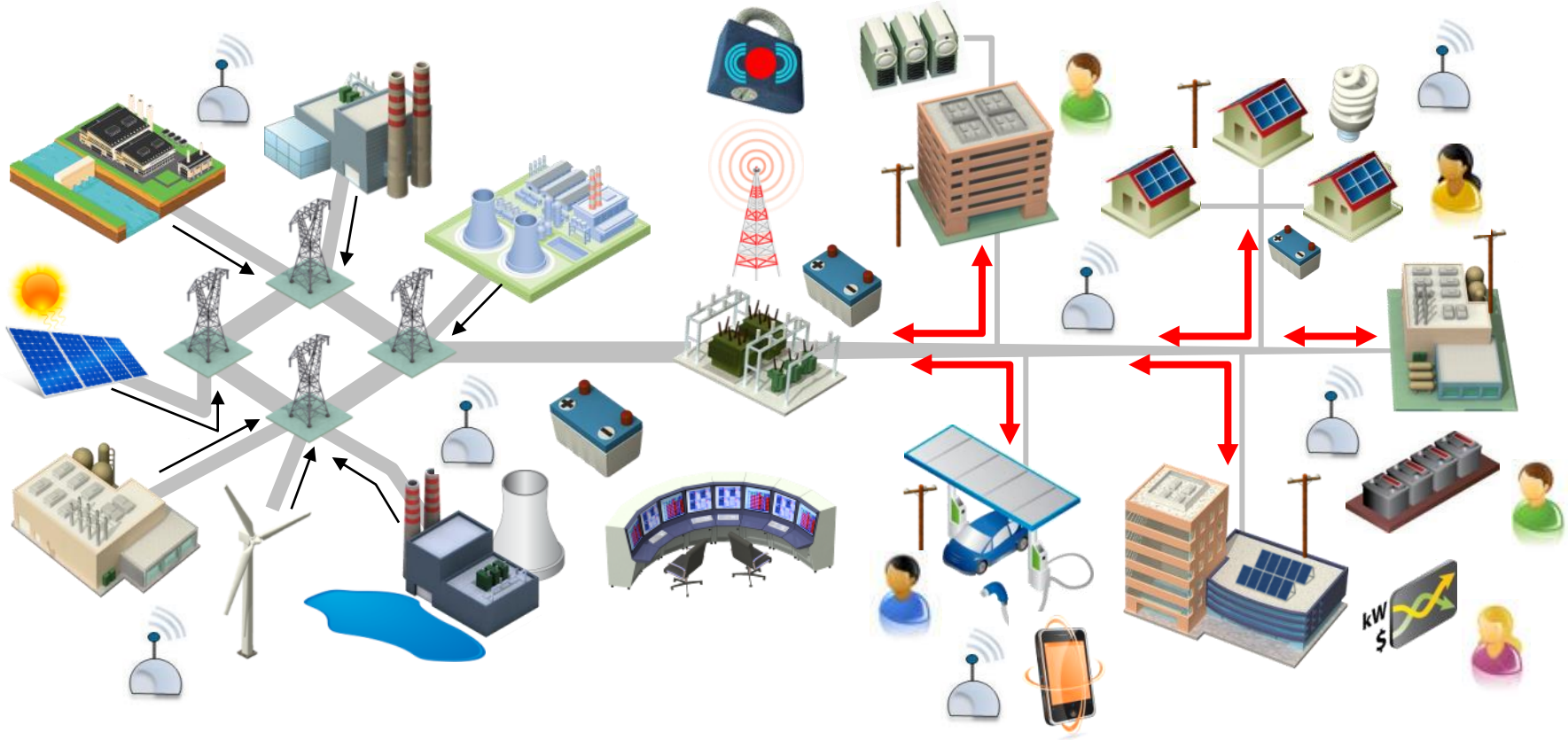
Transformation of the Power System



An Integrated Power System that Optimizes Energy Resources

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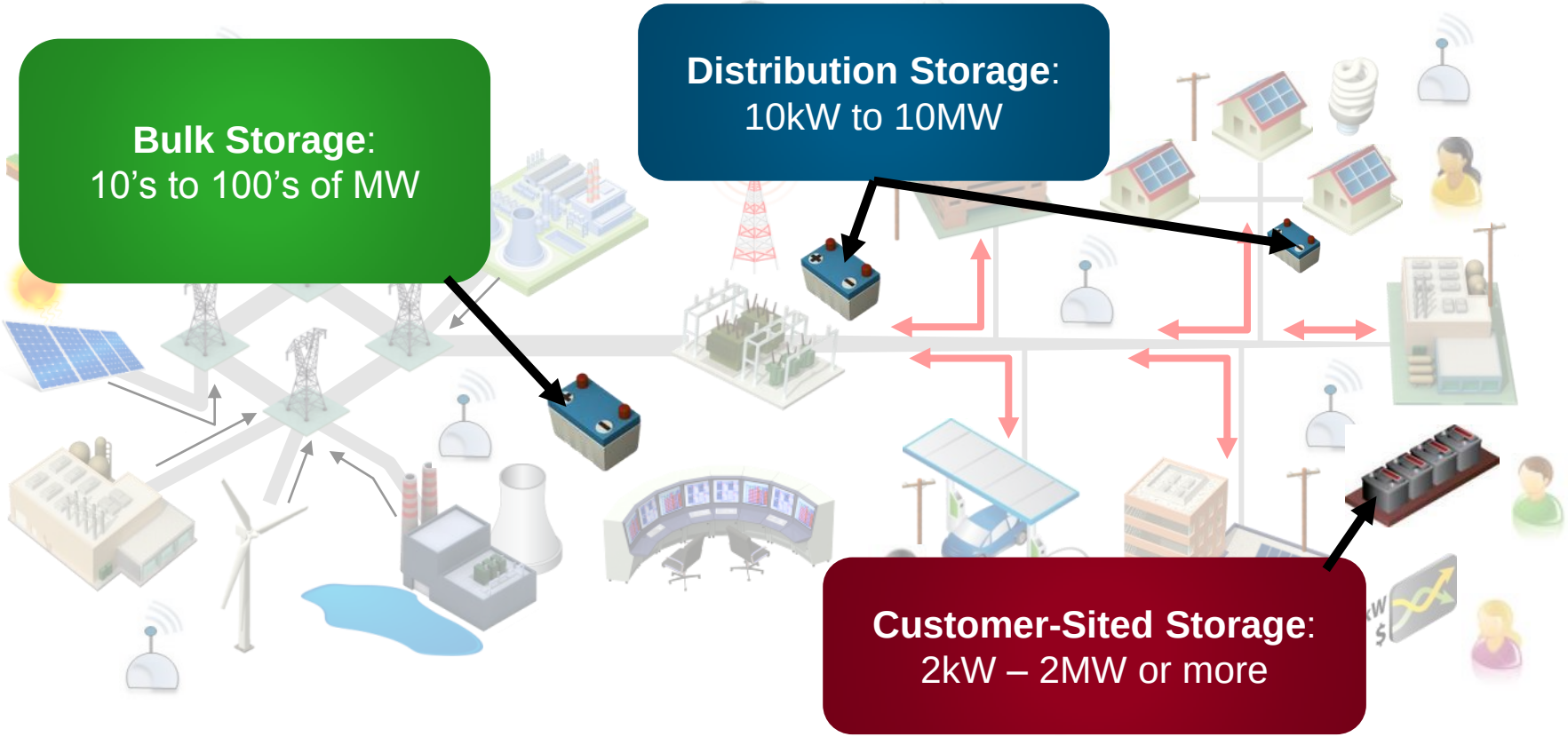
Transformation of the Power System



Energy storage can play different roles by location and size

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Potential roles of energy storage

- **Capacity Resource**: Provide peak demand support to avoid or defer building new traditional G, T, and D assets

- **Flexibility Resource**: System ramping, dynamic voltage control; support higher renewable penetration

- **Reliability / Resiliency Resource:** Provide temporary local power for outages

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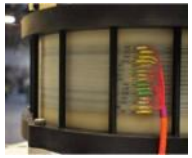
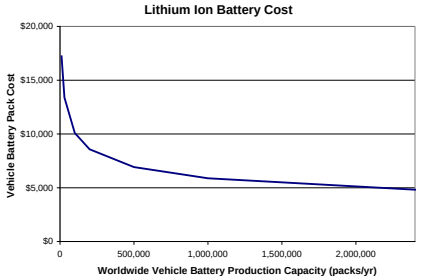
The historical challenges are fading

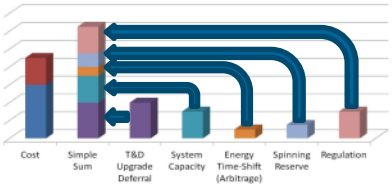
- Technical challenges
  - Performance
  - Life
  - Efficiency
- Economic Challenges
  - High Costs
  - Small Value Streams
- Regulatory Challenges
  - Lack of clear definition
  - Framework designed for existing grid



Advanced Technologies



Lower costs



New Business Models

Regulatory Rulings

Policy Action

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The industry is maturing…

- Storage is now part of a much bigger ecosystem
  - Small startups have grown large
  - Large multinationals are entering and investing billions in research and development
  - Technology is driven by consumer electronics and information industry

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Policy makers have also begun to weigh in…

- New storage legislation coming about in Germany, Japan, South Korea, Ontario, California, Puerto Rico, New York, New Jersey…
  - Most storage legislation creates incentives for customer-side storage
  - California has mandated 1.325 GW of utility energy storage by 2020

- FERC Rulings 755, 784, 792 open new doors for storage in electricity markets

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…but challenges to widespread deployment remain

- Tools for understanding the value and grid impacts of storage are still in development
- Grid-ready technology solutions are the exception, not the rule
- Grid deployment, integration, and operation of storage are still major unknowns

Industry players are racing to find solutions to these research questions

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Energy Storage Technologies

Options, Development, and Trends

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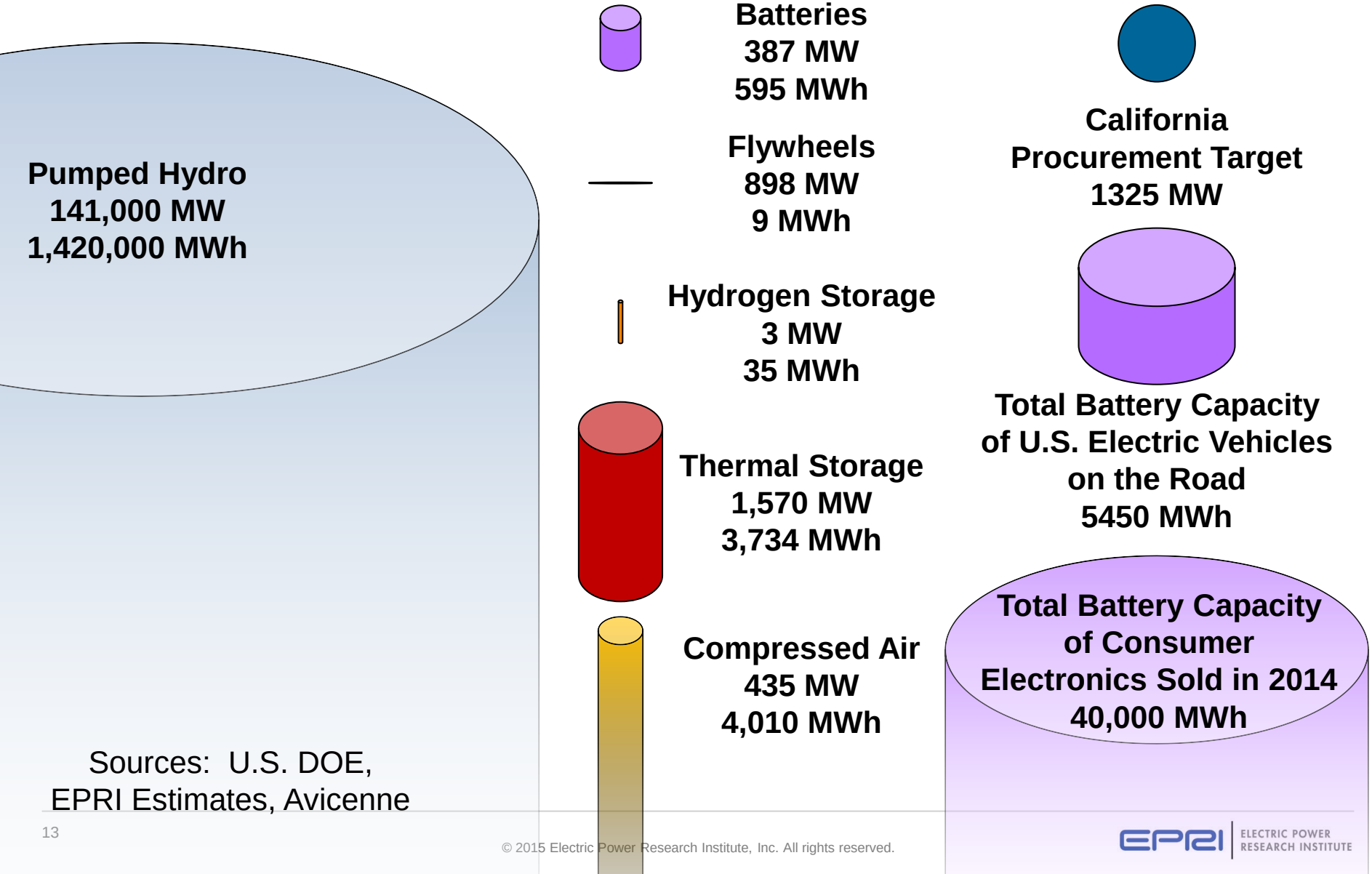
Total Deployed Grid Storage Worldwide, July 2014



Sources: U.S. DOE, EPRI Estimates, Avicenne

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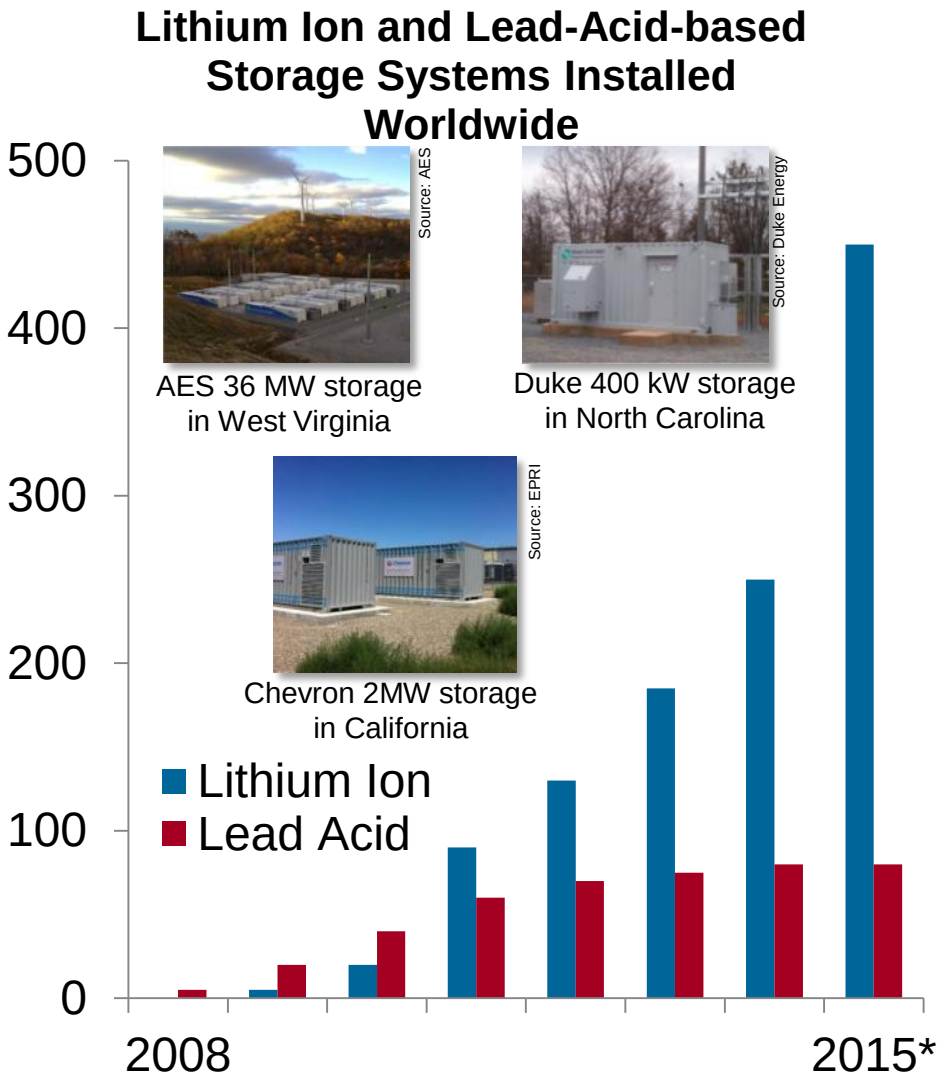
Deployment of stationary storage continues

- Investment in storage continues, particularly in lithium ion products for ancillary services
- Utilities are exploring options at the transmission and distribution level

5 MW battery storage system at PGE's Salem Smart Power Center

- Some developers are installing systems on the customer side of the meter



Source: U.S. DOE, EPRI Estimates

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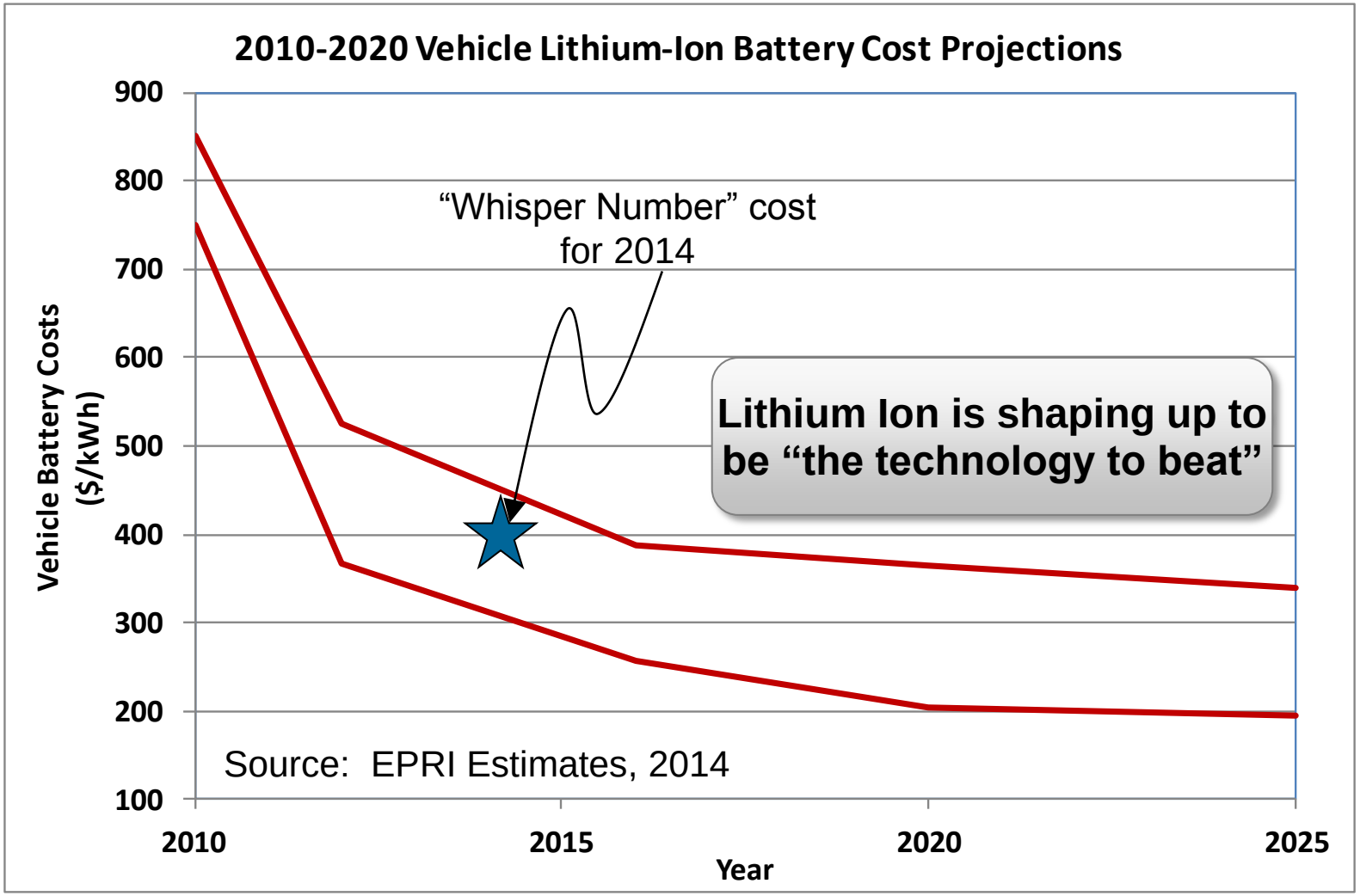
Lithium ion costs continue to fall…



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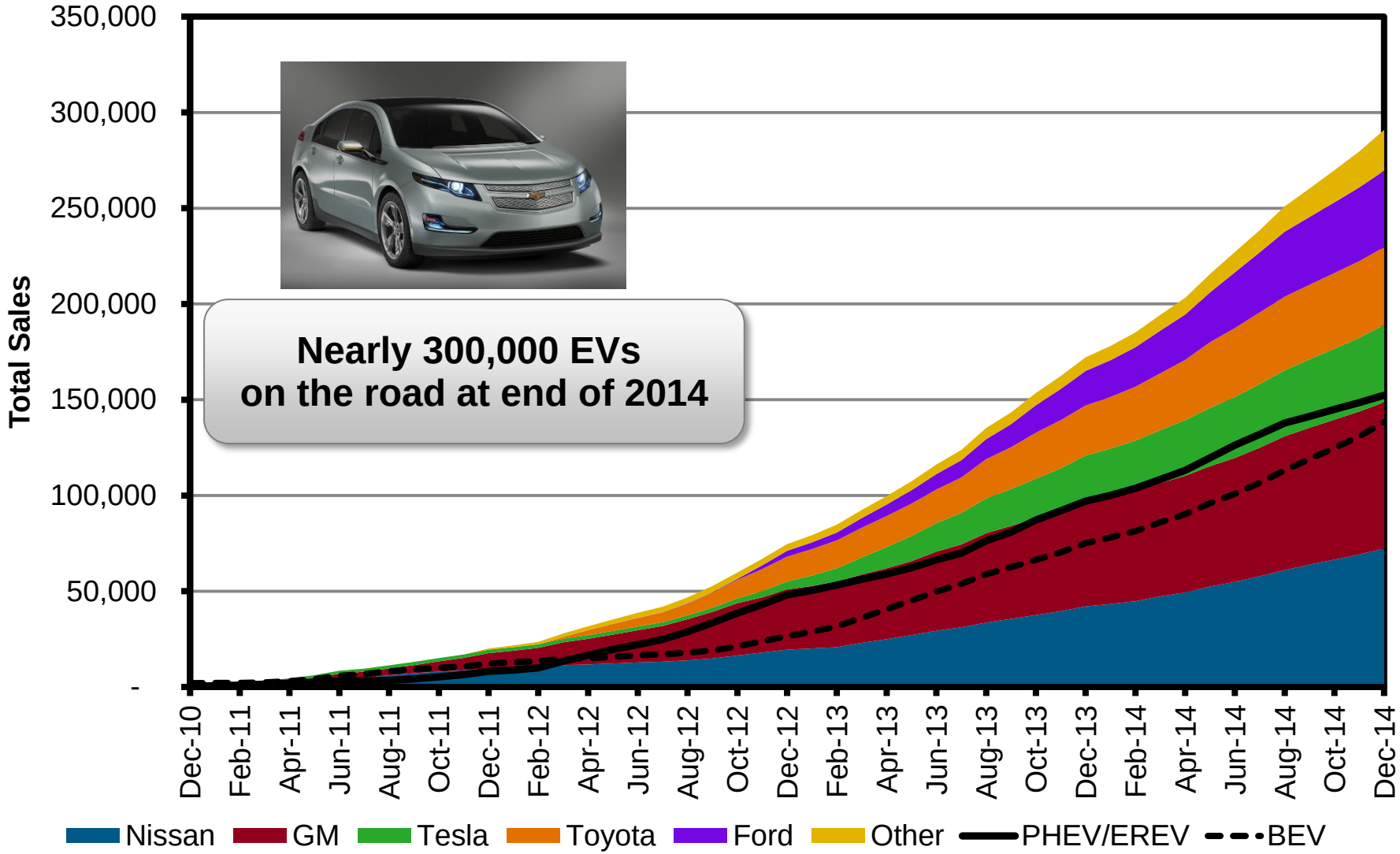
…driven by expanding vehicle markets



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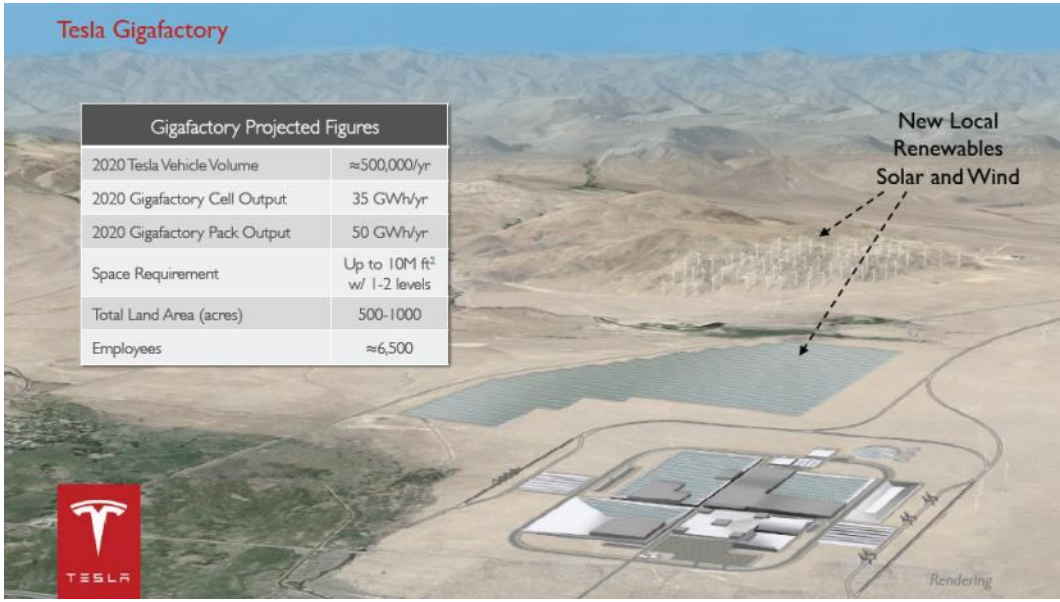
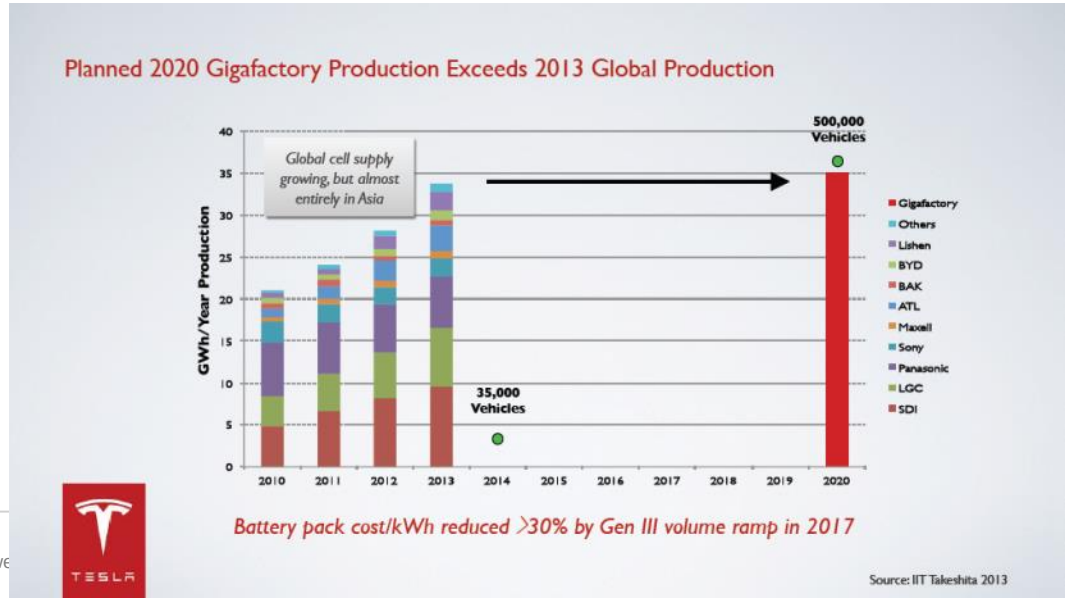
Tesla's Gigafactory – further cost reduction?

- Tesla is building plant to push further cost reduction
- Scale is dependent on vehicle *and* stationary markets
- Tesla is not alone in investing in capacity!





Source: Tesla Motors

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Will other technologies be viable?

- Lithium ion is compelling but has some weak spots
  - Cost for long-duration is still quite expensive
  - At very large scale, becomes bulky and potentially dangerous
  - Material costs and lifetime become issues
- More scalable technologies eventually could become more compelling
  - Flow batteries
  - Aqueous intercalation
  - Compressed air
  - Hydrogen (eventually)

Vanadium Redox Battery Stacks

Sodium Ion Battery (courtesy Aquion, Inc.)

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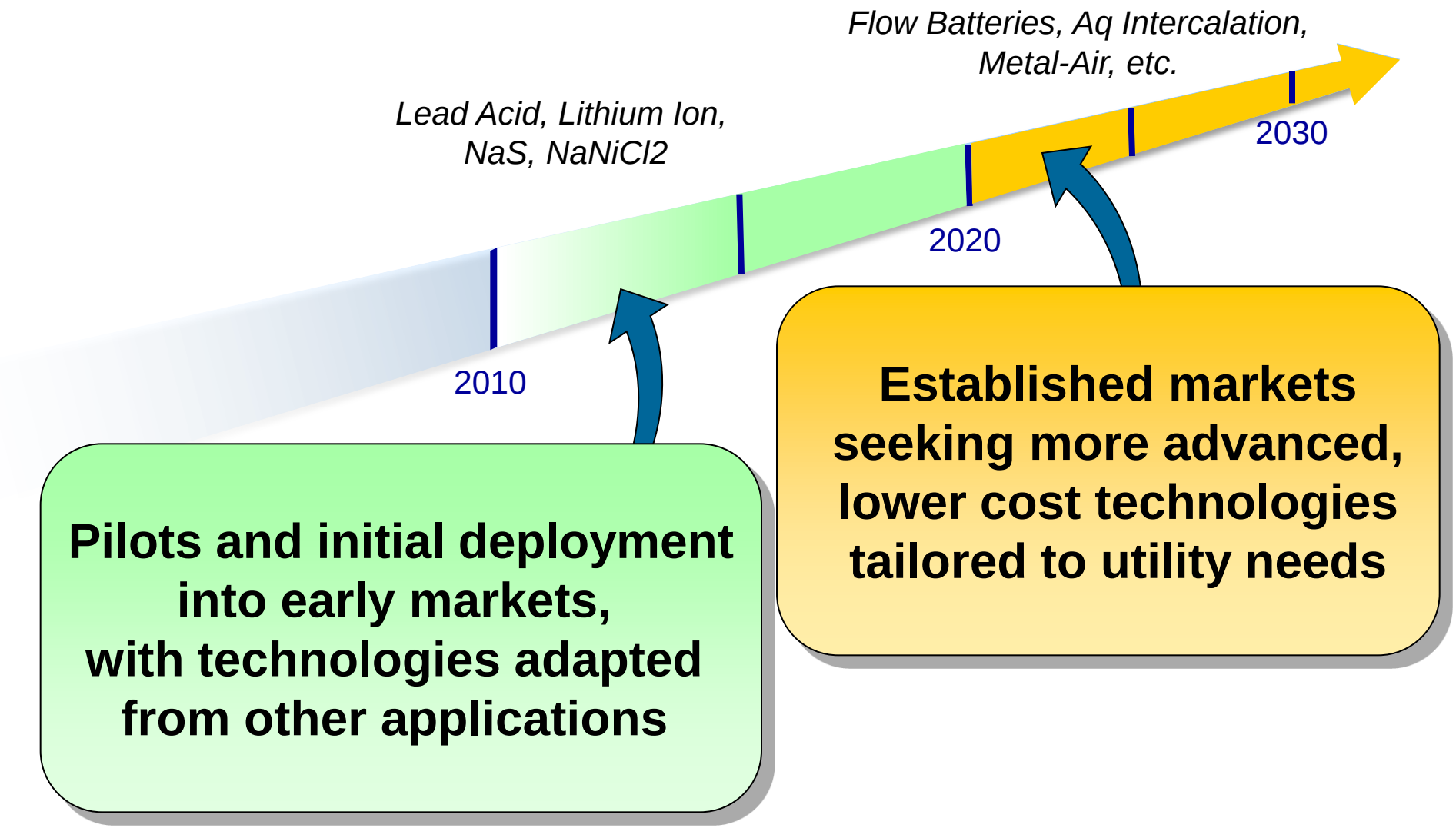
A likely path for storage adoption



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How can utilities respond?

- Storage is a limited opportunity at present
  - Incentives and markets can make storage compelling in some situations
  - More cost reduction is necessary before storage becomes widespread
  - Cost reduction over the next few years may affect the utility business model

- Utilities are well-placed to invest in storage as an opportunity
  - Utility-owned and operated storage can be rate-based assets
  - Make efforts to incorporate customer and third-party owned assets into the Integrated Grid

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Energy Storage Valuation

Issues, Key Takeaways, and Next Steps

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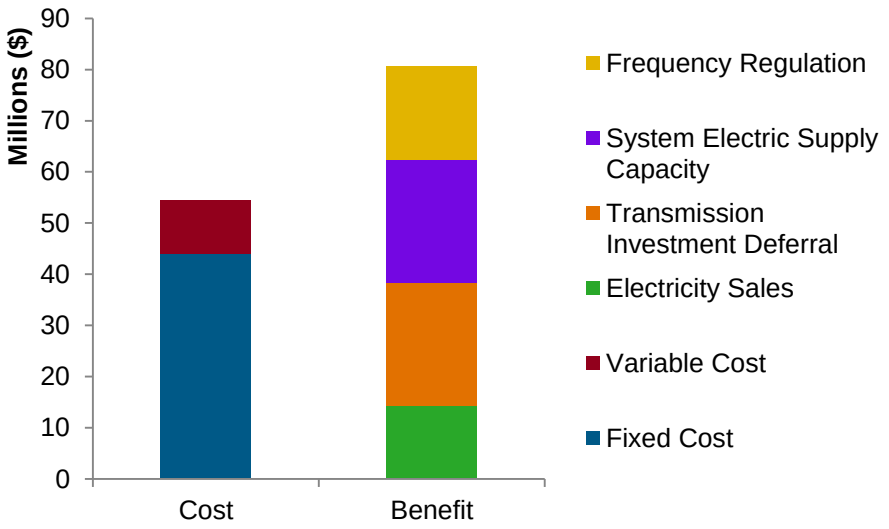
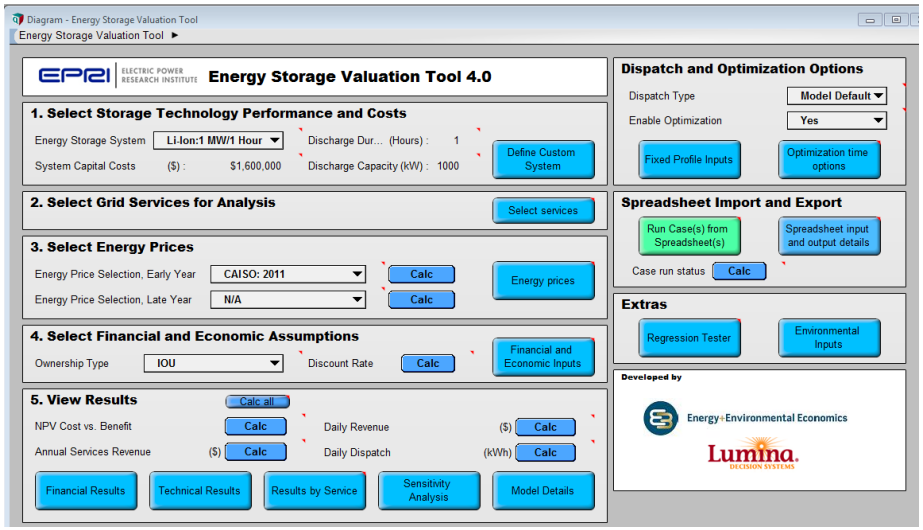
Developing analysis tools

- Energy storage requires an integrated analytical approach and new tools for effective evaluation and cost-effectiveness
- EPRI works with utilities, regulators, and stakeholders to develop standard analysis methodologies





EPRI Energy Storage Valuation Tool 4.0

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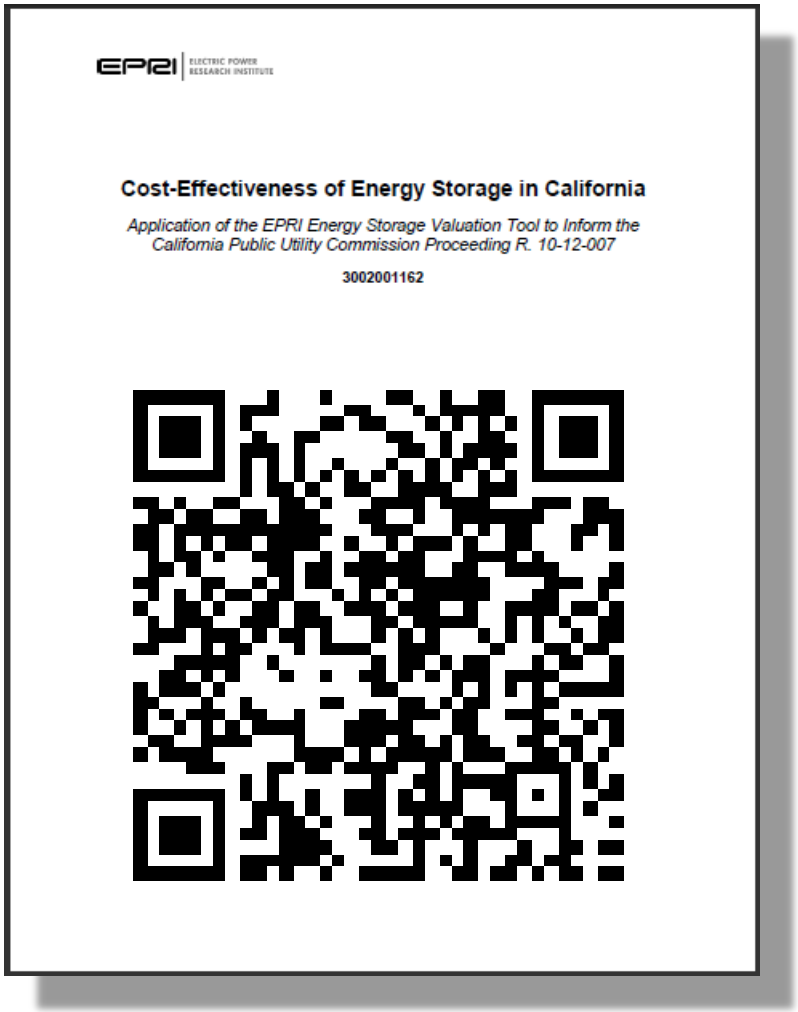
EPRI Analysis for Energy Storage in California

- "Energy Storage Cost-Effectiveness in California: Application of the Energy Storage Valuation Tool to Inform the California Public Utility Proceeding R.10-12-007"
- Product ID: 3002001162*
- Additional Input Worksheet and Updates Available at CPUC Storage OIR proceeding website



http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001162

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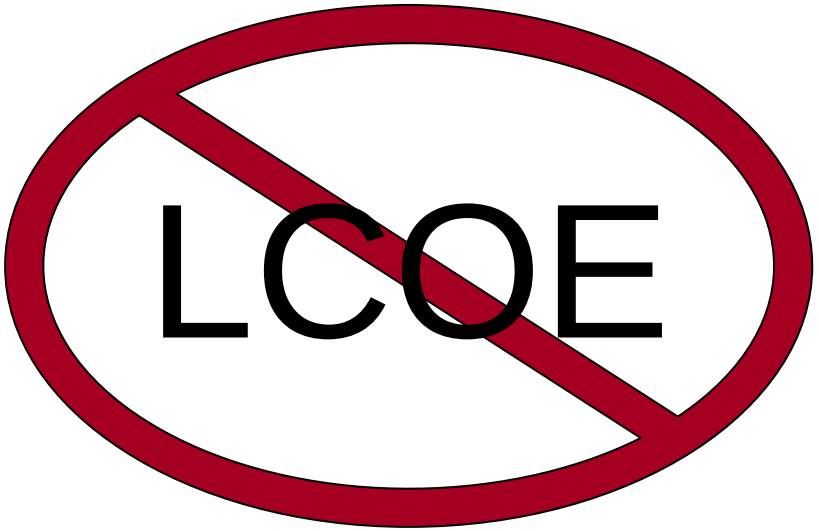
Understanding Storage Value Goes Beyond Cost

- Standard cost metrics for generation are not suitable for storage
  - Storage doesn't produce energy, so Levelized Cost of Energy (LCOE) is not an appropriate unit of measurement
  - Lifetime project net present value (NPV) is more straightforward



Integrated Approach is Required to Compare Value to Cost

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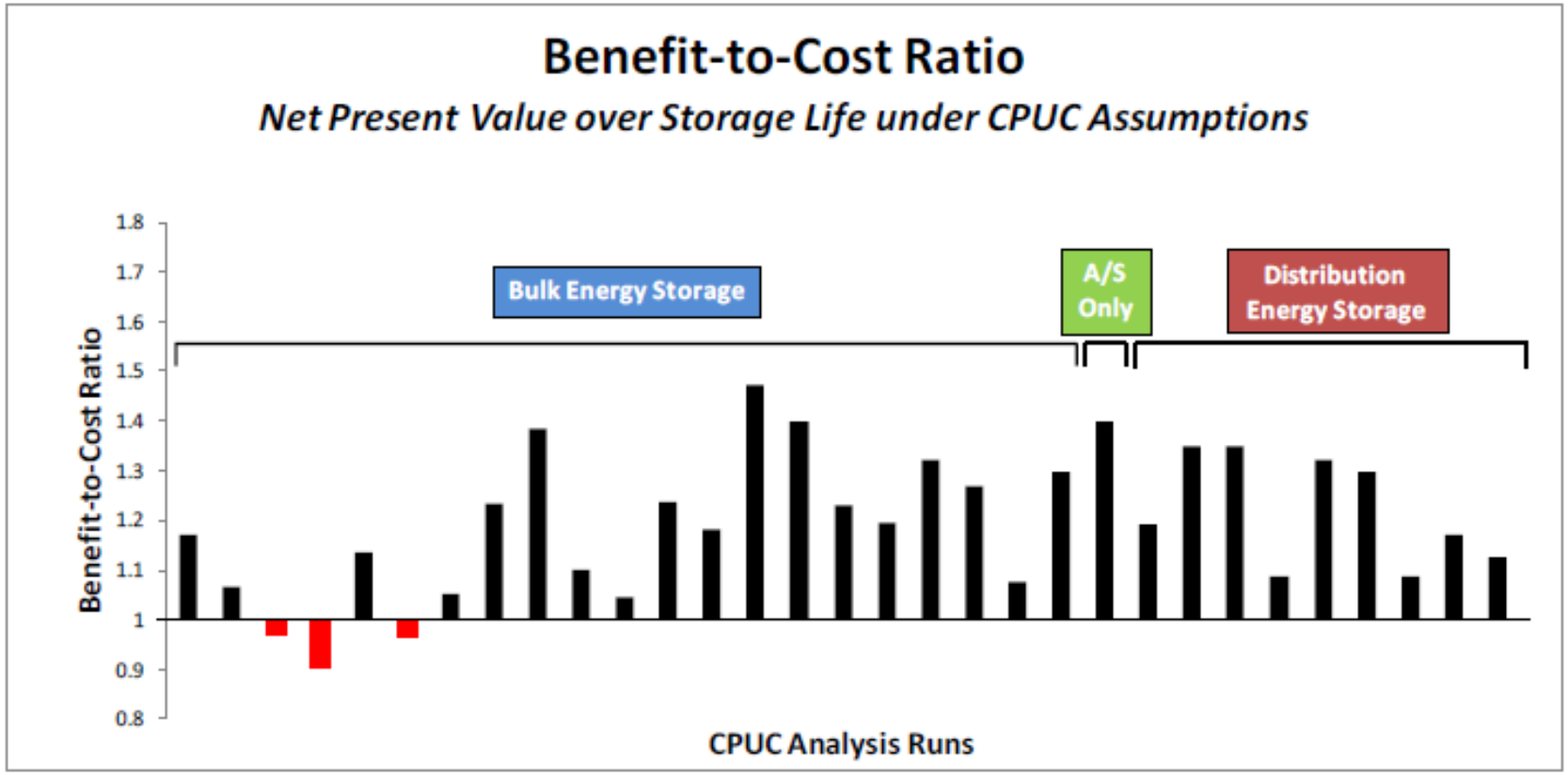
Overview of Benefit-to-Cost Ratio (California) Utility-Controlled Storage Cases



The majority of cases returned a B/C ratio greater than 1.
Cases with B/C ratio < 1 assumed no value of frequency regulation, high storage system capital cost, or had multiple battery replacements

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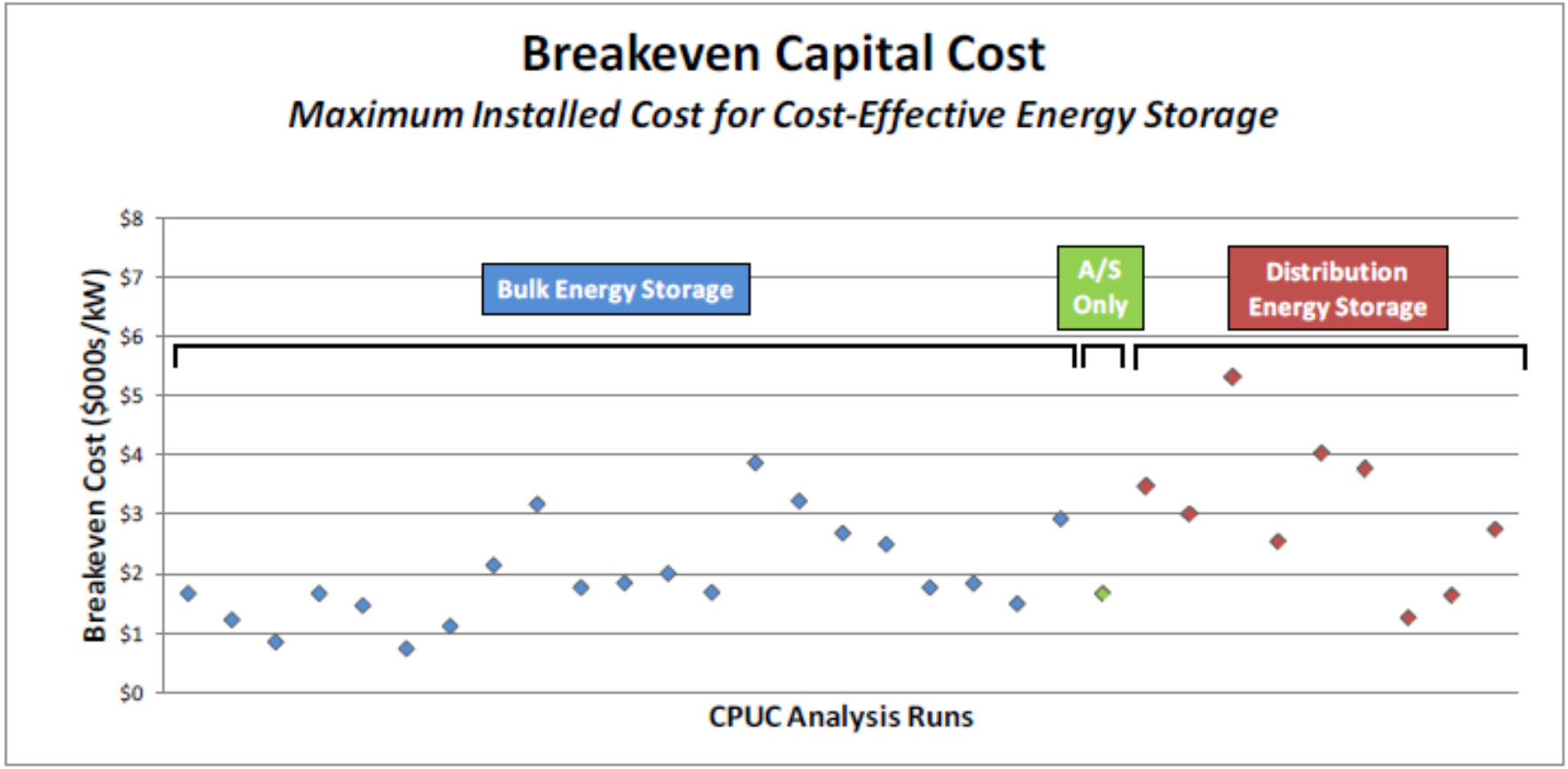
At what storage cost does a project break even?



Breakeven capital cost is the highest storage upfront cost resulting in NPV breakeven. Not easy to generalize -- Highly dependent on use case, scenario, and technology chosen

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Bulk Energy Storage Base Case in California Analysis

- **Benefit/Cost Ratio** = 1.17
- **Breakeven Capital Cost:** $842/kWh ($1684/kW) in 2013 inflation adjusted dollars

Base Case Inputs

Year 2020

50MW, 2hr (battery)

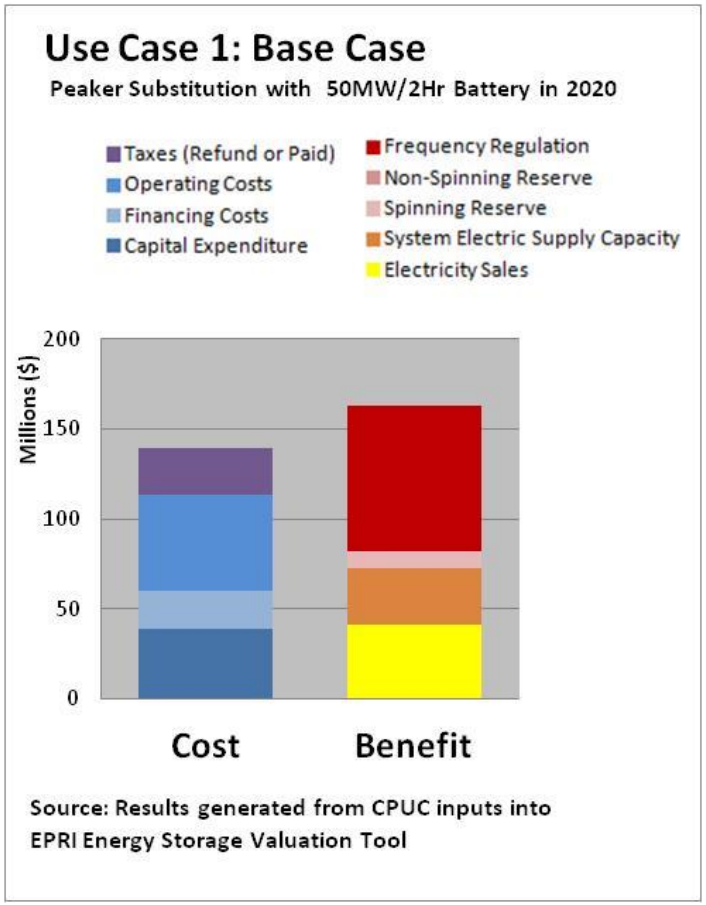
CapEx = $1056/kW, $528/kWh

20 year life on system with 1 Batt Replacement @ $250/kWh

11.5% discount rate

83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011



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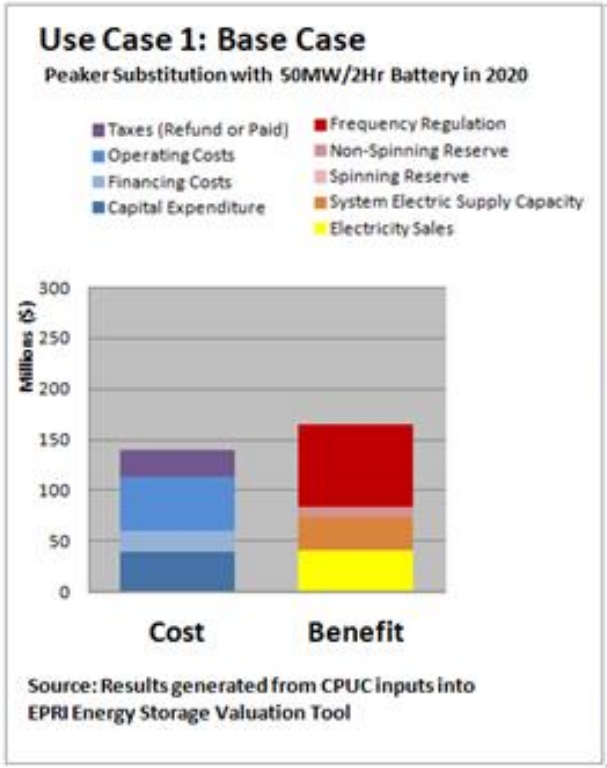
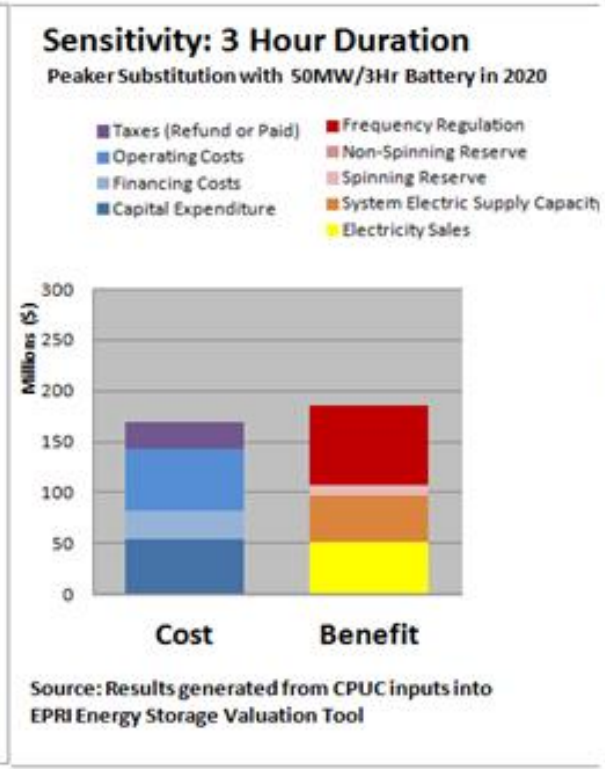
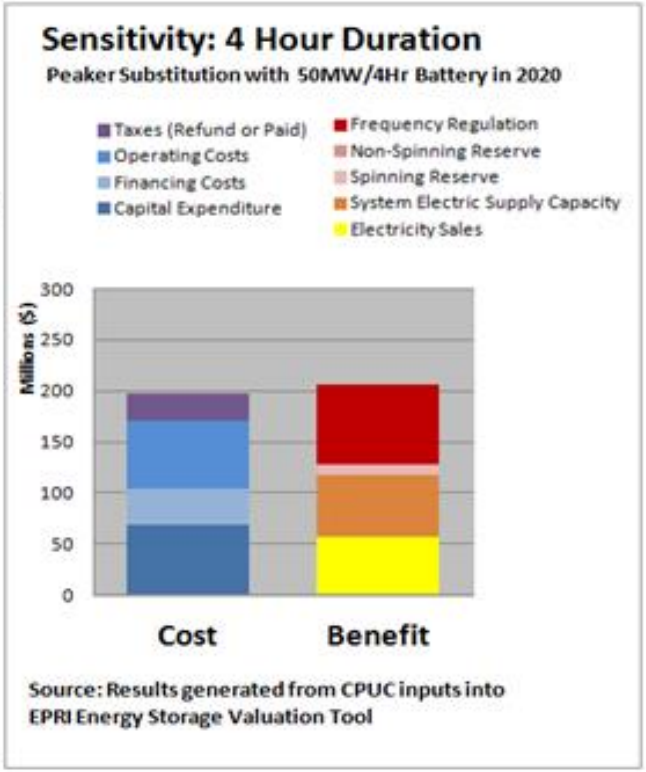
Sensitivity to Storage Duration Configuration
Base Case (2hr) vs. 3hr vs. 4hr

	Base Case	Duration 3hr	Duration 4hr
Breakeven Capital Cost in 2013 dollars	$842/kWh ($1684/kW)	$594 /kWh ($1781/kW)	$465 /kWh ($1860/kW)







Base Case Inputs

Year 2020; 50MW, 2hr (battery); CapEx = $1056/kW, $528/kWh; 1 Batt Replacement @ $250/kWh; 11.5% discount rate; 83% RT Efficiency; Energy & A/S prices escalated 3%/yr from CAISO 2011

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Sensitivity to Frequency Regulation Value

	Base Case	Base Case + 2x Reg	Base Case w/o Reg
Breakeven Capital Cost in 2013 dollars	$842/kWh ($1684/kW)	$1593 /kWh ($3186/kW)	$433/kWh ($865/kW)

<u>Input Summary</u>

Year 2020

50MW, 2hr (battery)

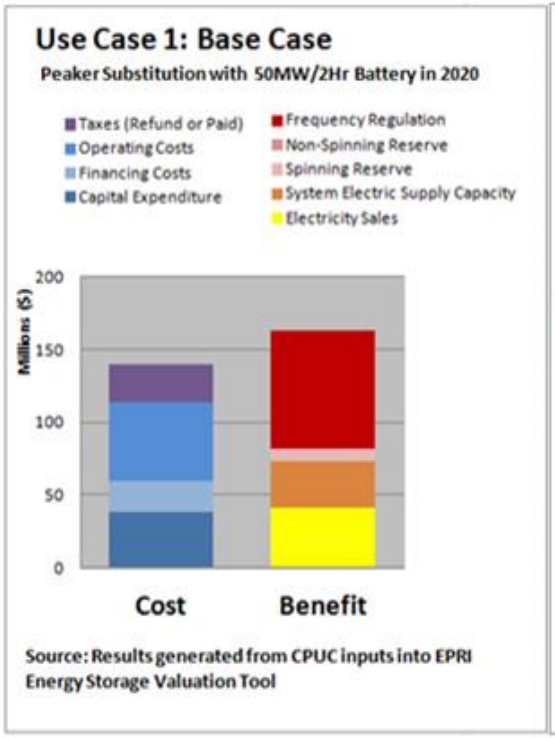
CapEx = $1056/kW, $528/kWh

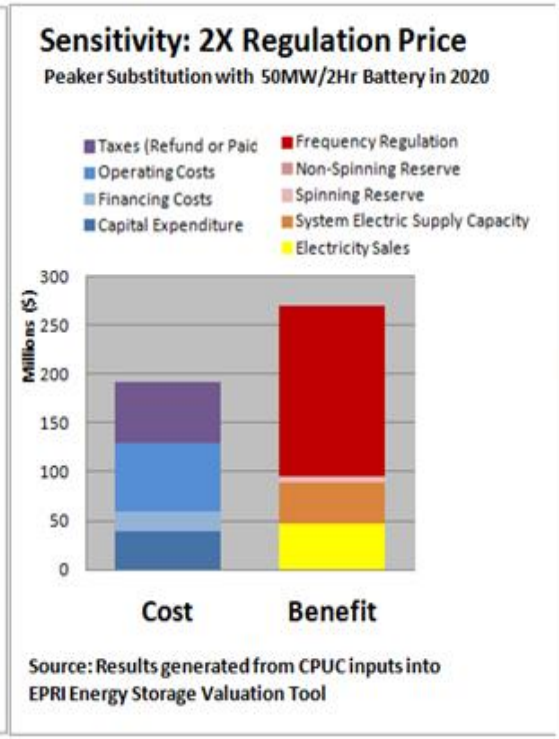
1 Batt Replacement @ $250/kWh

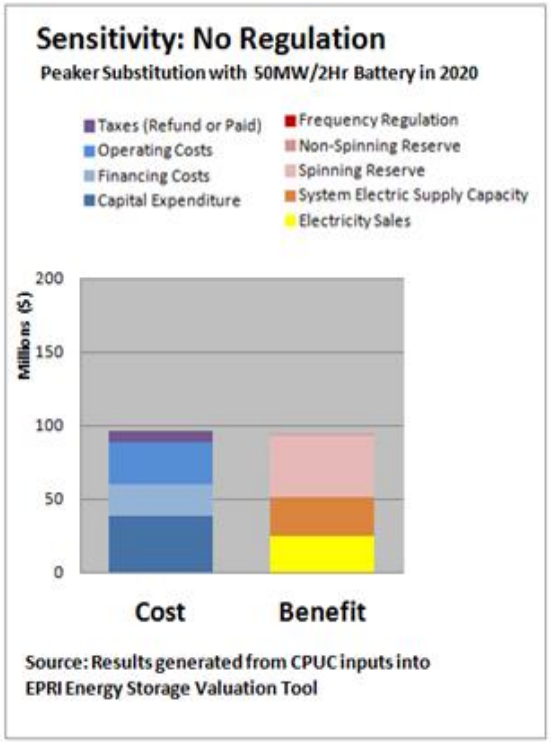
11.5% discount rate

83% RT Efficiency

Energy & A/S prices escalated 3%/yr from CAISO 2011







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What is the Case for Behind-the-Meter Energy Storage?

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Behind-the-Meter Energy Storage: Important to Consider both Customer & Total Resource Cost Perspectives

Customer Perspective

- Question: Does it make sense for customer to adopt?

Possible Value to Customer

- Bill Savings
  - Time-of-use energy shifting
  - Demand charge reduction
- Revenue
  - Demand response payments
  - Market services
- Policy Incentives
  - State / federal
- Customer reliability
  - Backup power

Total Resource Cost Perspective

- Question: How much value (cost) does the resource provide to the rest of the power system?

Possible Value to System

- Generation
  - Resource Adequacy
  - Energy Time-Shift
  - Ancillary Services
- Transmission
  - Avoided / Deferred Upgrades
  - Voltage Support / Loss reduction
- Distribution
  - Avoided / Deferred Upgrades
  - Voltage Support / Loss reduction
  - Improved PQ/ Reliability

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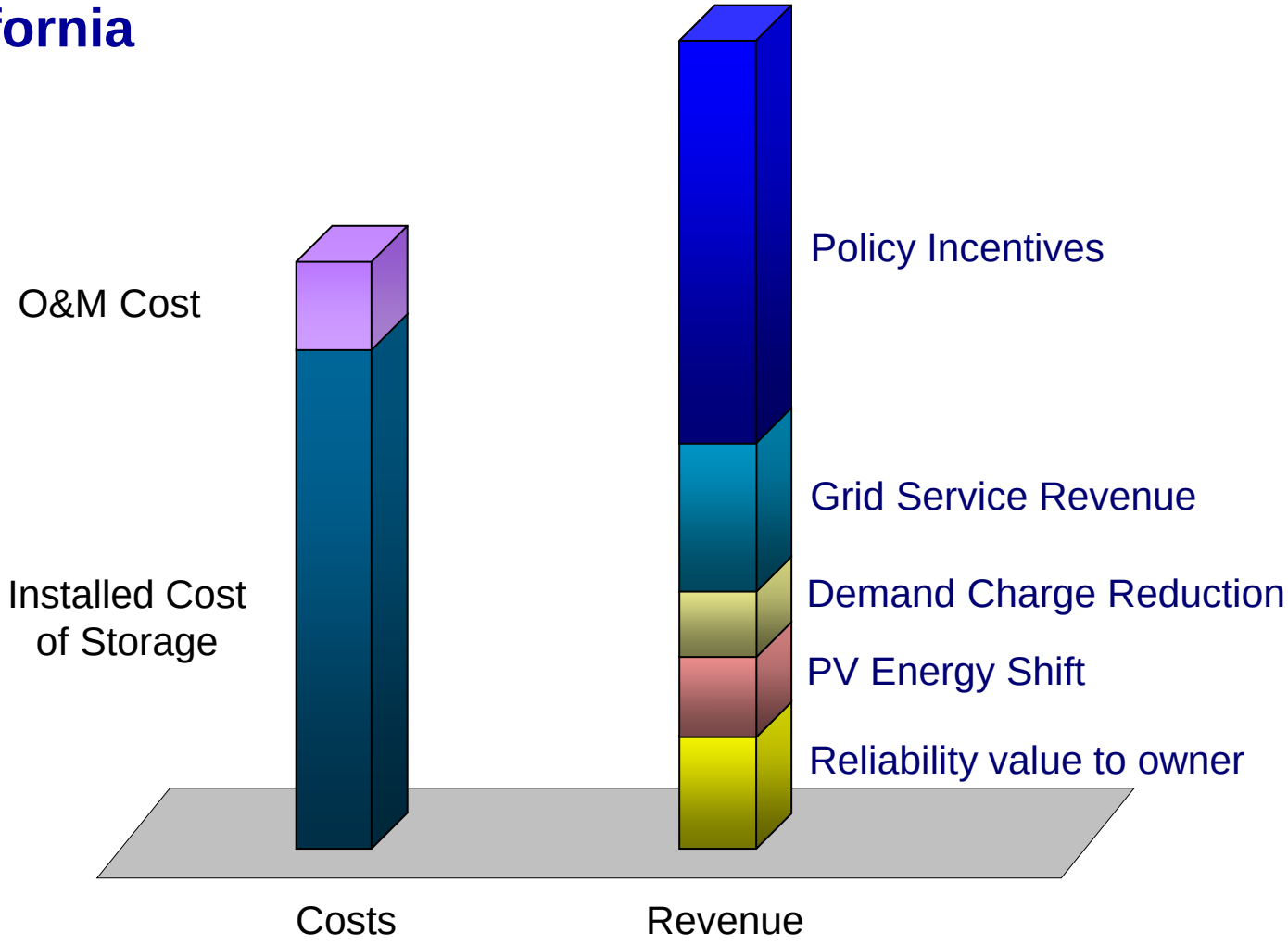
Customer Perspective: Behind-the-Meter Storage with Solar in California



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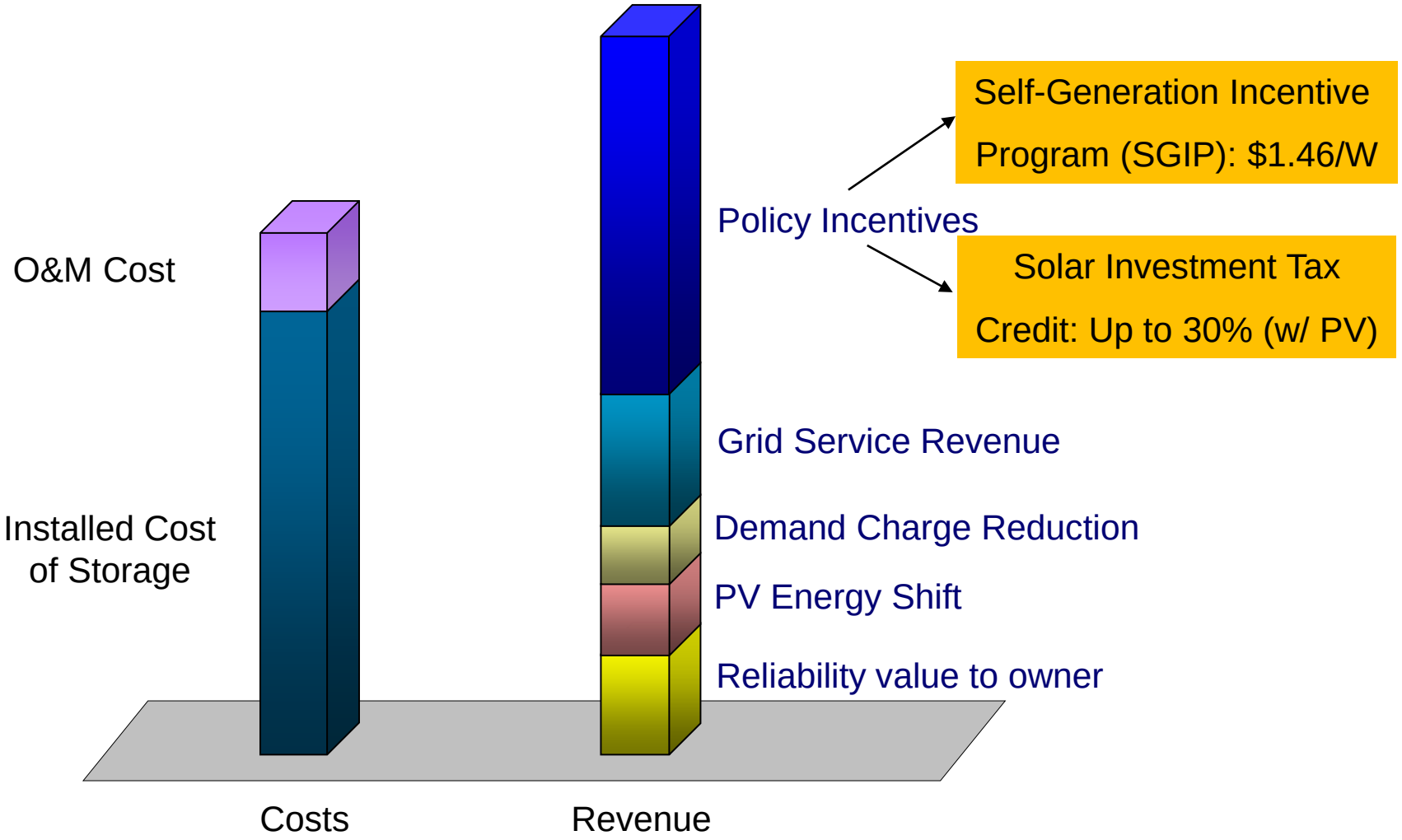
Customer Perspective (CA): Policy Incentives



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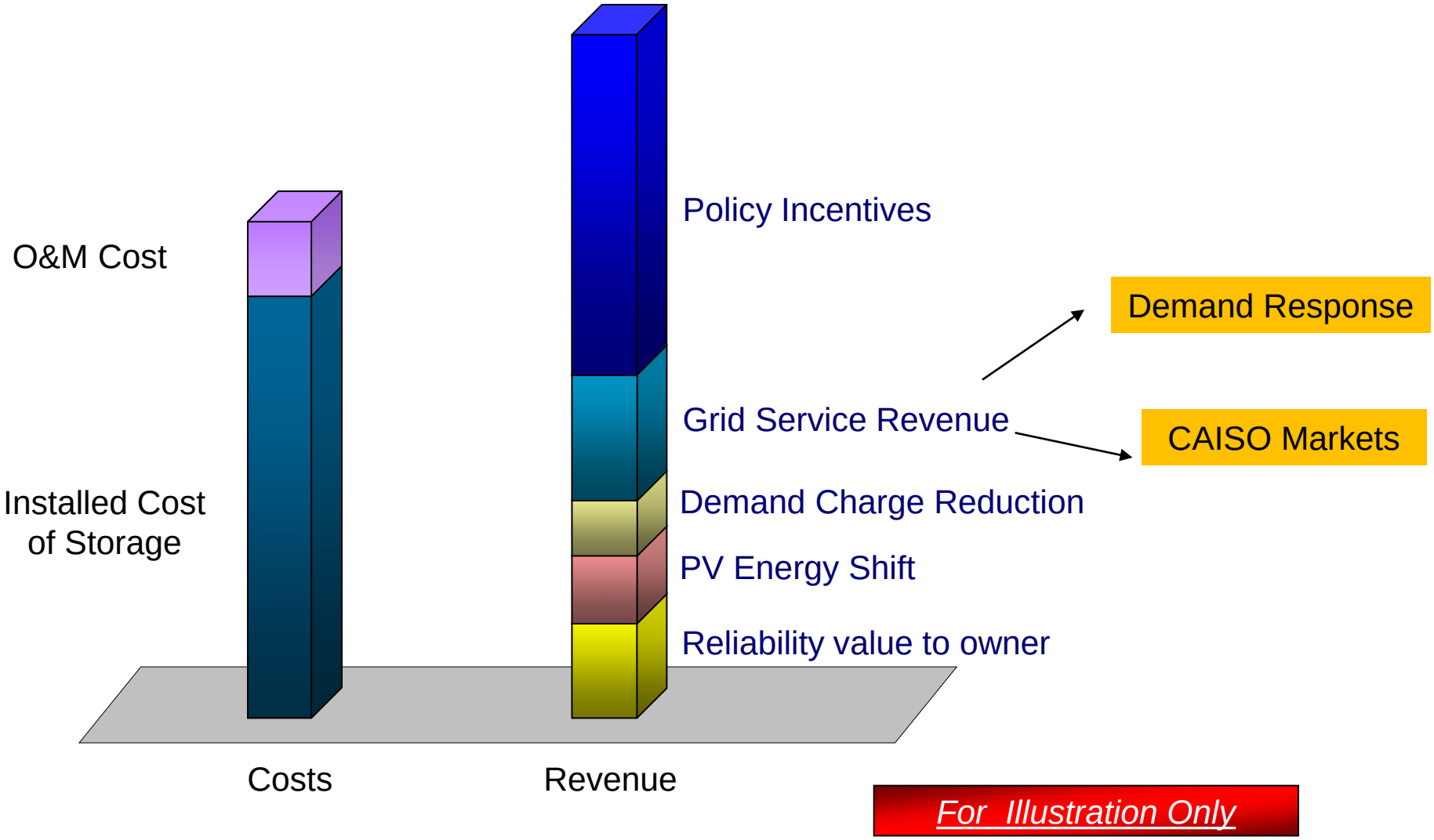
Customer Perspective (CA): Potential for Grid Service Revenue



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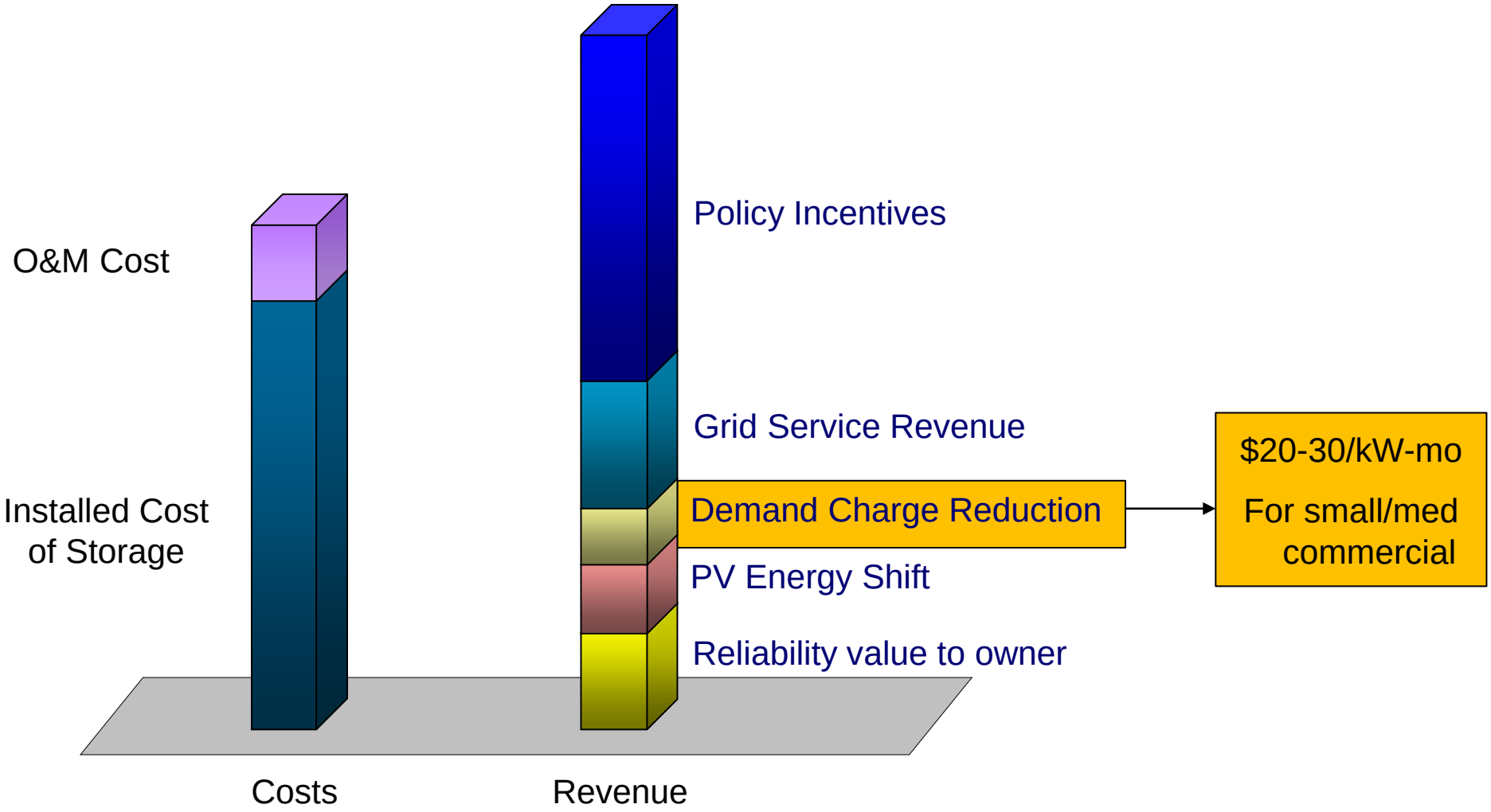
Customer Perspective (CA): Demand Charge Reduction



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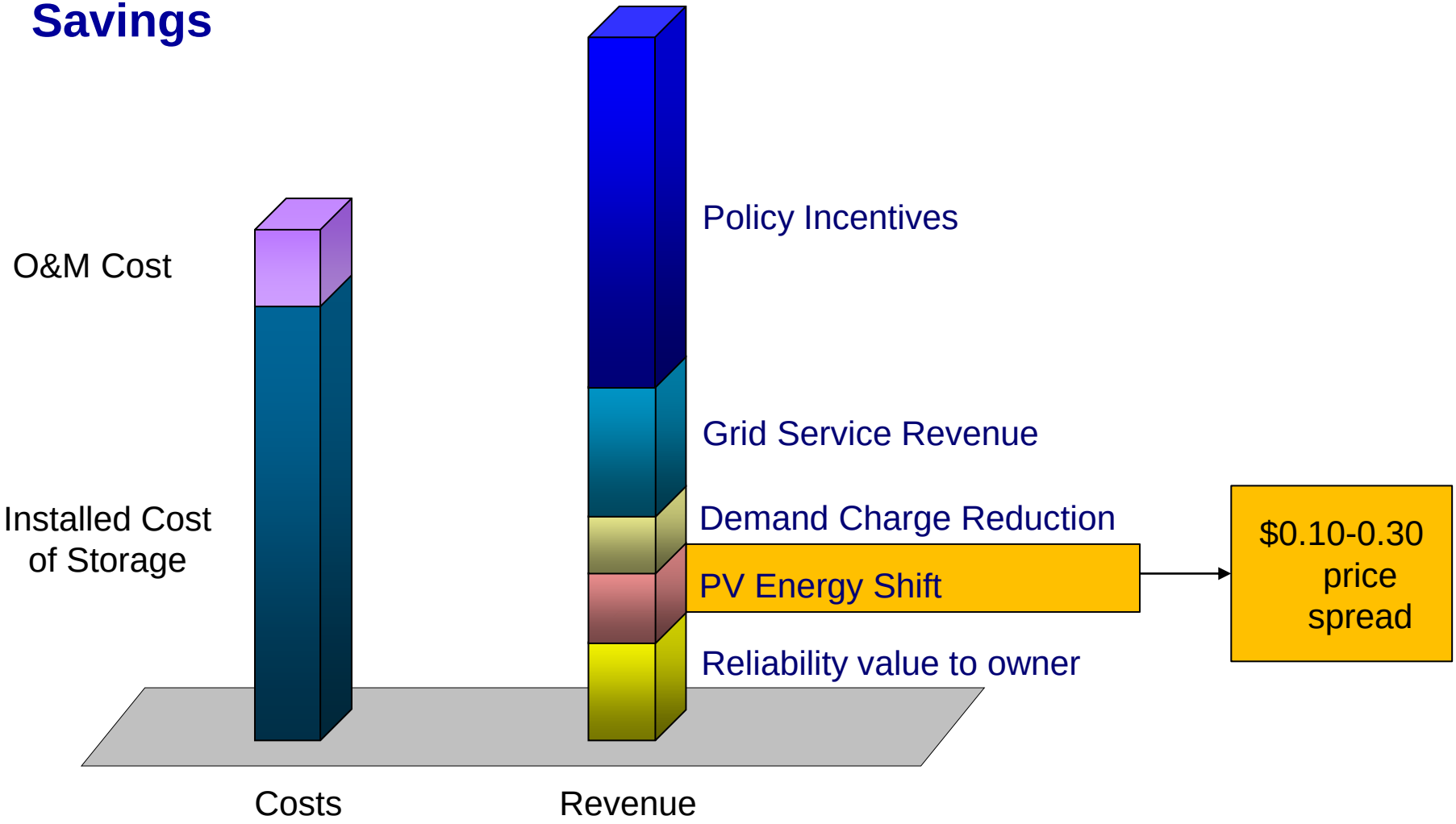
Customer Perspective (CA): Time-of-Use Energy Shifting Bill Savings



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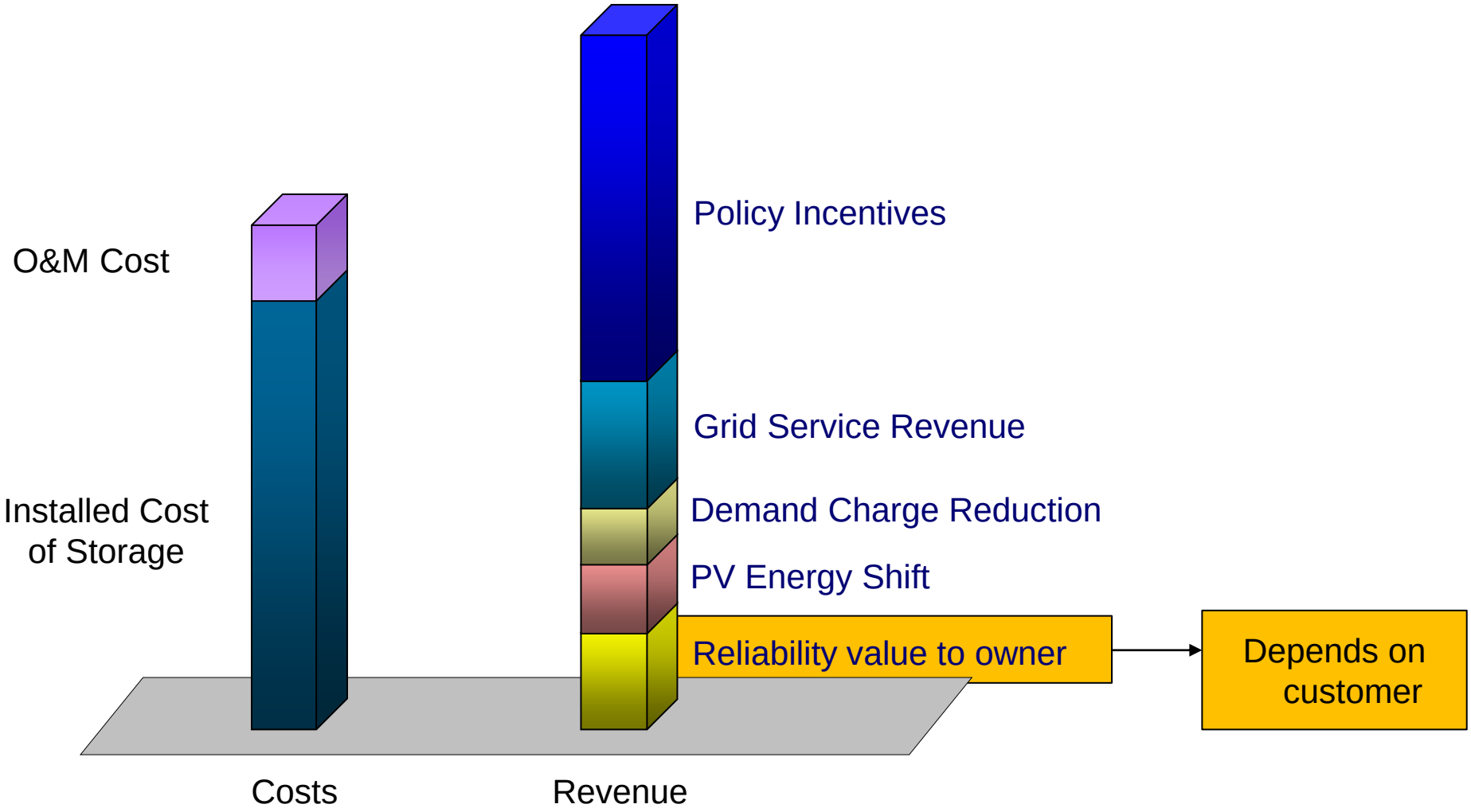
Customer Perspective (CA): Reliability / Backup Power



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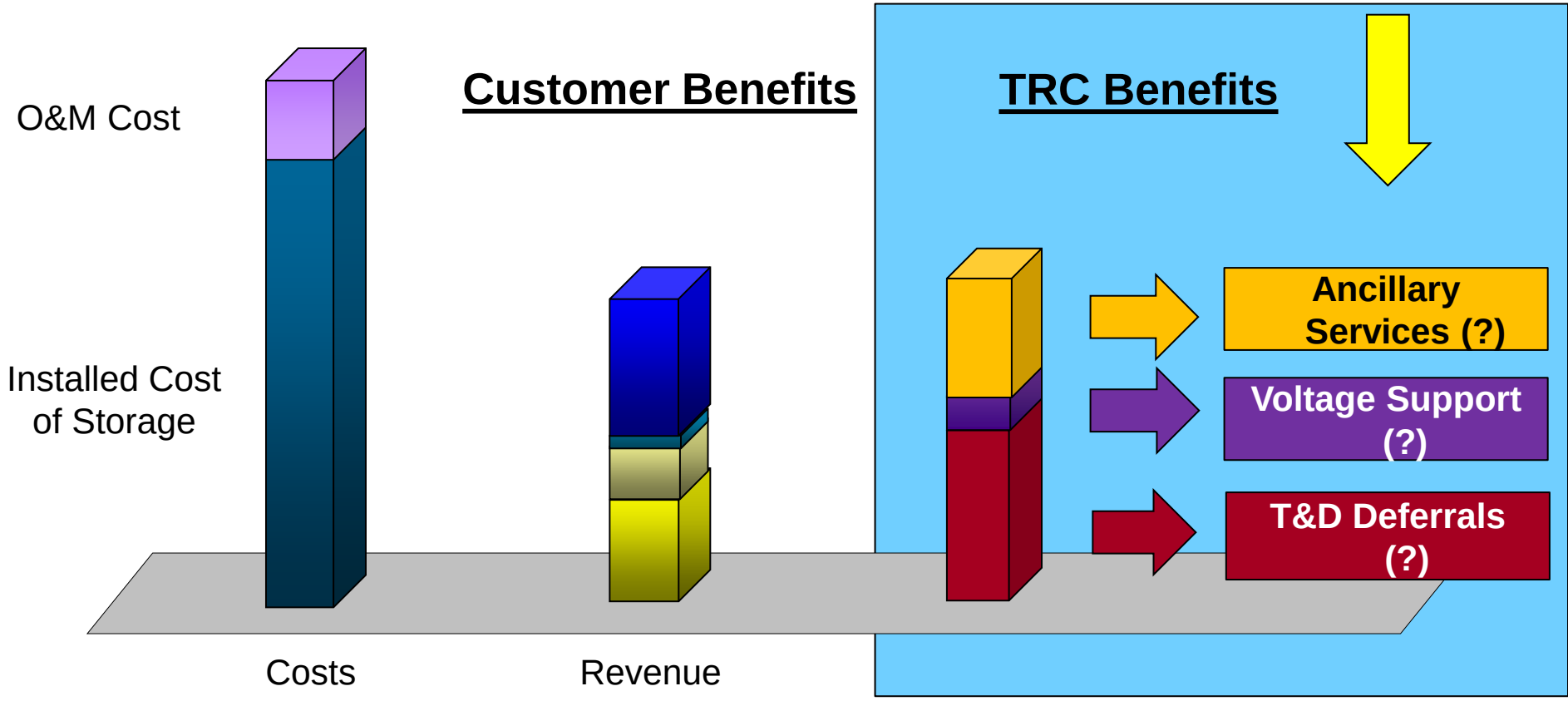
Total Resource Cost Perspective: Can Utility Rely on Customer Devices for System Reliability?



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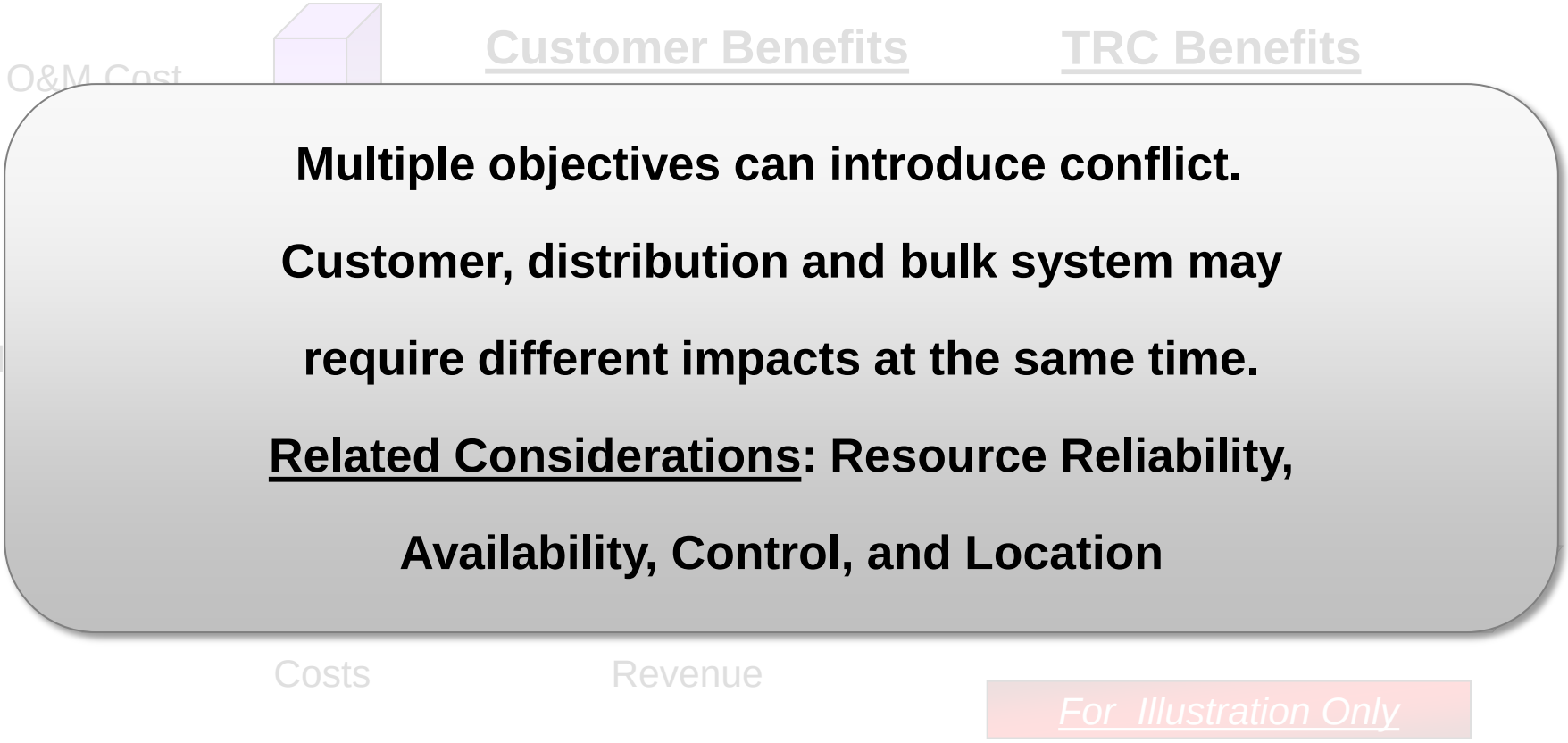
Technical Analysis is Required: May not be Possible to Realize All Desired Customer and System Benefits Simultaneously



Multiple objectives can introduce conflict.

Customer, distribution and bulk system may require different impacts at the same time.

Related Considerations: Resource Reliability, Availability, Control, and Location

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Next Steps

Laying the Groundwork for Informed, Safe, Reliable, and Cost-Effective Deployment of Energy Storage

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Storage Valuation Challenge – Too many watches, so we don't know what time it is

Debate needs to evolve to inputs, rather than model & approach

Models need to credible, validated, transparent

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Development of a Transparent, Public Energy Storage Simulation Tool

- Award approved by California Energy Commission
  - $1.9M = $1M CEC + $0.9M Cost Share
  - Partnered with E3, Lumina, Customized Energy Solutions, and others
- Build off EPRI Energy Storage Valuation Tool (ESVT)
- Deliver a Web-Accessible Tool to Public in mid-2016
  - Project is starting now
  - Support California PUC program evaluation for 2014 energy storage procurements
  - Support California Utilities, Developers, and Regulators for 2016 Procurements

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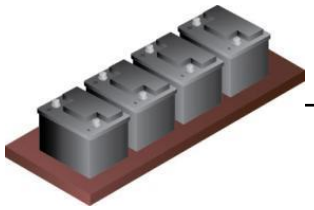
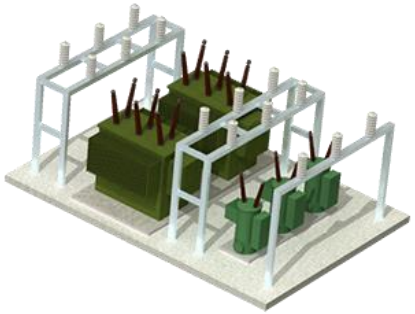
On the Hardware Side… Facilitating Grid-Ready Storage Systems

Energy Storage Technology

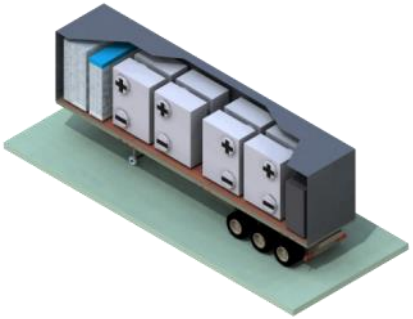
- Exploring technology tradeoffs
- Optimizing technology for utility applications





Grid integration

- Establishing best practices for siting and permitting
- Standardizing the interface with the grid
- Modeling and analyzing the effects of storage on the grid



Communications and Control

- Defining interoperable protocols
- Developing operational and dispatch algorithms

Power Conditioning

- Establishing appropriate operations and control
- Ensuring efficient and reliable operation

Storage System Product

- Ensuring safety and reliability
- Understanding cost and performance
- Simplifying procurement and operation through standardization of specification and interfaces

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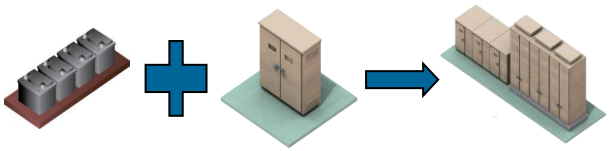
The Energy Storage Integration Council (ESIC) is a Forum to Address Technical Issues and Advance Storage Deployment

Mission Statement

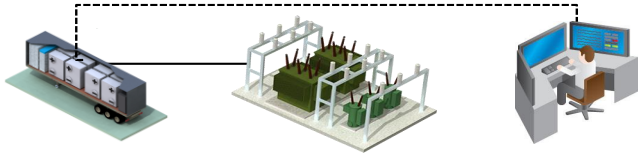
To advance the integration of energy storage systems through open, technical collaboration

guided by the vision of universally accessible safe, secure, reliable, affordable, environmentally-responsible, electricity

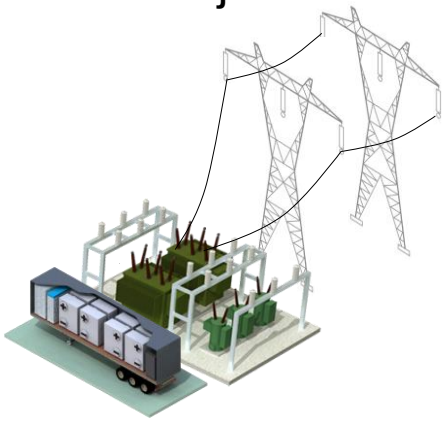
Integrated Products



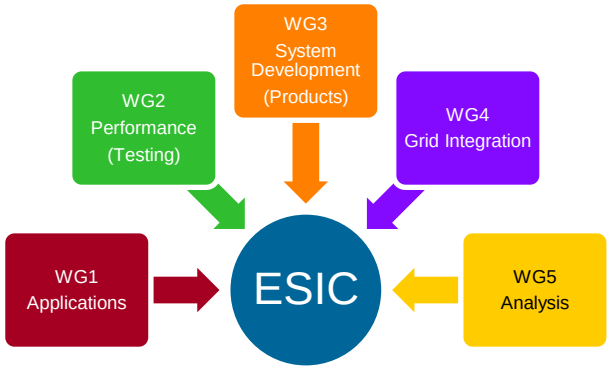
Interoperability, Security, and Analysis Tools



Safe and Reliable Projects



Five Working Groups



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- No money to participate, but we want your expertise
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- Join over 150 participating organizations, including:
  - Electric Utilities
  - Energy Storage Vendors
  - System Integrators / Project Developers
  - Researchers and Universities
  - Regulators
  - Other Stakeholders

Work Collaboratively to Develop Practical Guidelines and Identify Key Gaps to Facilitate Safe, Reliable, Cost-Effective Storage Deployment

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Together…Shaping the Future of Electricity

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Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

Financial Impacts of Net-Metered PV on Utilities and Ratepayers:

A Scoping Study of Two Prototypical U.S. Utilities

Andrew Satchwell, ***Andrew Mills***, Galen Barbose
Lawrence Berkeley National Laboratory

KY DER Valuation Workshop
April 15, 2015

This analysis was funded by the Solar Energy Technologies Office, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

SunShot
U.S. Department of Energy

Outline

- **Project overview**
- Base case results
- Sensitivity analysis
- Mitigation analysis
- Conclusions

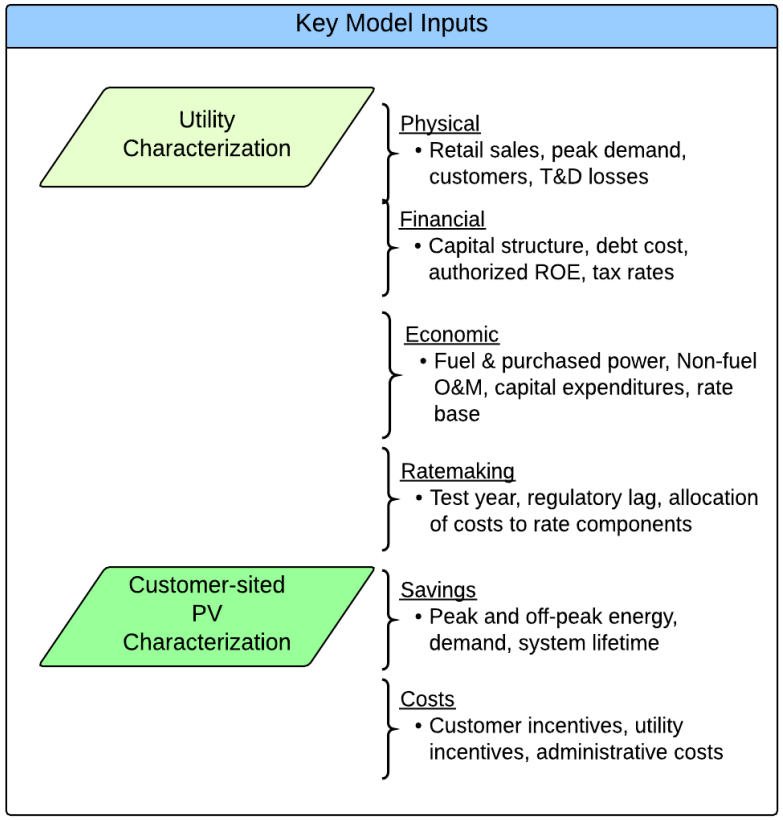
Framing the results of this analysis

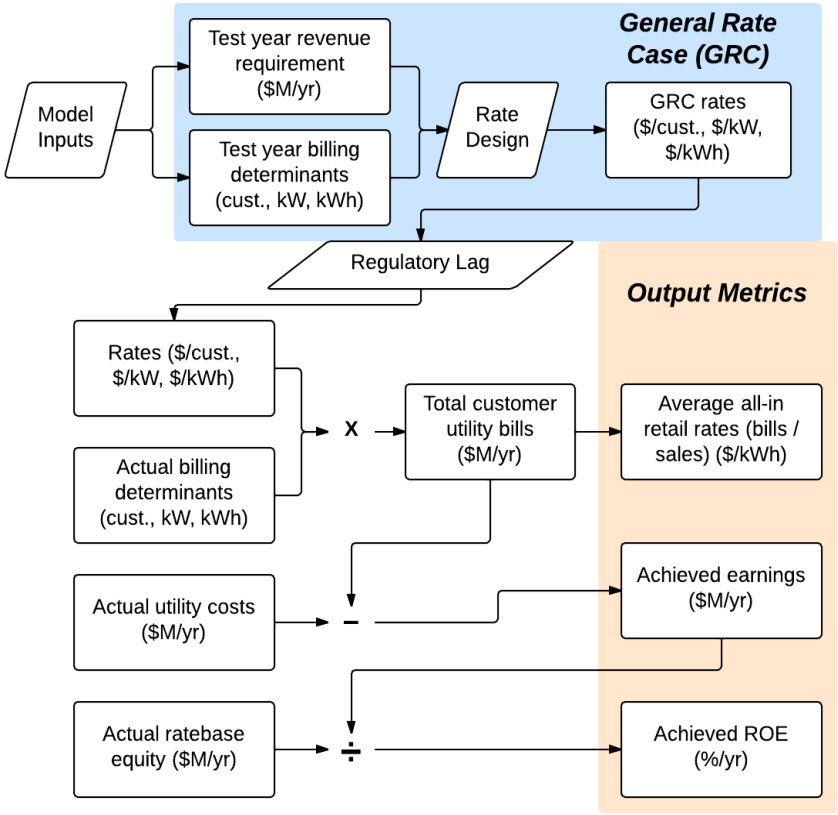
- Findings from this study do <u>not</u> support definitive statements about the impacts PV
- Rather, the results show that:
  - The impacts depend critically on the particular circumstances of the utility, and may or may not be significant
  - If significant, the impacts can be mitigated through various regulatory and ratemaking approaches (separately or in combination)

Project overview

- Scoping analysis that:
  - characterizes the scale of financial impacts of customer-sited PV on utilities
  - assesses the dependence of those impacts on underlying utility conditions
  - explores the efficacy and tradeoffs of potential mitigation approaches
- Leverages LBNL pro-forma financial model of utility costs and revenues
- Impact of PV measured in terms of estimated changes to three metrics:
  - utility achieved return-on-equity (ROE)
  - utility achieved earnings
  - customer average all-in retail rates

Model description





- Pro-forma financial model originally developed to quantify financial impacts of utility EE programs
- Quantifies utility annual costs and collected revenues over a long-term (e.g., 20-year) analysis period

Structure of the analysis

Two "prototypical" investor-owned utilities

- Southwestern vertically integrated utility
- Northeastern wires-only utility and default service provider

Analytical elements

- **Base case**: A reference point against which sensitivities and mitigation measures can be measured
- **Sensitivity cases**: How do the impacts of PV depend on the utility operating and regulatory environment?
- **Mitigation cases**: To what extent can the impacts of PV be mitigated through regulatory and ratemaking measures?

Dimensions of the analysis

- Customer-sited PV ramps up over 10 years, reaching 2.5% to 10% of retail sales (Sensitivity and Mitigation cases focus on 10% PV penetration)
- Utility costs and revenues modeled over 20 years to capture end-effects

Key boundaries of study scope and method

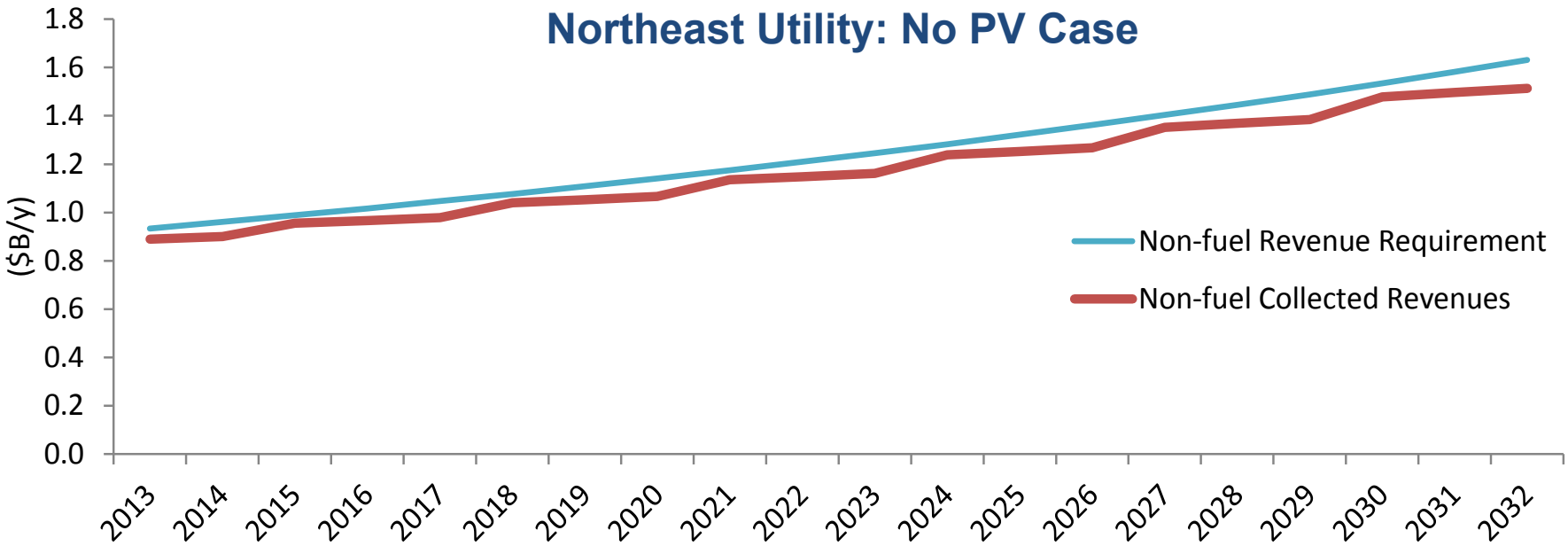
- Analysis is based on a financial modeling and does not constitute a detailed analysis of the value of PV
- Financial impacts captured at the utility-level, not customer-level; does not quantify cost-shifting or cross-subsidization among customer classes
- Is not a cost-benefit analysis of PV or of net-metering
- Does not consider impacts in combination with other distributed resources (storage, energy efficiency)
- Considers two different utilities, many sensitivity and mitigation scenarios, and multiple PV penetration levels, but does not cover every possibility

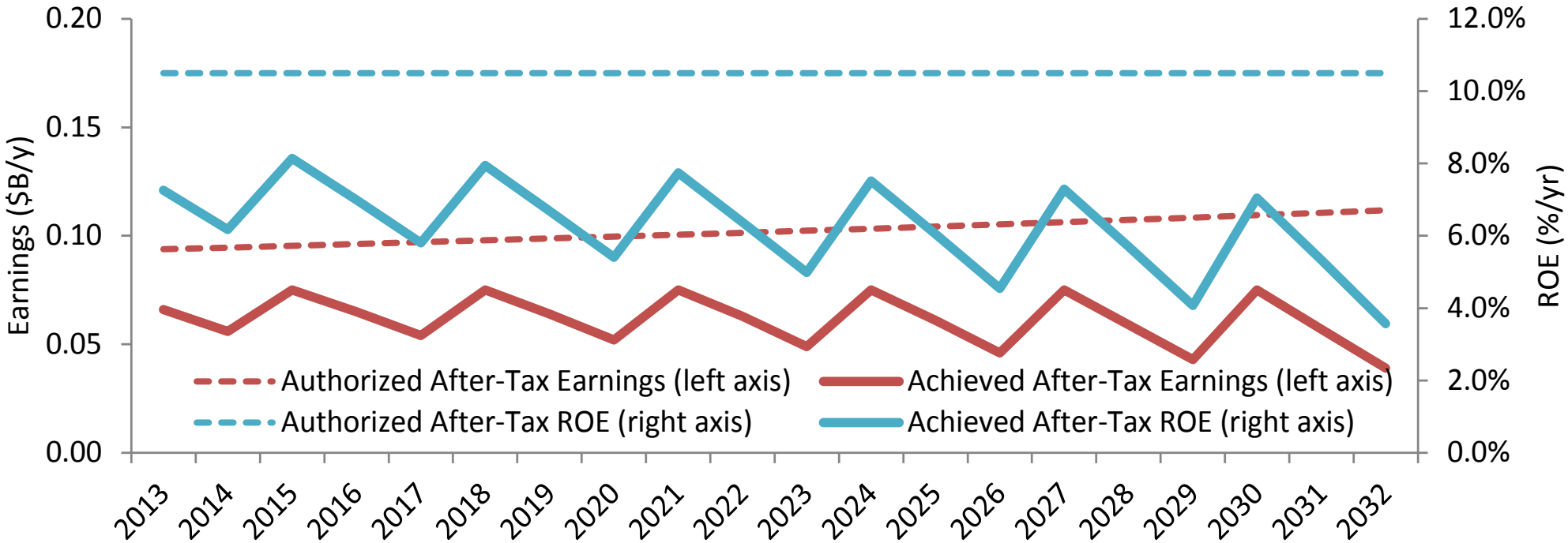
Prototypical Southwest and Northeast utilities

Key Input	Southwest Utility	Northeast Utility
Utility type	Vertically integrated	Wires-only
Asset Ownership	G, T, & D	D only
2013 Retail Sales Level (CAGR)	30,460 GWh (2.1%)	21,957 GWh (1.4%)
2013 Peak Demand Level (CAGR)	6,531 MW (2.1%)	5,655 MW (1.5%)
Commodity Costs CAGR	5.6%	6.6%
Non-fuel O&M CAGR	2.6%	3.4%
RPS Compliance Strategy	Build & Buy	Buy
2013 All-in Retail Rate Level	11.34 ¢/kWh	12.82 ¢/kWh
Frequency of GRC	3 years	3 years
Regulatory Lag	1 year	1 year
Test Year	Historic	Historic
Authorized ROE	10.00%	10.35%
Debt and Equity Share	46%:54%	57%:43%

CAGR = Compound Annual Growth Rate (over period from 2013-2022); GRC = General Rate Case

Relative growth in costs and revenues has large impact on earnings and ROE

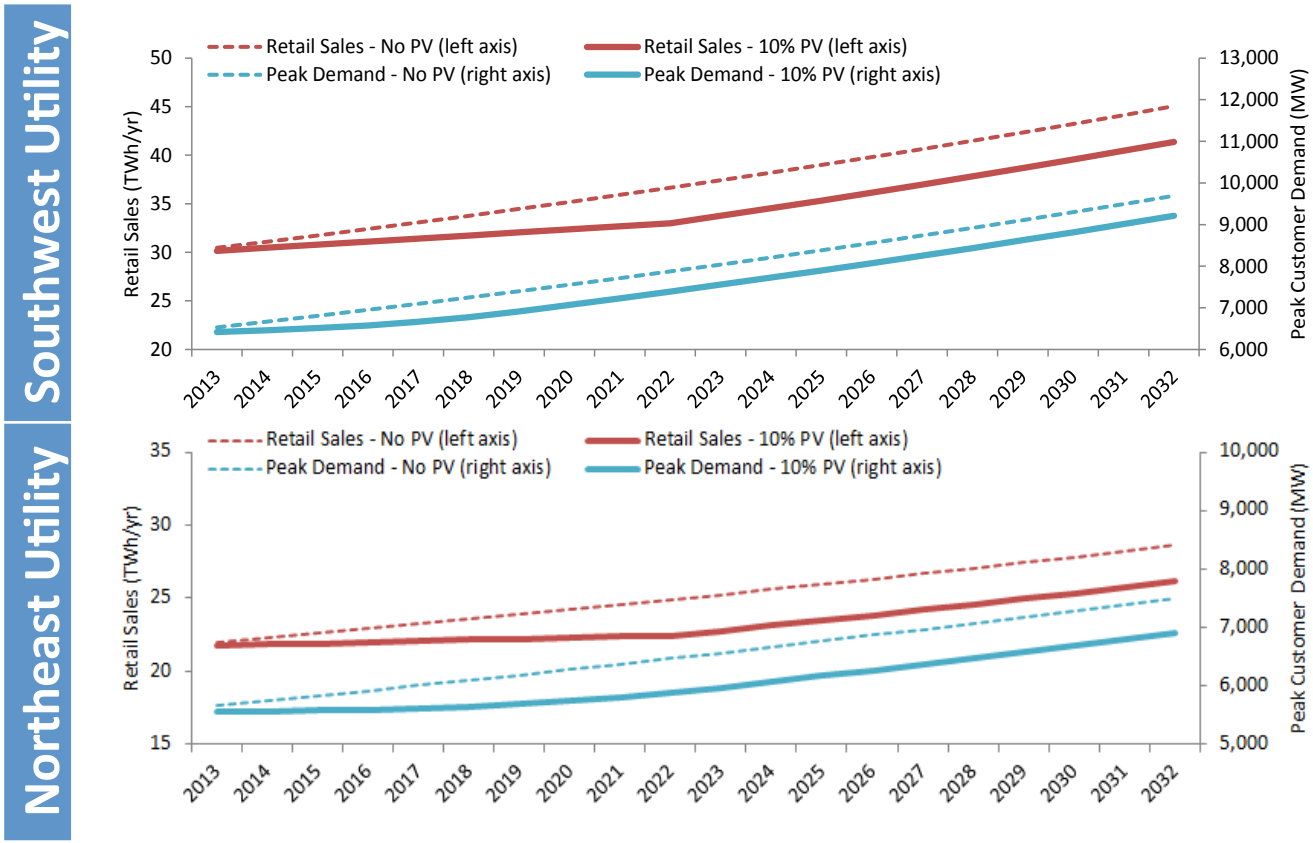




Outline

- Project overview
- **Base case results**
- Sensitivity analysis
- Mitigation analysis
- Conclusions

Customer-sited PV reduces utility retail sales and peak demand



- Customer-sited PV reduces sales on a one-for-one basis, but reduces demand by less because timing of maximum PV output does not perfectly coincide with customer peak demand
- Marginal impact of PV on peak demand also declines as the timing of the net system peak shifts as PV penetration grows

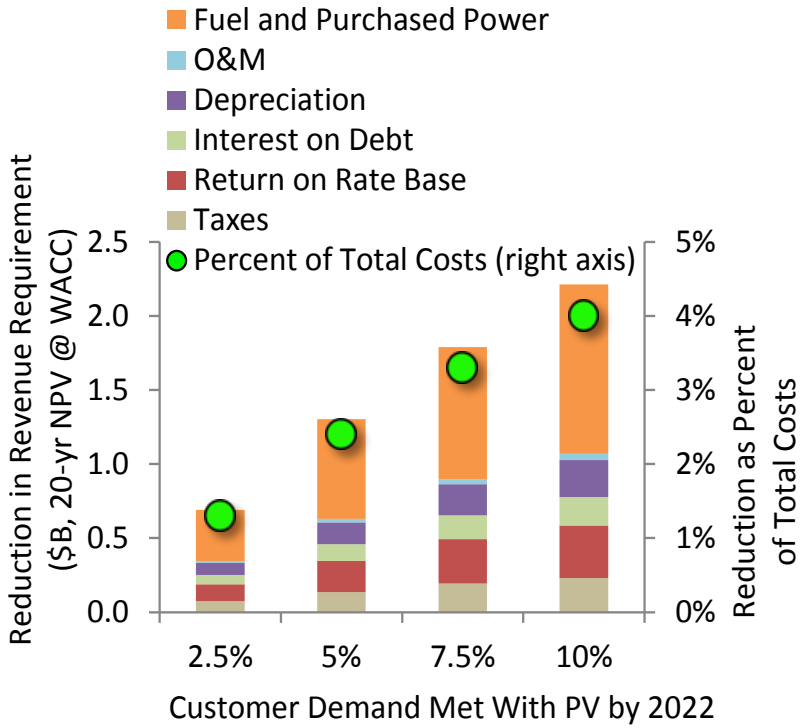
Sources of modeled cost reductions from customer-sited PV

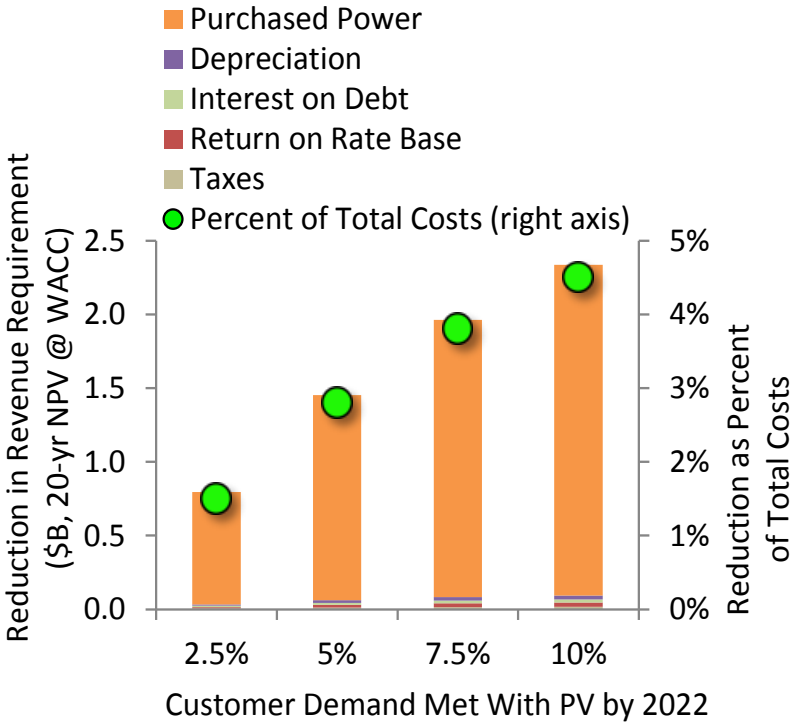
Cost Category	Southwest Utility	Northeast Utility
Fuel & Purchased Power	• Reduced fuel costs for utility-owned generation • Reduced energy and capacity market purchases and PPAs • Reduced RPS procurement costs* • Reduced losses	• Reduced energy and capacity market purchases • Reduced transmission access charges • Reduced RPS procurement costs* • Reduced losses
O&M	• Reduced O&M due to deferred utility-owned generation	• None
Depreciation Interest on Debt Return on Ratebase	• Deferred utility-owned generation • Reduced T&D CapEx	• Reduced distribution system CapEx
Taxes	• Deferred utility-owned generation • Reduced T&D CapEx • Reduced collected revenues	• Reduced distribution system CapEx • Reduced collected revenues

* The reduced RPS procurement costs occur as a result of the reduction in retail sales, upon which RPS obligations are based. We do not assume in the base-case that customer-sited PV is used directly to meet RPS obligations.

Utility cost reductions from PV

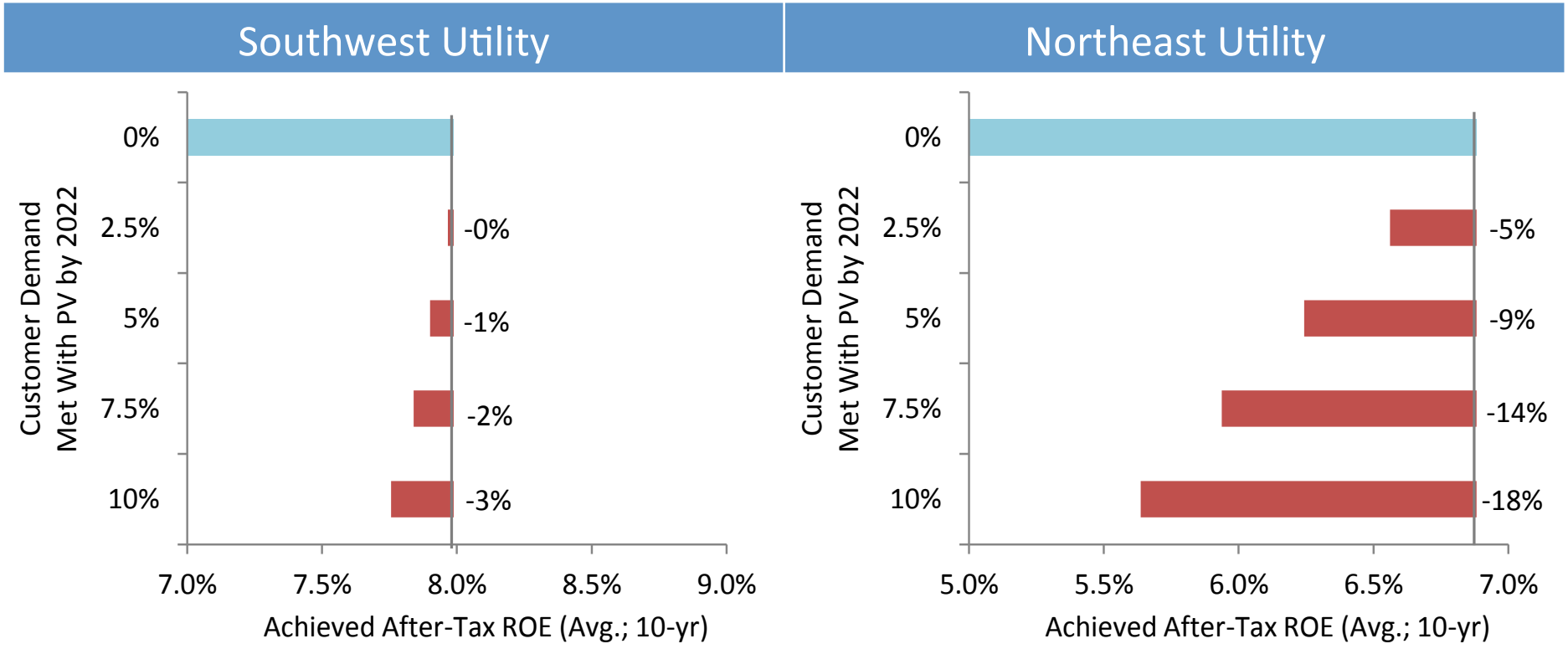
Southwest Utility	Northeast Utility





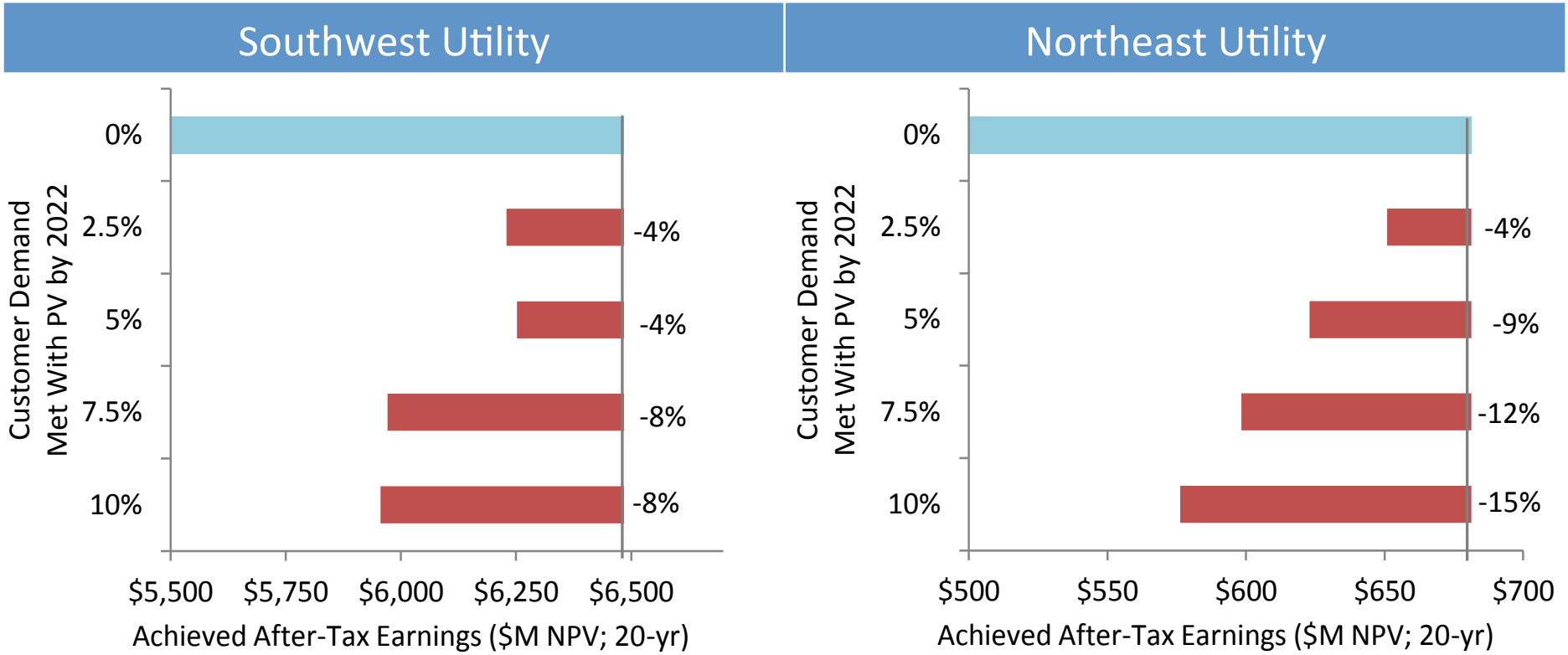
- Differences in composition of cost reductions between utilities are due to their differing cost structures: i.e., SW Utility owns generation while NE Utility procures all generation requirements via purchased power
- Assumptions related to deferral of generation and T&D investments, and to fuel and purchased power costs, are explored further in sensitivity analysis

Under base-case assumptions, PV reduces achieved ROE



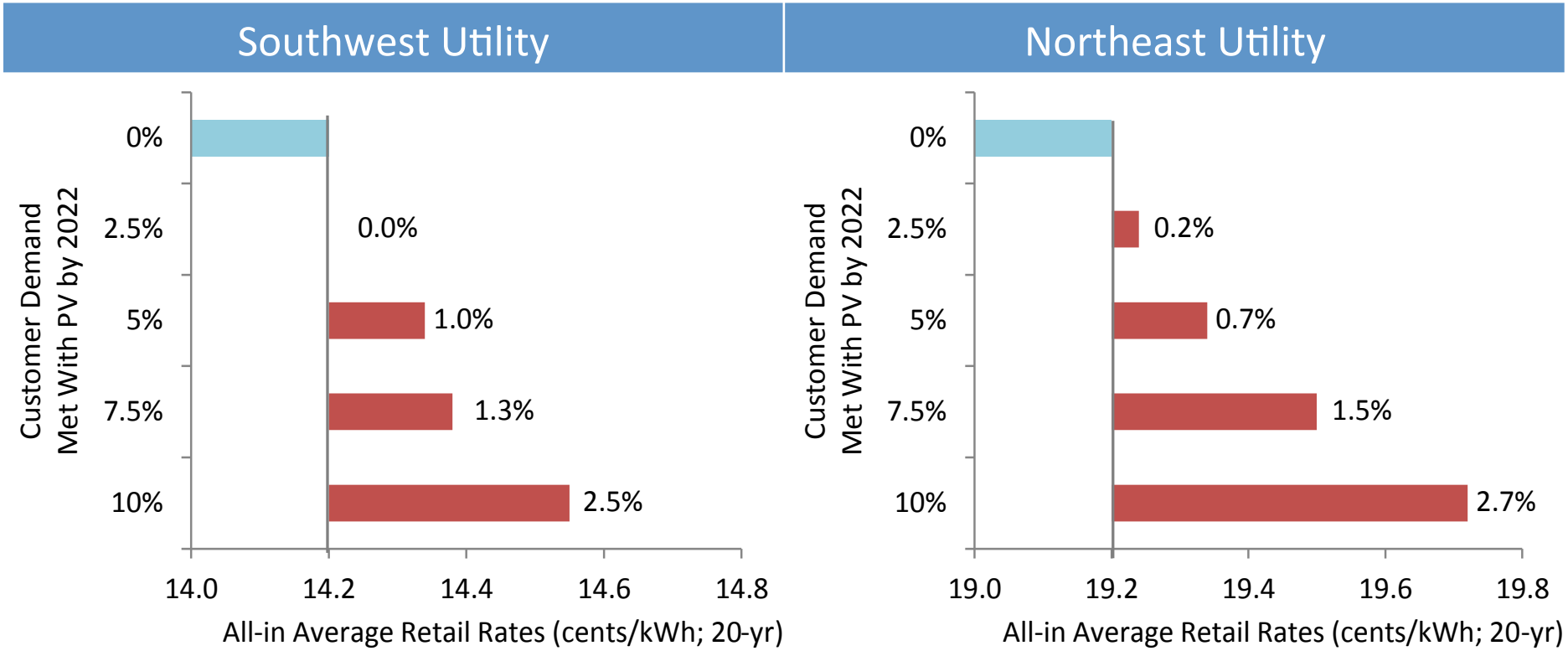
- Customer-sited PV reduces revenues by a greater amount than it reduces costs, leading to reduction in ROE ("revenue erosion effect")
- Impacts are larger for the NE utility, because of its higher assumed growth in fixed costs and its proportionally smaller rate base

Achieved earnings reduced by lost future investment opportunities



- PV reduces earnings as a result of both revenue erosion and also deferred capital investments ("lost earnings opportunity effect")
- Earnings impacts from deferred capital investments are most relevant to the SW Utility, which owns generation and transmission, though both utilities also experience earnings erosion from deferred distribution investments (in the base case)

Average customer rates increase slightly under base case assumptions



- Under base case assumptions, PV reduces sales and peak demand by a greater amount than it reduces costs, which causes average retail rates to increase
- Note, though, that these estimated rate impacts represent average impacts across all customers, thus do not directly measure cost shifting between PV and non-PV customers or for any individual customer class

Outline

- Project overview
- Base case results
- **Sensitivity analysis**
- Mitigation analysis
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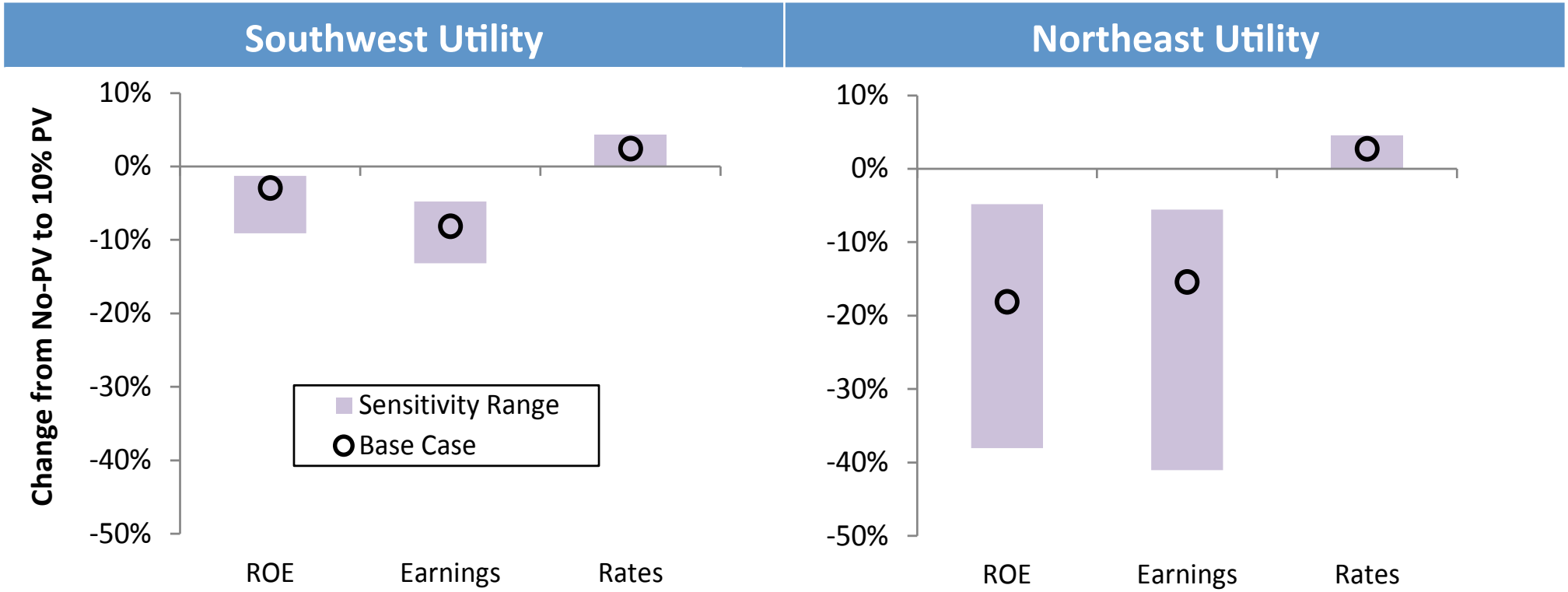
Sensitivity analysis overview

Objective: Illustrate the extent to which impacts of customer-sited PV on shareholders and ratepayers depend on underlying utility conditions

Sensitivities		Description	SW Utility	NE Utility
Utility Operating Environment	Value of PV	Higher/lower PV capacity credit and ability of PV to offset non-generation capital expenditure (CapEx)	●	●
	Load Growth	Higher/lower load growth	●	●
	Fixed O&M Growth	Higher/lower growth rate of fixed O&M costs	●	●
	Non-Generating CapEx Growth	Higher/lower growth rate of non-generation CapEx	●	●
	Fuel Cost Growth	Higher/lower growth rate of fuel costs or wholesale energy market prices	●	●
	Coal Retirement	Early retirement of existing coal generation	●	
	Utility-Owned Generation Share	Higher share of utility-owned generation	●	
	Utility-Owned Generation Cost	Higher/lower cost of utility-owned generation	●	
	Forward Capacity Market Cost	Higher/lower market clearing price in the ISO-NE forward capacity market		●
Utility Regulatory Environment	Rate Design	Higher/lower fixed customer charges	●	●
	Rate Case Filing Period	Shorter/longer period between general rate cases	●	●
	Regulatory Lag	Shorter/longer period from the filing of a general rate case to implementation of new rates	●	●
	Test Year	Use of current or future test year during general rate cases, instead of historical test year	●	●
	PV Incentives	$0.5/Watt rebate provided by the utility to customers with PV	●	●

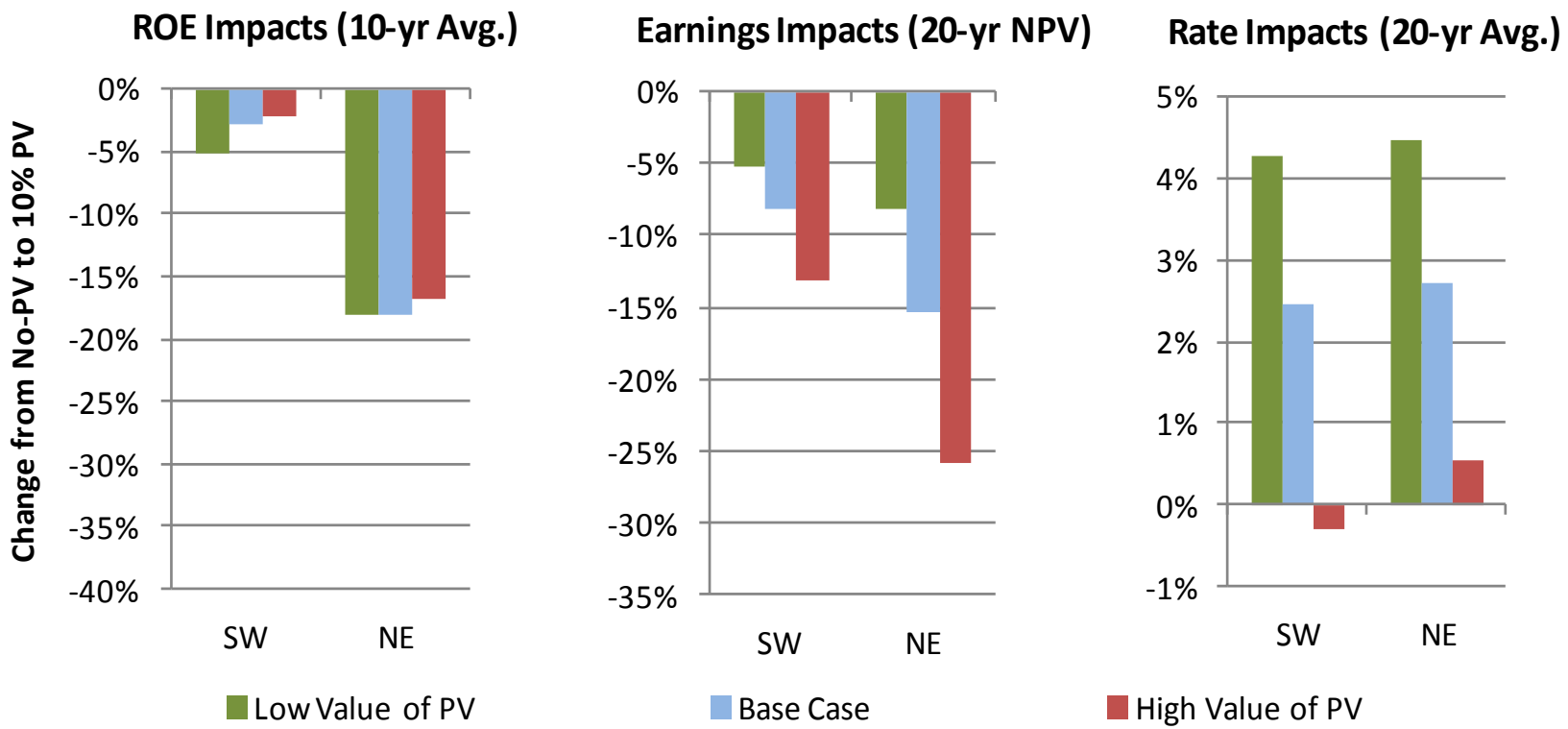
Sensitivity analysis summary



**All sensitivity cases focus on impacts under 10% PV trajectory for illustrative purposes*

- Impacts are directionally consistent, but their magnitude varies widely
- Shareholder impacts (ROE and earnings) are particularly sensitive to utility operating and regulatory environment, especially for NE Utility
- Greatest sources of sensitivity vary by metric and utility: e.g., for NE utility, choice of test year and load growth causes large swings in shareholder impacts, but value of PV is key for ratepayer impacts

Sensitivity analysis example: Value of PV



- Value of PV sensitivities consider alternate assumptions about the capacity value of PV and whether impacts on T&D costs are positive or negative
- Impacts can be quite sensitive to these assumptions, but implications are divergent for shareholders vs. ratepayers: High Value of PV results in *lower* ratepayer impacts but *higher* shareholder impacts

Selected additional sensitivity results

- **Load growth:** Shareholder and ratepayer impacts tend to be more significant with lower underlying load growth, partly because of reduced opportunities for deferral of capital expenditures
- **Rate structure:** Shareholder impacts tend to be more severe when retail rates rely predominantly on volumetric energy charges, because of greater revenue erosion
- **Ratemaking process:** Shareholder impacts are more severe when longer lags exist within the ratemaking process (e.g., longer periods between rate cases or use of historic test years)
- **Utility cost growth:** Shareholder and ratepayer impacts also depend on magnitude and growth of various utility cost elements, though the degree and direction of those sensitivities depend on the type of cost and how it is recovered (i.e., via fuel adjustment clause or via rates set in rate case)

Refer to report for details on the full set of sensitivity cases

Outline

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- **Mitigation analysis**
- Conclusions

Mitigation analysis overview

Objective: Explore the efficacy and potential tradeoffs associated with regulatory and ratemaking measures for mitigating the impacts of PV

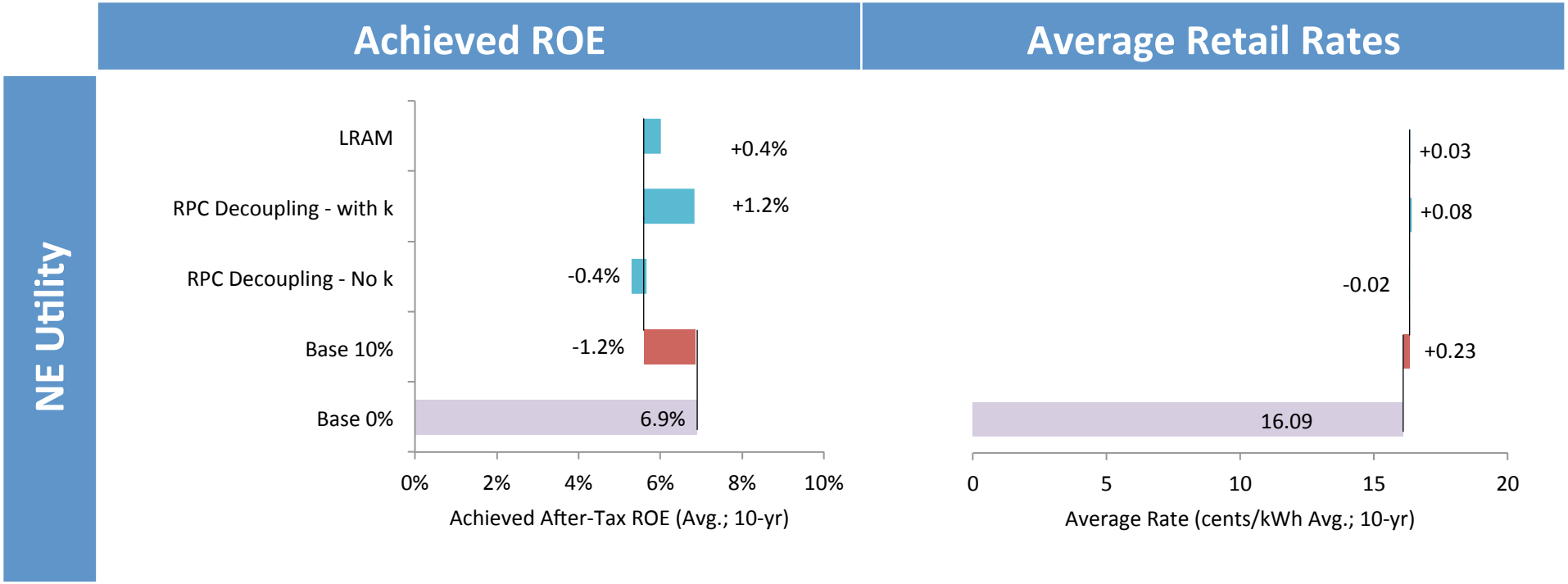
Mitigation Measure	Revenue Erosion	Lost Earnings Opportunities	Increased Rates
Revenue-per-Customer (RPC) Decoupling	●		○
Lost Revenue Adjustment Mechanism (LRAM)	●		○
Shareholder Incentive		●	○
Shorter Rate Case Filing Frequency	●		○
No Regulatory Lag	●		○
Current & Future Test Years	●		○
Increased Demand Charge & Fixed Charge	●		○
Utility Ownership of Customer-Sited PV		●	○
Customer-Sited PV Counted toward RPS			●

● Primary intended target of mitigation measure
○ May exacerbate impacts of customer-sited PV

Example results

- Mitigation scenarios borrow from measures implemented with energy efficiency programs, though are not an exhaustive set of options
- Mitigation analysis focuses on impacts under 10% PV trajectory, for illustrative purposes

Decoupling and LRAM mitigate revenue erosion effect

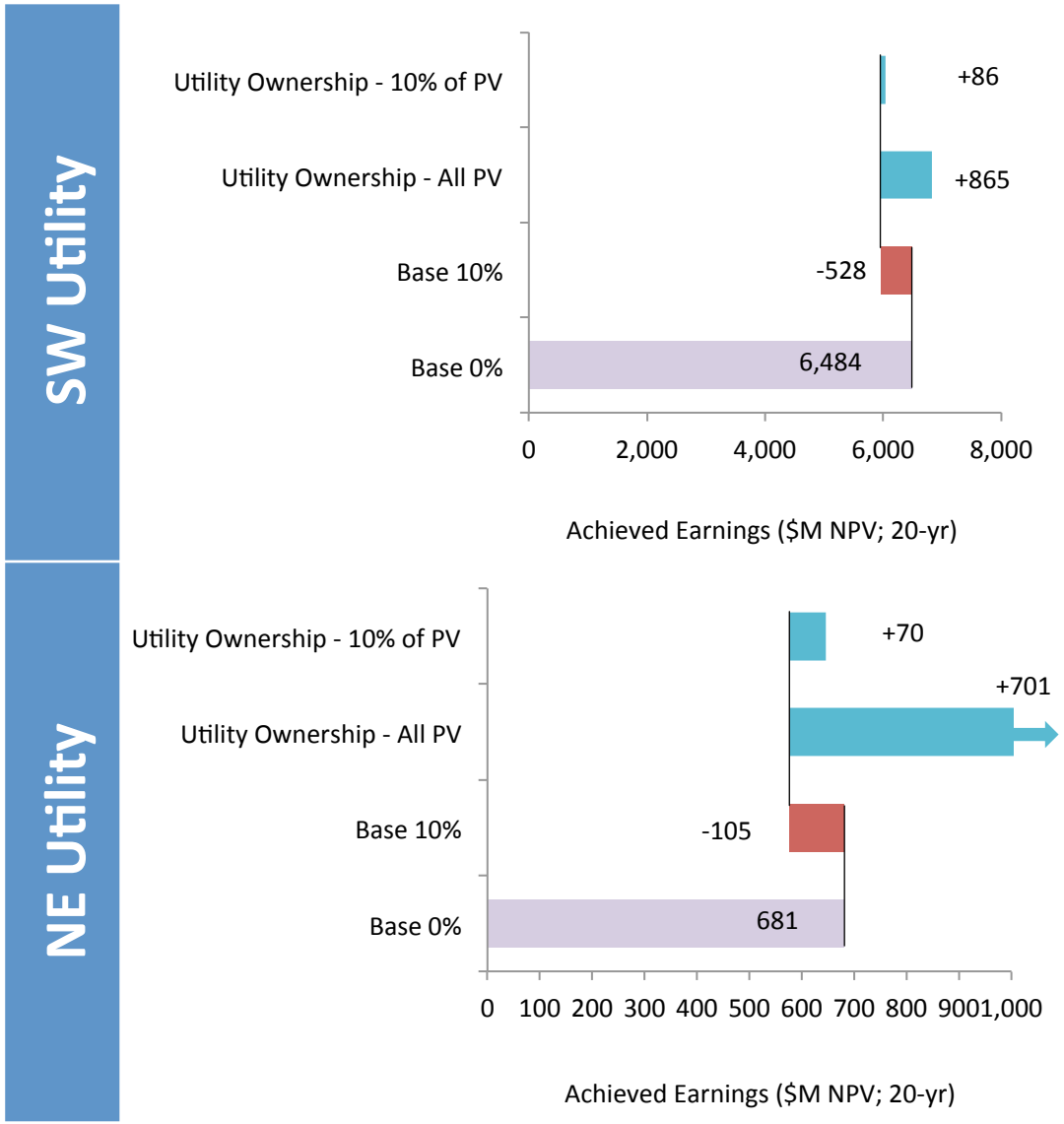


- RPC decoupling and LRAM mitigate revenue erosion impacts from customer-sited PV, thereby improving ROE, but degree of mitigation varies by utility and depends on design (e.g., k-factor)
- Mitigation of shareholder impacts in these cases necessarily entails an increase in average retail rates, illustrating one form of tradeoff

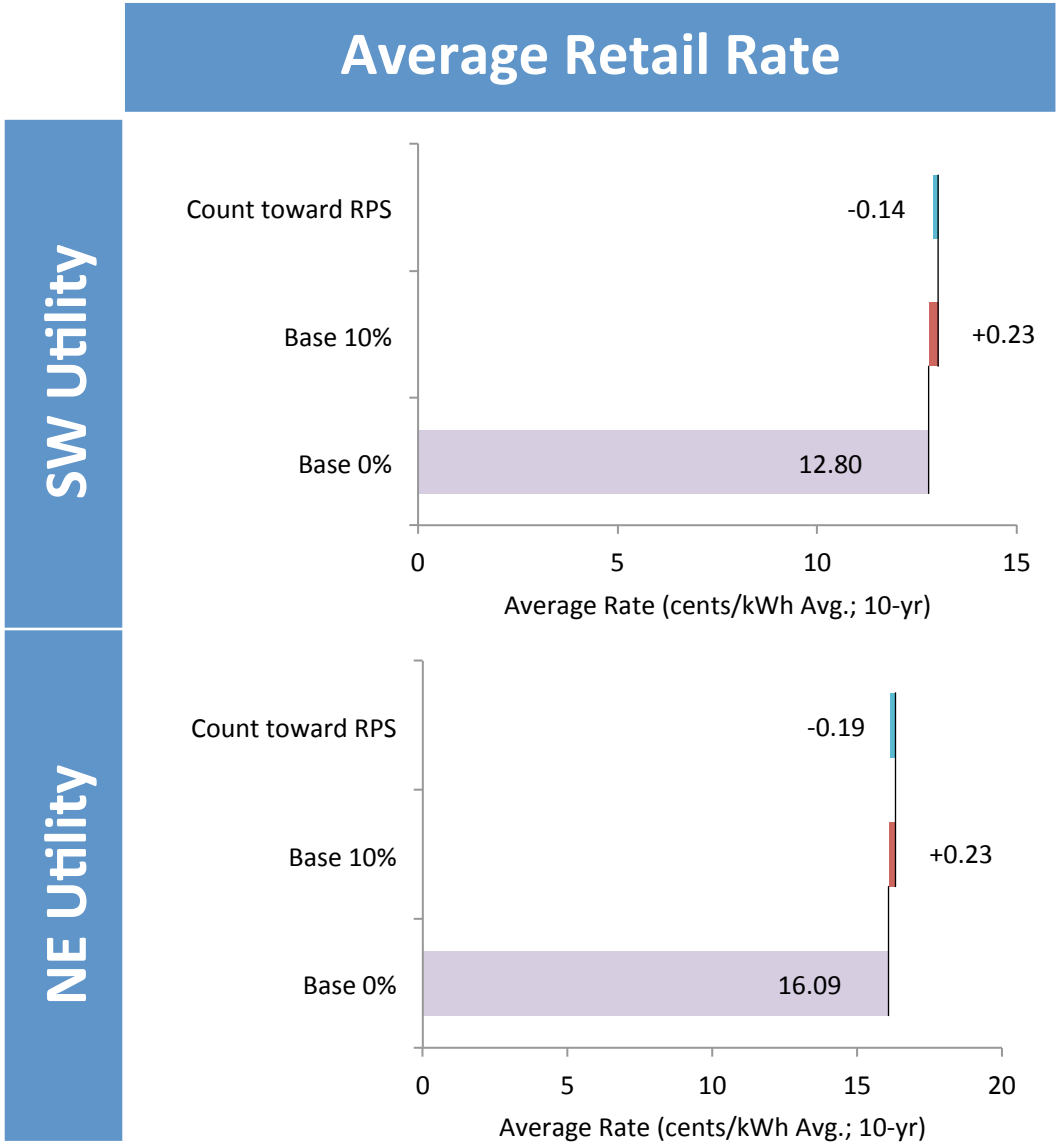
Utility ownership of PV may provide substantial earnings opportunities offsetting the impacts

- Utility ownership and capitalization of customer-sited PV provides increased earnings, offsetting most or all the financial impacts to shareholders
- NE Utility could see substantial increases in earnings by investing in customer-sited PV especially given otherwise limited opportunities for capital investment
- Utility ownership or financing of customer-sited PV may raise significant policy and/or regulatory issues around risk sharing, competition, and generation asset ownership

Achieved Earnings



Counting customer-sited PV towards utility RPS compliance mitigates rate impacts



- Applying renewable energy certificates (RECs) generated by customer-sited PV to utility RPS compliance reduces a portion of RPS compliance costs and reduces average retail rates
- There is no change in shareholder impacts as RPS compliance costs are a pass-through to customers (and RECs do not offset investments in renewable generation)

Outline

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Conclusions

- Even at penetration levels significantly higher than today, the impacts of customer-sited PV on average retail rates may be relatively modest (though we stress that our analysis does not isolate cost-shifting per se)
- In comparison, impacts on utility shareholders are potentially much more pronounced, though they depend highly upon the specifics of the particular utility
- Various “incremental” changes to utility business or regulatory models (as opposed to wholesale paradigm shifts) can mitigate the impacts of customer-sited PV on utility ratepayers and shareholders
- However, those measures generally entail important tradeoffs, either between ratepayers and shareholders or among competing regulatory and policy objectives

Potential areas for future research

As a scoping study, one final objective was to highlight additional questions and issues worthy of further analysis, including to:

- Benchmark the impacts of customer-sited PV against other factors affecting utility profitability and customer rates
- Examine the combined impacts from customer-sited PV, aggressive energy efficiency, and other demand-side measures
- Examine differential impacts among customer groups, including cost-shifting from PV to non-PV customers
- Examine a broader range of mitigation options and combinations thereof
- Continue improving methods for estimating the avoided costs from customer-sited PV
- Identify strategies for maximizing the avoided costs of customer-sited PV

For more information

Download the full report and companion briefing:

http://emp.lbl.gov/publications

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Andrew Mills | admills@lbl.gov

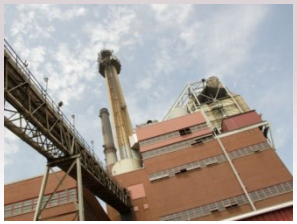
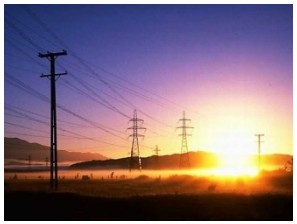
Galen Barbose | glbarbose@lbl.gov

Thanks to the U.S. DOE's Solar Energy Technologies Office for funding this work

PPL companies

Distributed Energy Resources and Resource Planning

Chuck Schram
Director - Energy Planning, Analysis & Forecasting
April 15, 2015

Planning Challenges

- Distributed generation will result in lower net load
  - *On-peak, off-peak, or both?*
  - *How much of customer's load is still served by utility?*
  - *Over time, forecasts will adjust and potentially trend lower*
  - *Planning has to consider how trends affect existing and future resources*
  - *Highlights need for metering considerations and monitoring of DER*

Planning Challenges

- Obligation of utility
  - *Does customer want utility to plan to serve entire load?*

Planning Challenges

- Obligation of utility
  - *Does customer want utility to plan to serve entire load?*
  - *Grid reliability and stability*

DER is still a future planning challenge

- LG&E/KU peak demand is growing at 50-55 MW per year
  - *50 projects at 1 MW to change resource needs by one year*
- Technology development and cost trends are monitored as part of Integrated Resource Planning

Treatment of Distributed Energy Resources in Resource Planning

Tom Rice
Senior Manager, Capacity Planning & Fleet Strategy
TVA

How we plan for DG - the simple answer

We don’t…

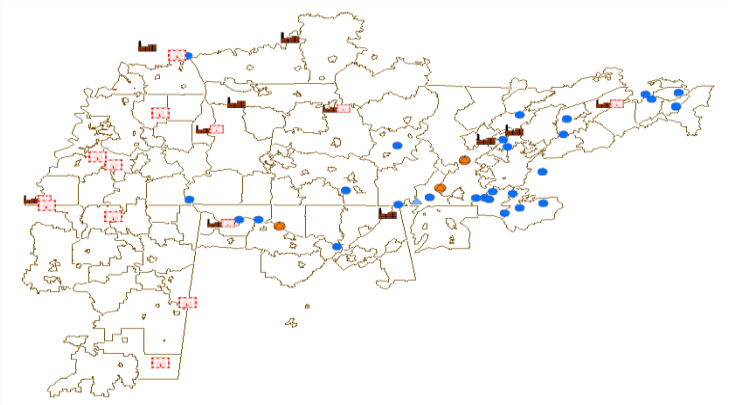
How we plan for DG - the evolving answer

We'll have to

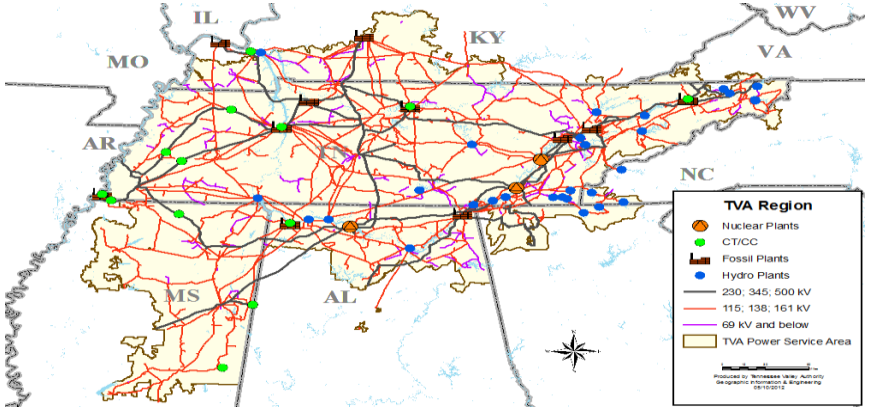
while maintaining low cost and high reliability

TVA Has a Long History Integrating Complex Systems

TVA River System & Resources



TVA Transmission and Power System



Power service territory covers 80,000 square miles in 170 counties. TVA operates more than 50 power plant sites and 16,000 miles of transmission lines.

TVA's Unique Structure Presents Challenges and Opportunities

TVA is primarily a wholesaler, with some large industrial and federal retail customers

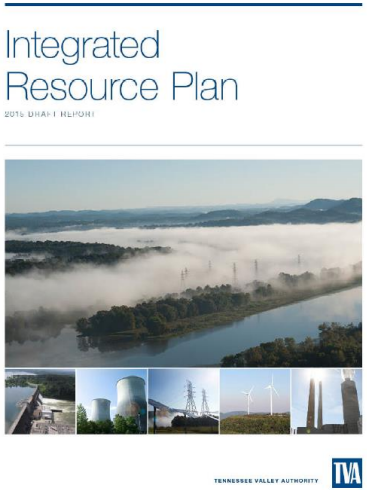
- 155 local power companies have the relationship with end-use customers
  - 9 million service area population
  - 650,000 businesses and industries

The key is effective partnerships

Current Efforts / Studies

Distributed Generation – Integrated Value (DG-IV)
A METHODOLOGY TO VALUE DG ON THE GRID

Stakeholder process to establish methodology to value energy, capacity, environmental, transmission, and distribution attributes of DG resources



18-Month Stakeholder and public process includes a specific high-DG penetration future to determine impacts to TVA

Key Issues Remain

- Determining the cost and benefits of DG relative to central station generation within TVA's least-cost planning mandate
    - Are economies of scale irrelevant?
    - Mechanism to determine distribution-level impacts and visibility
    - Ability to maintain high reliability (backup)
- Cost and value drivers lead to rate design issues:
    - Cost recovery (TVA and Local Power Company)
    - Participant vs. non-participant equity
- Ability to communicate the value of grid services (mindset)

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Helping Utilities Make Smart Solar Decisions

Solar Overview:

Markets, Pricing, & Emerging Opportunities

April 15, 2015

Business Confidential

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INTRODUCTIONS & OVERVIEW

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About SEPA

SEPA's unique mission is aimed at utility issues …

SEPA is an educational non-profit (501 c3)

- Celebrating over 20 years of service to utilities and solar
- Membership based – approx. 900 members
- Providing unbiased information focused on supporting utilities and their needs as they relate to solar adoption
- Providing exclusive member programming, research, education, collaboration and consulting services

Membership

500+ Utility

425+ solar industry & stakeholder

52% of electricity customers

+90% of installed solar capacity

…delivered through tailored education, publications, best practices, & consultation

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Aligning Solar and Utilities
Sampling of Utility Members

Pedernales Electric Cooperative, Inc.

SDGE connected
A Sempra Energy utility

DEMEC
DELAWARE MUNICIPAL ELECTRIC CORPORATION

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

Westar Energy

PGE
Portland General Electric

cps ENERGY

conEdison

DUKE ENERGY

SRP

Xcel Energy
RESPONSIBLE BY NATURE

NIPSCO 1912 100 YEARS 2012

GEORGIA POWER
A SOUTHERN COMPANY

TVA

aps

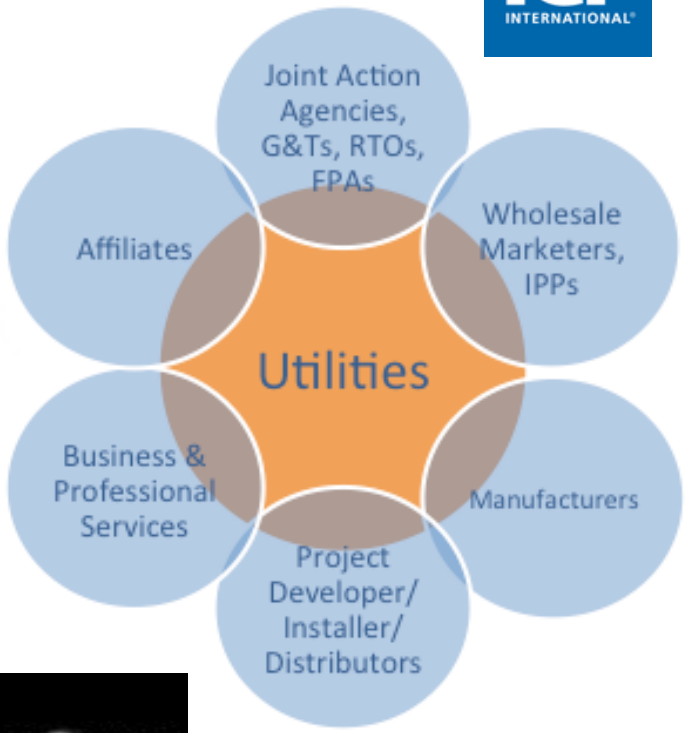
PG&E

Dominion

PSE PUGET SOUND ENERGY

OG&E

Aligning Solar and Utilities
Sampling of Non-Utility Members



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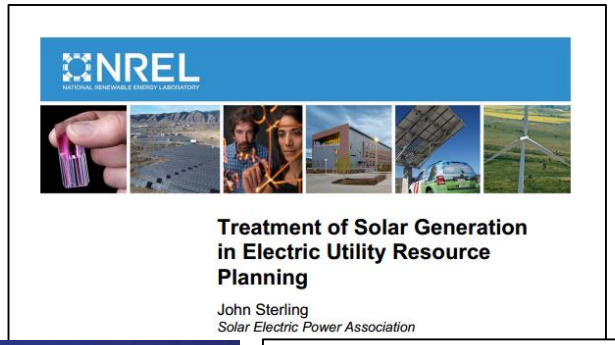
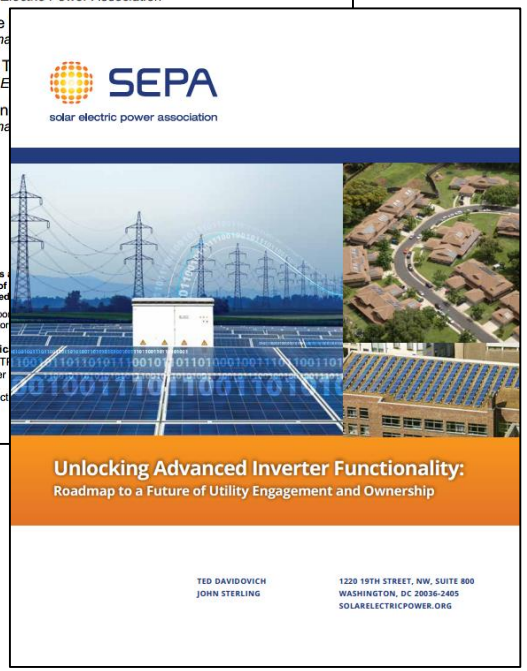
SEPA Events, Products, & Services

UTILITY SOLAR CONFERENCE SEPA





UTILITY SOLAR DATABASE
Powered by SEPA

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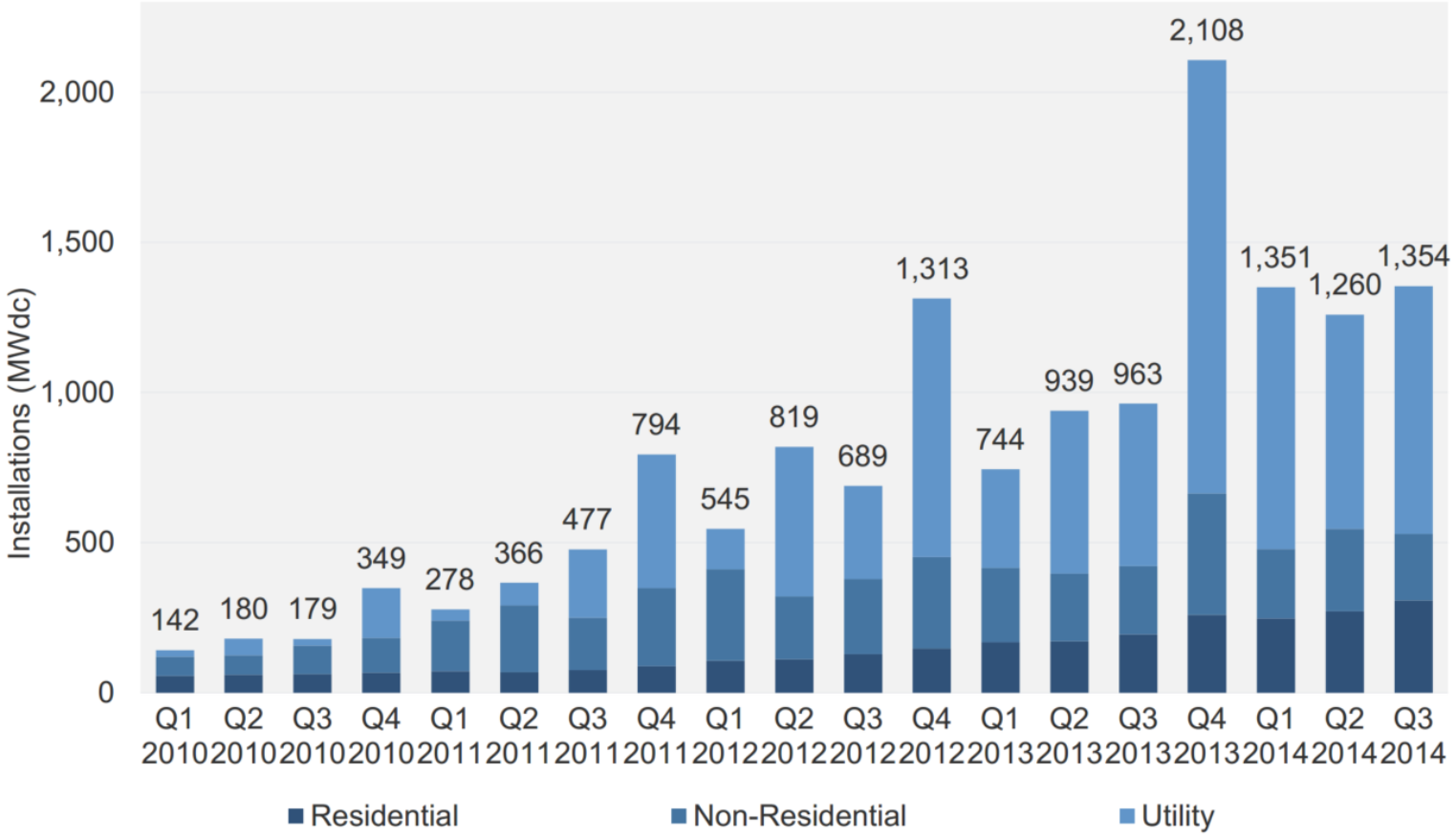
SOLAR MARKET OVERVIEW

Market Segments over Time



Source: GTM/SEIA U.S. Solar Market Insight Report (Q3 2014)

Drivers for DG Market Growth

Core DG growth drivers:

Fundamental Economics

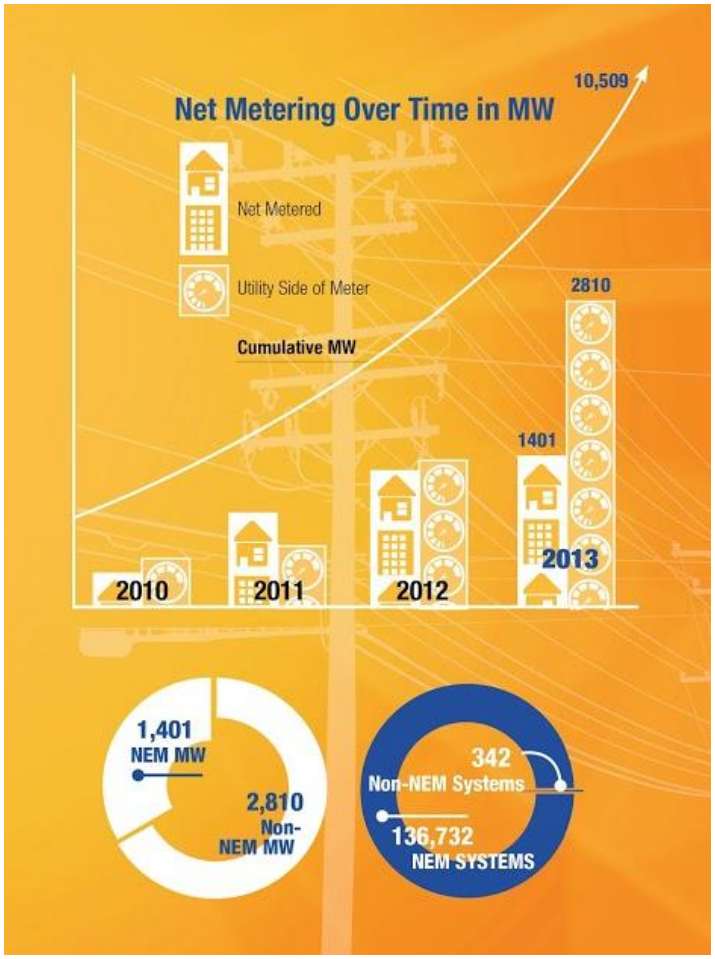
- Upward pressure on utility costs/rates
- Declining PV costs (60%/3 ys)

Policy

- State Renewable Energy Standards
- Net Metering
- Federal Incentives (ITC/MACRS)

Consumer Preference

- Innovation in customer financing (leases &PPAs)
  - Leveraging cost of capital to turn ROI to cash flow
  - Securitization & public funding
- Increasing demand by customers for choice



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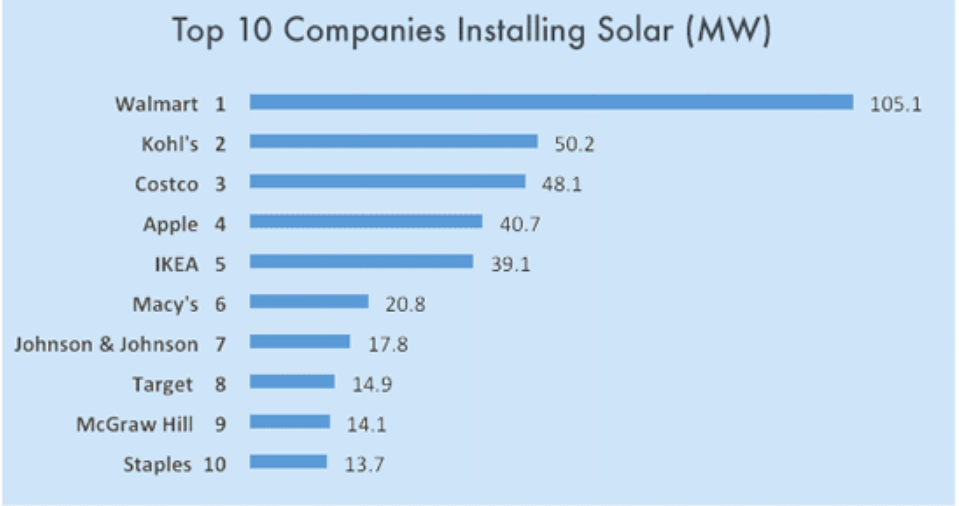
DG Growing Among C&I Customers

Despite rates that contain less subsidy

- 569 MW currently installed at over 1,000 locations by top 25 corporate solar users
- Apple recently reached agreement to buy 130 MW from First Solar
  - $848M transaction
  - Largest solar procurement deal for a non-utility; nearly triples Apple's stake in solar

Fact: Since 2012, top U.S. companies have ramped up their solar capacity by more than 100 percent.



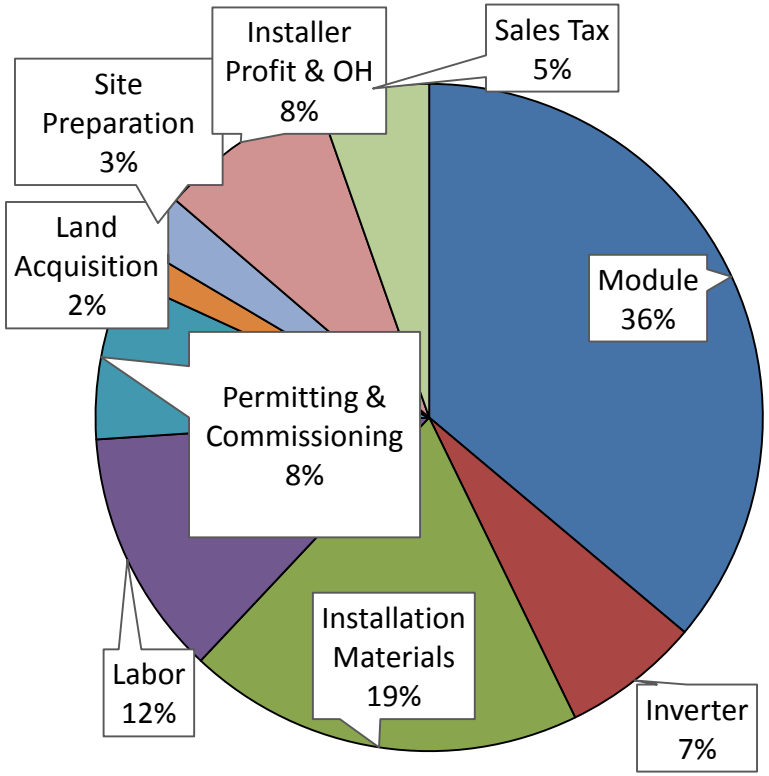
SEIA 2014 Solar Means Business Report

PRICING UPDATE

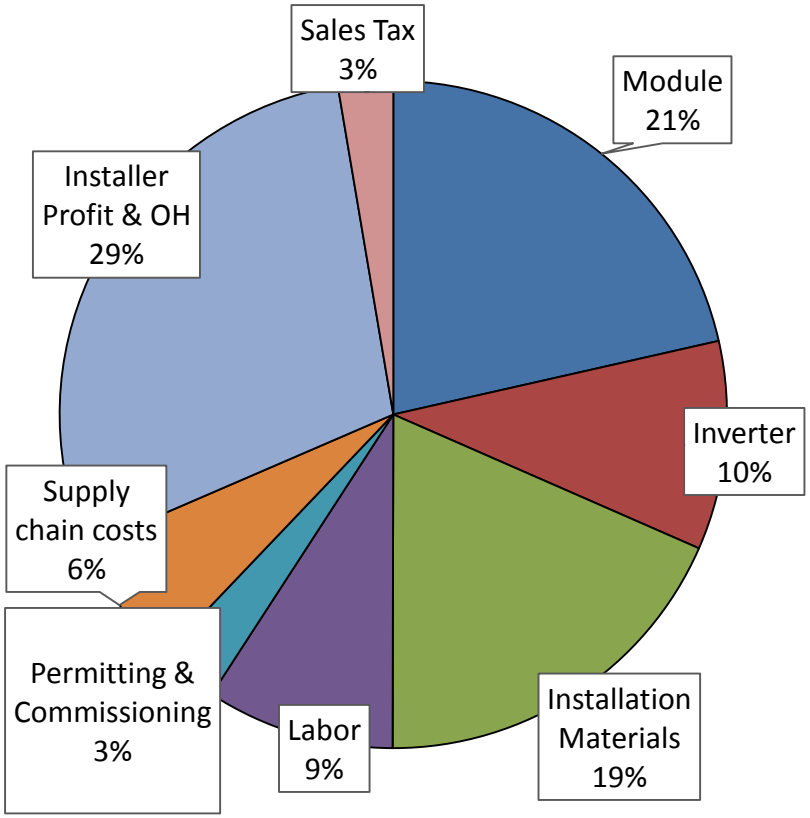
Sources of Cost

Economies of scale play a significant role in solar cost efficacy

Utility-Scale Fixed – $1.80/W



Residential Rooftop - $3.29/W



NREL/DOE "Q2/Q3 '14 Solar Industry Update" (October 31,2014)

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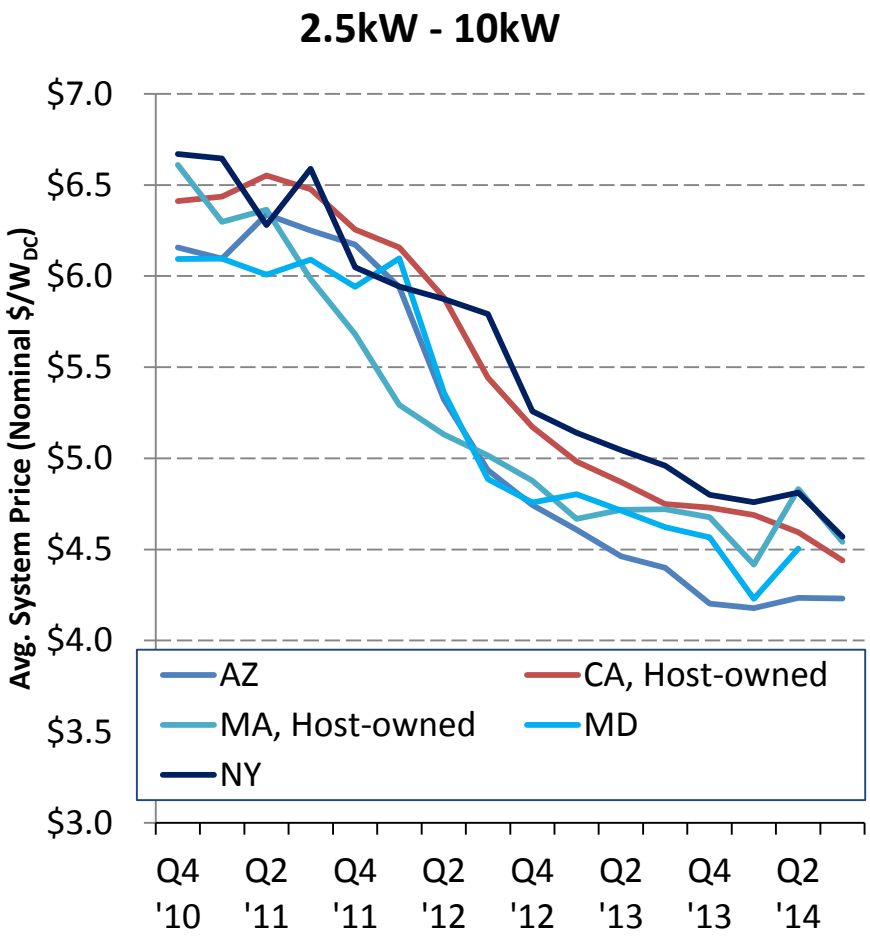
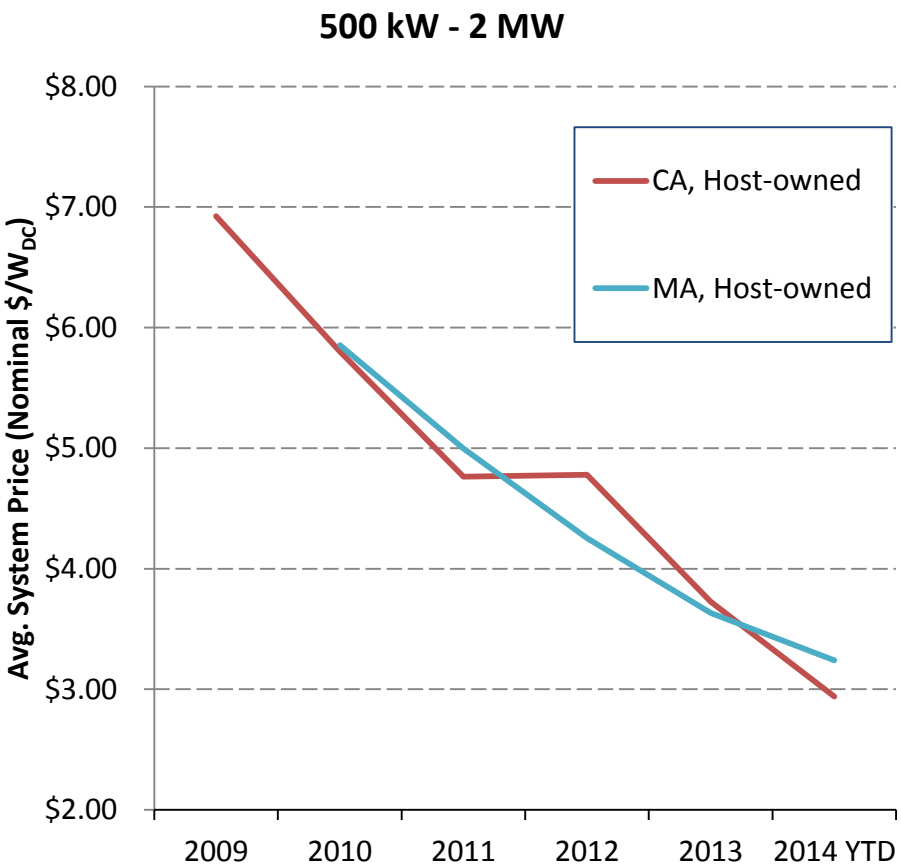
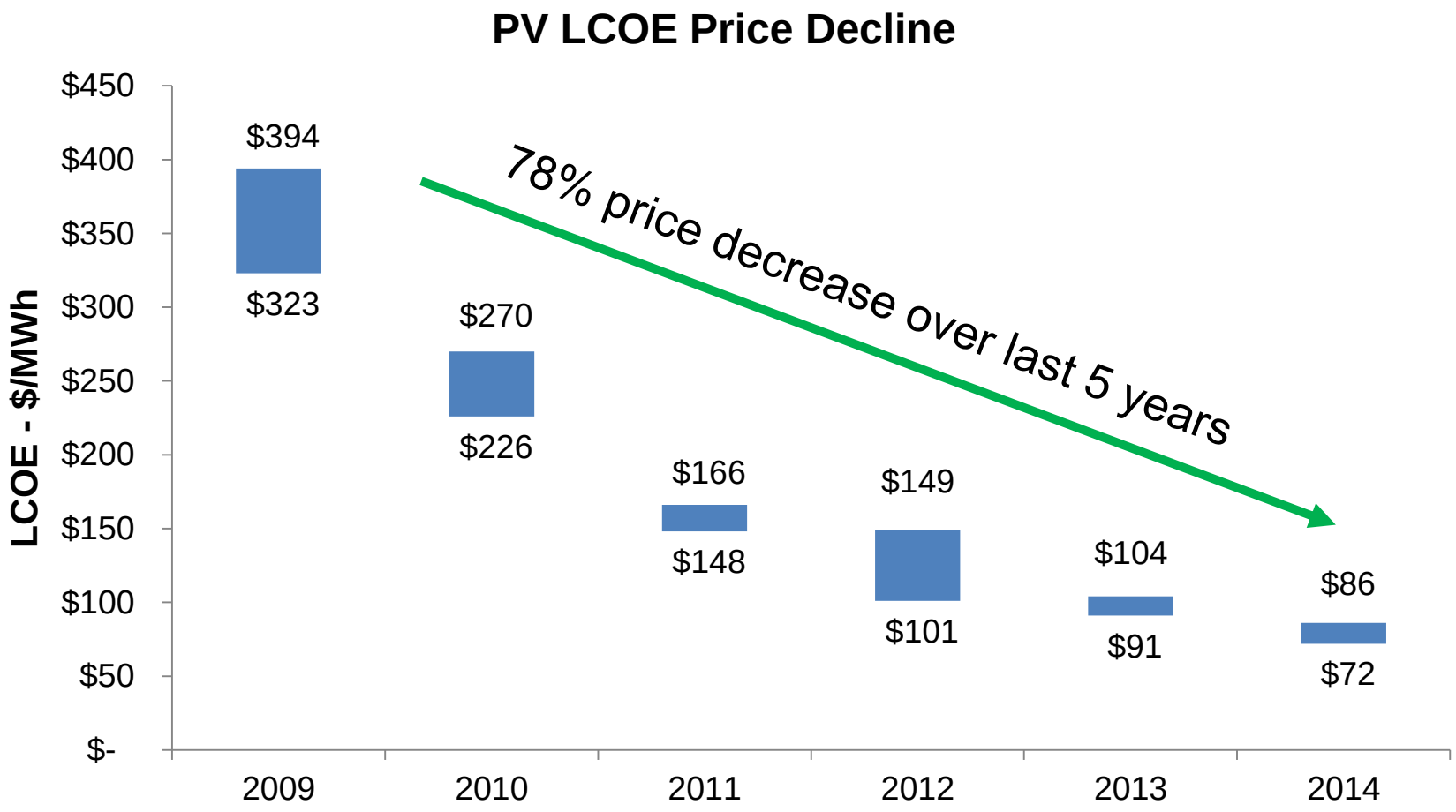
PV System Pricing Update – Distributed





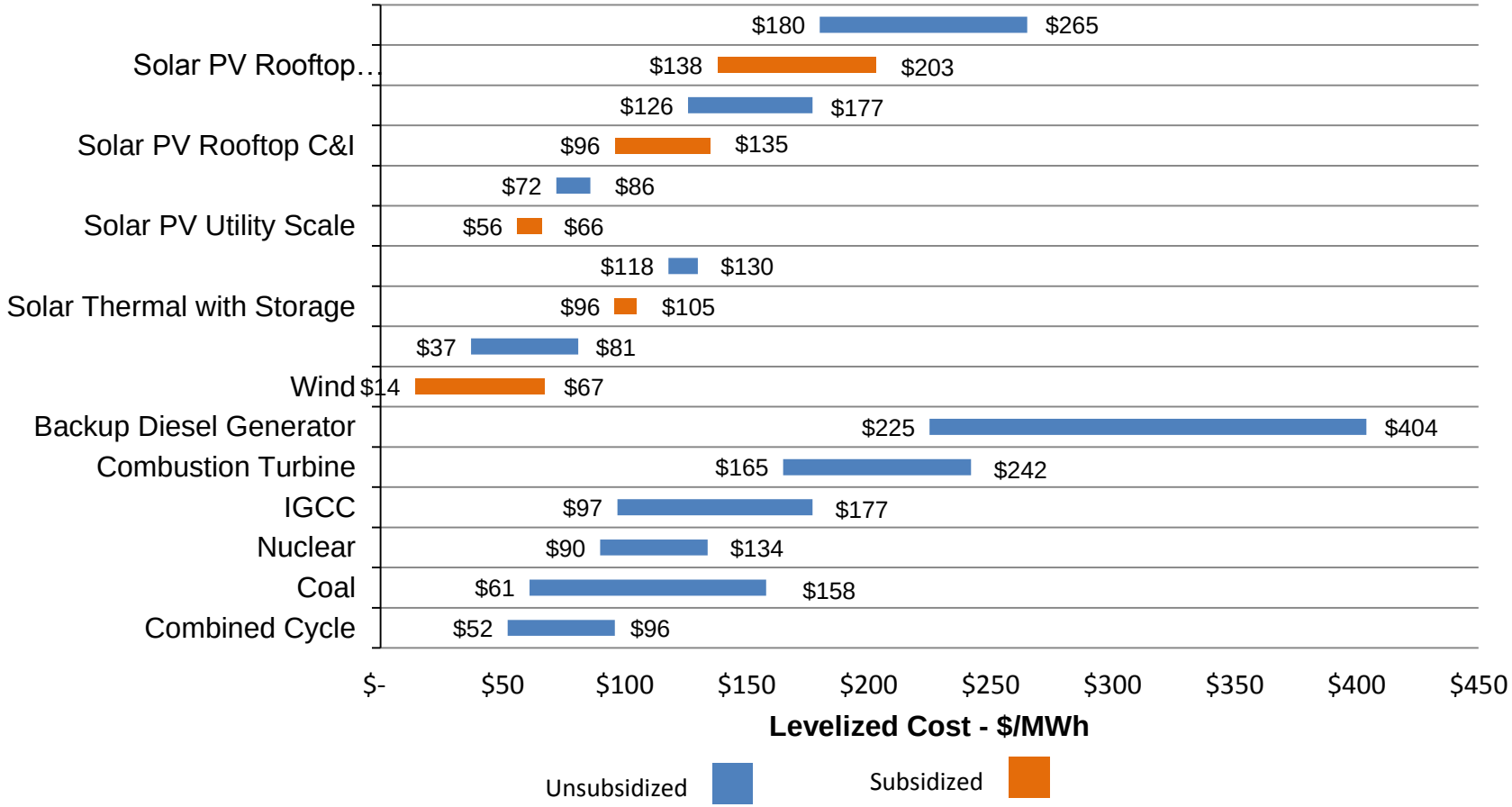
NREL/DOE "Q2/Q3 '14 Solar Industry Update" (October 31,2014)

Utility-Scale Solar PV LCOE History



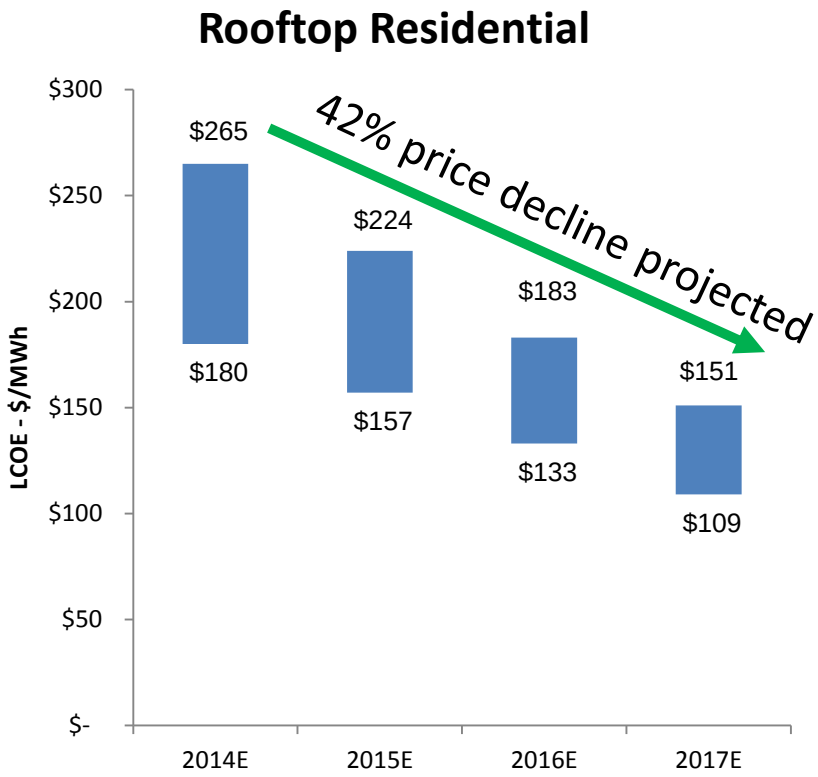
Lazard's Levelized Cost of Energy Analysis - Version 8.0

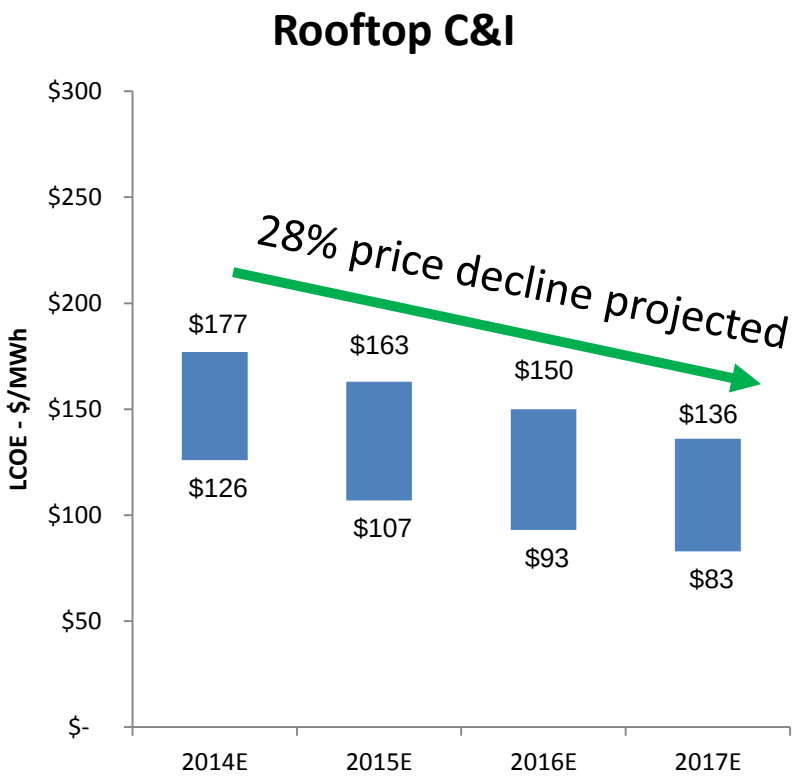
Renewable Technology LCOE



"Lazard's Levelized Cost of Energy Analysis – Version 8.0" (September 2014)

LCOE Forecast Comparison





Lazard's Levelized Cost of Energy Analysis - Version 8.0

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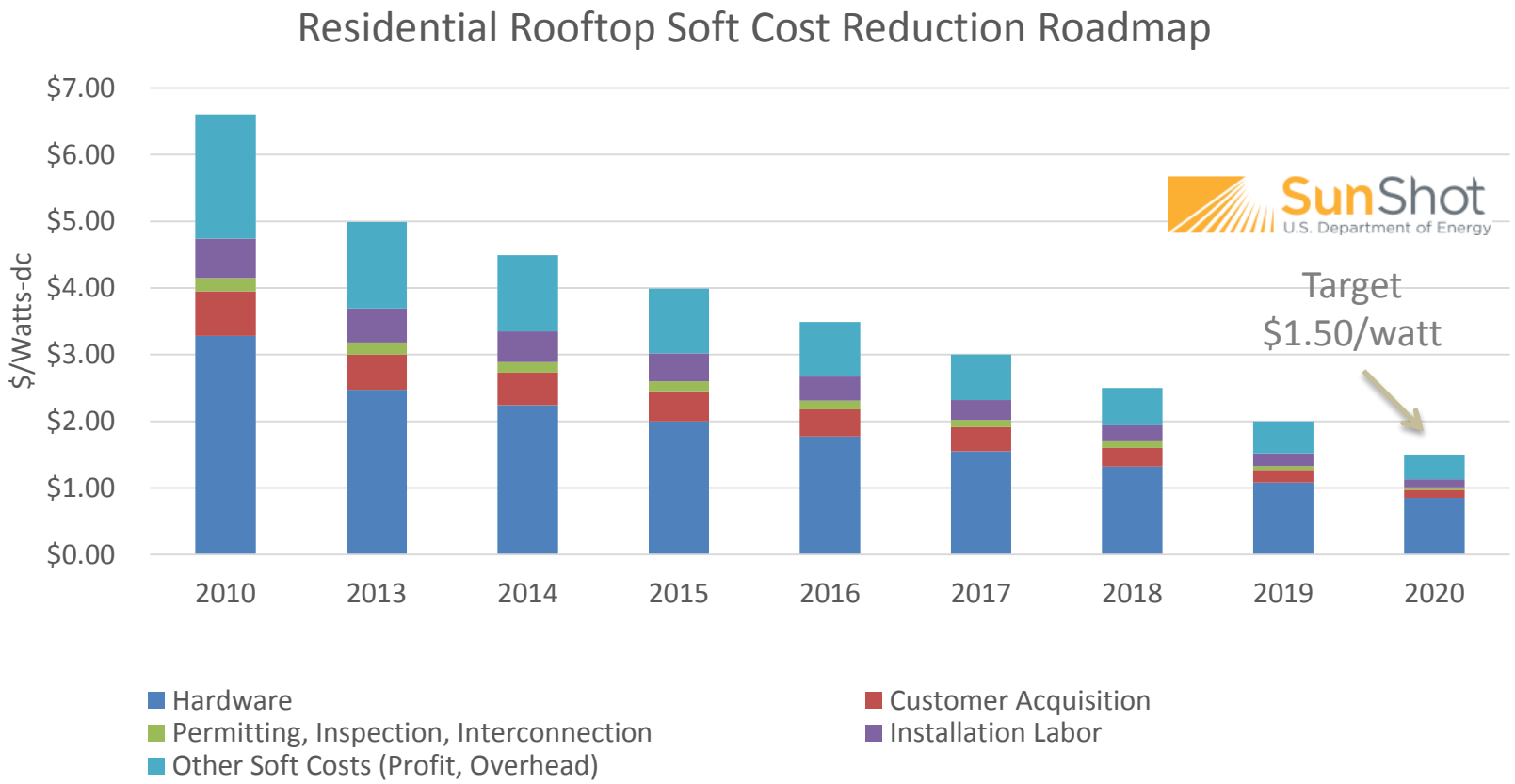
Cost Declines Key Focus of DOE

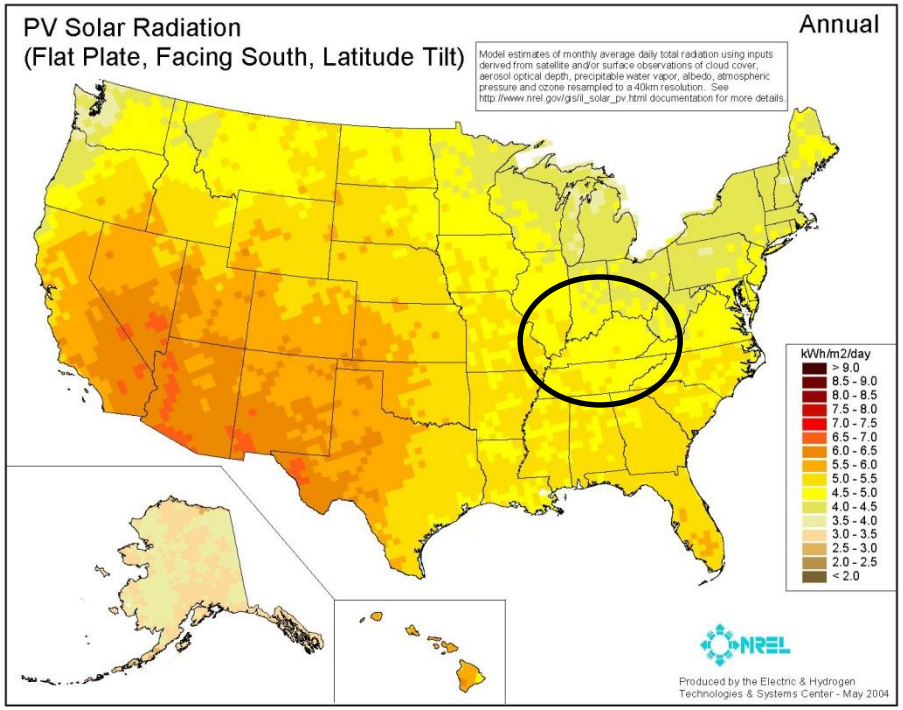
Residential solar costs are projected to continue cost declines to $1.50/watt in 2020

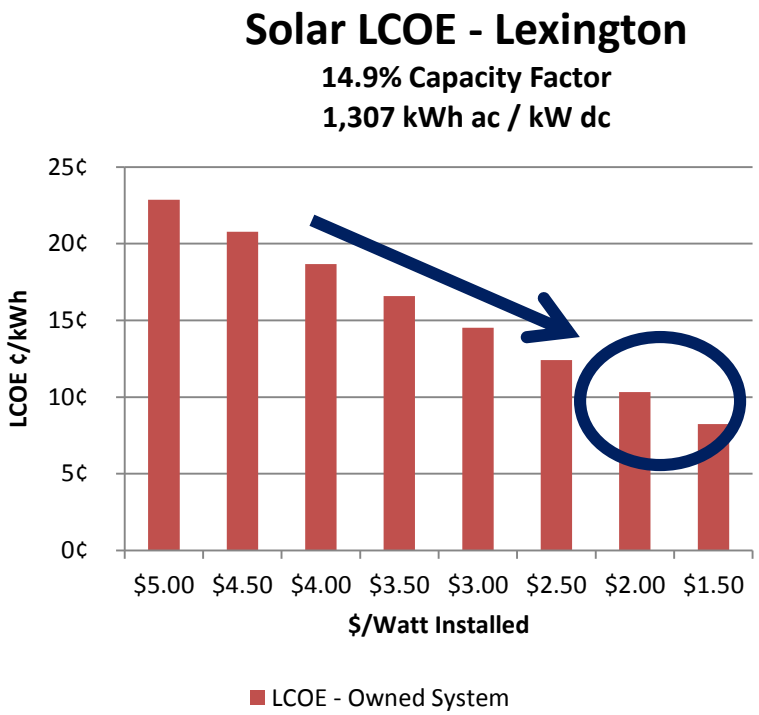


Non-Hardware ("Soft") Cost-Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics, 2013-2020 (NREL, Aug 2013)

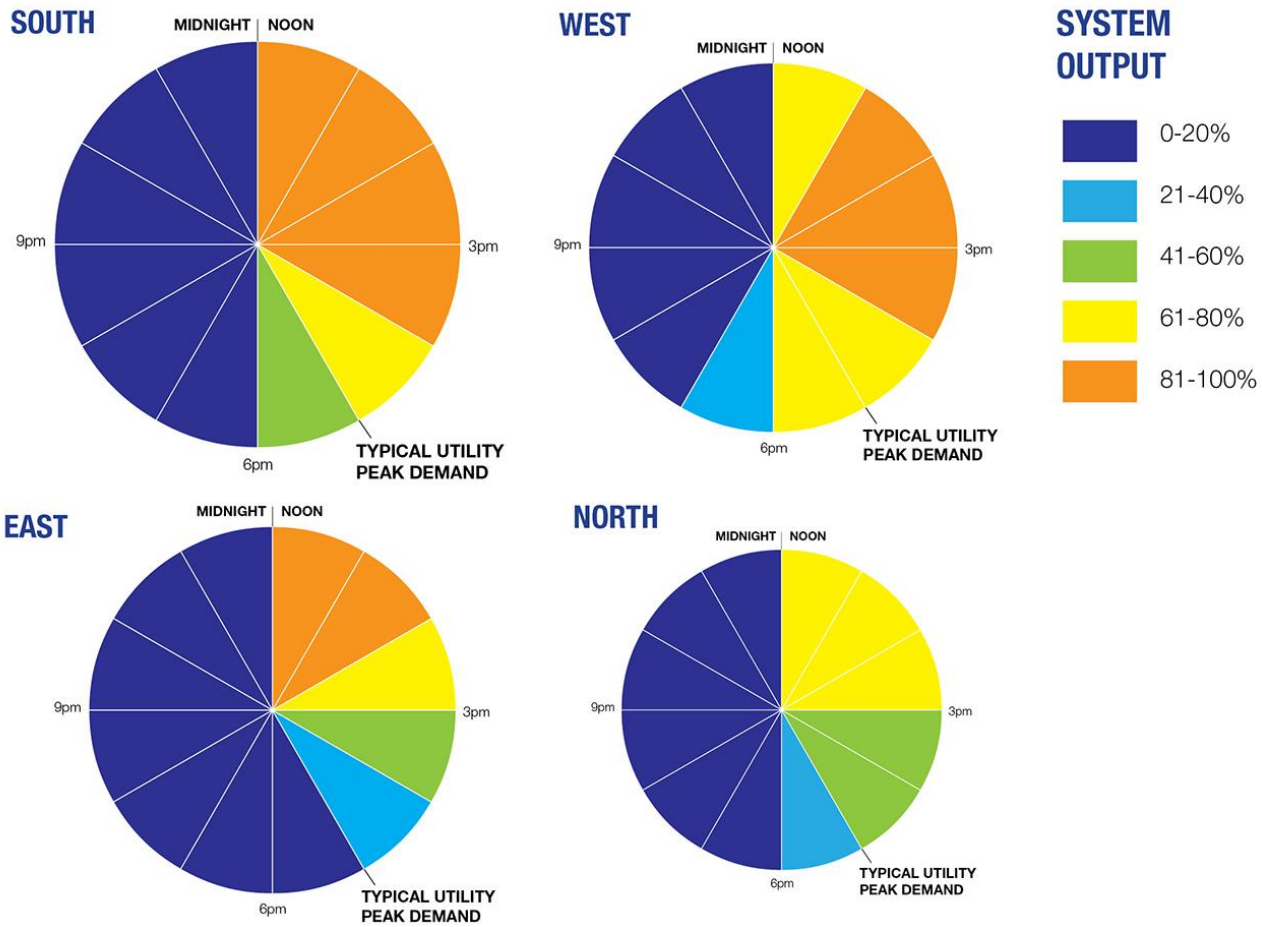
Solar in Kentucky

Low retail rates & moderate solar resource





Impact of Orientation to Timing & Level of Production



Source: Solar Fundamentals Volume 1: Technology, SEPA (February 2015)

NET ENERGY METERING ALTERNATIVES

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Net Metering Defined

Today 43 states and over 400 utilities offer some form of net energy metering

- ✓ Net Energy Metering (NEM) is a billing mechanism applied to existing rates that credits solar system owners for the electricity exported onto the grid

  Under the simplest implementation a customer's billing meter "runs backwards" as solar electricity is generated and exported to the electricity grid, and forwards as electricity is consumed from the grid

- ➢ **Signals for reconsidering the application of NEM in its current format**
  - ❑ PV cost declines and upward rate pressure sending poor signals to customers
  - ❑ Utility cost recovery impacts become significant
  - ❑ Cross-customer subsidy for solar is no longer aligned with public policy objectives
  - ❑ Incentives within net metering are material but not transparent
  - ❑ Customers and PV market have gained enough sophistication to understand and implement alternatives

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Ratemaking and NEM

Types of Utility Charges	Allocation of Costs		
	Typical Residential	Typical Non-Residential	
Customer Charges ($/month)	• Metering • Billing		Not Typically Impacted by Solar DG
Demand Charges ($/kW)	• Not typically applicable	• Generation, Transmission, and Distribution capital investments	Not Typically Impacted by Solar DG
Volumetric Energy Charges ($/kWh)	• Generation, Transmission, and Distribution capital investments • Fuel costs • Variable O&M expenses	• Fuel costs • Variable O&M expenses	Typically Sheltered by NEM
Adjustor Clauses ($/kWh)	• Fuel adjustment clauses • Renewable program costs		Typically Sheltered by NEM

For more information, *see* SEPA's "Ratemaking, Solar Value and Solar Net Energy Metering – a Primer" (July 2013)

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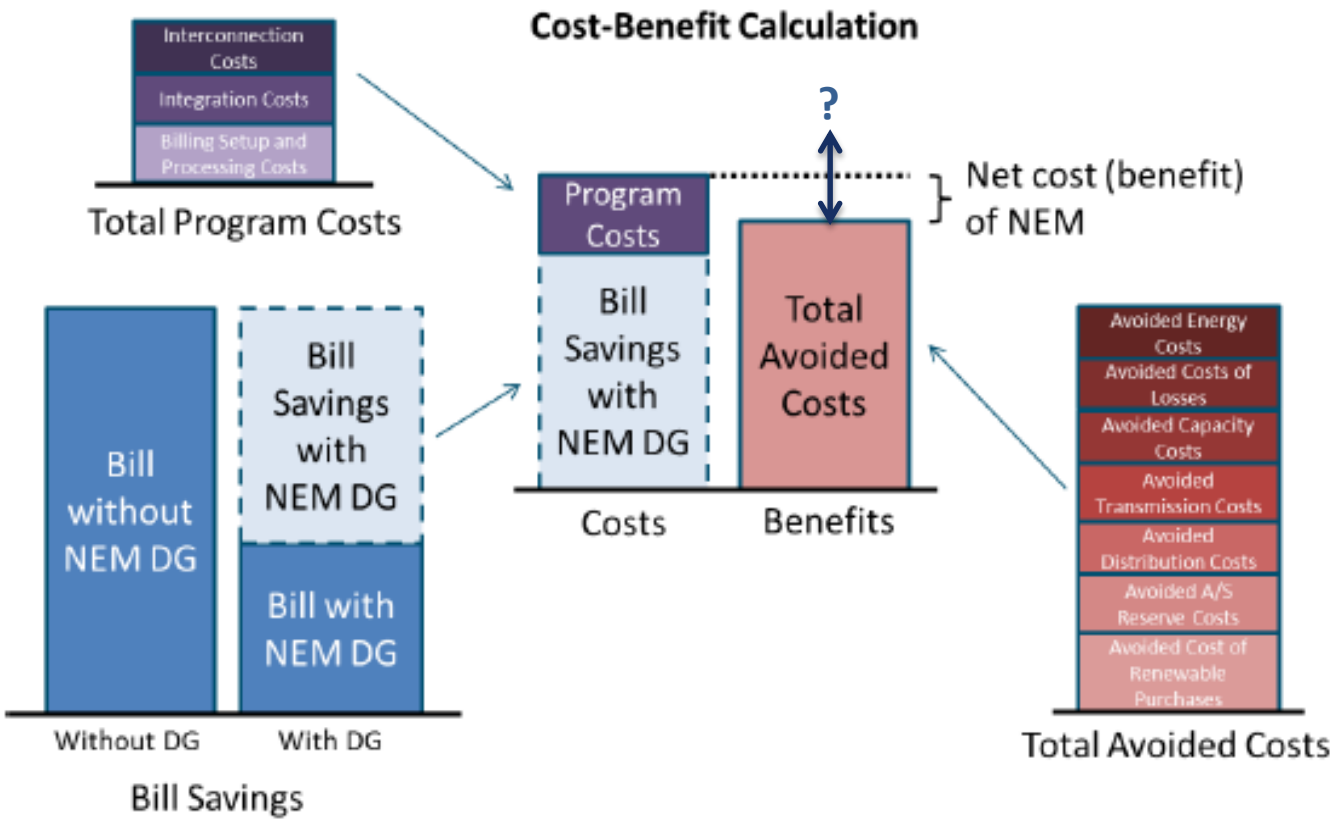
Addressing Solar DG Transaction

	CAMP 1	CAMP 2				
	Business as Usual	**Reforming the Solar Customer Transaction (NEM/rate reform)**				
RATE CONSTRUCT	**Single Transaction (Rate) Approach**				**Two or More Transactions (Rates)**	
	Apply NEM	Reform Existing Rates (all customers or solar only)			Solar Rate	Reform All Rates
MODEL	Current Rates	Increased Fixed Charge and/or Minimum Bill	Demand Charge	Stand-by or Solar Charge	Independent Energy Sale and Solar Purchase Rates	Value of Services
ATTRIBUTES	• Currently applicable rates result in an acceptable transaction • Solar penetration does not warrant action	• Add or increase basic service charge ($/month) • Raise minimum bill requirements ($/month)	• Add or increase customer fee for demand ($/kW/month)	• Charge for stand-by capacity, based on DG system size ($/kW/month or ($/kW/yr)	• Retain existing rates for services provided from utility to cust. • Establish second rate to purchase from customer	• Design rates to reflect itemized services from utility to cust. and from cust. to utility

Cost-benefit Calculation
The root of the debate



*Not drawn to scale

California Net Energy Metering R ate p aye r I m p a c t s E va l u ati o n
Prepared by California Public Utilities Commission Energy Division October 28, 2013 (E3)

Challenges to be Addressed

- Reconciliation of cost and value perspectives
  - Need to talk about the transaction more holistically
- Roadmap to a sustainable solar transaction
  - Seek long-term sustainability for both the utility and the market through *incremental* market transformation
- Development of a transition plan that can achieve broad stakeholder support is the key to success
- SEPA is looking to kick-start these discussions with its 51st State Initiative
  - Seeking input nationally on how to design an electricity market and transaction in a hypothetical 51st State, where no conditions currently exist
  - 13 qualifying submissions received: http://www.sepa51.org/submissions.php

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Community Solar, Utility Rooftop Ownership, & Advanced Inverters

EMERGING DISCUSSIONS

What is Community Solar?

What it is…

- Voluntary, rooftop alternative for groups of participants
- Supply is most often larger, ground-mounted PV system
- Participants are involved in a two-way transaction
  - Participants pay a cost to participate (via subscription or direct ownership)
  - In exchange, participants receive benefits, which may include kWh offset, immediate or anticipated rate savings, return on investment

What it isn't…

- Bulk purchasing program for customer rooftops
- Green pricing program
- Charity program

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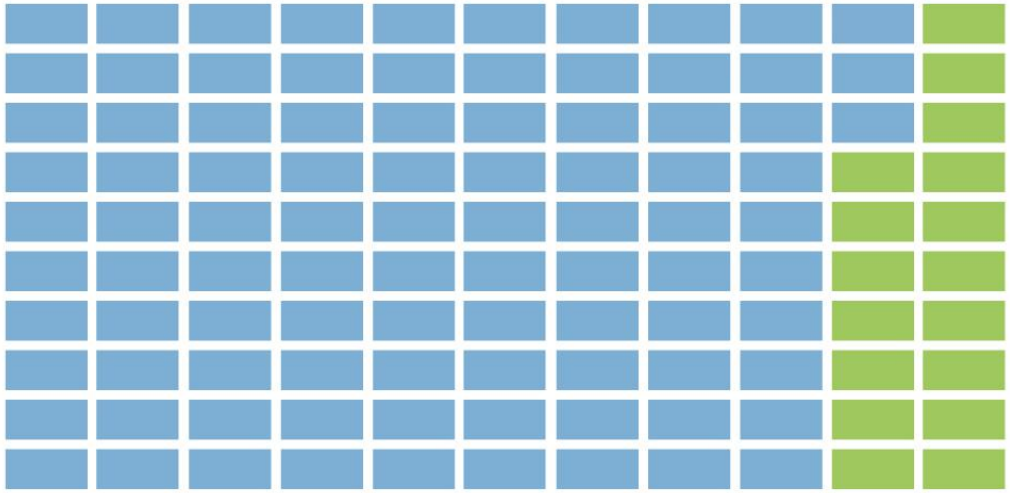
What are Participants Buying?



Capacity Offering **74%**

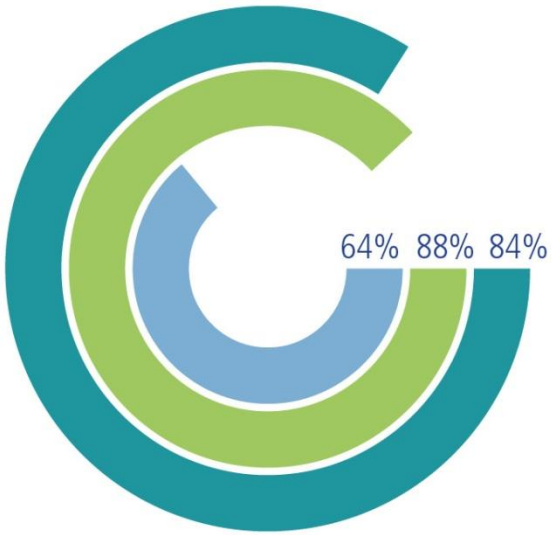
Rate Offering **17%**

A breakdown of active and planned community solar program structures.

Capacity Offering	Rate Offering
Customer purchases or leases blocks of capacity – often in panel increments – and, in some cases, receives a virtual or simulated net metering rate	Customer purchases blocks of energy output, measured in kWh, at a predetermined and sometimes fixed rate, potentially offering a hedge against higher future utility rates

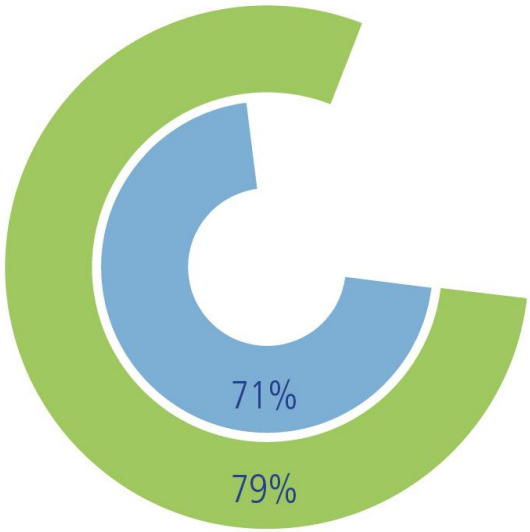
"Expanding Solar Access Through Utility-led Community Solar", SEPA (September 2014)

How Successful are They?



Average community solar program subscription amount, based on available capacity

Public Power IOU Co-op



Average subscription amounts: Capacity vs. Rate

Rate offer Capacity offer

"Expanding Solar Access Through Utility-led Community Solar", SEPA (September 2014)

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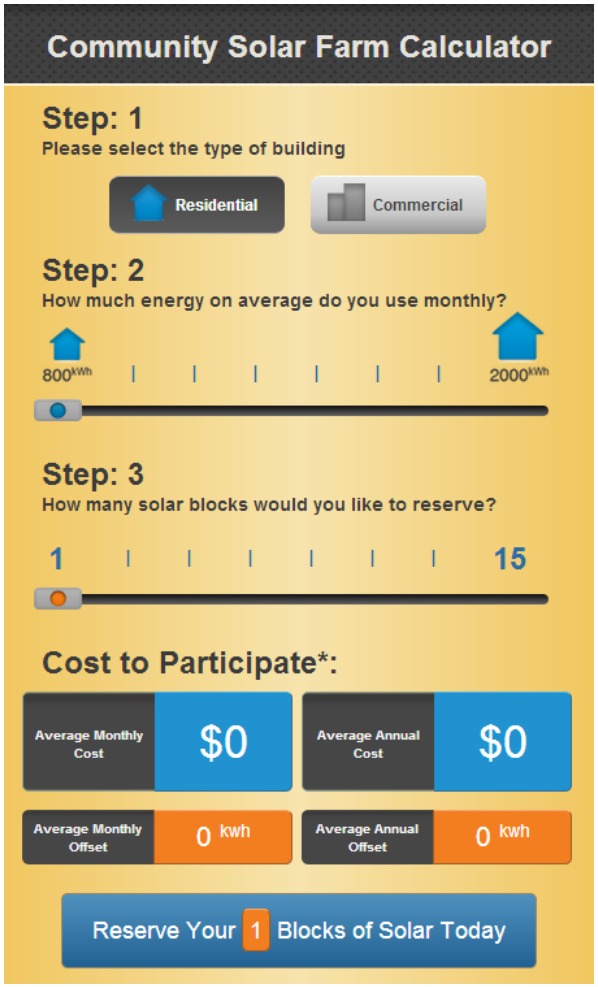
Program Example:
Orlando Utilities Commission

- Offer: 1 kW blocks, up to 15 kW at $0.13/kWh fixed based on actual plant generation; net metered bill credit
  - Equates to $.025/kWh (residential) or $.015/kWh (commercial) more than current customer rates
- Phase 1 Supply: 400 kW
- Term: 25 years
- Performance risk: No guarantee
- Additional details:
  - Customers pay a $50 deposit (refundable after 2 years)
  - Fully subscribed in 6 days; active waiting list for Phase 2



Utility-Owned Residential Rooftop Models

APS Rooftop Ownership

- Utility installed and owned rooftop PV
- 10 MW cumulative program size for about 1,500 customers
- Customers get a $30 monthly bill credit for 20 years (lease payment for rooftop real estate)
- Competitive process using local contractors
- Precedent – APS already has two rooftop ownership models in place (Flagstaff pilot project and Schools & Government)

Tucson Electric Power

- Utility owned rooftop PV
- 3.5 MW or about 600 customers
- Customers get a fixed monthly rate for 25 years
  - Flat monthly bill (e.g., $100)
  - Usage band of +/- 15% off of average historical consumption
- Competitive process using local contractors
- Strong interest already in program; first installations about to occur

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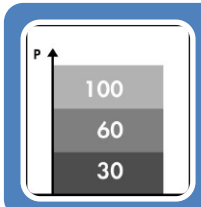
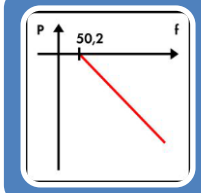
Advanced Inverters



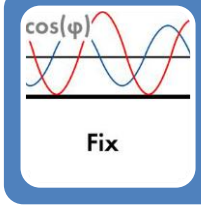
Remote Dispatch

- Ability to control PV generation to a specified % of nominal power



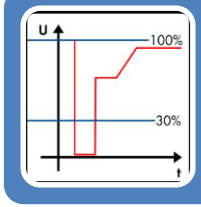
Over Frequency Response

- Ability to automatically reduce active power with frequency deviations



PF Control Mode

- Ability to supply/absorb reactive power during PV operation
- Ability to control Power Factor



Fault Ride-Through

- Ability to supply reactive current during fault ride-through period

- Significant promise in this technology
- Grid-reactive settings currently leveraged in Germany
- Potential for remote settings and controls on the horizon
  - Challenges on two-way communications still being researched

German Association of Energy and Water Industries (BDEW) Guidelines

Defining the Opportunity

Inverters represent nexus between DG resource and the electric distribution system

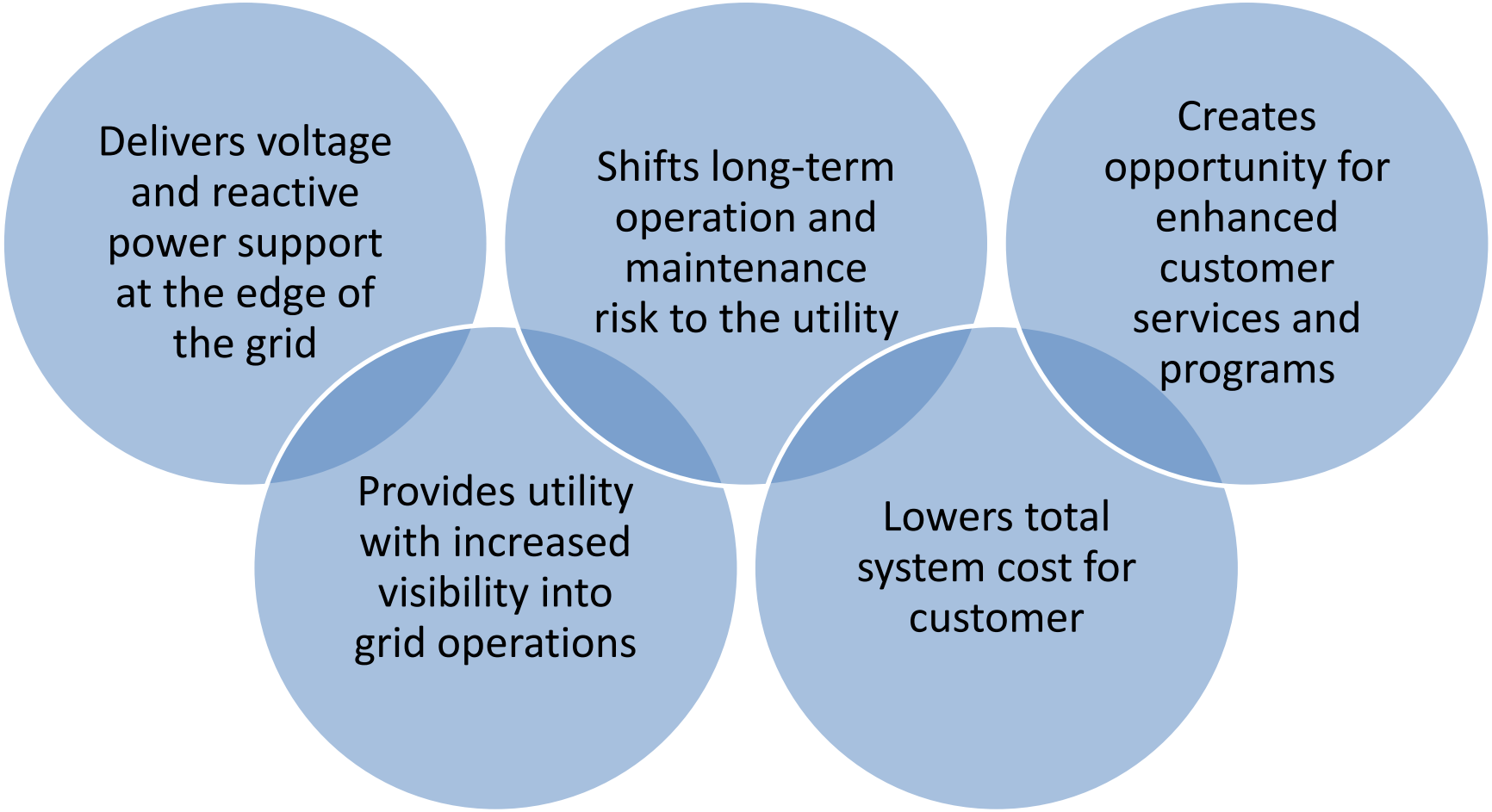
→

What entity is best positioned to enable these capabilities?

→

Who should own these resources?

Advanced Inverter Ownership Rationale



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