Metrics and Valuation Framework for Distribution System Planning

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GMLC 1.1: Metrics Analysis

High Level Summary

Project Objectives

Work directly with *strategic* stakeholders to confirm the usefulness of *new and enhanced existing* metrics that will guide grid modernization efforts to maintain and improve:

- **Reliability,**
- **Resilience,**
- **Flexibility,**
- **Sustainability,**
- **Affordability, and**
- **Security.**

Expected Outcomes

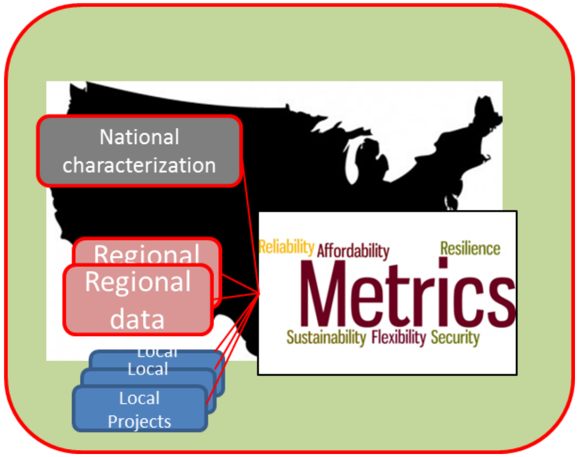
✓ Definition, Validation, and Adoption of metrics and analysis approaches by leading industry stakeholders and regional partners

✓ Better alignment of DOE R&D priorities with stakeholder and public-interest objectives

Value Proposition

✓ Ensuring that all stakeholders understand how grid modernization investments will affect and benefit them

✓ Audiences: grid modernization technology developers and investors; utility and ISO technology adopters or sponsors; federal, state, and municipal regulatory or oversight authorities; **and electricity consumers** (i.e., the ratepayers**)**



GMLC 1.1: Metrics Analysis

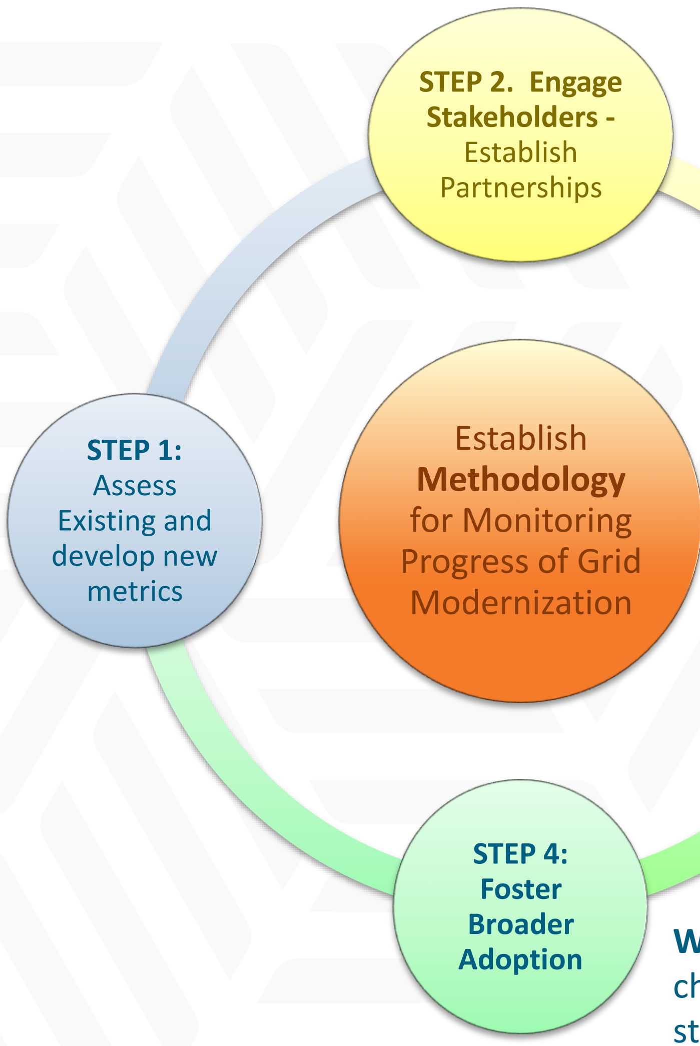
Approach

3-year project
9 national labs

Utilities and ISO/RTOs
Federal and State regulators,
Municipal authorities,
Industry associations

Work closely with existing channels (EPA, EIA, IEEE standards, best practice

Collaborate with GMLC Portfolio researchers



Utilities and key stakeholders will test metrics for self-assessment

GMLC Regional Partners will apply metrics

Work closely with existing channels (EPA, EIA, IEEE standards, EPRI, best practice

GMLC 1.1: Metrics Analysis
Accomplishments to Date

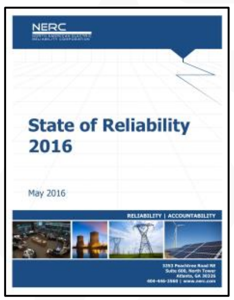
Reliability

Lead: Joe Eto (LBNL)

Value: new metrics for reliability value-based planning and bulk power system assessment

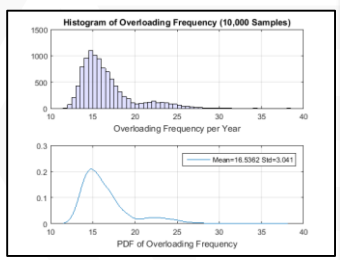
New metrics for distribution that capture the economic cost of interruptions to customers

eReliabilityTracker



New metrics for system impacts using North American Electric Reliability Corporation transmission/generation availability data

Approach and tool for and demonstration of probabilistic enhancement of existing transmission planning metrics



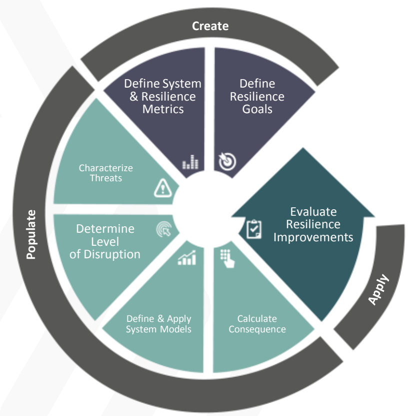
Next steps: new metrics/processes for:
- NERC State of Reliability report
- transmission planning

Resilience

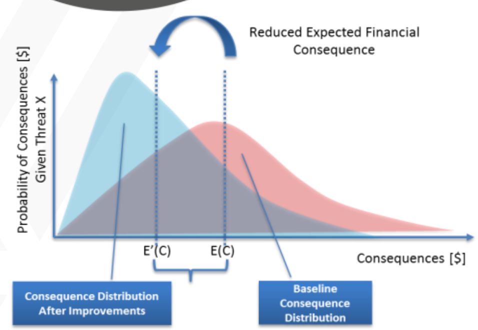
Lead: Eric Vugrin (SNL)

Value: create new metrics/process for resilience investm.

Analysis Process



Results



Next steps: Validate with New Orleans

GMLC 1.1: Metrics Analysis
Accomplishments to Date

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Flexibility

Lead: Tom Edmunds(LLNL)

Value: Develop and demonstrate usefulness of new flexibility metrics

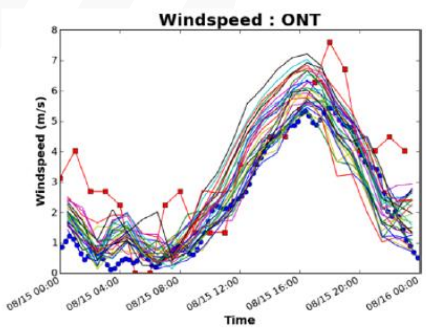
Developed large set of candidate metrics that represent network properties of flexibility and lack of flexibility, engaging stakeholders to identify most useful metrics

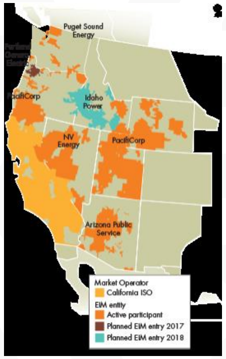
Lagging indicators

- Requires statistical analysis of market and grid conditions to reveal curtailments, loss of load, or other economic impacts caused by insufficient flexibility.

Leading indicators

- Requires production cost simulations with weather and other uncertainties to design for sufficient flexibility.
- Use production cost models to examine tradeoffs between different sources of flexibility.





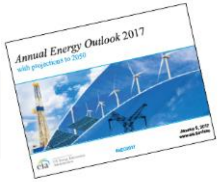
Next steps: Work with CAISO, ERCOT to adopt flexibility metrics

Sustainability

Lead: Garvin Heath (NREL)

Value: Identify needed improvements to GHG reporting

Ability of federal greenhouse gas data products to capture changes in electric-sector CO_2 emissions that might result from future grid modernization varies, depending on coverage of certain energy sources anticipated to grow.

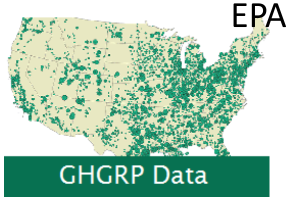


EIA: AEO

EPA: eGRID

EIA: MER

EPA: GHGRP



Next steps: Assess usefulness and availability of data for impacts on water resources

GMLC 1.1: Metrics Analysis

Accomplishments to Date

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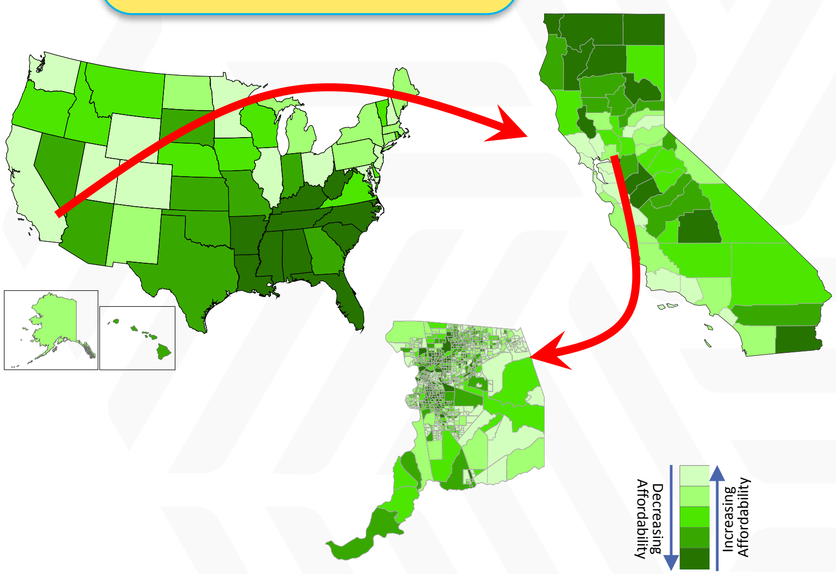
Affordability

Lead: Dave Anderson (PNNL)

Value: Establish new metrics based on cost burden to consumers

Cost Burden Metrics (**emerging**)

- Customer electricity cost burden
- Electricity affordability gap
- Affordability gap headcount
- Temporal indices of these metrics



Next steps: Validating metrics with Regional Partners (Alaska, New Orleans)

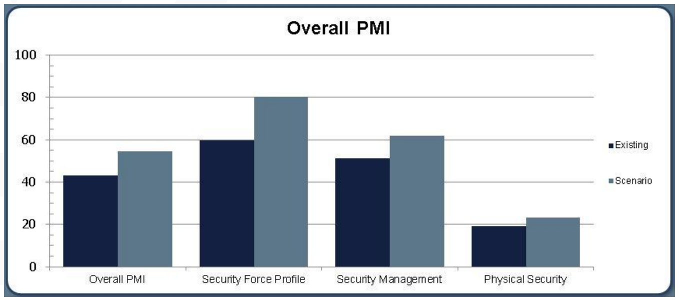
Security

Lead: Steve Folga (ANL)

Value: Spur electric industry adoption of DHS Protective Measures Indices (i.e., security metrics)

Survey/analysis Process

Results



Next steps: Validate PMI Approach with ComED and Idaho Falls

Landscape of Existing and Proposed Metrics

Reliability

Distribution Reliability

Existing metrics	Existing (data needed)
SAIFI	Total customers served
SAIDI	
CAIDI	Customer interruption duration
CAIFI	
CTAIDI	
ASAI	Customer hours service availability
	Customer service hours demanded
MAIFI	Total customer momentary interruptions
CEMI	Total customers experiencing more than n sustained outages
CEMSMI	Total customers experiencing more than n momentary interruptions
CI	Customers interrupted
CMI	Customer minutes interrupted
ASIFI	Total connected kVA of load interrupted
ASIDI	Total connected kVA served
CELID	total number of customers that have experienced more than eight interruptions in a single reporting year
SARI	Circuit outage number and duration
COR	number of correct operations
	total number of operations commanded
DELI	total distribution equipment experiencing long outages
DEMI	length of interruption (by equipment type)
ACOD	Transmission circuit outage and duration
ACSI	
TACS	total amount of equipment that have more than N # of interruptions in a single year
FOHMY	Outages per hundred miles per year

Proposed Metrics	Proposed Data Needed
Interruption Cost	Customers interrupted (by type of customer)
	Characteristics of interruptions by customer type (e.g., duration, start time)

Landscape of Existing and Proposed Metrics

Resilience

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Resilience

Existing (metrics)	Existing (data needed)
Cost of recovery	
Utility revenue lost	outage cost for utility ($)
Cost of grid damage	total cost of equipment repair
Cost per outage	

Proposed Metrics	Proposed (data needed)
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	
Cost of recovery	
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided
	$ / kVA
Critical services without power	number of critical services without power
	total number of critical services
Critical services without power after backup fails	total number of critical services with backup power
	duration of backup power for critical services
Loss of assets and perishables	
Business interruption costs	avg business losses per day (other than utility)
Impact on GMP or GRP	
Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

Interdependence of Metrics
Reliability and Resilience

Distribution Reliability

Existing metrics	Existing (data needed)	Proposed Metrics	Proposed Data Needed
SAIFI	Total customers served	Interruption Cost	Customers interrupted (by type of customer); Characteristics of interruptions by customer type (e.g., duration, start time)
SAIDI			
CAIDI	Customer interruption duration		
CAIFI			
CTAIDI			
ASAI	Customer hours service availability		
	Customer service hours demanded		
MAIFI	Total customer momentary interruptions		
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	total number of operations commanded		
DELI	total distribution equipment experiencing long outages		
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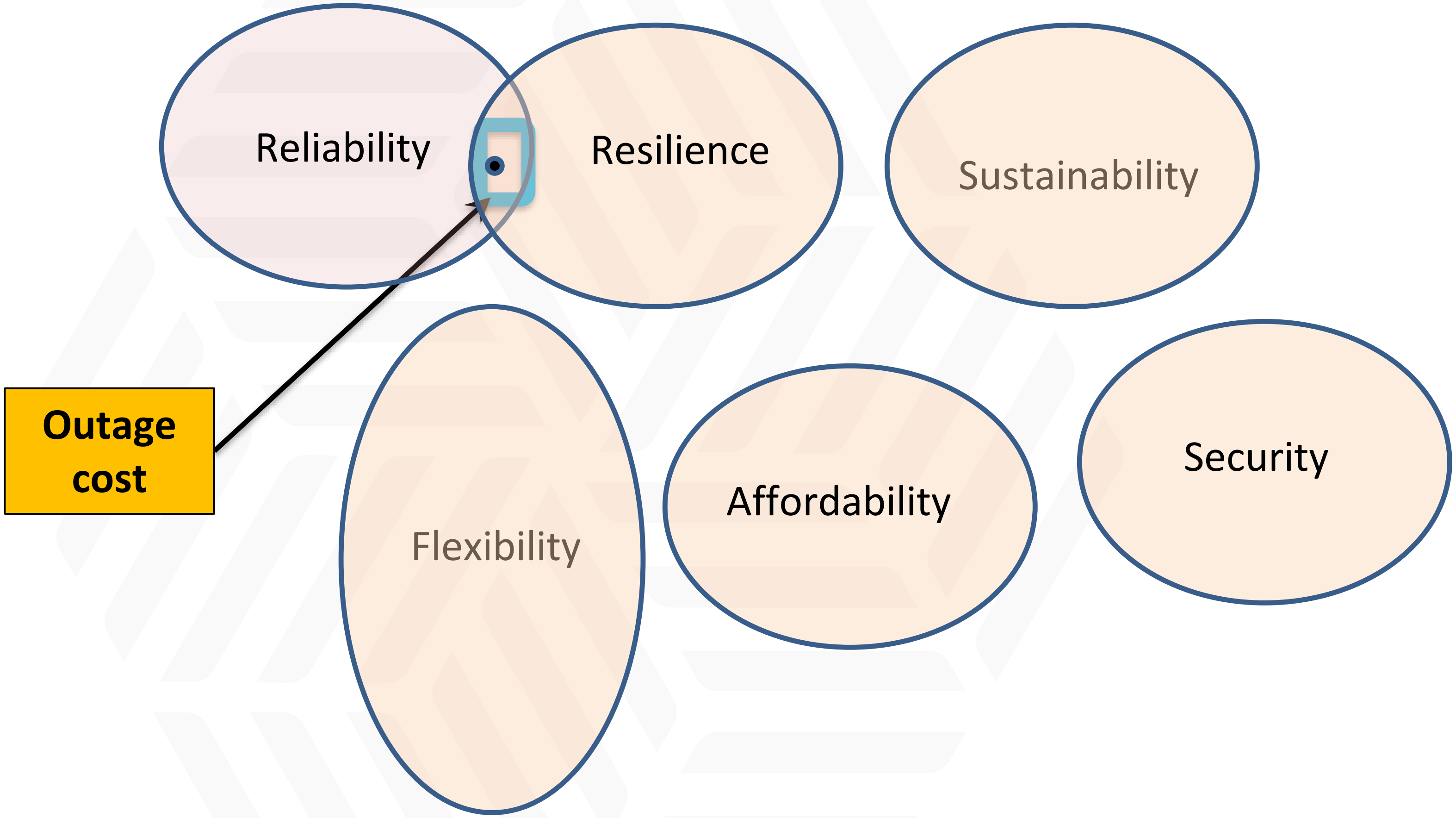
ACOD	Transmission circuit outage and duration		
ACSI			
TACS	total amount of equipment that have more than N # of interruptions in a single year		
FOHMY	Outages per hundred miles per year		

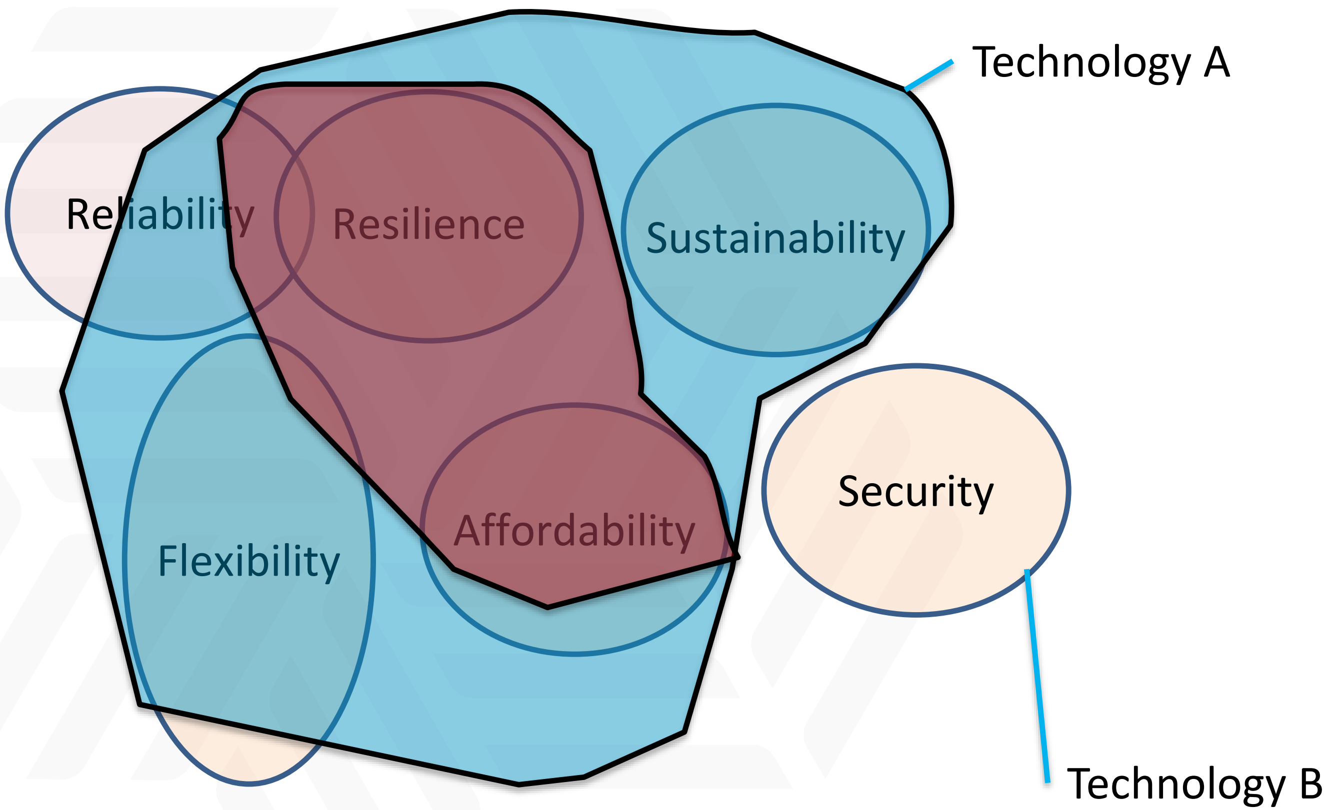
Resilience

Existing Metrics	Existing (data needed)	Proposed Metrics	Proposed (data needed)
Cost of recovery		Cumulative customer-hours of outages	customer interruption duration (hours)
Utility revenue lost	outage cost for utility ($)	Cumulative customer energy demand not served	total kVA of load interrupted (by customer?)
Cost of grid damage	total cost of equipment repair	Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served (by customer?)
Cost per outage		Cumulative critical customer-hours of outages	critical customer interruption duration
		Critical customer energy demand not served	total kVA of load interrupted for critical customers
		Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
		Time to recovery	Thresholds? What does recovery mean?
		Cost of recovery	Same as above
		Loss of utility revenue	outage cost for utility ($)
		Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
		Avoided outage cost	total kVA of interrupted load avoided; $ / kVA
		Critical services without power	number of critical services without power; total number of critical services
		Critical services without power after backup fails	total number of critical services with backup power; duration of backup power for critical services
		Business interruption costs	avg business losses per day (other than utility
		Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
		Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

Interdependence of Metrics only between 2 Metrics Areas



Technologies Impact Several Metrics



Synergy between Metrics and Valuation

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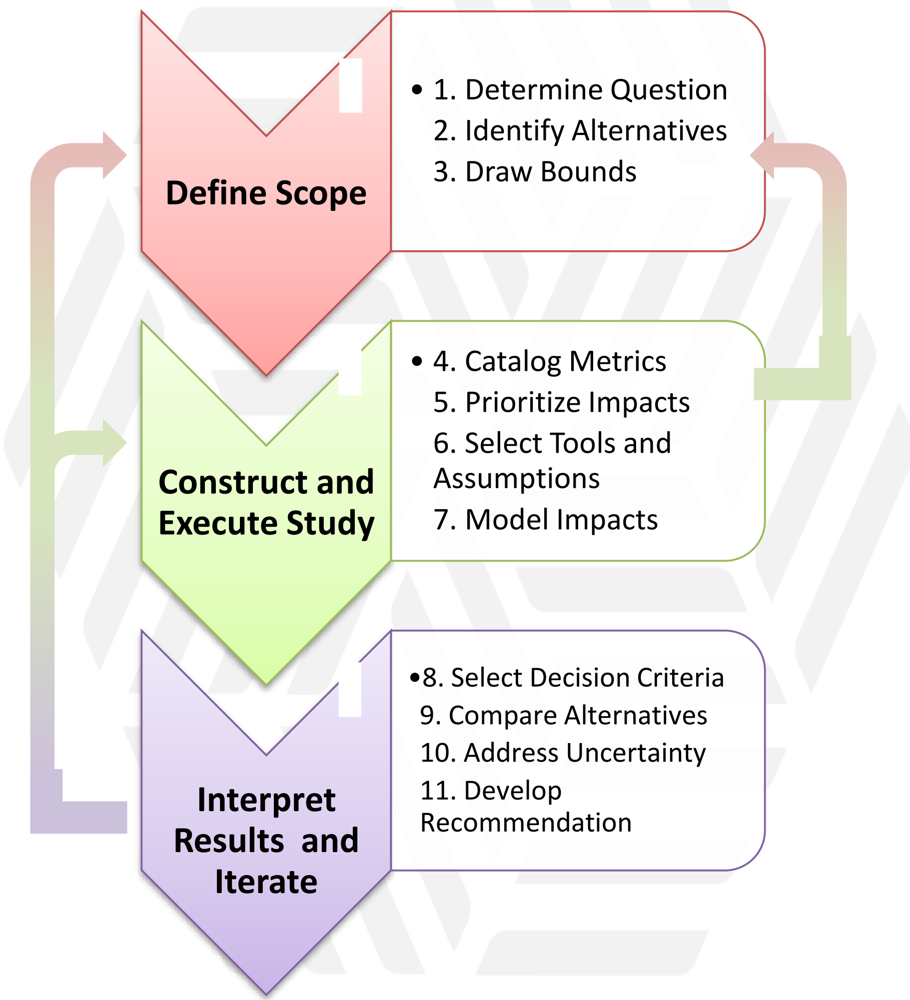
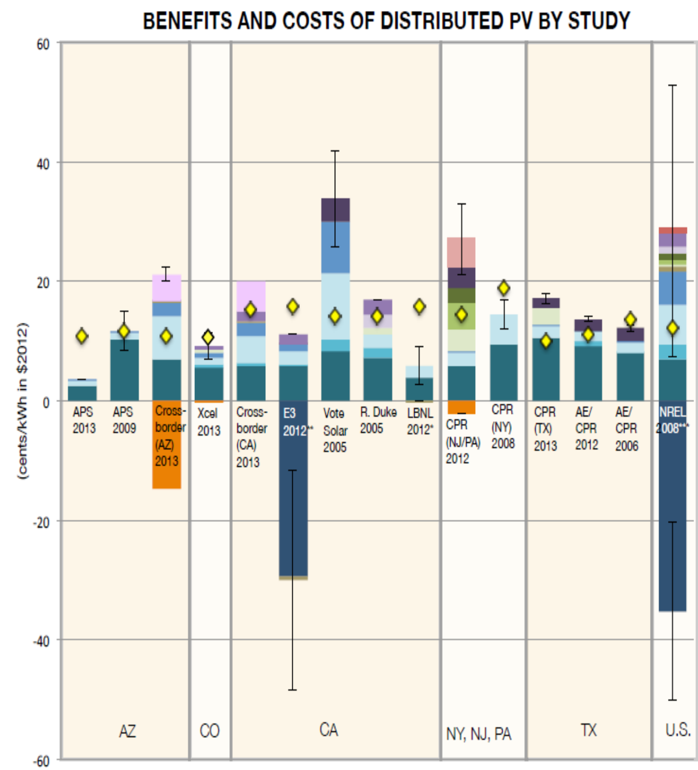
- Metrics = the language by which one expresses changes in system operations and system states and their impacts to customers and the environment
- Valuation = estimating cost of a technology or policy <u>and</u> the monetary or non-monetary values of the changes (before and after deployment) and their impacts.
- Thus, with more refined and richer set of metrics, more precise and more comprehensive valuation can be performed.
- However, methods and tools need to be created to support valuation to project likely changes to the system and their impacts to customers and the environment.

Valuation Framework Development

The "Framework" is really a set of guidelines on how to move through a valuation as a process to reveal all assumptions and models used



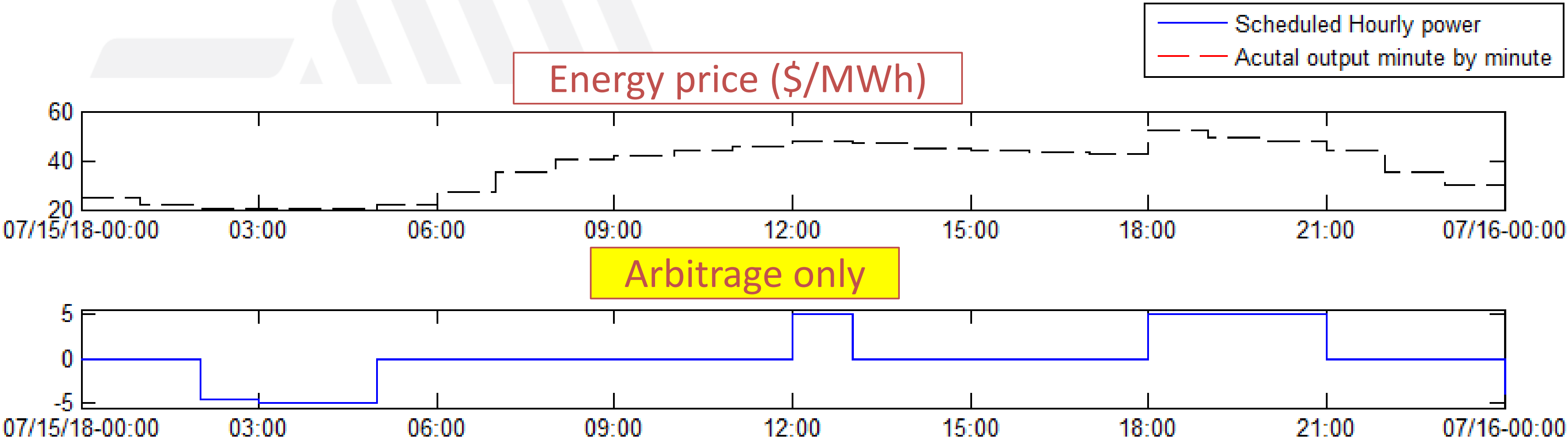


From RMI *"A review of solar PV benefit and cost studies"*

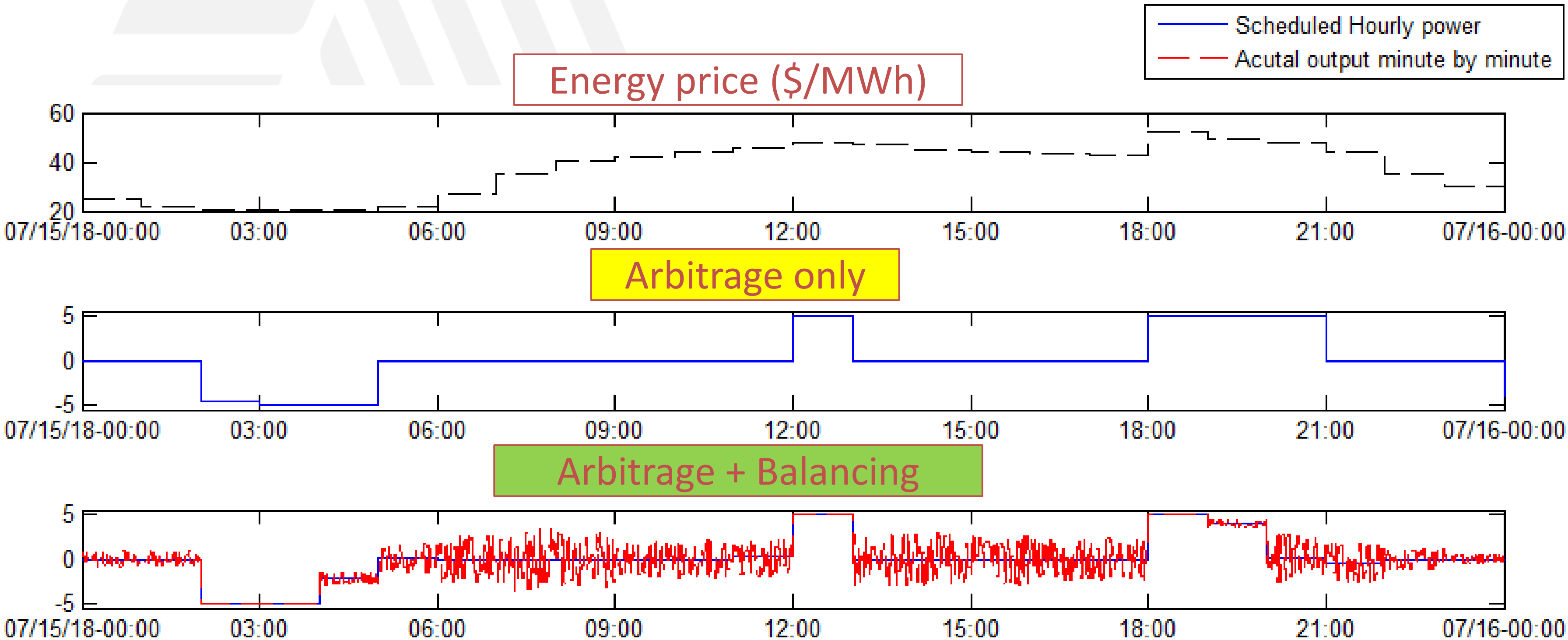
Example Valuation: Distributed Energy Storage

- ALL Storage provides flexibility most systems "desire/need" under growing renewable technology deployment
  - Question: Which location, which size, and how to control it
- Storage technology is expensive, thus requires to capture multiple values to be cost-effective.
  - Requires operational optimization ALL THE TIME
- What are the right business cases for storage?
  - How does performance and storage type matter?
  - How to value multiple benefits?

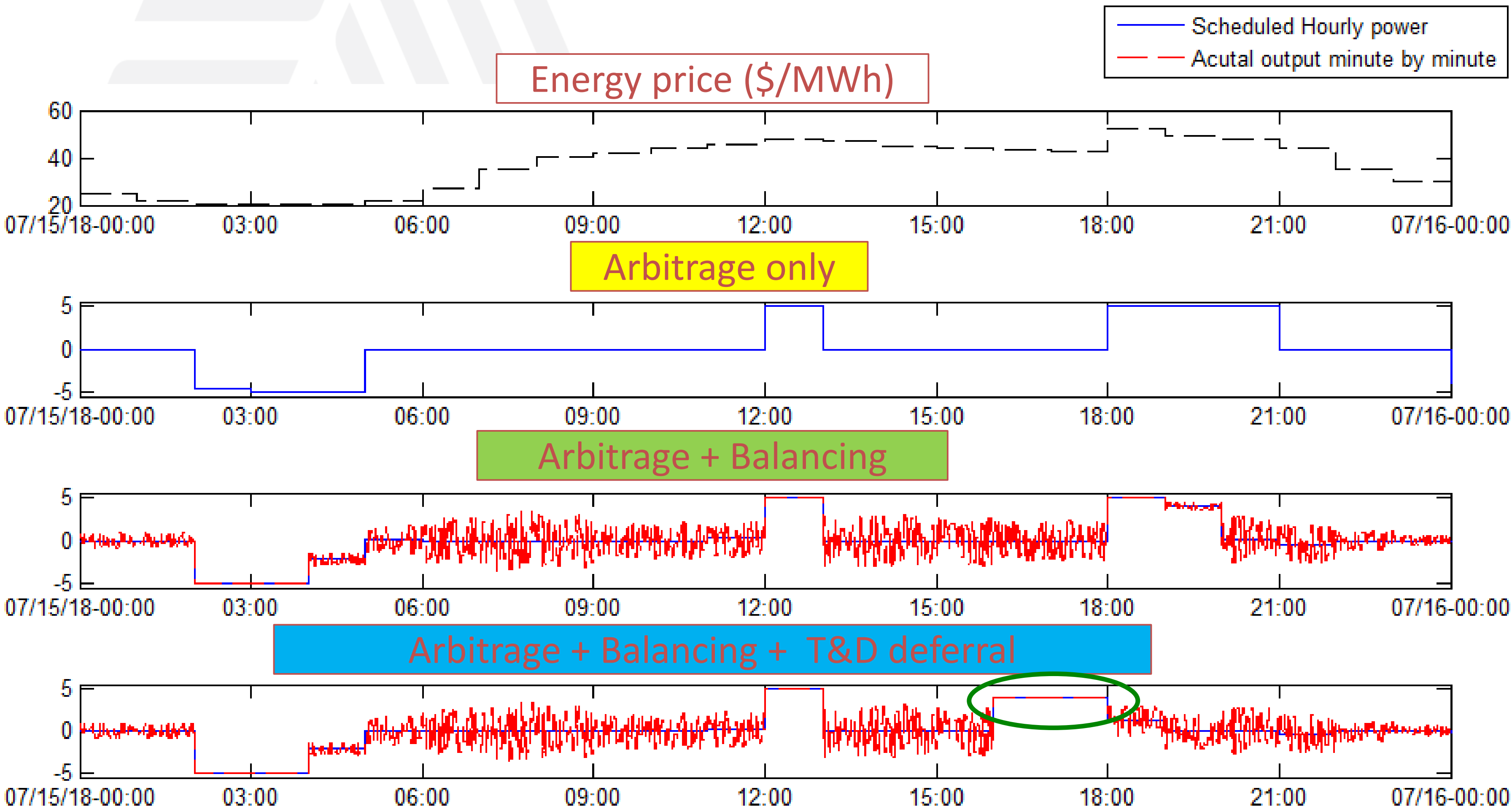
How to value multiple benefits?



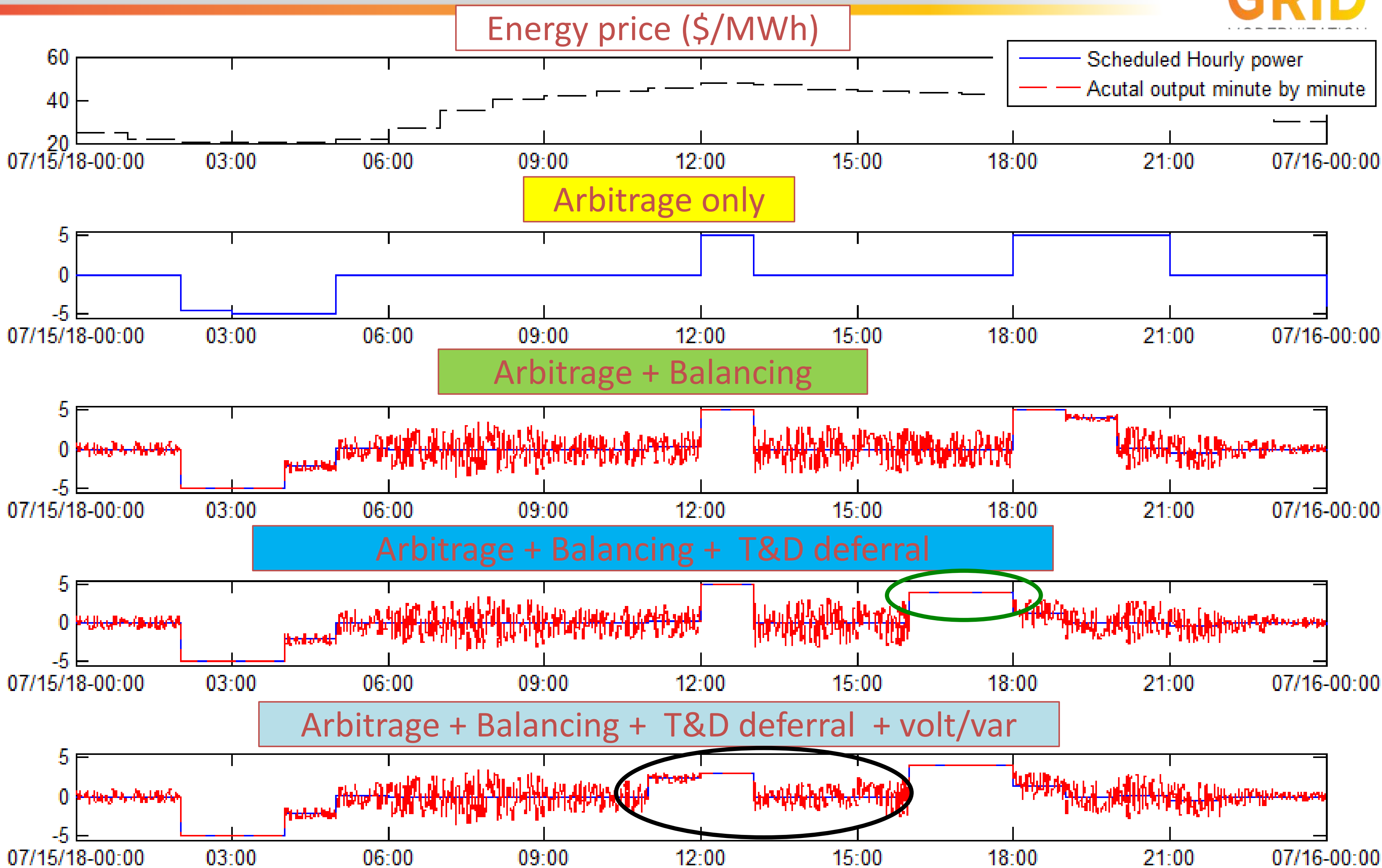
How to value multiple benefits?



How to value multiple benefits?



How to value multiple benefits?



Battery Storage Evaluation Tool (BSET) Graphical User Interface

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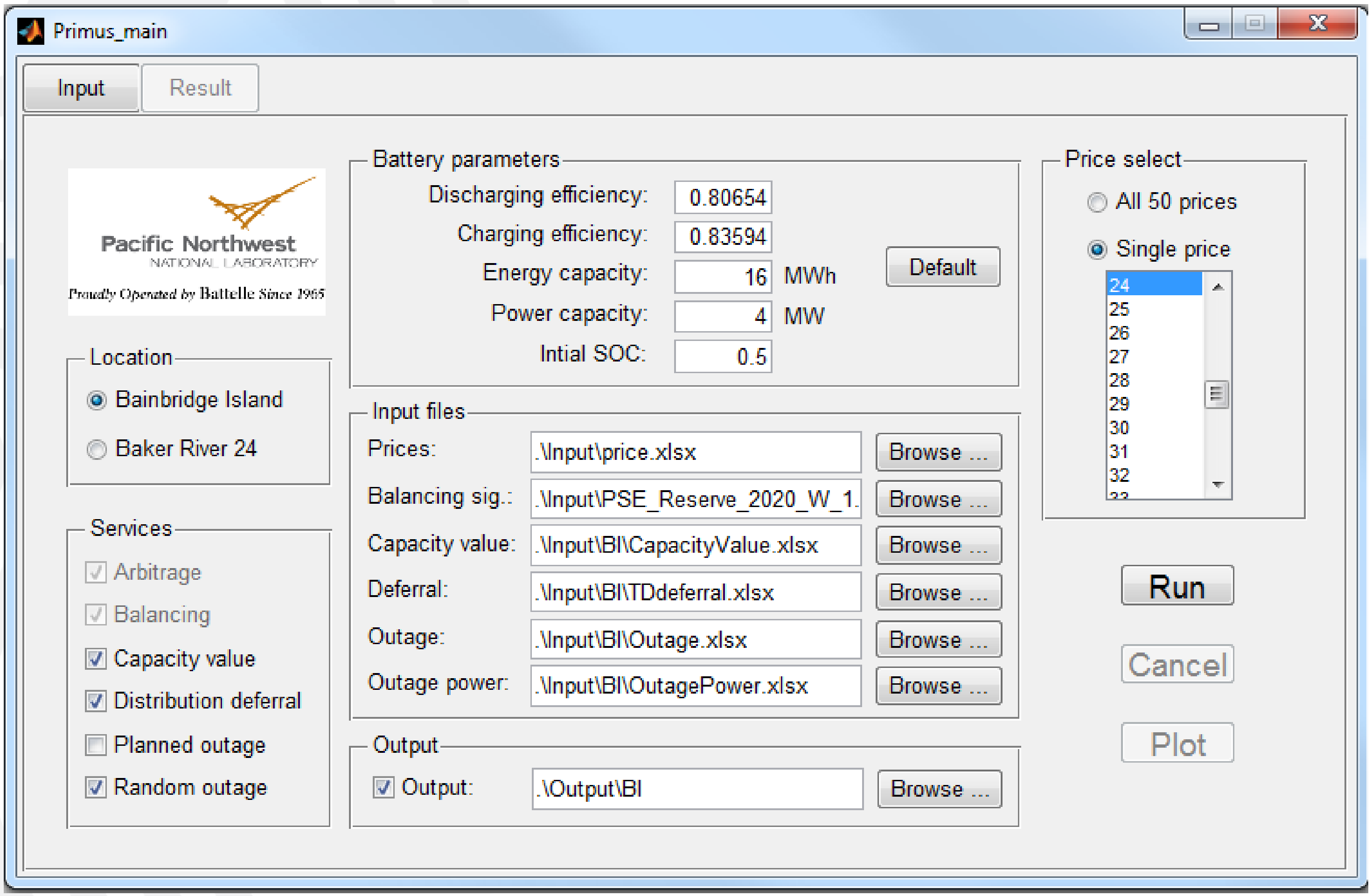
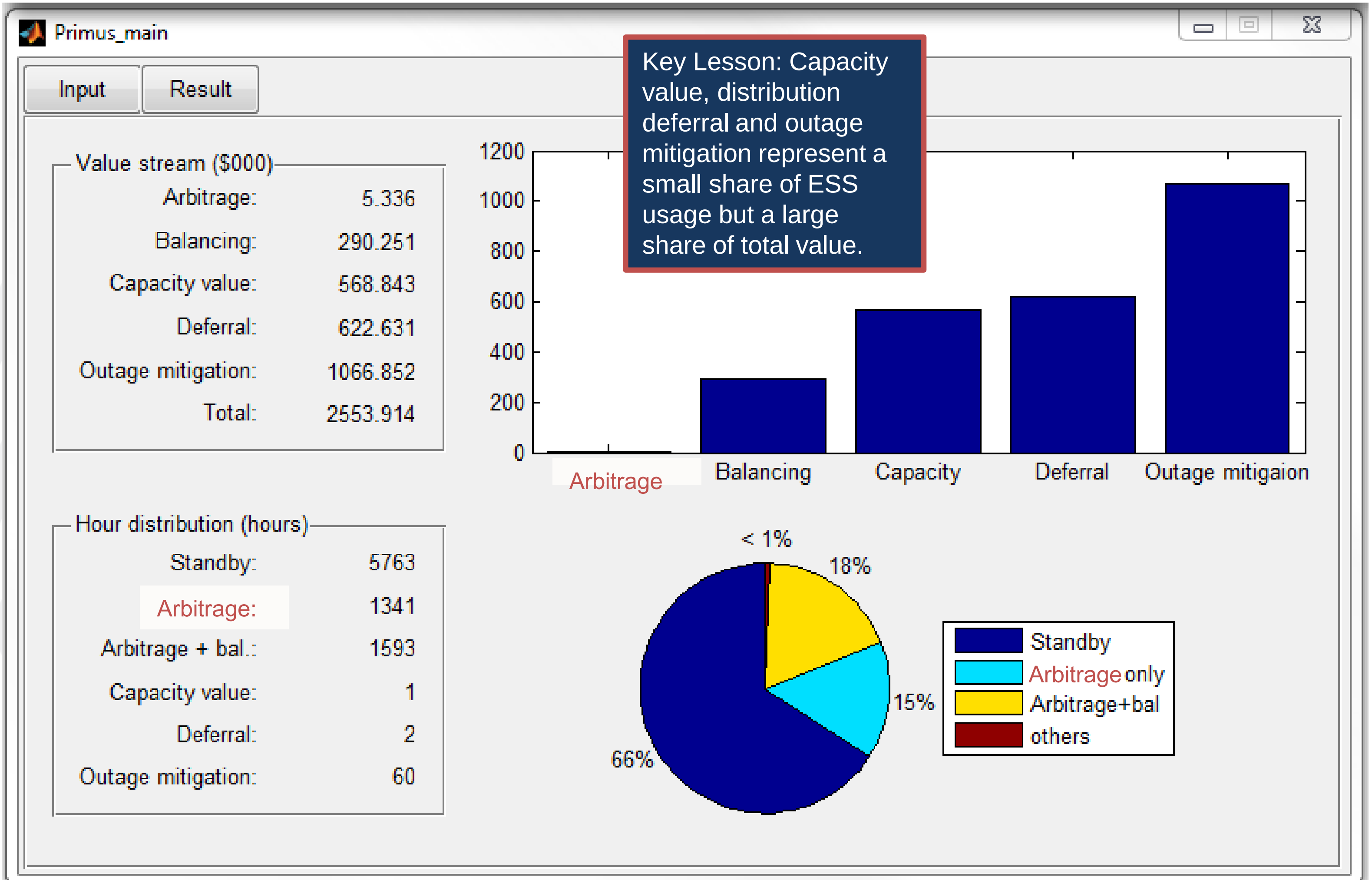
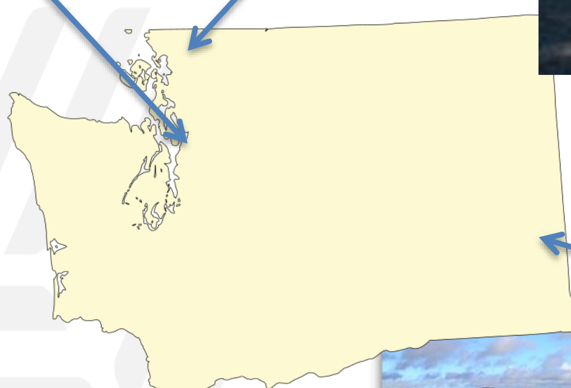


BSET Output



Key Lesson: Capacity value, distribution deferral and outage mitigation represent a small share of ESS usage but a large share of total value.

Washington State CEF Energy Storage Projects



2 MW / 4.4 MWh lithium-ion/phosphate battery – Glacier, WA

2MW / 1 MWh Li-ion system
2MW, 8.8 MWh UET vanadium-flow- Everett, WA

Total – 7 MW / 15 MWh; $14.3 million state investment / $43 million total investment for energy storage systems

1 MW / 3.2 MWh UET vanadium-flow battery – Pullman, WA

Washington CEF Matrix

Use Case and application as described in PNNL Catalog	Avista	PSE	Sno – MESA1	Sno – MESA2	Sno - Controls Integration
UC1: Energy Shifting					
Energy shifting from peak to off-peak on a daily basis	Y	Y	Y	Y	
System capacity to meet adequacy requirements	Y	Y	Y	Y	
UC2: Provide Grid Flexibility					
Regulation services	Y	Y		Y*	
Load following services	Y	Y		Y*	
Real-world flexibility operation	Y	Y		Y*	
UC3: Improving Distribution Systems Efficiency					
Volt/Var control with local and/or remote information	Y		Y	Y	
Load-shaping service	Y	Y	Y	Y	
Deferment of distribution system upgrade	Y	Y			
UC4: Outage Management of Critical Loads		Y			
UC5: Enhanced Voltage Control					
Volt/Var control with local and/or remote information and during enhanced CVR events	Y				
UC6: Grid-connected and islanded micro-grid operations					
Black Start operation	Y				
Micro-grid operation while grid-connected	Y				
Micro-grid operation in islanded mode	Y				
UC7: Optimal Utilization of Energy Storage	Y	Y			Y

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Summary of Best Practice for Storage Valuation

- Developing clear understanding of the function of storage. Function will drive valuation process
- In most cases, cost-effectiveness requires to estimate bundled values
- Bundling multiple services is challenging and requires optimization to make decisions which is the highest valued service to capture.
  - Valuation Trap:
    - Double counting of resources
    - Over-committing available resources
- Performance of storage technology matters in the valuation process
- Not all values of grid services are easily obtainable.
  - Market based values are preferred, however, don't help if value is to be estimated into the future
  - For non-market services, simulations and avoided cost estimation become necessary. This often requires a lot of modeling effort

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- General valuation methods:
  - New York: Staff White Paper on Benefit-Cost Analysis in the Reforming Energy Vision Proceeding: 14-M-0101 https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/c12c0a18f55877e785257e6f005d533e/$FILE/Staff_BCA_Whitepaper_Final.pdf
  - Rhode Island: Docket 4600: Stakeholder Working Group Process: http://www.ripuc.org/eventsactions/docket/4600page.html
  - California: SCE: Distribution Resource Plan. July 1, 2015: available at http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/BF42F886AA3F6EF088257E750069F7B7/$FILE/A.15-07-XXX_DRP%20Application-%20SCE%20Application%20and%20Distribution%20Resources%20Plan%20.pdf

GMLC 1.1: Backup Slides

Use-cases and baselining (selected next steps)

Affordability

Baselining lagging and leading metrics with Alaska Villages

Resilience

Use-cases analysis with New Orleans validating the process for leading metrics

Flexibility

- Reducing the set of lagging metrics by statistical analysis (CAISO, ERCOT)
- Reducing the set of leading metrics by modeling (CAISO)

Coordination with other GMLC Projects

Valuation Project

Outreach and Dissemination

- Reference Document 3.0
- EPRI webinars
- High visibility event(??)

Implementation Plan in Year 3

- Identifying who will own metrics
- who will have access to data

Applicability of Metrics

Individual Metrics are used for specific applications, policy questions, and/or events
Not all metrics are used all the time!

- Event type:
  - **Normal operations:** reliability, flexibility, sustainability, security
  - **Catastrophic events:** resilience/reliability
- Stakeholder:
  - **Regulator/utilities**: reliability, security, affordability, sustainability, resilience, flexibility
  - **RTO/ISO**: reliability, flexibility

Landscape of Existing and Proposed Metrics
Flexibility

Flexibility

Existing Metrics	Existing (data needed)
Variable energy resource penetration	Variable resource nameplate capacity
	System peak load
Flexibility turndown factor	Must run capacity (MW/year)
	Non-dispatchable capacity (MW/year)
Net demand ramping variability	Total load
	Load less VERs
Flexible capacity need	Max 3 hour ramp in net load
	Monthly peak load
System regulating capability	Regulating reserve
	Demand response
Demand response	% of total installed capacity
Flexible resource indicator	Natural gas-fired combustion turbine nameplate capacity
	15% of hydropower capacity
	Wind nameplate capacity
Periods of flexibility deficit	hours
Insufficient ramping resource expectation	maximum and minimum rated output
	start up time
	ramp up and ramp down rate
	forced outage rate
	production levels
Flexibility metric (ISO-NE)	Expected load over time period *t*
	Expected variable load over time period *t*
Loss of load due to flexibility deficiency	All data needed for production cost model
Binding flexibility ratio	All data needed for production cost model
Renewable curtailment	MWh of wind and solar curtailment
Percentage of unit-hours mitigated	Out of market transaction data
Control performance standards	CPS1 and CPS2 data

Proposed Metrics	Proposed Data Needed
Ratio of peak to min daily net load	Peak net load by season
	Minimum net load by season
Solar curtailment	Curtailed solar load (MWh) by season and time of day
Wind curtailment	Curtailed wind load (MWh) by season and time of day
Negative prices	Negative prices by season and time of day
Max ramp rate in net load	Ramp rate (MW/min) by season and time of day
Positive price spikes	Fraction of hours upper limit hit annually
	$/MWh maximum price
	Fraction of hours price increase by x% by season and time of day
Out of market actions	MWh annual
Net load forecasting errors	Day ahead, 4 hour ahead, and 1 hour ahead forecasts
	Realized hourly net loads

Landscape of Existing and Proposed Metrics
Sustainability

Sustainability			
Existing Metrics	**Existing Data Needed**	**Proposed Metrics**	**Proposed Data Needed**
GHG Emissions (measure)	Fuel combustion (by fuel type)	GHG Emissions (measure)	Fuel combustion for all generation types and capacities
	Emissions factor (by fuel type)		Emissions factor for all generation types and capacities
Hourly Emissions (continuous monitoring)	Hourly average concentration	Hourly Emissions (continuous monitoring)	Hourly average concentration for all generation types and capacities
	Hourly average volumetric flow rate		Hourly average volumetric flow rate for all generation types and capacities
	Hourly heat input rate		Hourly heat input rate for all generation types and capacities
Water Intensity	m^3/MWh (by generation type)	Water Intensity	m^3/MWh (by generation type) - consistent definition and calculation
Water Scaritcy	m^3 of water	Water Scaritcy	m^3 of water - consistent definition and calculation
Water Availability	m^3 of water	Relative Water Risk	water intensity / water scarcity

Landscape of Existing and Proposed Metrics
Affordability

Affordability

Existing Metrics	Existing data
Levelized cost of electricity (LCOE) - Utility	NPV cost of project (costs considered vary by stakeholder)
	construction
	operating
	taxes
	financing
	salvage
	incentive
	NPV total electricity generated over life of asset
Internal Rate of Return (IRR) - Utility	equilibrium discount rate
Simple Payback Period - Utility	time to undiscounted equilibrium after first investment
Net Revenue Requirements - Utility	fuel costs
	O&M costs
	depreciation
	taxes
	return on rate base
Avoided Cost - Utility	energy avoided from other generators
	capacity
	reconfigure substations
	transmission expansion or contraction
	distribution expansion or contraction

Proposed Metrics	Proposed Data Needed
Household electricity burden - Customer	annual residence net electricity bill
	annual household income (Census or other sources)
Household electricity affordability gap - Customer	household electricity cost burden
	affordable cost burden threshold
Household electricity affordability gap index - Customer	previous affordability gap
	current affordability gap
Household electricity affordability headcount index - Customer	previous household exceeding affordability threshold
	current households exceeding affordability threashold
Annual average customer cost - Customer	total revenue (by geographic area, customer class)
	total consumption (by geographic area, customer class)
Average customer cost index - Customer	previous average customer cost
	current average customer cost
Affordability threshold	Percent of household income deemed affordable to spend on electricity

Landscape of Existing and Proposed Metrics

Security

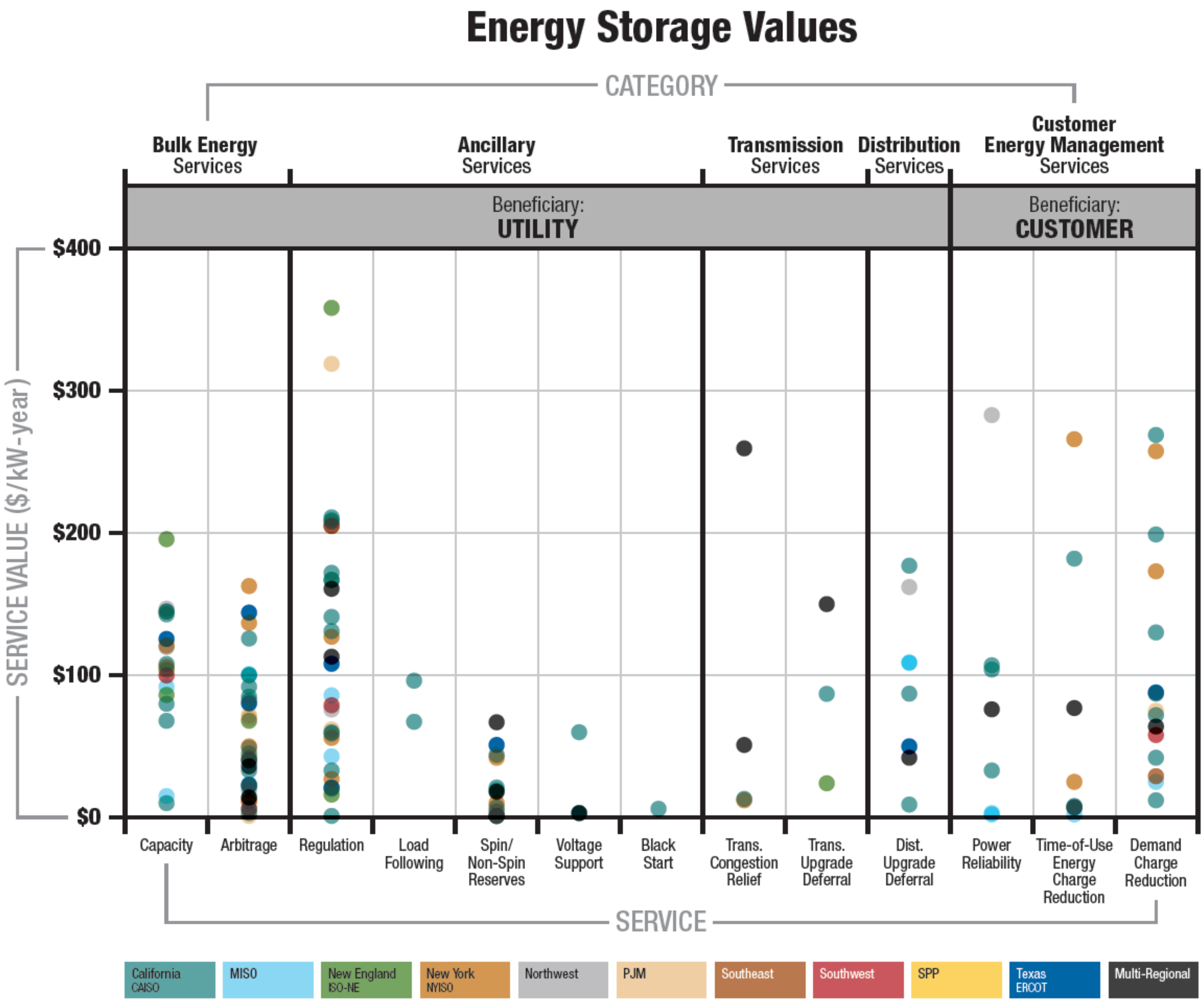
GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Security

Existing Metrics	Existing Data Needed
Physical Security Protective Measures Index (infrastructure agnostic)	Input from facility owners/operators
Security Force Protective Measures Index (infrastructure agnostic)	Input from facility owners/operators
Security Management Protective Measures Index (infrastructure agnostic)	Input from facility owners/operators
Information Sharing Protective Measures Index (infrastructure agnostic)	Input from facility owners/operators
Annualized Loss Expectancy	Single loss expectancy
	Annualized Rate of Occurrence
Reportable cyber security incidents	Number of cyber incidents that result in loss of load
Reportable physical security incidents	Number of physical incidents
Copper theft	
Attacks	Number of successful and unsuccessful attacks
Alarms	Number of false or nuisance alarms
Monitoring equipment condition	Number of malfunctions of security equipment
Security personnel performance	Score on security training exercises
	Score on security tests
Vandalism	Number of incidents of vandalism

Proposed Metrics	Proposed Data Needed
Physical Security Protective Measures Index (electric specific)	Default aggregated data from DHS by electric infrastructure type; publically available data
Security Force Protective Measures Index (electric specific)	Default aggregated data from DHS by electric infrastructure type; publically available data
Security Management Protective Measures Index (electric specific)	Default aggregated data from DHS by electric infrastructure type; publically available data
Information Sharing Protective Measures Index (electric specific)	Default aggregated data from DHS by electric infrastructure type; publically available data

Note: the above table only identifies proposed Physical Security metrics; Cyber Security metrics to be determined depending on DOE concurrence.



Energy Storage Values
CATEGORY
Bulk Energy Services
Ancillary Services
Transmission Services
Distribution Services
Customer Energy Management Services
Beneficiary: UTILITY
Beneficiary: CUSTOMER
SERVICE VALUE ($/kW-year)
$400
$300
$200
$100
$0
Capacity
Arbitrage
Regulation
Load Following
Spin/ Non-Spin Reserves
Voltage Support
Black Start
Trans. Congestion Relief
Trans. Upgrade Deferral
Dist. Upgrade Deferral
Power Reliability
Time-of-Use Energy Charge Reduction
Demand Charge Reduction
SERVICE
California CAISO
MISO
New England ISO-NE
New York NYISO
Northwest
PJM
Southeast
Southwest
SPP
Texas ERCOT
Multi-Regional