EPRI ELECTRIC POWER RESEARCH INSTITUTE

Value of the Integrated Grid

Utility Integrated Distributed Resource Deployment

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Technology Innovation

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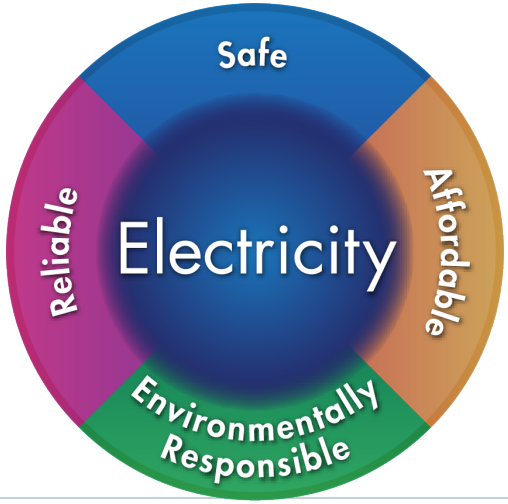
Electric Power Research Institute

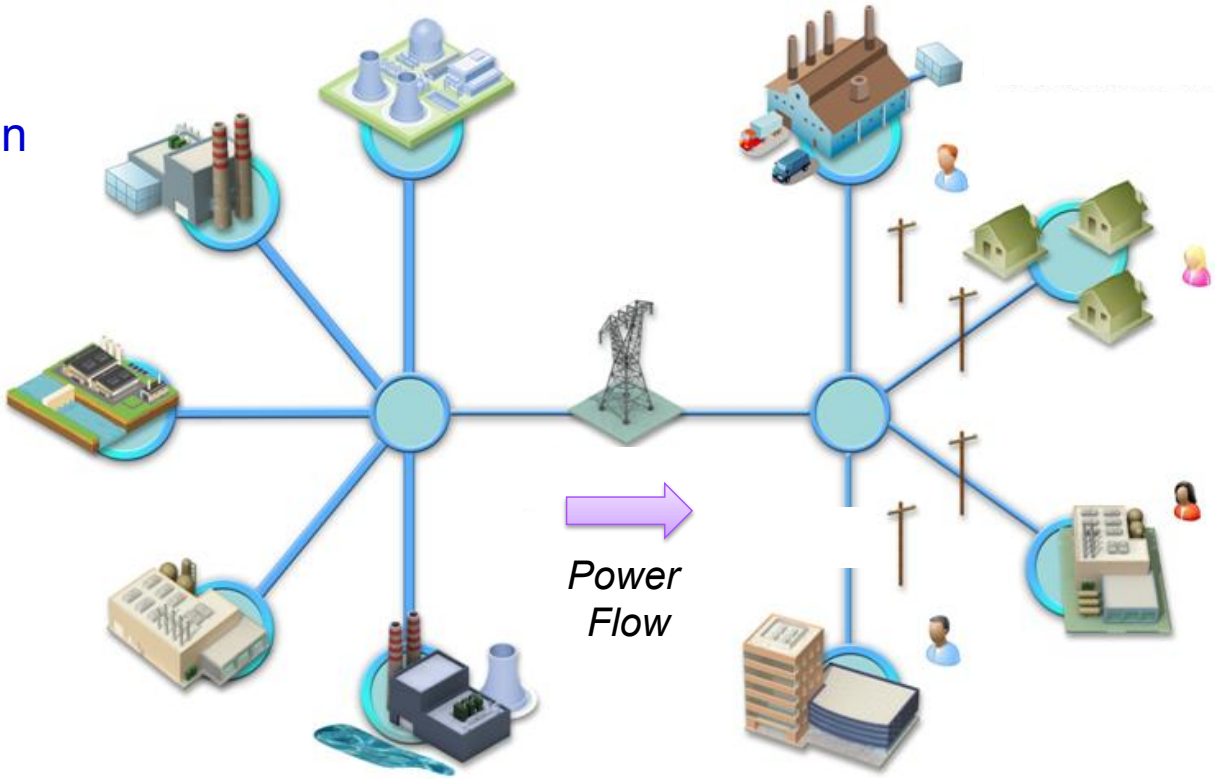
Our Mission…

Advancing safe, reliable, affordable and environmentally responsible electricity for society through global collaboration, thought leadership and science & technology innovation



The Traditional Electric Power System

Central Generation



Predictable Consumption

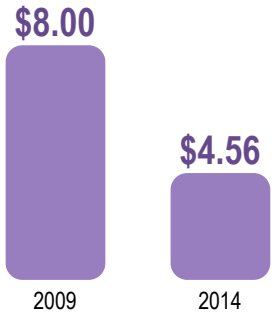
Consumer Options are Driving Change…

Need to Improve Understanding of Customer Expectations & Decisions

Graphics Courtesy SCE

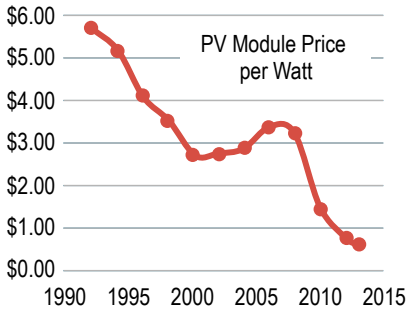
Outlook of Residential and Commercial PV

43% decline in 5 years



Residential PV System Price

Key contributor to price reduction



PV Module Price Trend

Trends

Residential PV installations exceeded non-residential

More than 1/3 of residential PV installations came on-line without any state incentive

School, government, and nonprofit PV installations increasing

Future price decline will depend on addressing soft costs

Factoids[1]

Residential system prices fell 7%, from $4.91/W (1Q13) to $4.56/W (1Q14)

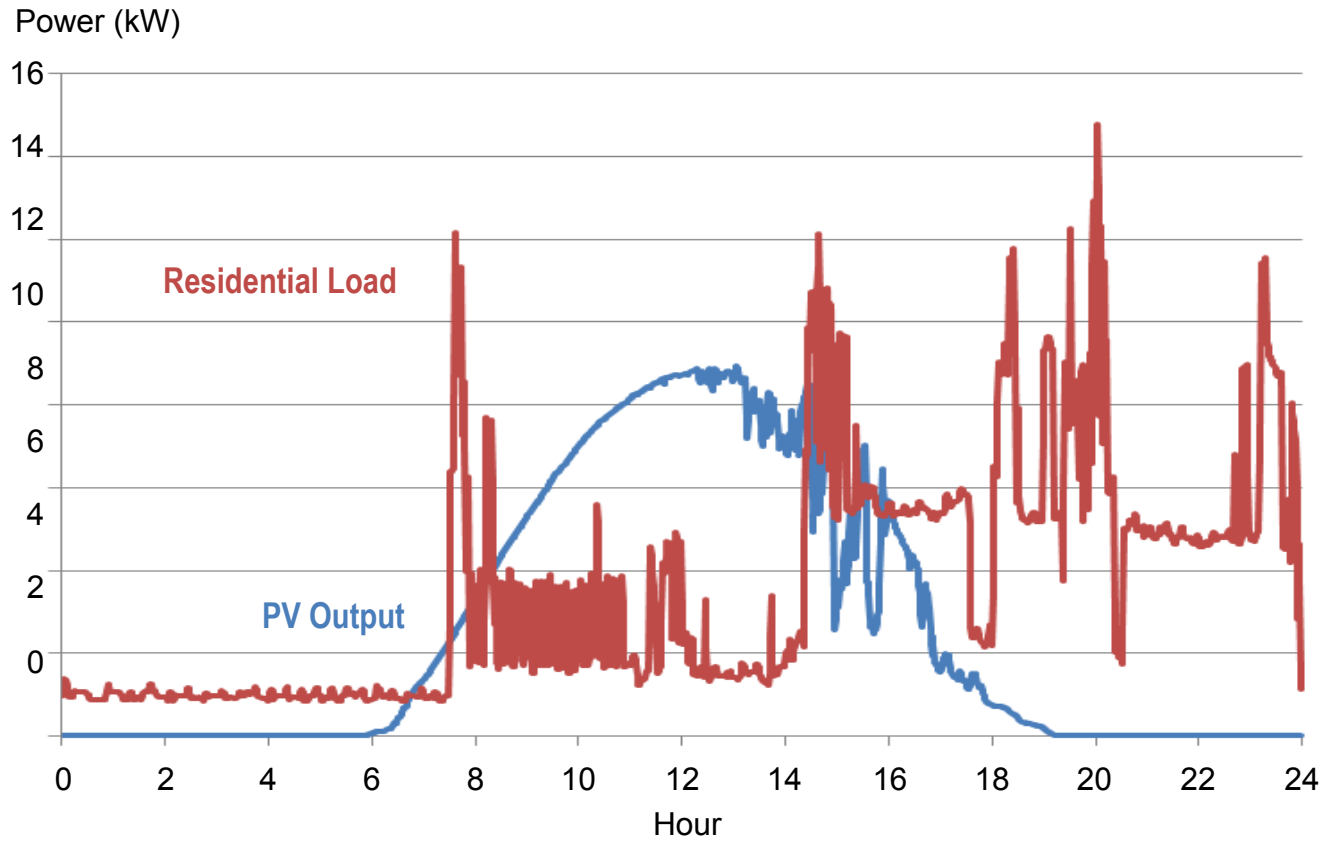
Non-residential system prices fell 5.7% year-over-year, from $3.95/W to $3.72/W

Supply Chain, Overhead and Margins – largest cost category (40%)

Other significant include the PV module (20% of total pricing) and direct installation labor (13%) of total pricing).

[1] *SEIA/GTM Research 1Q2014 PV*

Value of the Grid to DER



Lithium Ion Technology Outlook

Projected Cost (in $/kWh) 2015 2020

$180-$225

$100-$120

$1000-$1200

$500-$600

$400-$500

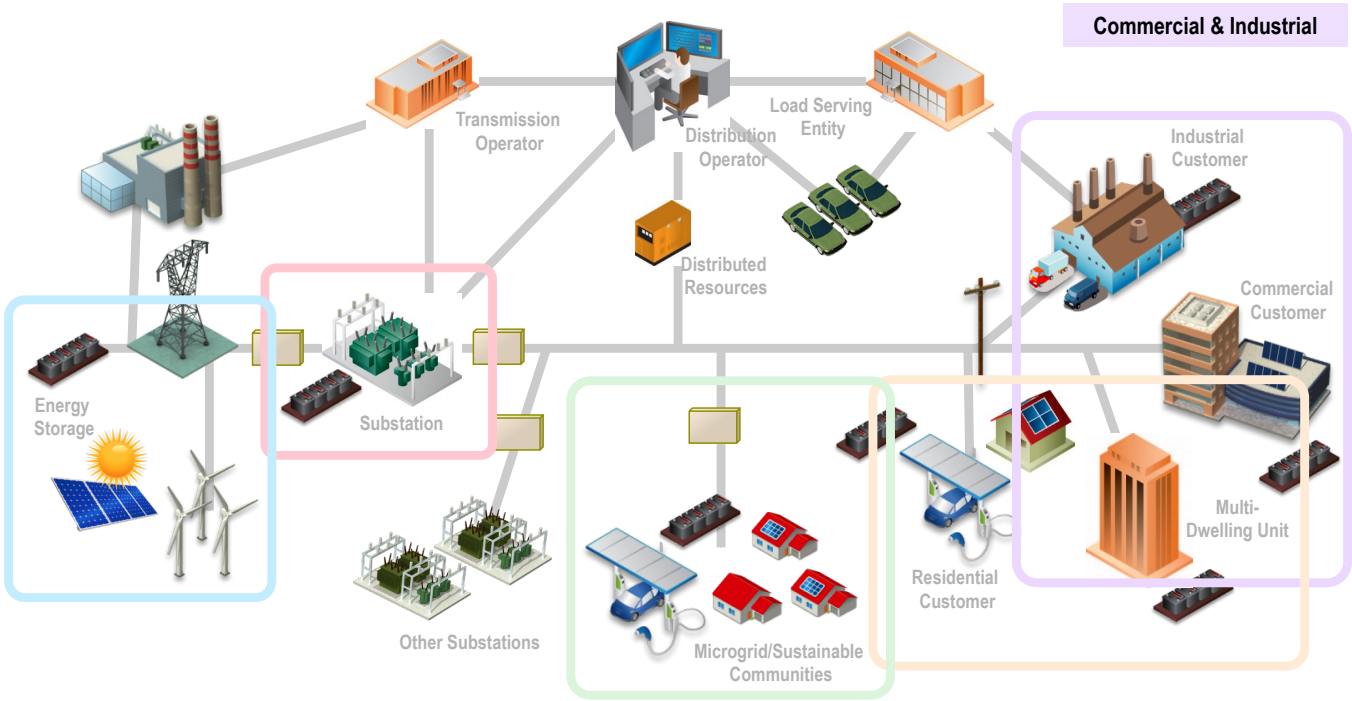
$200-$250

$800-$1000

$400-$500

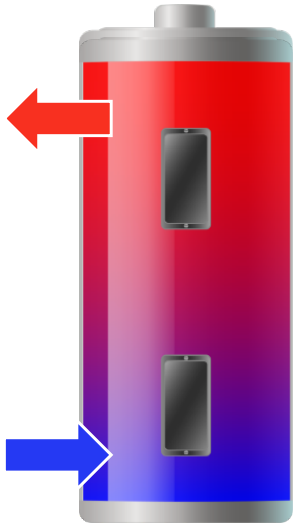
Costs can differ significantly at the cell, battery pack, and complete system levels

Energy Storage Applications



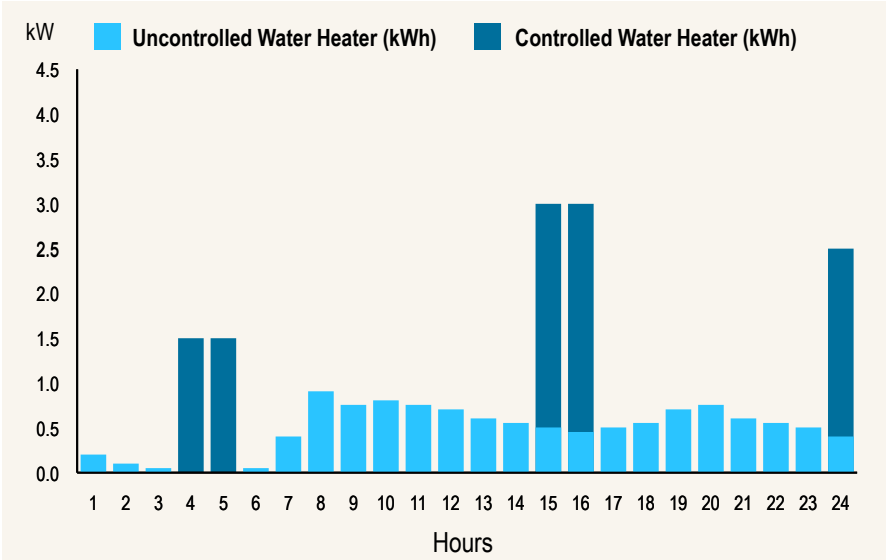
Energy storage has potential applications across the entire electricity enterprise value chain

Smart Appliance as a Grid Resource
Water Heater – Passive Energy Storage



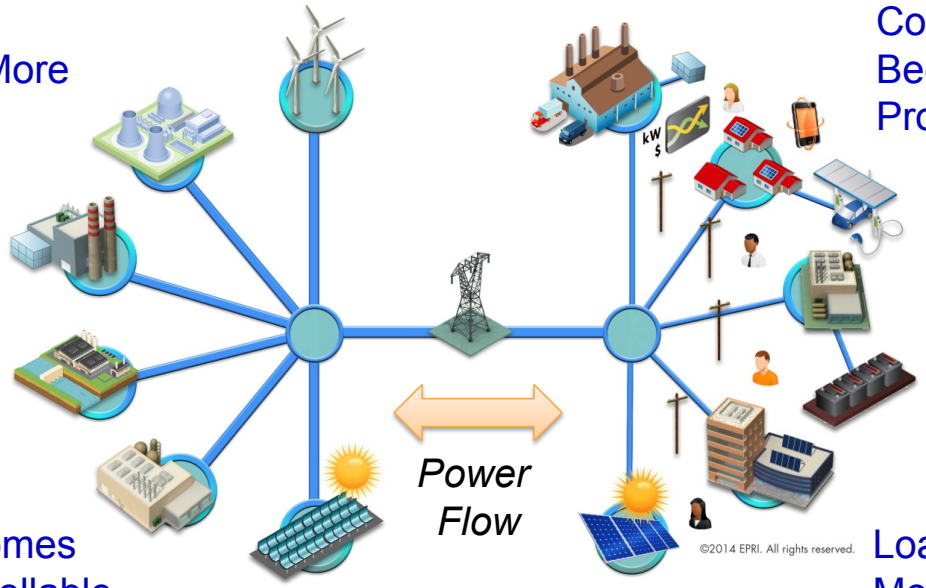
Smart appliances will make it easier to engage customers in demand response programs…

Intelligent set point control to provide grid benefits



The Power System – *Looking Forward*

Generation Becomes More Flexible



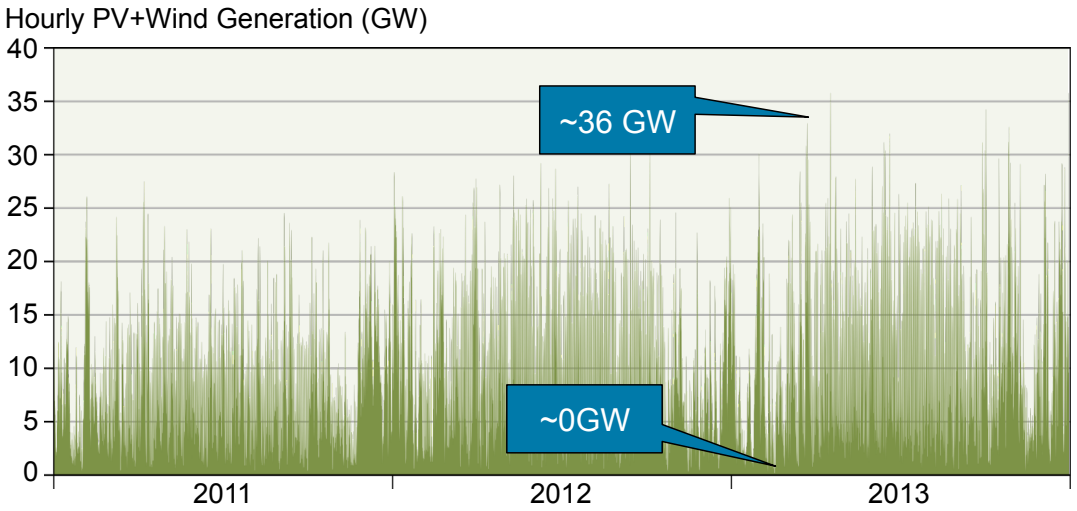
Consumers Become Energy Producers

T & D Becomes More Controllable and Resilient

Loads Become More Interactive and Dynamic

A More Dynamic End-to-End Power System

Insights From a Real Power System



Insights from a Dynamic System

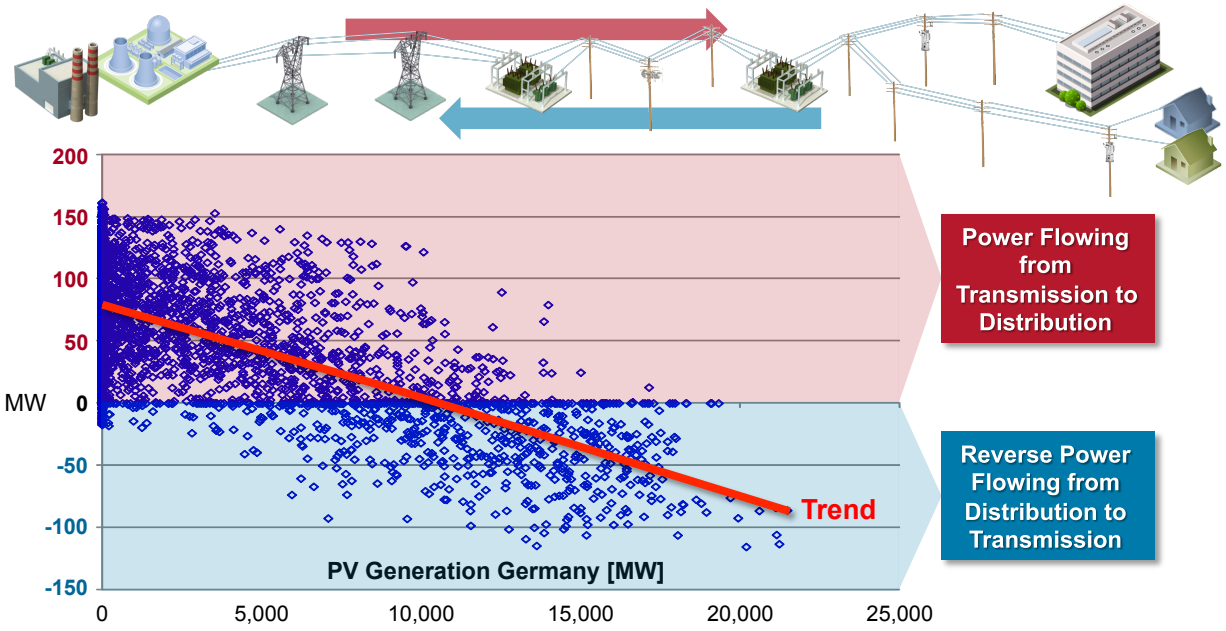
Maximum Hourly Ramp ~10GW

Maximum Hourly Down Ramp ~7GW

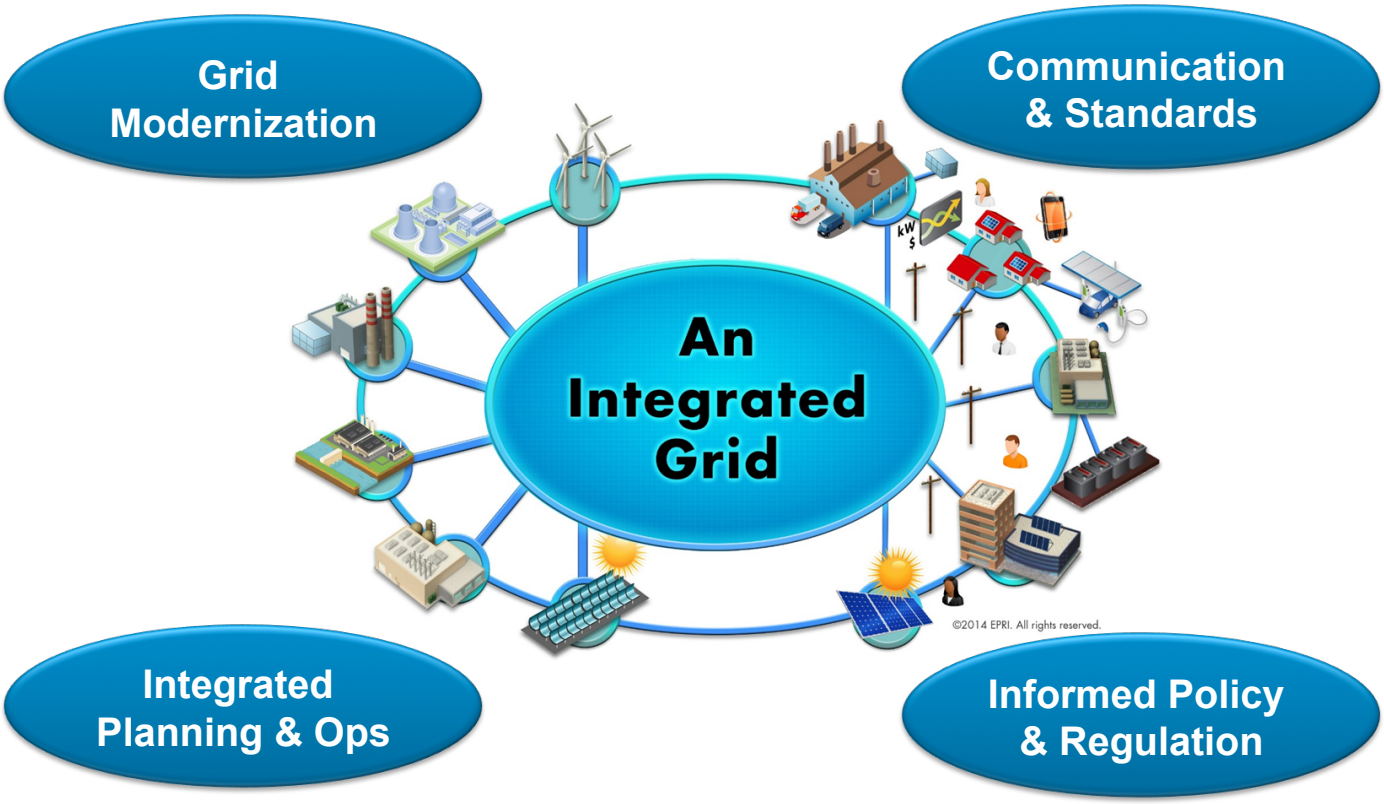
When the Scale of Balancing Becomes Unpredictable and Dynamic

Insights From a Real Power System

When the T&D System Becomes Increasingly Dynamic

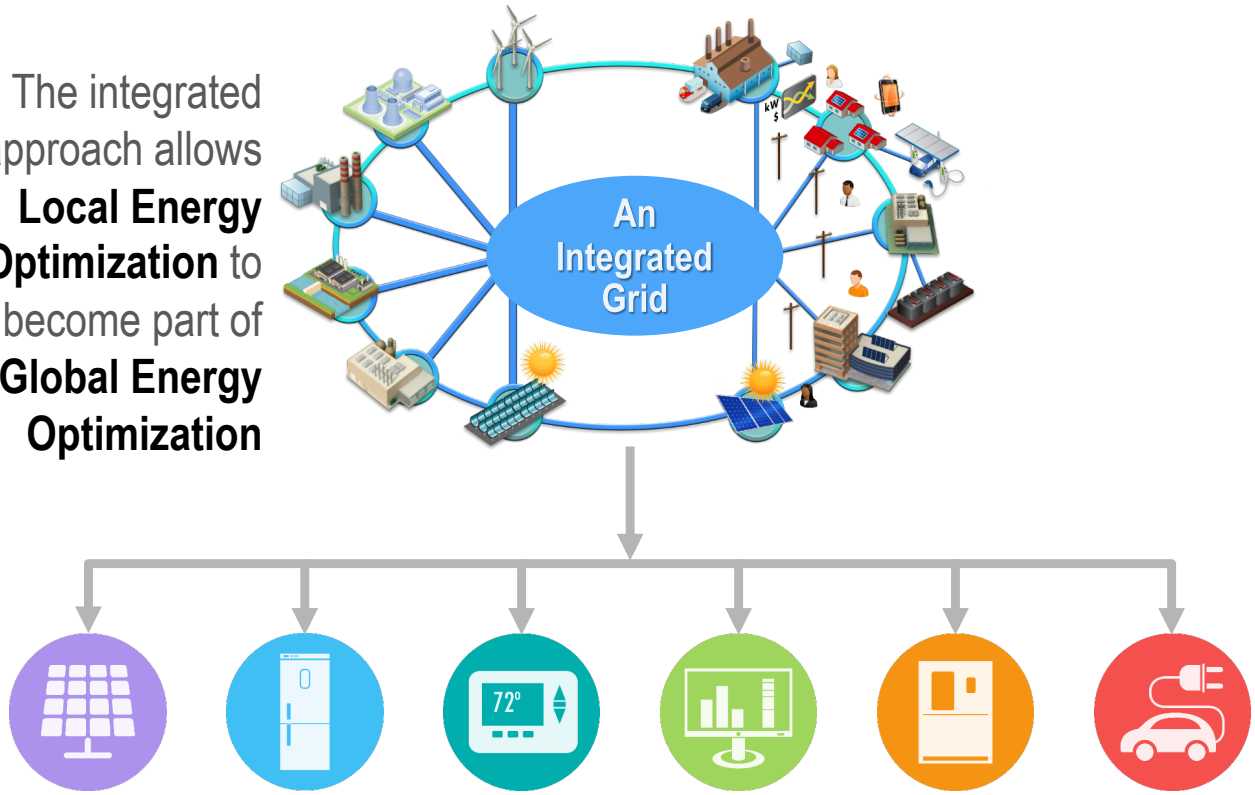


Vision of the Future...



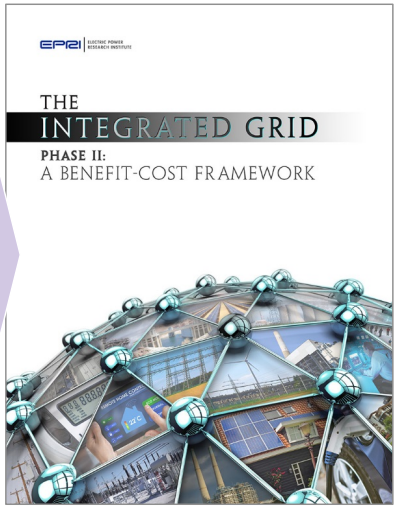
Integrated Approach to Deploying Distributed Energy Resources (DER)

The integrated approach allows **Local Energy Optimization** to become part of **Global Energy Optimization**



EPRI's Integrated Grid Concept

Phase 1	Phase 2	Phase 3
Integrated Grid (IG) Paper	Benefit/Cost Assessment	Integrated Grid (IG) Pilots
FEB 2014	FEB 2015	NOW

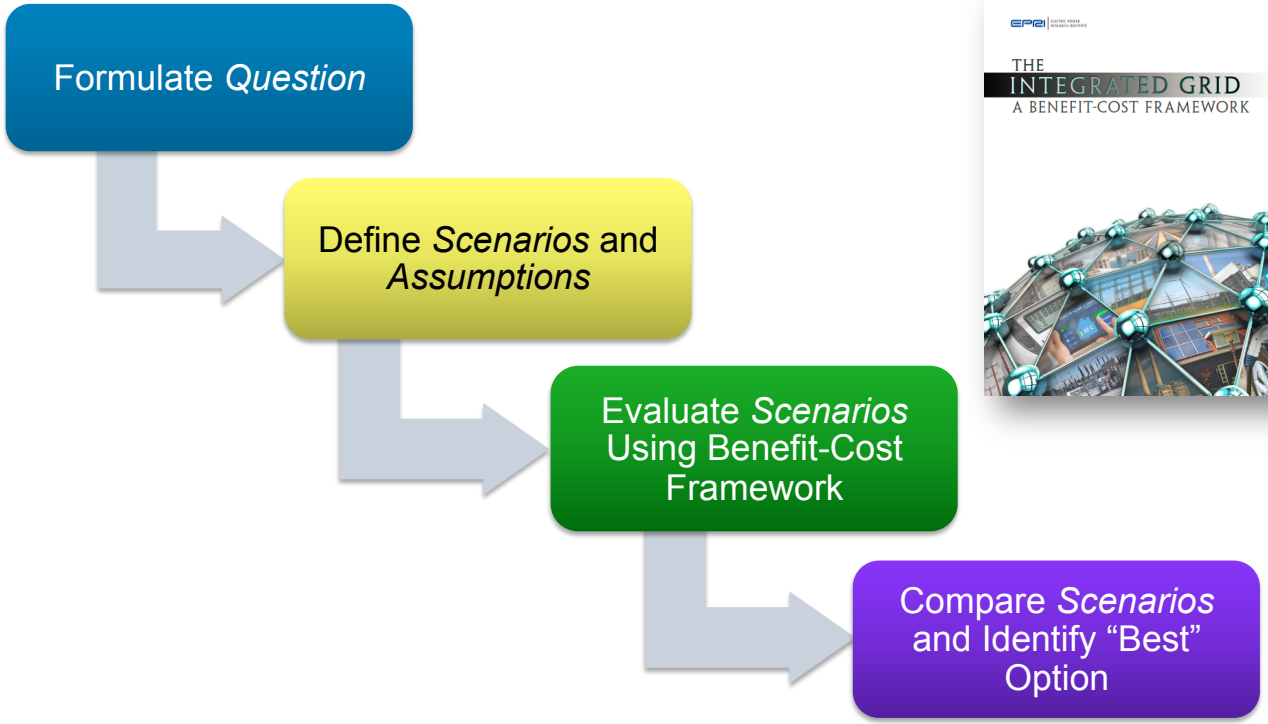


Extensive Electricity Sector Stakeholders in All Phases

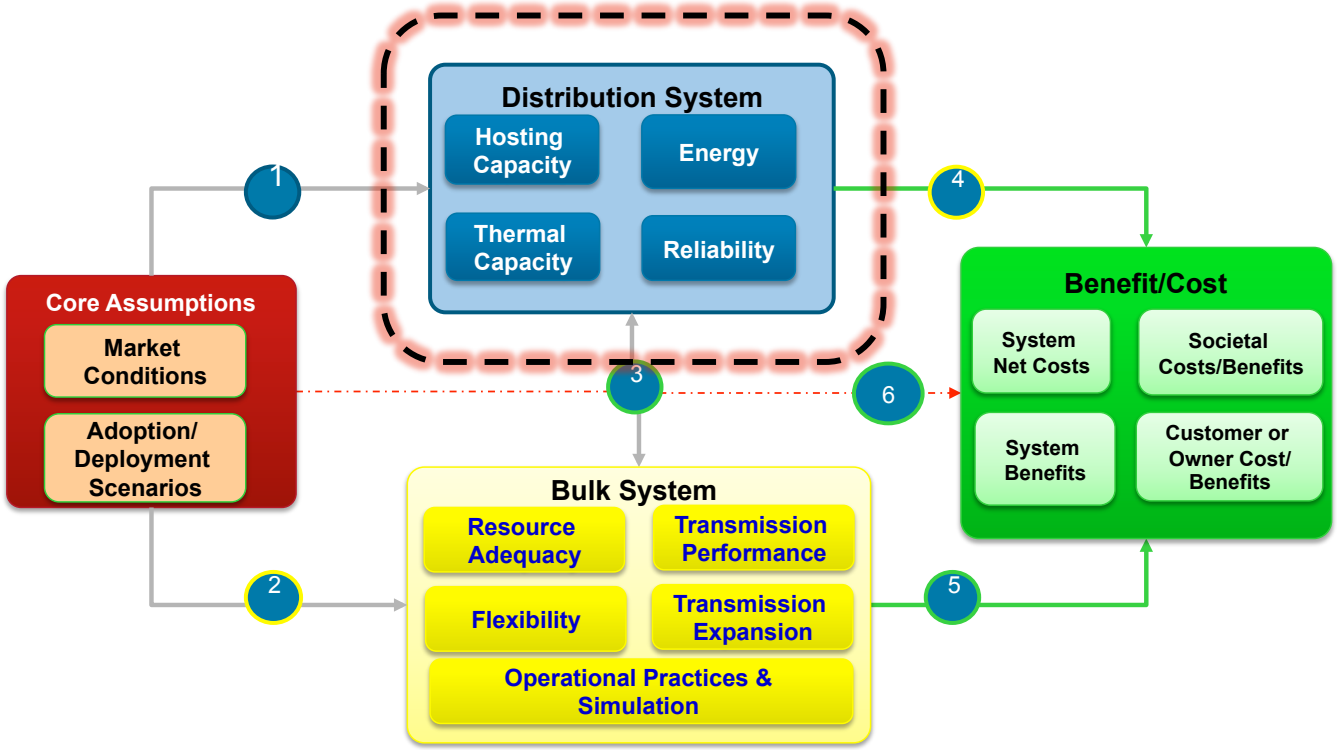
The Board of Directors of the National Association of Regulatory Utility Commissioners recognized the contributions of EPRI's "Integrated Grid" for evaluating the value of energy resources and grid connectivity, and commended EPRI for its beneficial analytical framework and communications outreach to stakeholders.

http://integratedgrid.epri.com

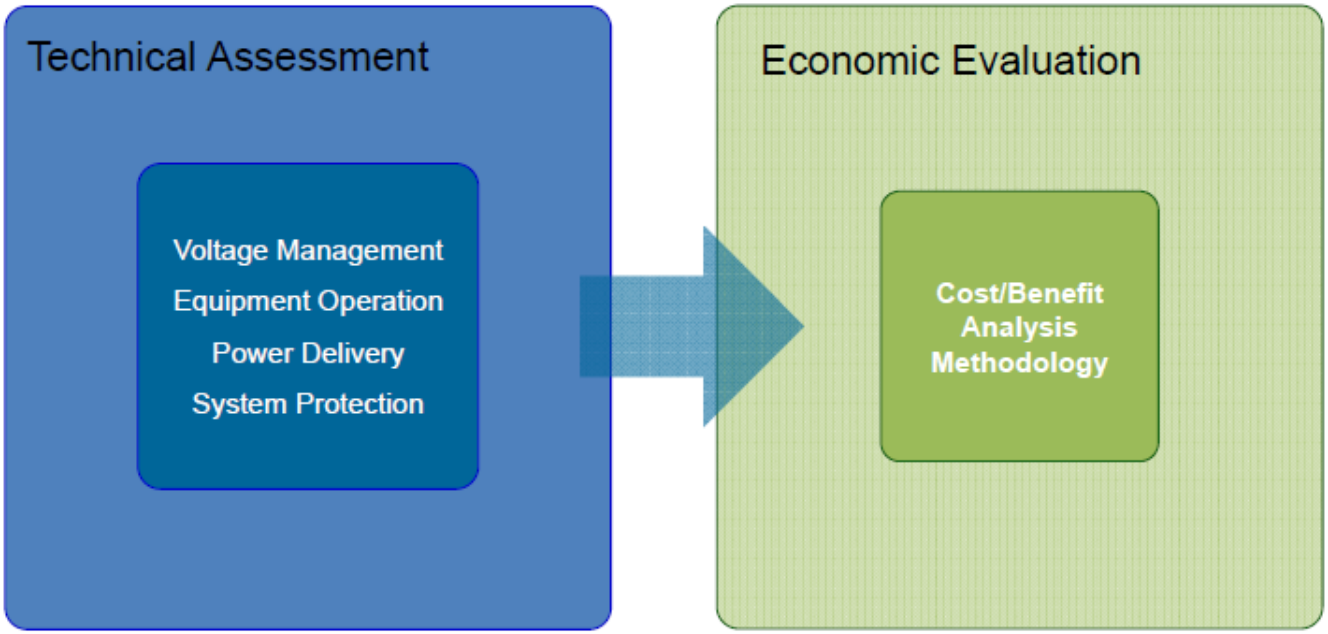
Steps to Apply Benefit-Cost Framework



EPRI's Integrated Grid Benefit-Cost Framework

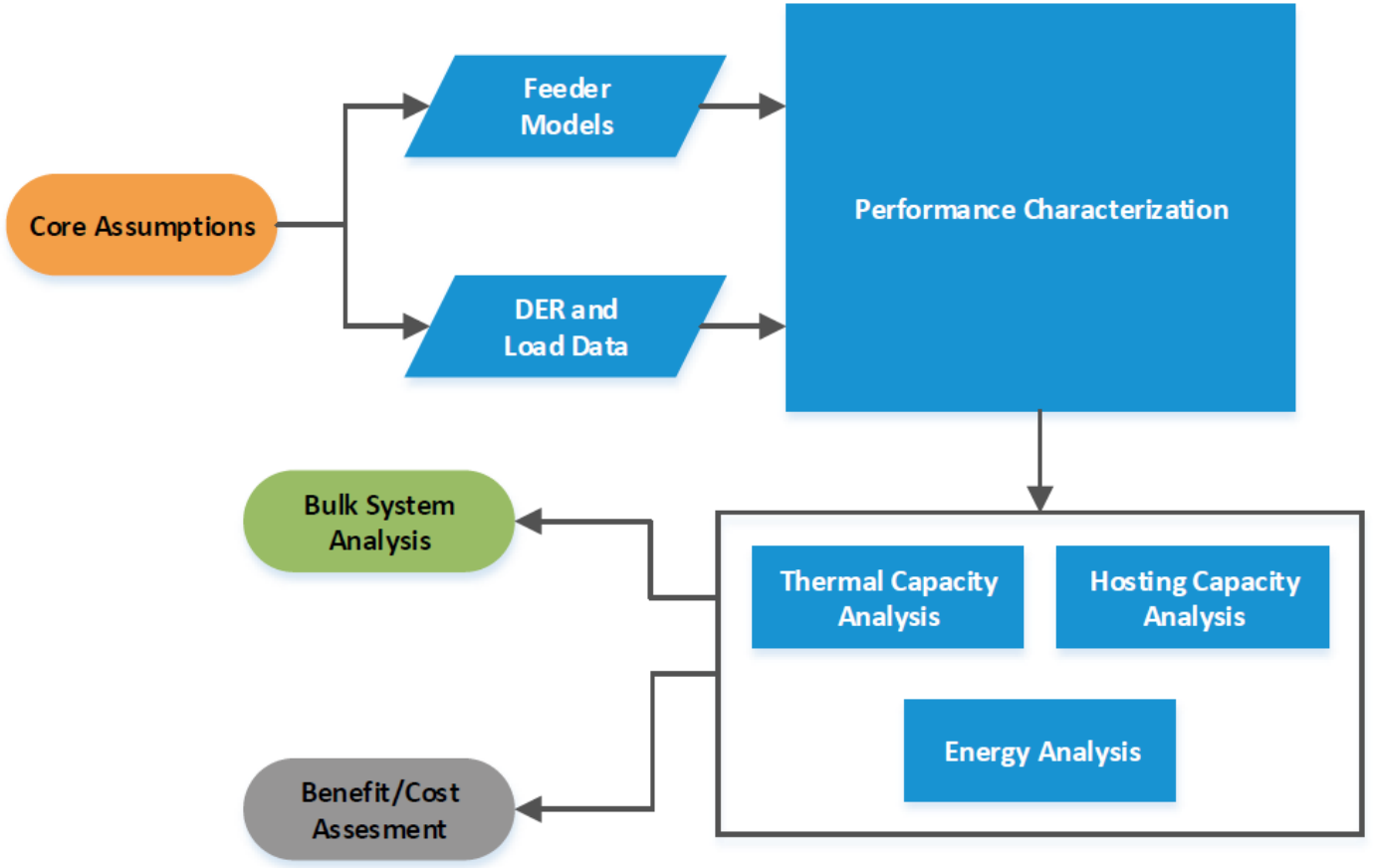


Distribution Impact – The Basics



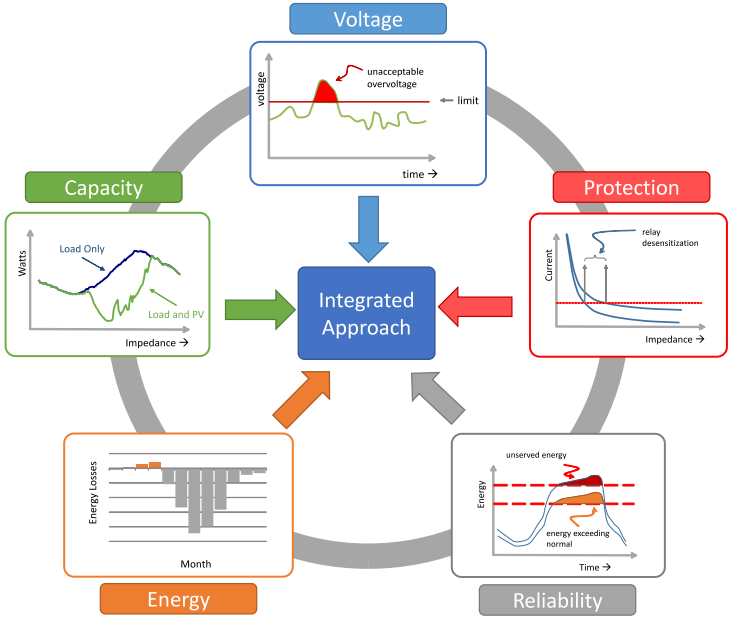
Understanding the Costs and Benefits of Increasing Grid Penetrations of Photovoltaics, EPRI, Palo Alto, CA: 2014. 3002003270

Distribution Framework Flowchart

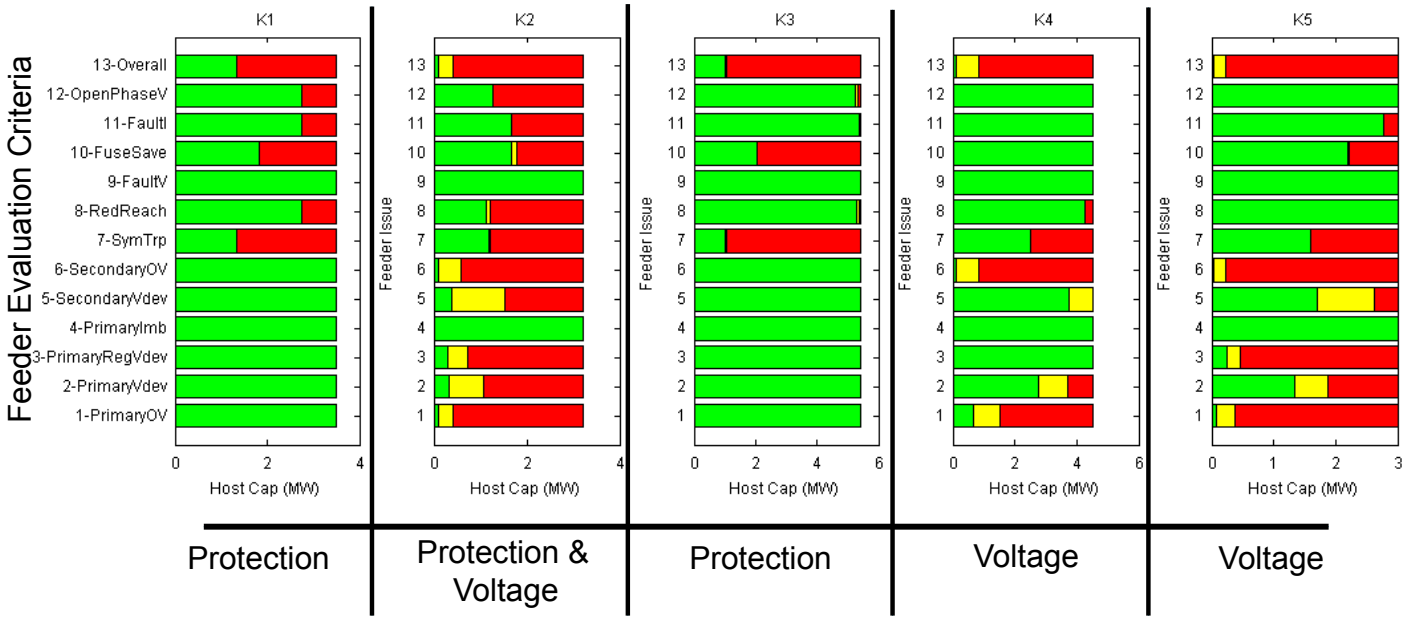


EPRI's Integrated Approach to Distribution Assessment

- **Hosting Capacity Analysis**
  - Voltage
  - Protection
- **Thermal Capacity Analysis**
  - Deferral of system upgrades
  - Loss of life
- **Energy Analysis**
  - Distribution losses
    - Primary and secondary
    - Load and no-load losses
  - Energy consumption
- **Reliability Analysis**



Results from Hosting Capacity Analysis
How much PV can a feeder hold before needing upgrades?



All penetrations in this region are acceptable, regardless of location

Some penetrations in this region are acceptable, site specific

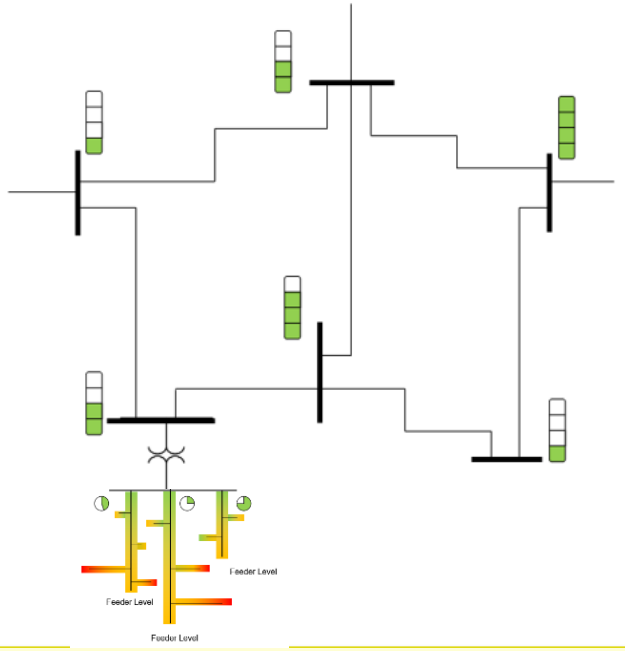
No penetrations in this region are acceptable, regardless of location

Assessing DER Across Entire Distribution System

EPRI Approach

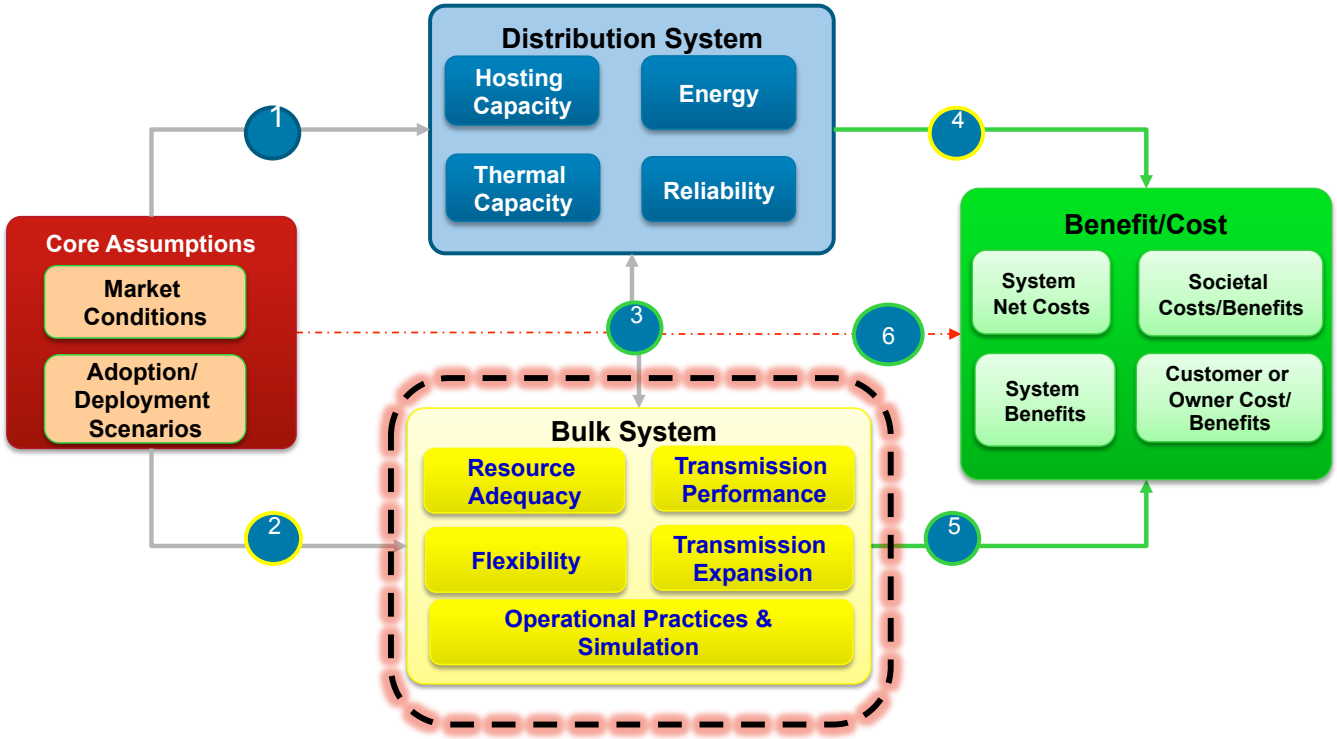
- Uses current utility planning tools and data (In beta-testing with CYME and SynerGEE)
- Evaluates each feeder individually
- Can be applied throughout entire system (1000's of feeders) in automated fashion
- Feeder-level results that are aggregated up to substation level for bulk system analysis
- Captures impact and value efficiently w/o sacrificing accuracy

System-Wide Assessment
Capturing Feeder-Specific Results

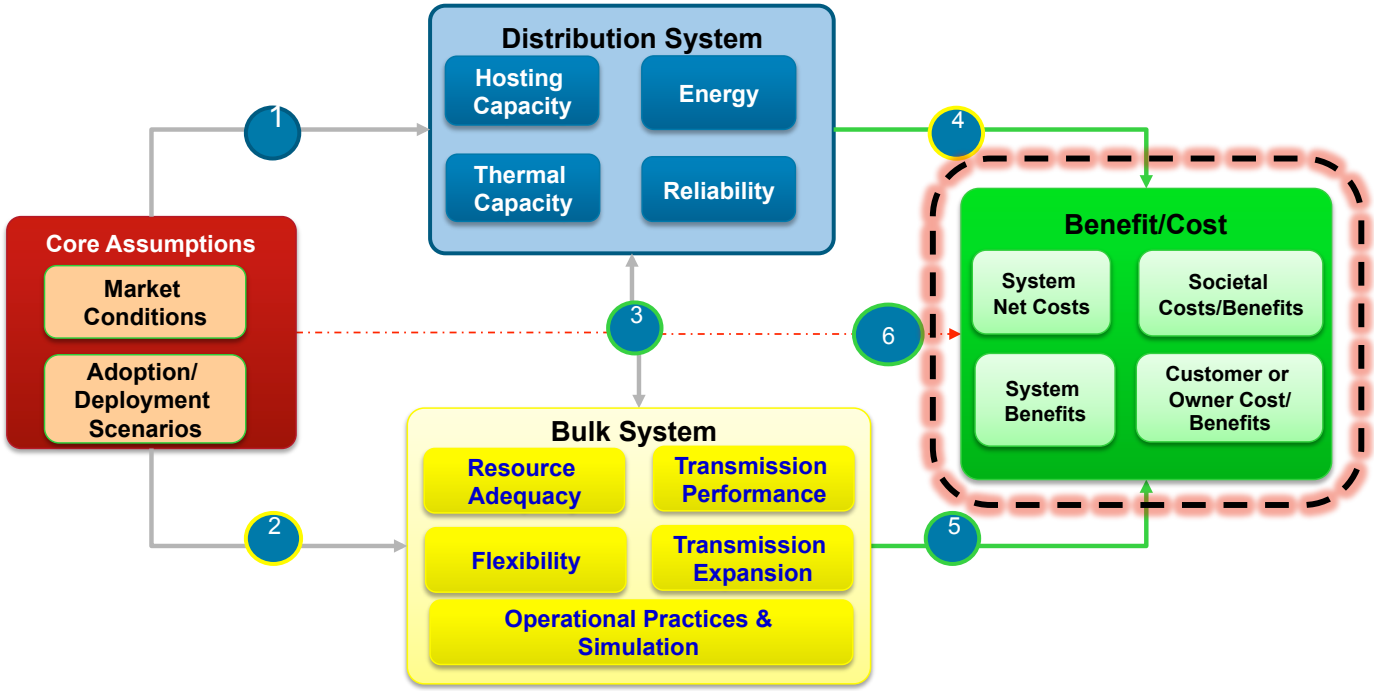


* *Streamlined Methods for Determining Feeder Hosting Capacity for PV*, EPRI, Palo Alto, CA: 2014. 3002003278

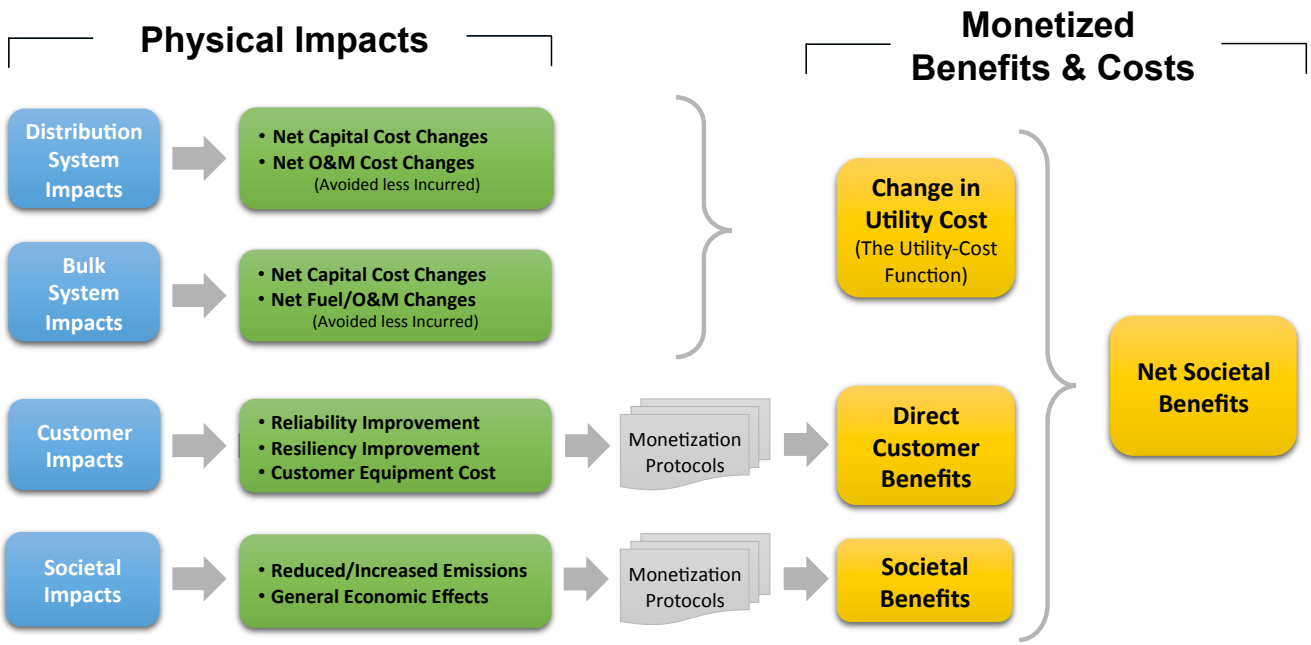
EPRI's Integrated Grid Benefit-Cost Framework



EPRI's Integrated Grid Benefit-Cost Framework



Benefit-Cost Framework

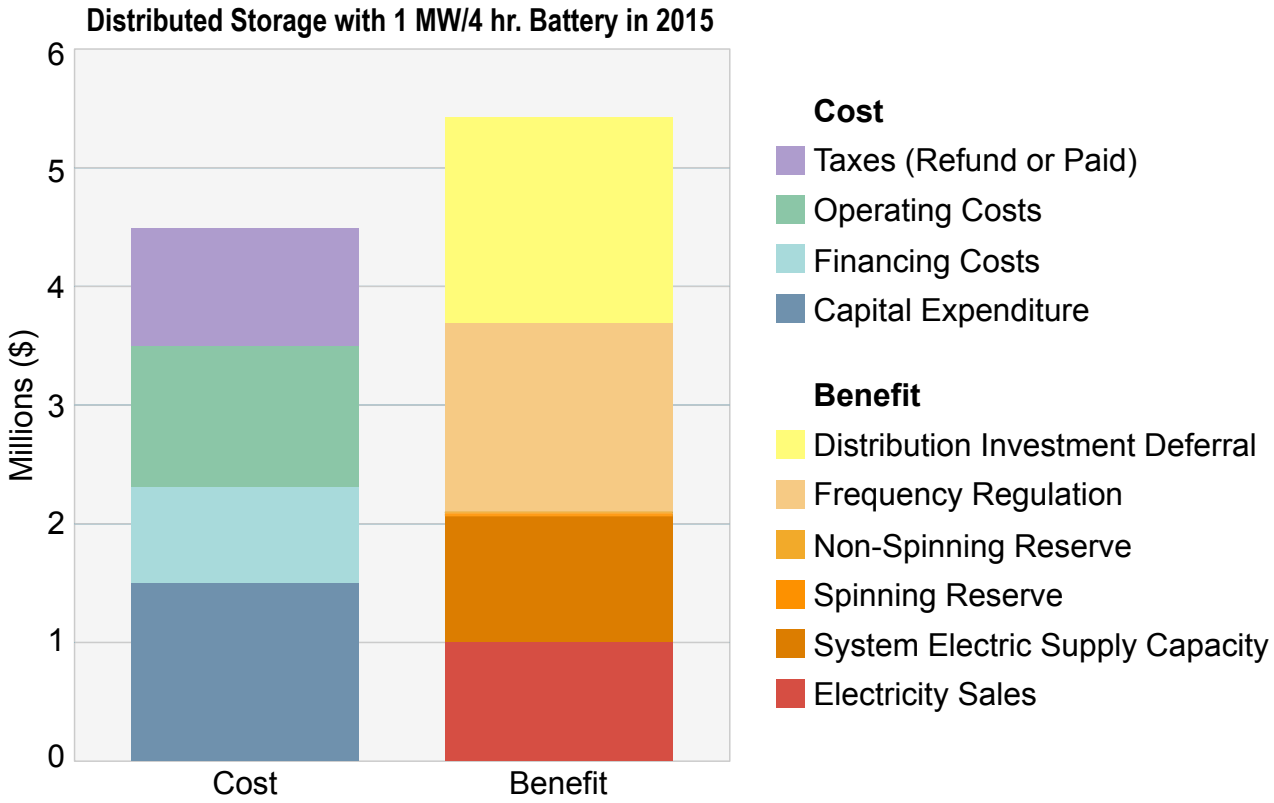


Economic Viewpoint that is Comprehensive and Flexible

Distributed Energy Resource Impacts

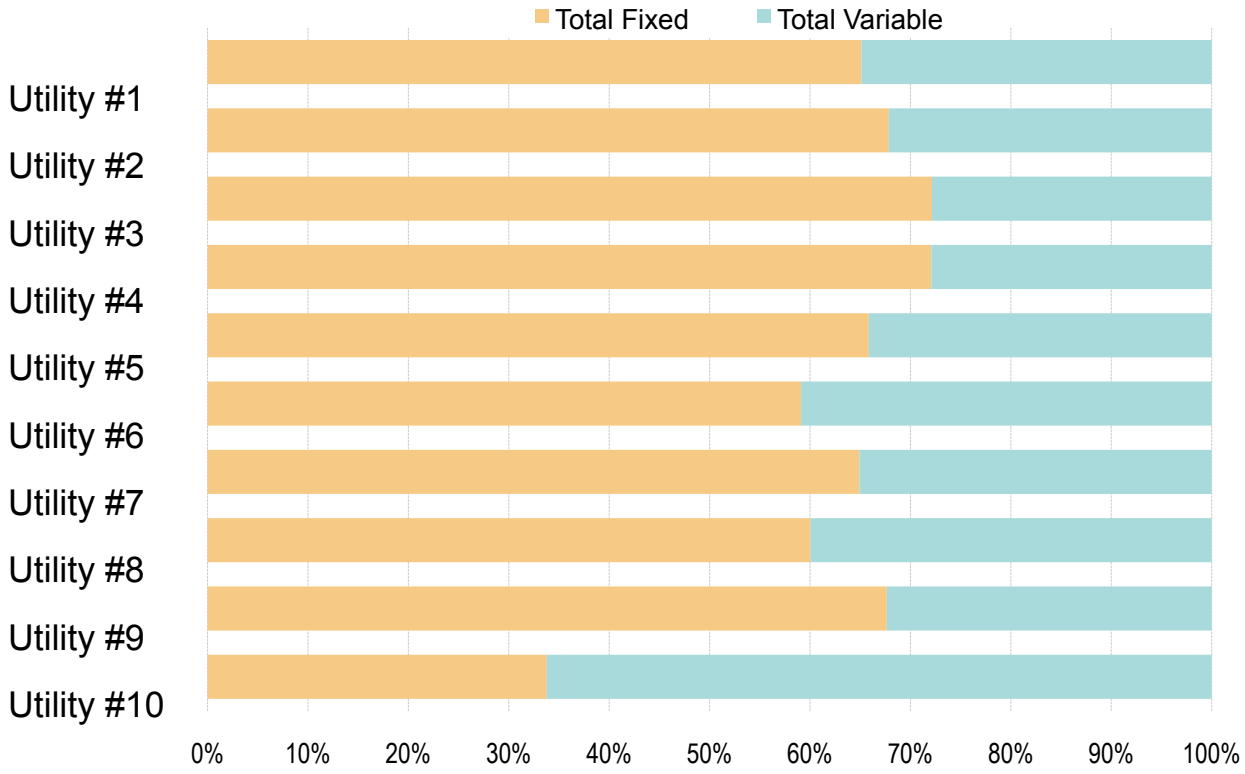
Element	Impacts	*Benefit*	*Cost*
Distribution	Loss Reduction	x	
	Capacity Upgrade Deferral	x	
	Reconductoring		x
	Line Regulators/STATCOMS		x
	Relaying /Protection		x
	LTC accelerated wear		x
	Voltage upgrade		x
	Smart Inverters	x	x
	O&M		x
Bulk Power System	Generation Mix/Requirement Changes	x	x
	Deferral of Transmission Upgrades	x	
	Transmission losses	x	
	O&M	x	x
	Fuel Savings	x	
	Congestion	x	
	System Operations/Uncertainty		x
Customer	DER Investments		x
Societal	Emissions - CO2/GHG, Hg, SOx, NOx	x	
	Cyber Security	x	
	Health	x	
	Macroeconomic effects	x	

Distribution System Integrated Storage Benefit-Cost



Source: Results generated from CPUC inputs into EPRI Energy Storage Valuation Tool

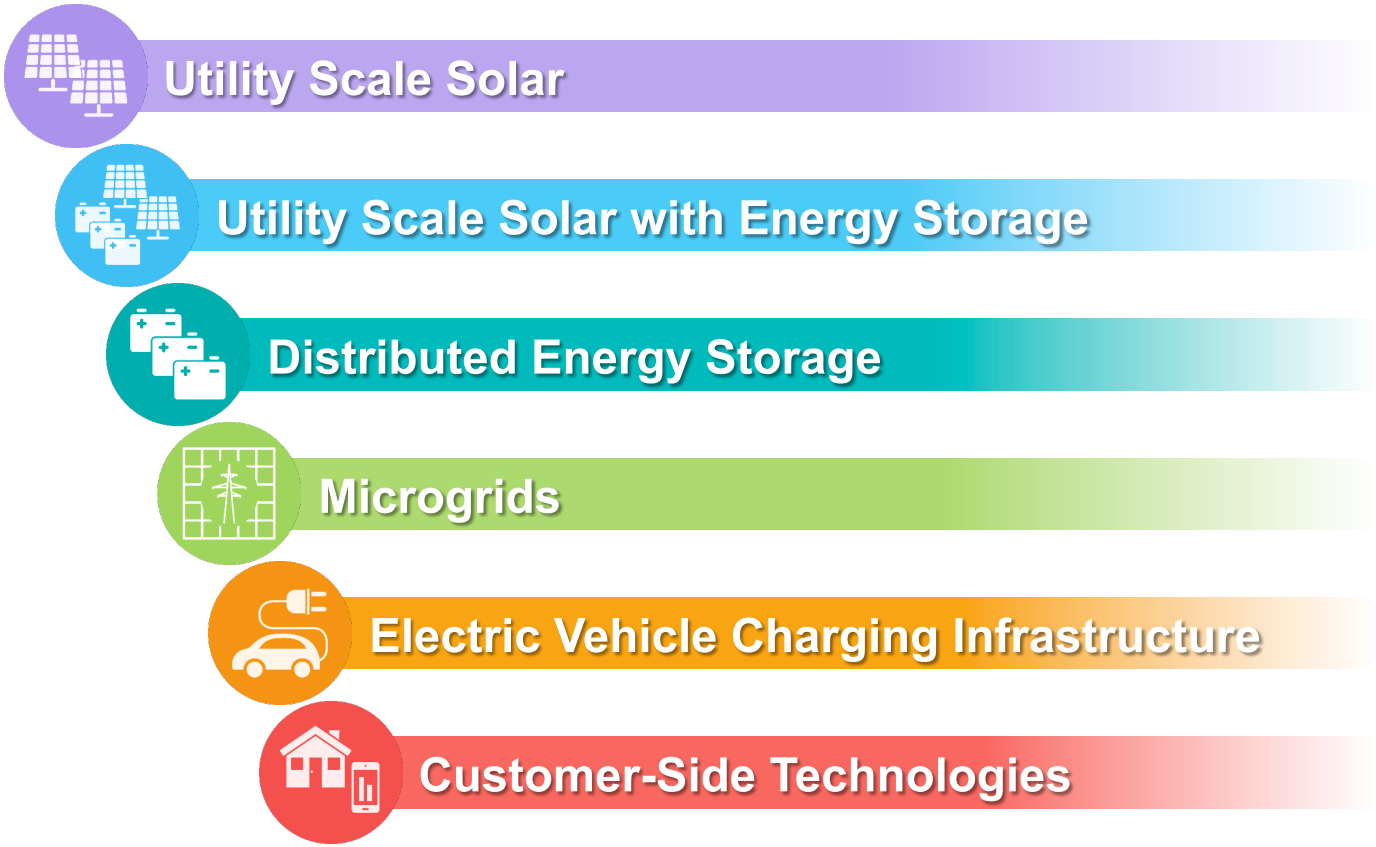
Cost Composition of Residential Bills
(approximated from public data)



Analysis of cost for 10 representative US utilities

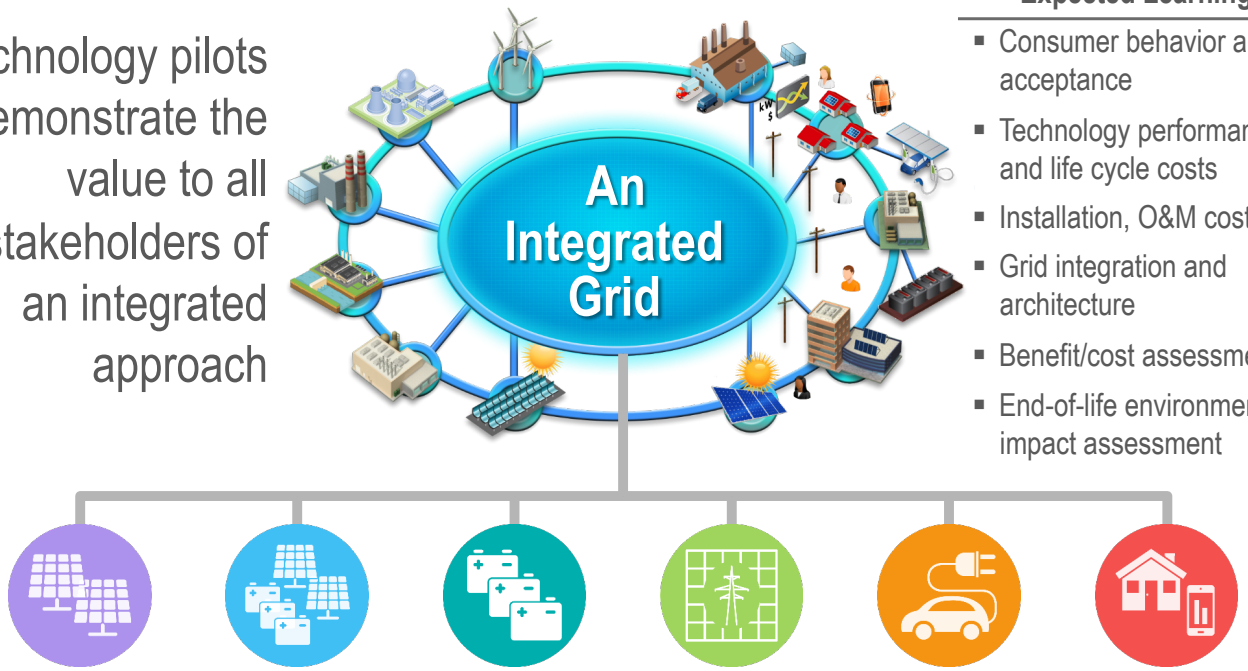
Putting IG Framework to the Test

Pilot Projects



Outcome of Integrated Grid Technology Pilots

Technology pilots demonstrate the value to all stakeholders of an integrated approach



Expected Learnings

- Consumer behavior and acceptance
- Technology performance and life cycle costs
- Installation, O&M costs
- Grid integration and architecture
- Benefit/cost assessment
- End-of-life environmental impact assessment

Together…Shaping the Future of Electricity

For More Information:
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http://integratedgrid.epri.com