EPRI Integrated Grid *Framework and Applications*

Valuation of Transactive Energy Systems

Technical Meeting

PNNL Richland, WA

Erin Erben,

Eugene Water & Electricity Board

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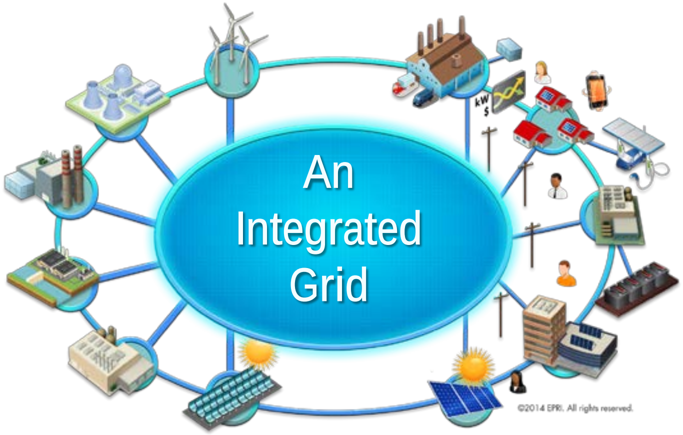
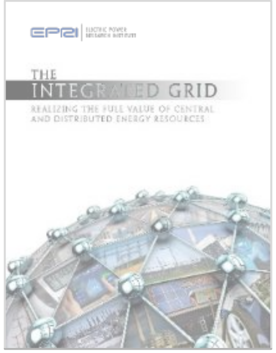
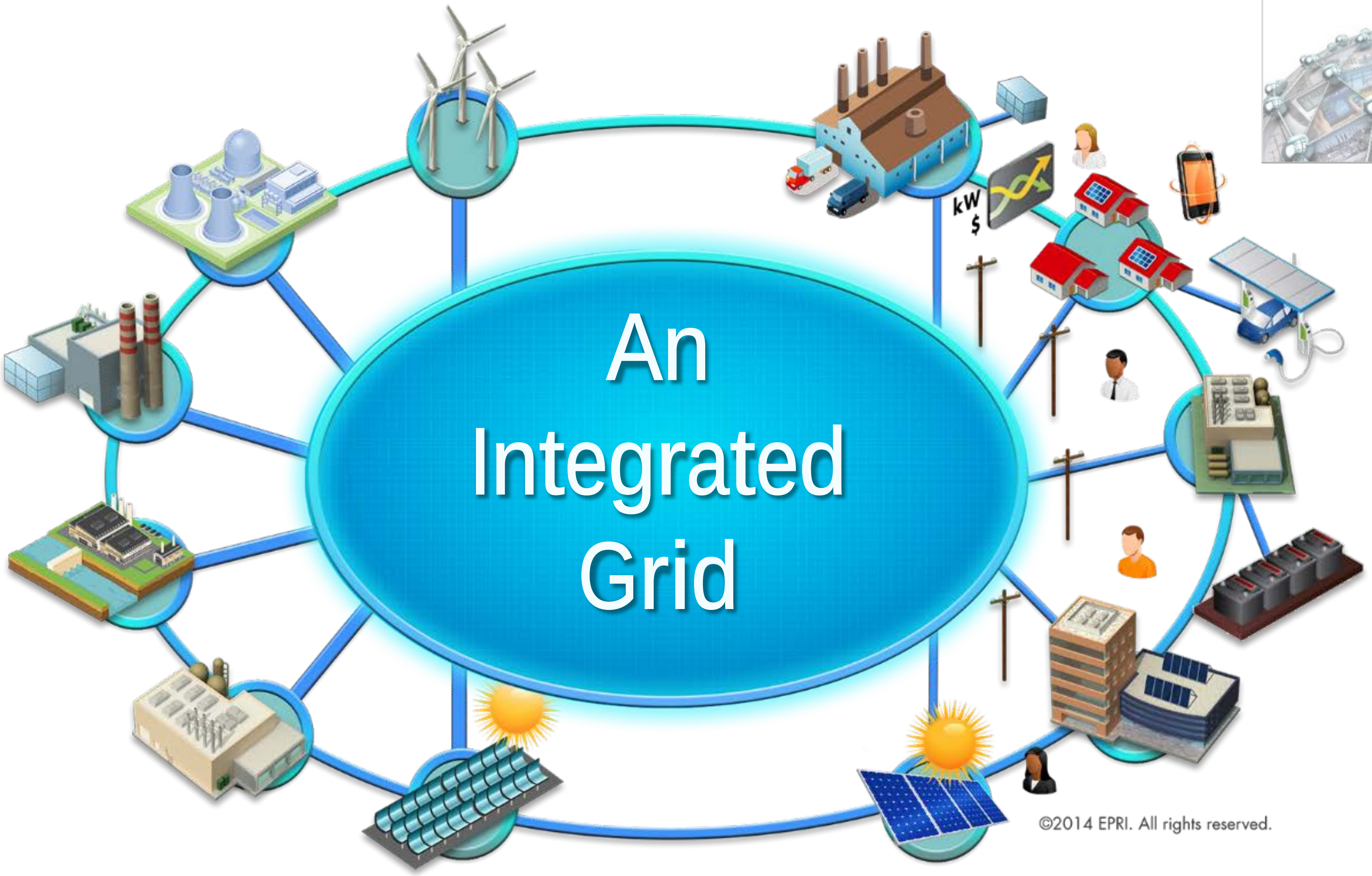
Overview of Integrated Grid Benefit/Cost Framework

Erin Erben



The *Evolving* Power System





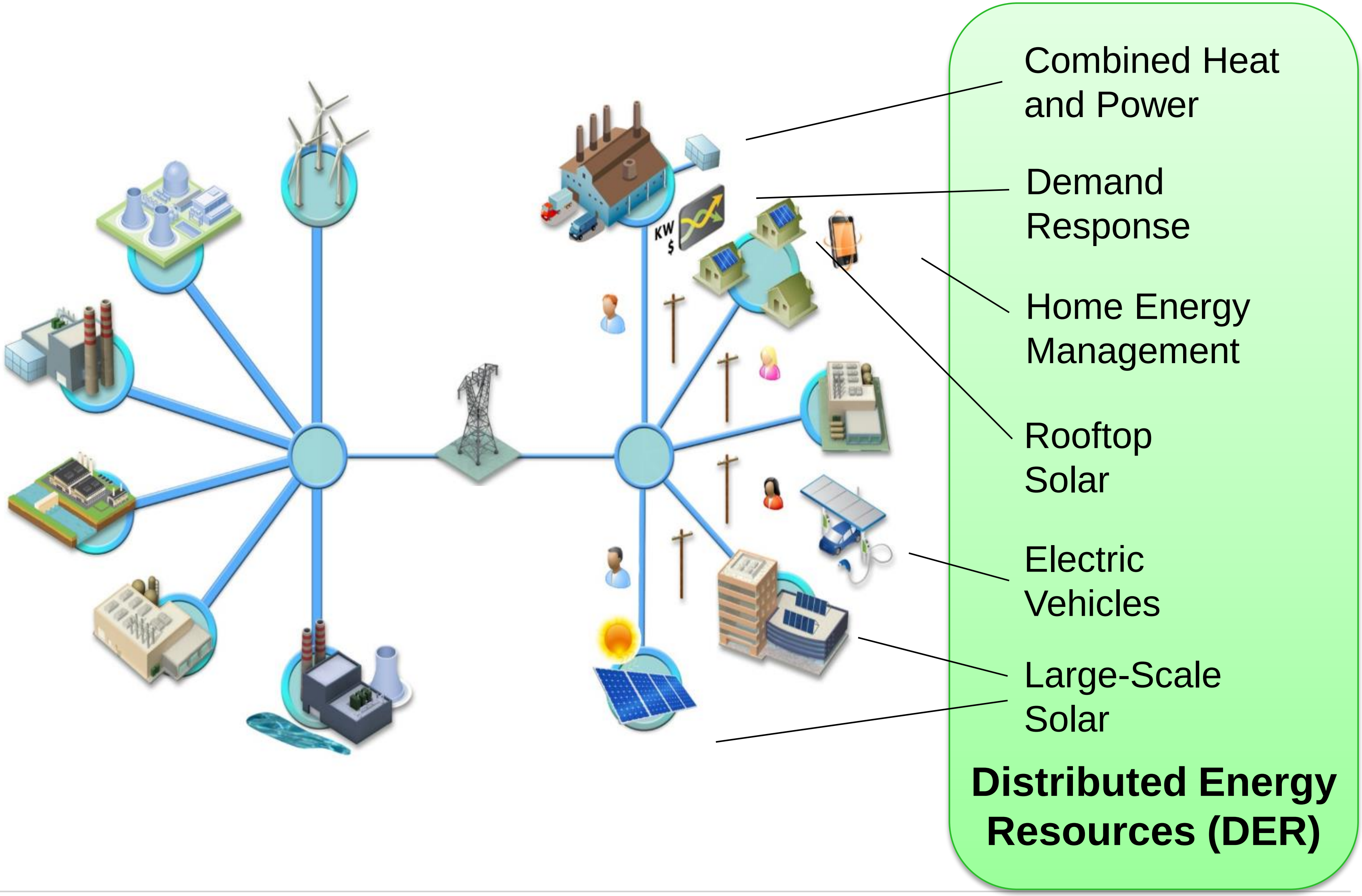
Dynamic Power System Requires an End-to-End *Integrated Approach*

Distributed Generation Resources (DER)

DER are electricity supply sources that fulfill the first criteria below, and one (or more) of the second, third or fourth:

1. Interconnected to the electric grid, in an approved manner, at to below IEE medium voltage (69 kV)
2. Generate electricity using any primary fuel
3. Store energy and can supply electricity to the grid form that reservoir
4. Involve load changes undertaken by end-use (retail) customers specifically in response to prices or other market-based incentives

Resources Considered by the Framework



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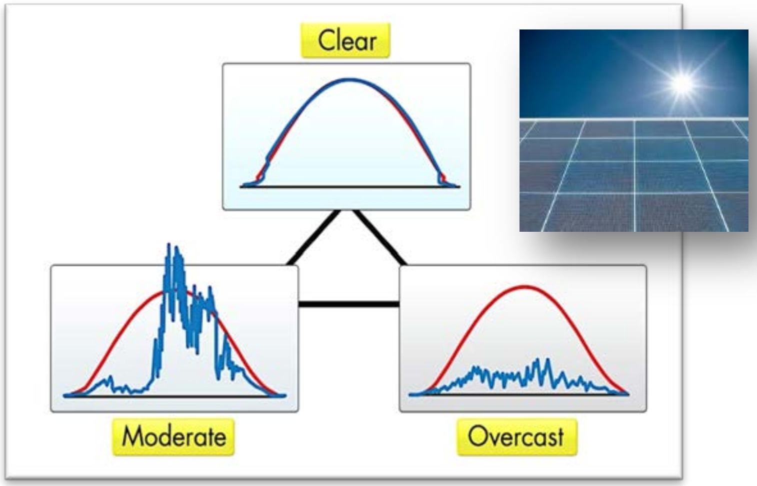
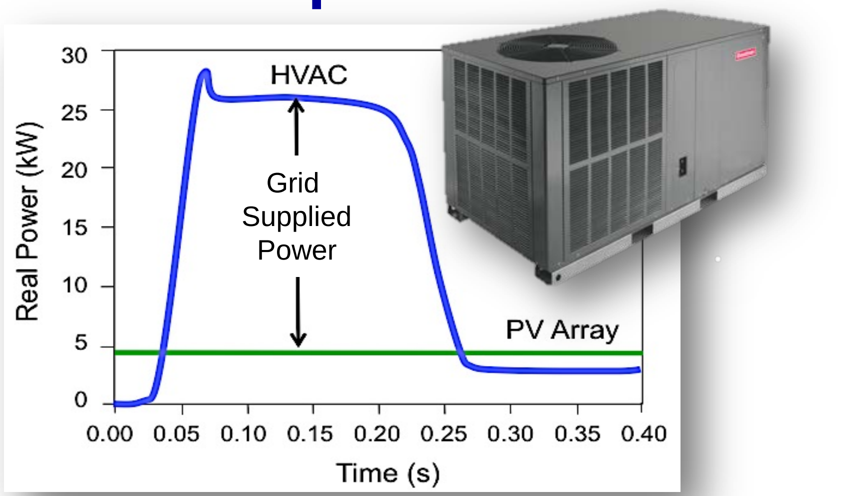
The Challenge – A Few Examples

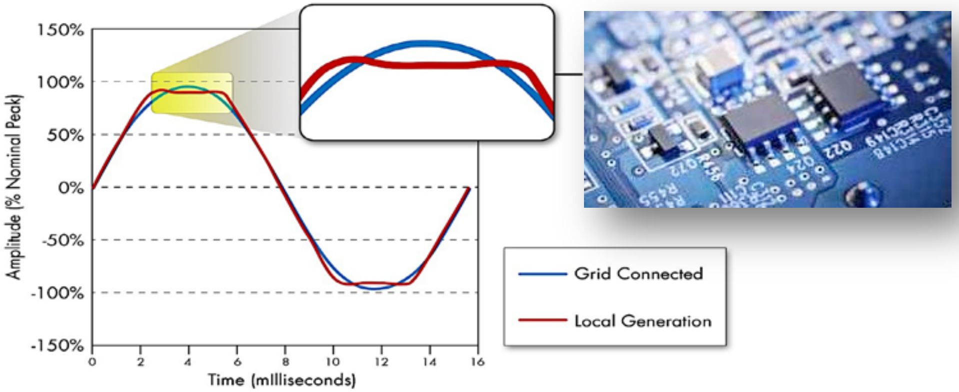
24 by 7 Electricity



Startup Power



Voltage Quality



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Strategic Planning with DER

Research Questions

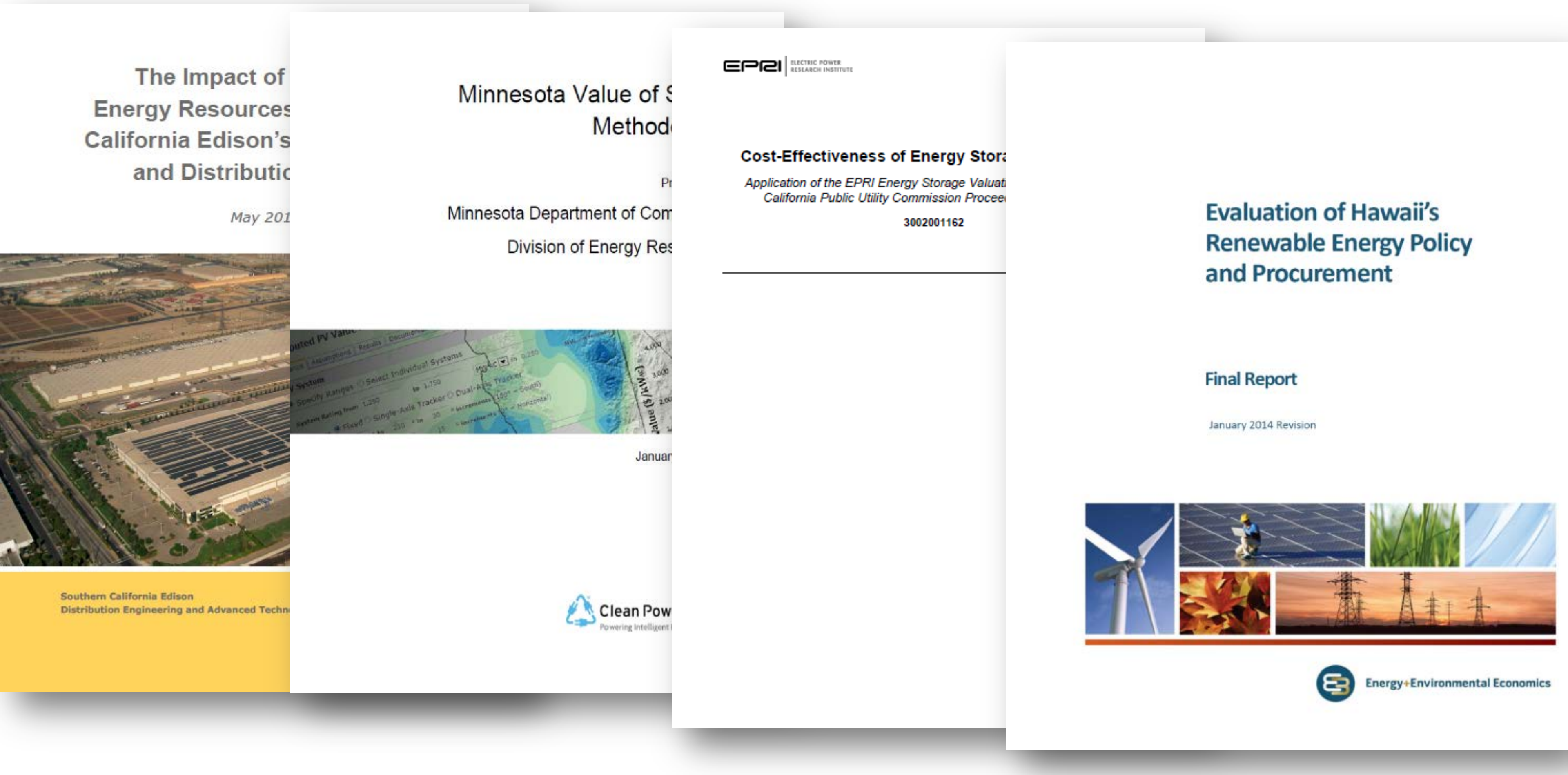
- Value of Solar?
- Storage Deployment?
- Community Solar?
- Smart Inverter Cost/Benefit?
- Proactively Upgrade?

Core Assumptions

- Study Timeframe
- Regulatory Framework
- Resource Mix
- Expected DER Growth
- Environmental Impact

Analytical process must be consistent, repeatable, and transparent

Integrated Grid Benefit/Cost Framework
Building Upon Prior Efforts



Need comprehensive approach: connecting all puzzle pieces

Value of Solar Study Comparison

Comparison of Value of Solar Studies

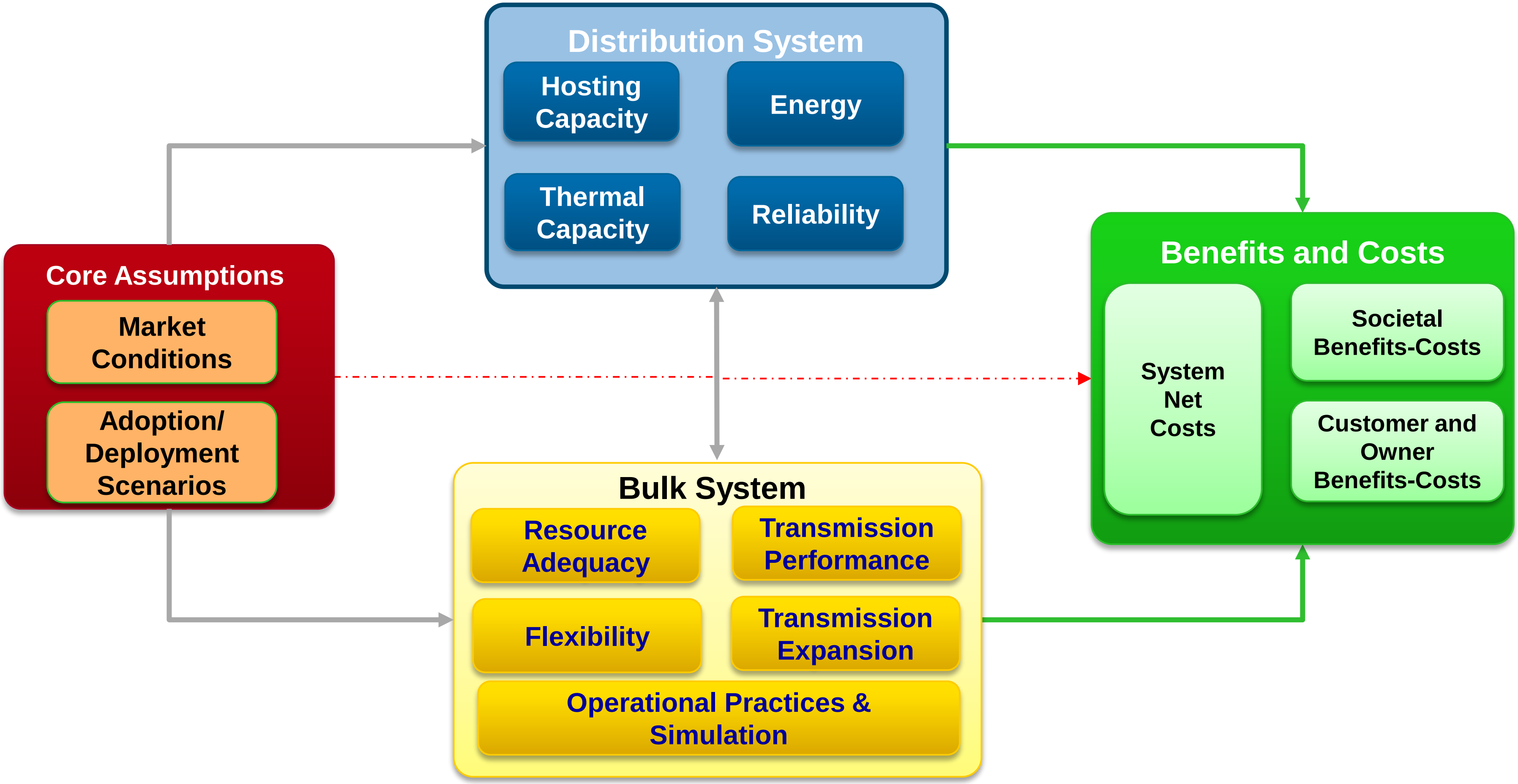
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Author	Vote Solar	R. Duke	Clean Power	Navigant	RW Beck	E3	LBL	E3	LBL	Clean Power Res	APS	Xcel	Princeton	E3	IREC 1	Clean Power Res	Solar SA	Cross-border	Cros-Border
	Benefit Category	2005		2006	2008	2009	2011	2012				2013								
								benefits only		meta-analysis				round-table		meta-analysis				
1	Customer costs				x				x											
2	Energy Benefits	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	Capacity (Gen)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4	Financial Risks		x	x	x					?	x		x	x	x	x	x	x		x
5	Capacity (T&D)	x		x	x	x	x		x	?	x	x	x	x	x	x	x	x	x	x
6	Grid Support Services				x		x	x	x	?				x	x	x			x	x
7	Security Risk				x									x		x	x			
8	Environmental Benefits	x	x	x	x		x		x		x		x	x	x	x	x	x	x	x
9	Social Benefits				x		x							x		x	x			

- Only *Energy Benefits* (row 2) and *Capacity (row 3)* were included in all studies
- Only 1 study (col 4) included all 9 benefit categories
- Some trend toward being more inclusive of categories (2013 vs, 2010)
- Recent new categories:
  - Customer satisfaction
  - Hedging savings
  - Market animation

Shortcomings of a *Value-of* Approach

- Futility of trying to unpack retail tariffs
  - You can't reverse-engineer retail rate constructed for bottom-up cost of service protocols and the art that goes into rate making.
  - Benefits and cost don't align fully with rate-making or accounting categories
  - No way to ensure there is no double counting or know what we don't know (missed benefits and cost)
- Need to trace impacts from source to sink
  - Locational impacts are the source
  - Effects on system (market) operation are the final sink
  - Along the way there are many transformational situations that effect the flow of costs and
- CBA, not just benefits
  - Decision makers should consider all implications of an investment
  - CBA allows comparison of alternatives

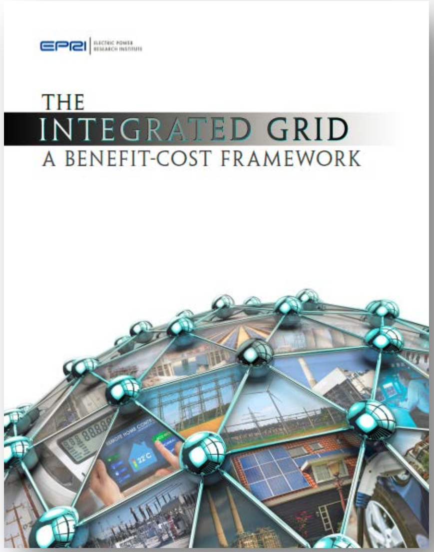
EPRI's Integrated Grid Benefit - Cost Framework



Analytical Process that is Consistent, Repeatable and Transparent

Steps to Apply Cost-Benefit Framework

1. Formulate *Question*
2. Define *Scenarios* and *Assumptions*
3. Evaluate *Scenarios* Using Benefit - Cost Framework
4. Compare *Scenarios* and Identify “Best” Option



Features of the Benefit-Cost Framework

- Comprehensive: Can include any quantifiable impacts from distribution to bulk system, with or without externalities
- Flexible: Designed to address a variety of economic questions from a variety of perspectives
  - Can adopt
    - a utility-planning perspective for guiding decisions, or
    - a broader societal perspective for policy implications

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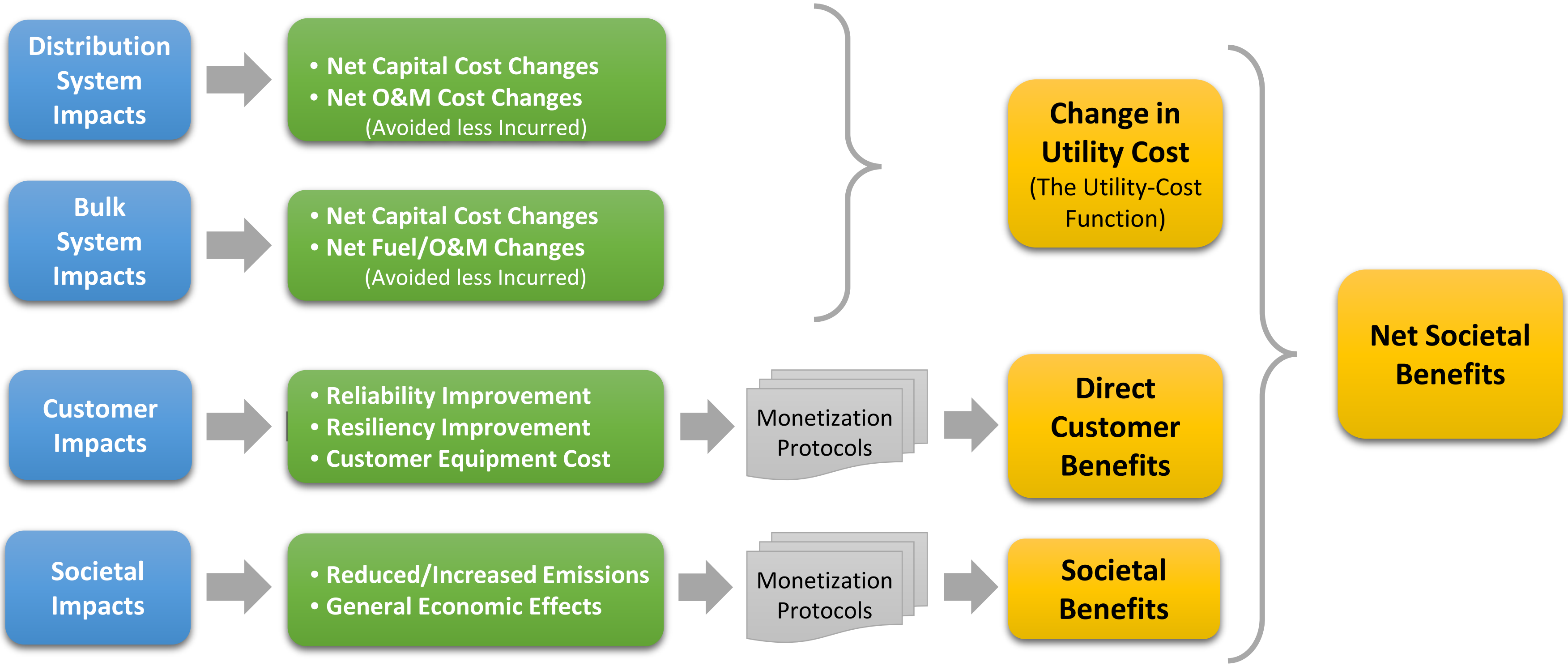
EPRI's Benefit-Cost Framework



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DER Impacts → Benefits and Costs

Element	Impacts	Benefit	Cost
Distribution	Loss Reduction	●	
	Capacity Upgrade Deferral	●	
	Reconductoring		●
	Line Regulators/STATCOMS		●
	Relaying /Protection		●
	LTC accelerated wear		●
	Voltage upgrade		●
	Smart Inverters	●	●
	O&M		●
Bulk Power System	Generation Mix/Requirement Changes	●	●
	Deferral of Transmission Upgrades	●	
	Transmission losses	●	
	O&M	●	●
	Fuel Savings	●	
	Congestion	●	
	System Operations/Uncertainty		●
Customer	DER Investments		●
Societal	Emissions - CO_2/GHG, Hg, SOx, NOx	●	
	Cyber Security		●
	Health	●	
	Macroeconomic effects	●	

Some Overarching Issues

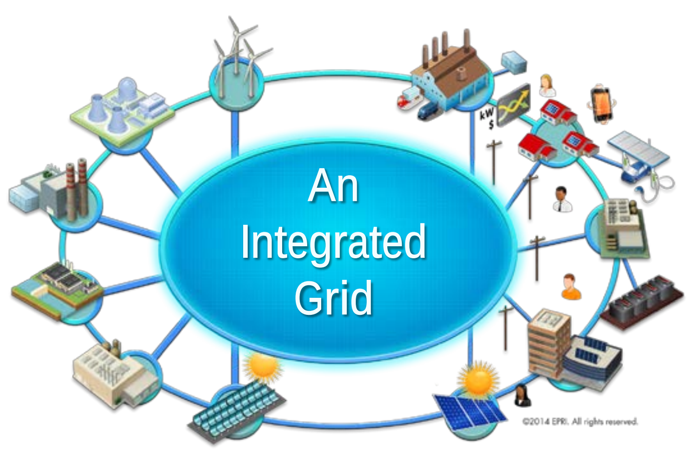
- Who is responsible for achieving an IG
  - Area with organize whole market
  - Federal Power Agencies
  - Vertically integrate utilizes
  - MUNIs and COOPs?

- What role does pricing play is achieving an IG?

- Should a Transitive Energy System be subject to a Cost/Benefit Analysis?

Applications
Integrated Grid
Benefit/Cost Framework

Jeff Roark



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Questions

Distribution Impacts of DER

Jeffrey D. Roark
Electric Power Research Institute

Transactive Systems Valuation
Technical Meeting

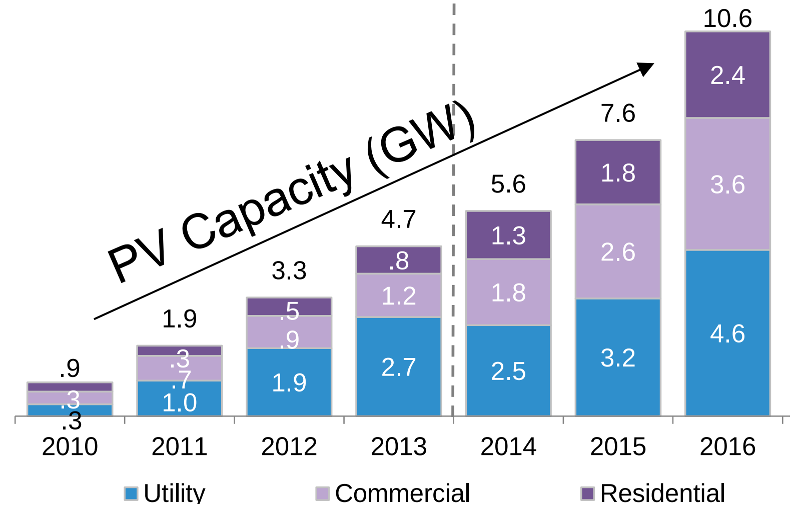
PNNL
Richland, WA
July 7, 2015

Distribution System is Changing

Planning

Landscape

- Most new gen connecting at grid “edge”
- The “edge” is the distribution system
- Distribution has least amount of utility visibility/control



Drivers – Disruptive Innovations

- PV/wind
- Dispatchable resources (ES, CHP, etc..)
- Zero Net Energy homes
- Microgrids

Challenges for Utilities

- **Accommodate** disruptive innovations
- **Improve** efficiency
- **Incorporate** demand response
- **Increase** resiliency
- The list goes on…

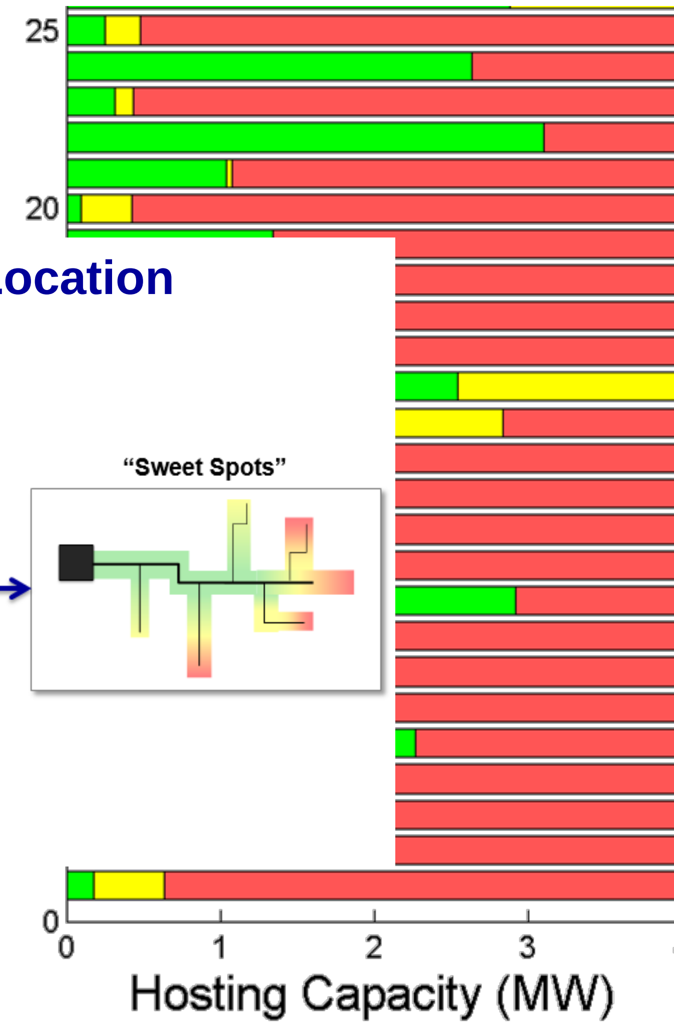
Solution is to be smarter at modeling, planning, and integrating.

Distribution Systems Respond Uniquely to DER

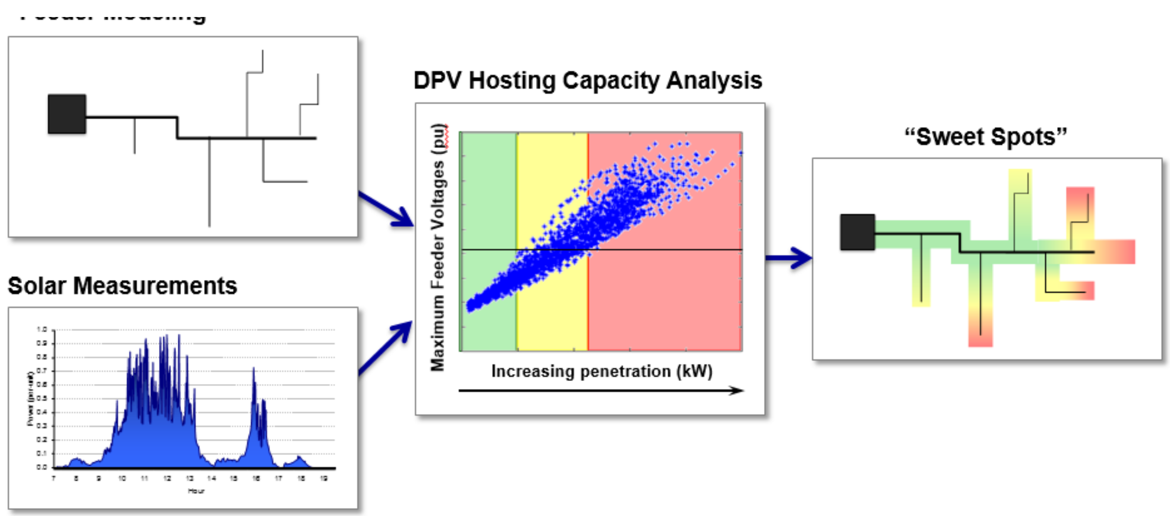
What matters most?

- DER technology and Impacts
- DER size and location
- Feeder construction and operation

Feeder Construction and Operation



Hosting Capacity: DER Size *and* Location



DER Technology and Impacts

- Voltage
- Protection coordination
- Thermal capacity

All Impacts Below Threshold	Impact Depends (on size & location)	All Impacts Above Threshold

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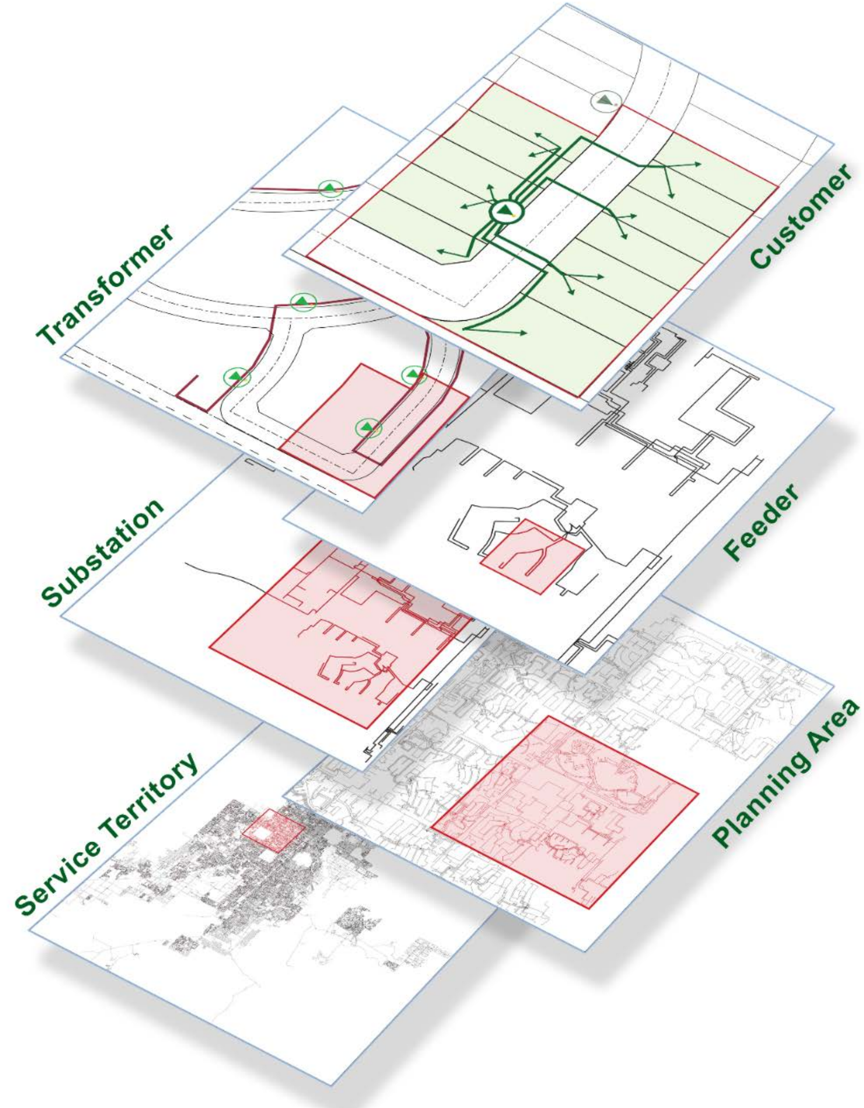
Distribution System is Immense in Scale

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

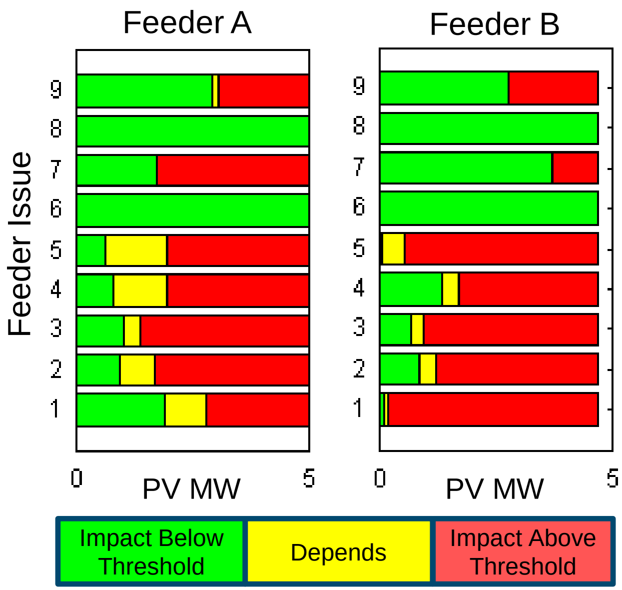


Distribution diagrams courtesy of Salt River Project

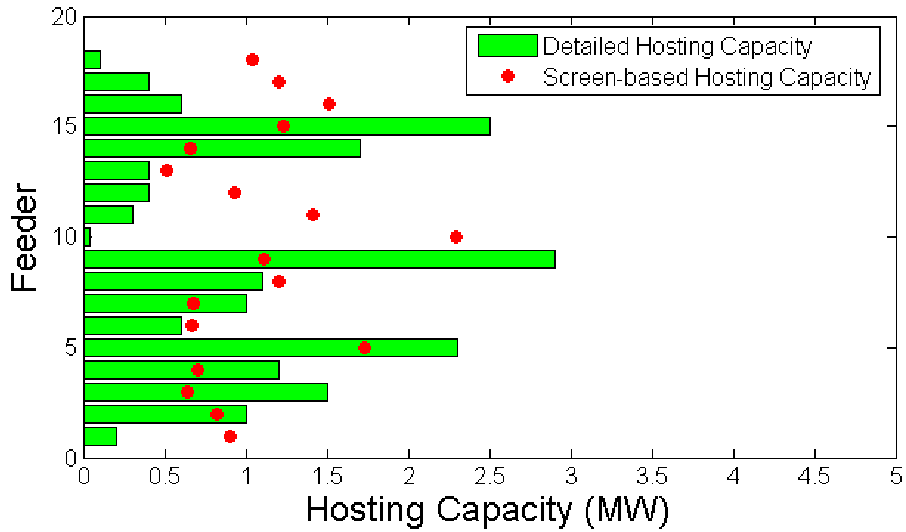
Current Analysis Methods Aren't Sufficient

- *Detailed* system analysis requires significant time/resources
- Work-arounds have included:
  - Detailed analysis on select feeders and extrapolating results to others
  - Simplified screening analysis on all feeders

Extrapolation Problem:
Similar feeders with different results



Screening Problem:
Under and over conservative results



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New Methods are Needed

Capture what matters most:

- Size and location of DER
- Unique response characteristics of the distribution systems
- Unique DER technology

Key Components of an Effective Method

Granular	• Capture unique feeder-specific responses
Repeatable	• As distribution feeders change
Scalable	• System-wide assessment
Transparent	• Clear and open methods for analysis
Proven	• Validated techniques
Available	• Utilize readily available utility data and tools

} EPRI's Streamlined Hosting Capacity Method

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Streamlined Hosting Capacity Method – What is it?

The Input

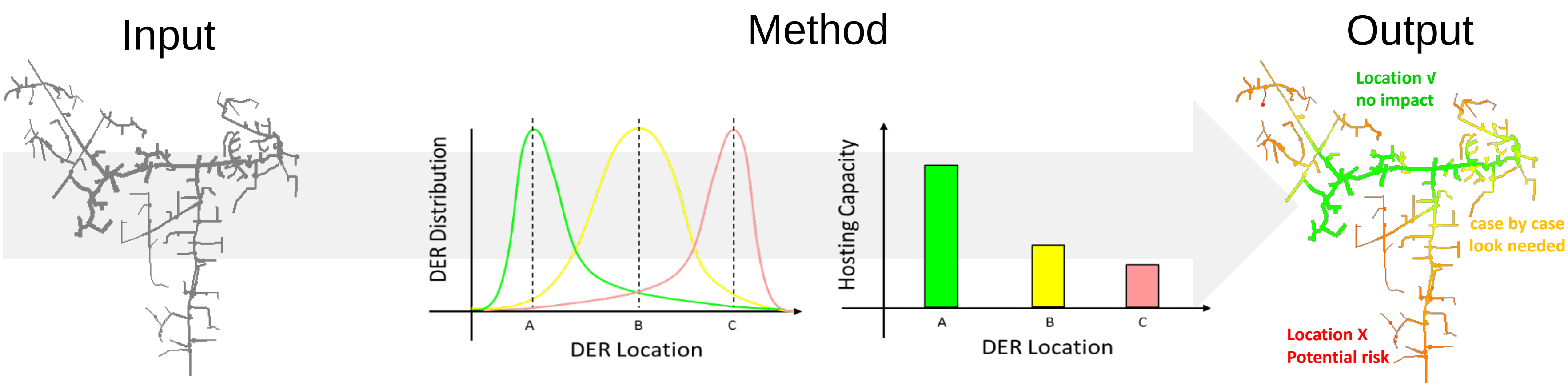
- Utilizes existing planning tools
  - CYME, Milsoft, Synergi

The Method

- Developed from years of detailed hosting-capacity analysis
- Validated and open methods

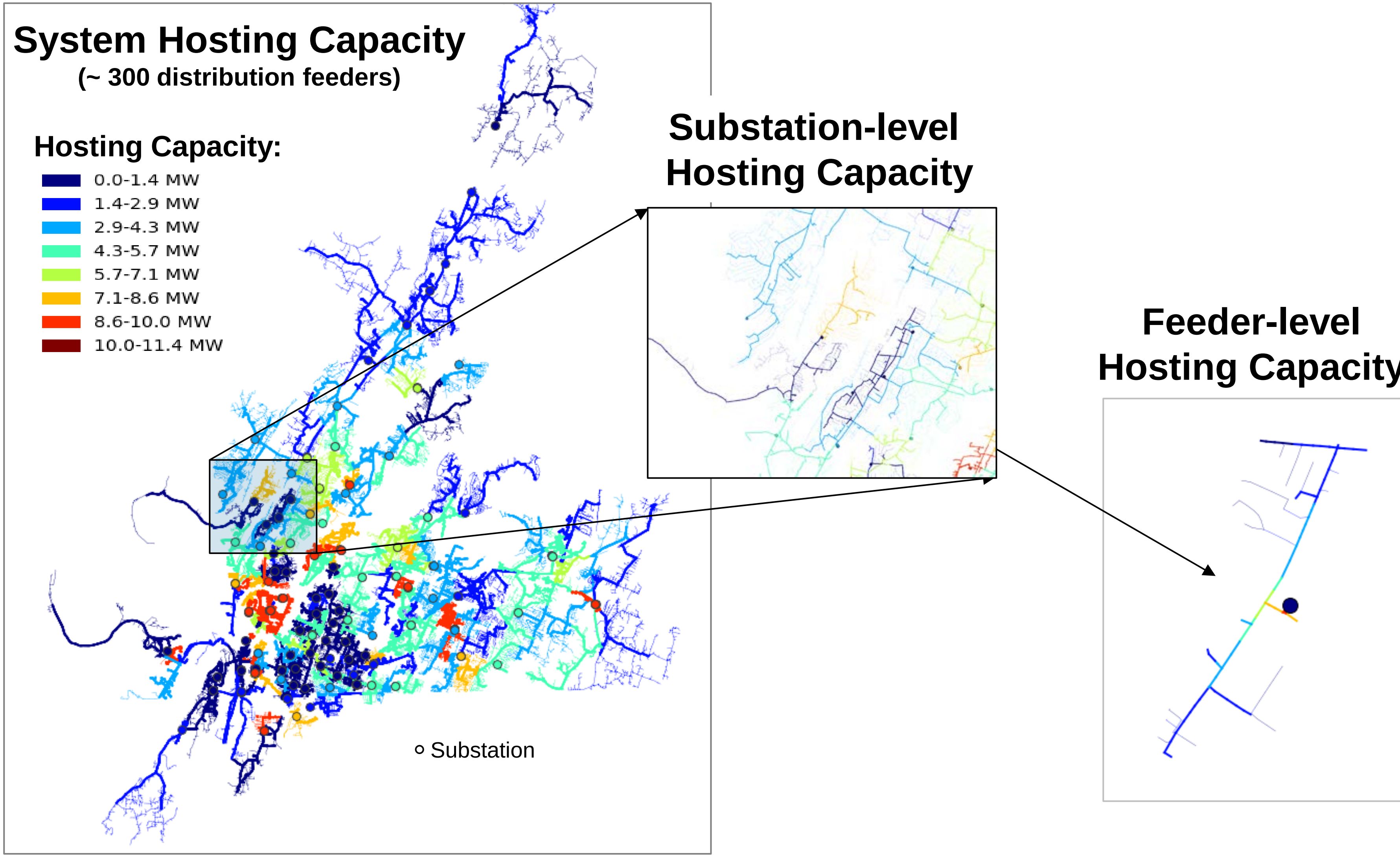
The Output

- Effectively and efficiently analyzes each and every feeder in system
- Considers DER size and location
  - Small distributed and large centralized DER
- Considers DER technology and impacts
  - PV, wind, storage, etc.
  - Voltage, thermal, protection



Details on Streamlined Method: [EPRI Report 3002003278, 2015]

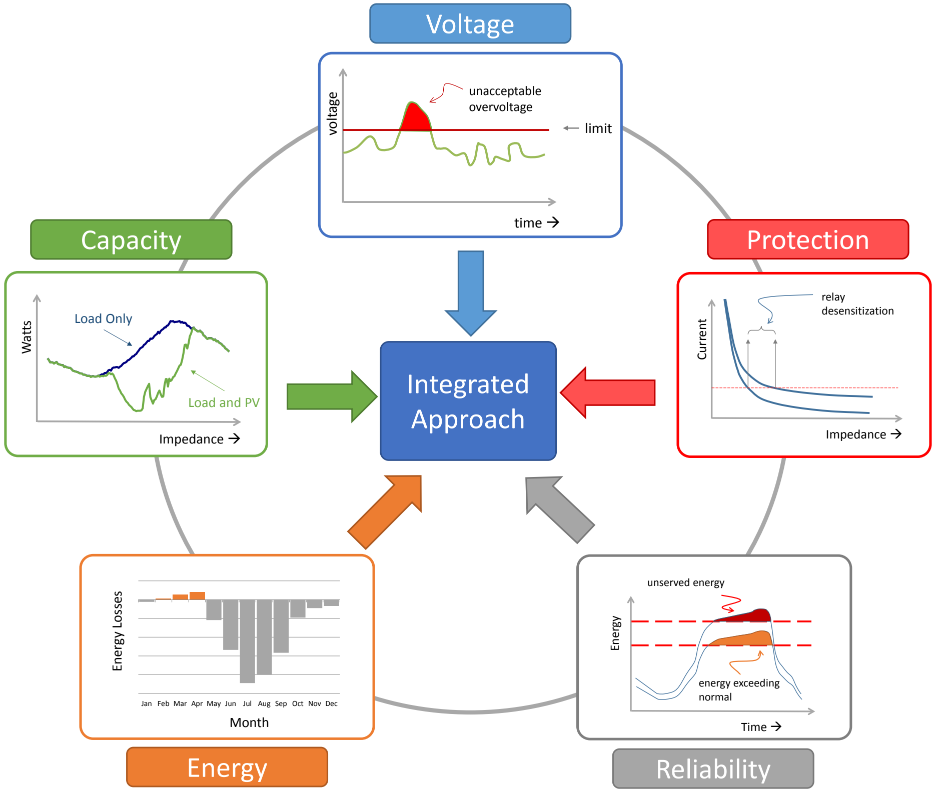
Sample Results from Integrated Grid Projects



Initial analysis results from in Integrated Grid study, results preliminary

Hosting capacity analysis is only the first step…

- Accommodation at Penetrations *Beyond* Hosting Capacity
  - Voltage Limits
  - Protection Issues
- Thermal Capacity Analysis
  - Deferral of upgrades
  - Loss of life
- Energy Analysis
  - Distribution losses
  - Energy consumption
- Cost/Benefit Analysis



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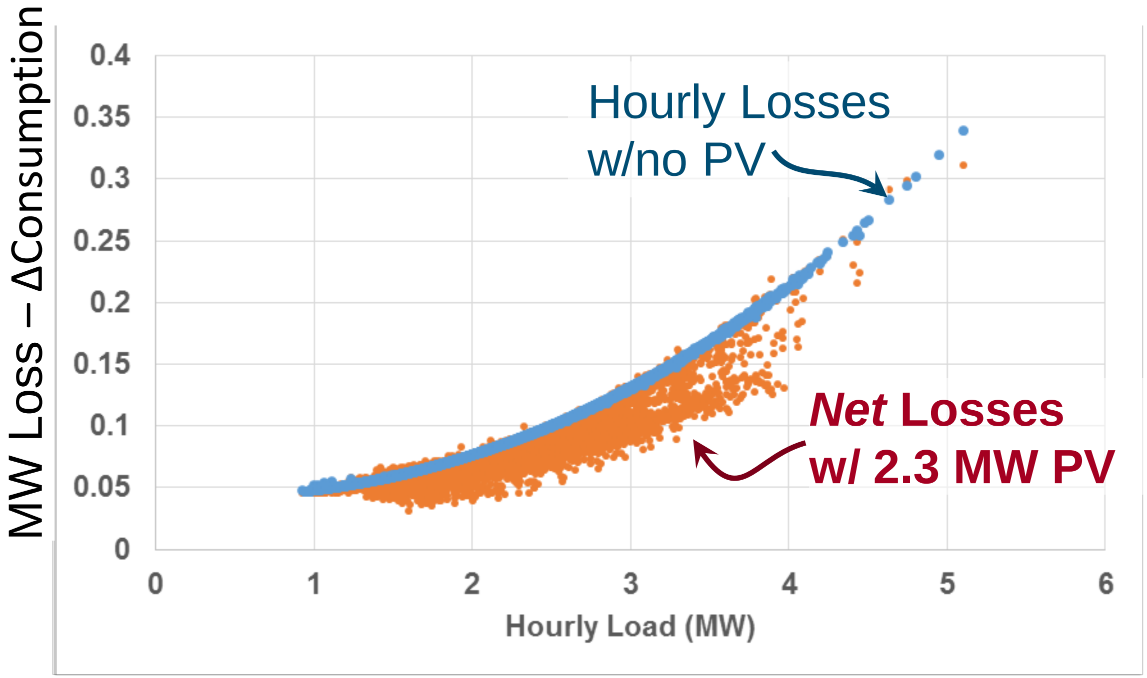
PV Reduces Losses…
But May Increase Consumption



The important quantity is *net* loss reductions.

Cost/Benefit Analysis Considerations

Modeling & Analysis Outputs	Economic Analysis Outputs	EPRI Study Outputs
Thermal capacities (load shape changes)	Capacity upgrade deferral ($)	
Voltage regulation	Capital costs for integration ($)	Distribution ($/kWh$_{DER}$)
Capacity upgrades		
Switched capacitor, tap changer & regulator operations	Change in O&M expenses ($) and shortened asset life	
Protection		
Distribution Energy Losses (kW, kWh)		Distribution Losses (marginal % basis)

Sample Results:
Upgrades to Mitigate Voltage & Protection Issues

Impact Area	Technical Objectives	Upgrades Considered
Voltage	Mitigate adverse voltages and/or additional control operations	Reconductoring
		Service transformer replacement
		Service upgrade
		Add voltage regulator
		Smart inverters
Protection	Mitigate inadvertent protection operations	Directional relay/settings
		Reconductoring
		Grounding recloser/transformer
		Breaker replacement
		Direct transfer trip

Sample Voltage & Protection Assessment Results

Example Feeder (.5 MW and 1 MW Cases)

20-yr Levelized ¢/kWh-generated Beginning 2016

Mitigation Option	Non-Optimal		Optimal	
500 kW Scenario (Voltage Issues Only)				
Option 1	Reconductor 1mi of 3ph	2.00	Reconductor 0.3mi of 3ph	0.60
Option 2	Add Voltage Regulator	0.79	Add Voltage Regulator	0.79
Option 3	Smart Inverter	0.01	Smart Inverter	0.01
1000 kW Scenario (Voltage Issues Only)				
Option 1	Reconductor 4.9mi of 3ph Upgrade 2 services	4.91	Reconductor 3mi of 3ph Upgrade 3 services	3.01
Option 2	Add Voltage Regulator Reconductor 3.5mi of 3ph	4.05	Add Voltage Regulator Reconductor 1.6mi of 3ph	2.15
Option 3	Smart Inverter	0.01	Smart Inverter	0.01

(Specific to a set of financial and economic assumptions)

Sample Voltage & Protection Assessment Results

Example Feeder (2 MW Case)

20-yr Levelized ¢/kWh-Generated Beginning 2016

Mitigation Option	Non-Optimal Location	Cents /kWh	Optimal Location	Cents /kWh
2000 kW Scenario (Voltage Issues Only)				
Option 1	- Reconductor 11.4mi of 3ph - Reconductor 7 mi 1ph - Upgrade 15 services - 7 xfmrs - Directional relaying at sub	7.39	- Reconductor 11.4mi of 3ph - Reconductor 7 mi 1ph - Directional relaying at sub	7.36
Option 2	- Add 3ph Voltage Regulator (15y) - Reconductor 11.4mi of 3ph - Reconductor 7mi of 1ph - Directional relaying at sub	7.58	- Add 3ph Voltage Regulator (15yr) - Reconductor 11.4mi of 3ph - Reconductor 7mi of 1ph - Directional relaying at sub	7.58
Option 3	- Smart Inverter - 600 kvar capacitor bank - Reconductor 2mi 3ph - Directional relaying at sub - Line recloser	1.30	- Smart Inverter - 600 kvar capacitor bank - Reconductor 2mi 3ph - Directional relaying at sub - Line recloser	1.26

(Specific to a set of financial and economic assumptions)

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Summary Results for 3 Unique Feeders

- K3 and S1 allowed no capacity deferral because of headroom on the feeders. On K2, PV allowed deferral of a transformer upgrade by one year (year 20→21).
- Mitigation of voltage and protection issues was required for feeders K2 and S1, mostly for over-voltage. Protection issues appeared at high penetrations.
- PV reduced losses in all cases, but rising voltages caused consumption to increase.

		Feeder K2	Feeder K3	Feeder S1
	PV MW	20-yr Levelized cents per kWh-generated beginning in 2016		
Capacity Deferral	0.5 MW 1 MW 2 MW	-.15 ¢/kWh	0	0
Accom-modation Costs	0.5 MW 1 MW 2 MW	.01 to 2 ¢/kWh .01 to 5 ¢/kWh 1 to 7 ¢/kWh	0	0.64 ¢/kWh 0.3 to 0.8 ¢/kWh 0.2 to 0.8 ¢/kWh
Loss Analysis		Percent *Change* in Losses		
Losses (line & core)		-5.4% per MW_{PV}	-2.2% per MW_{PV}	-2.4% per MW_{PV}
Losses (net)		-.6% per MW_{PV}	-0.5% per MW_{PV}	-0.3% per MW_{PV}

(Results are specific to financial and economic assumptions appropriate for the owner utilities.)

Case Study Results - Key Insights

Key Insights

- Each feeder has a unique technical impact from various levels of PV.
- Utility planning practices impact the potential to defer transformer and/or conductor capacity.
- PV *reduces* line losses, but consumption *increases* when voltage increases. There is usually a net reduction of losses.

Thoughts & Questions for Transactive Energy

- Many distribution issues are confronted first in the *planning* timeframe rather than the *operations* timeframe.
- Smart inverters can defer other hardware upgrades in the planning timeframe, but must be operated properly to fulfill this role over time.
- Control of DER in the operating timeframe may be able to stand in place of hardware upgrades. Must it be committed in the planning timeframe?

Together…Shaping the Future of Electricity

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