EPRI | ELECTRIC POWER RESEARCH INSTITUTE

THE INTEGRATED GRID

REALIZING THE FULL VALUE OF CENTRAL AND DISTRIBUTED ENERGY RESOURCES

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Michigan
June 19, 2014

Electric Power Research Institute

Together…Shaping the Future of Electricity

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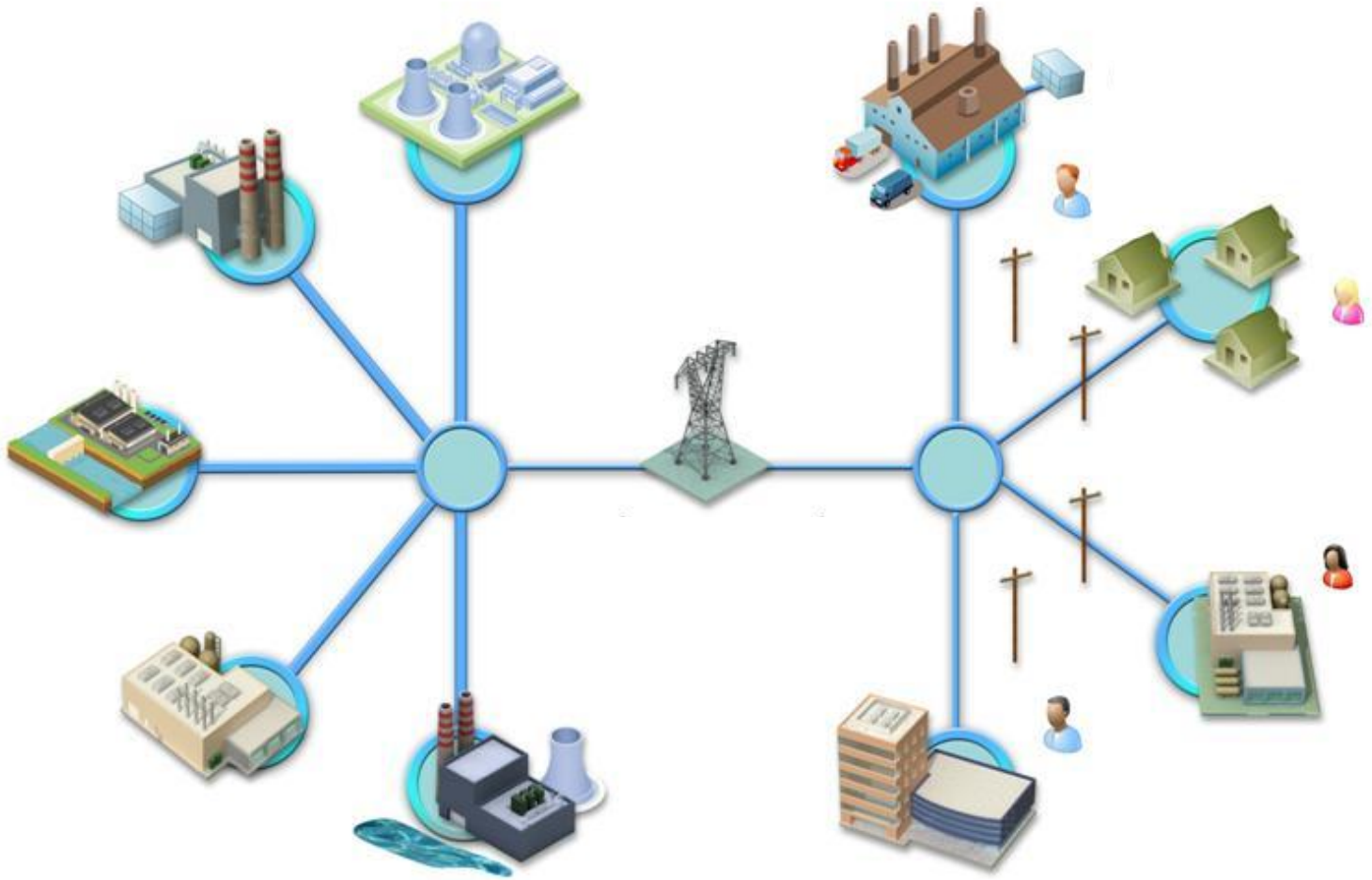
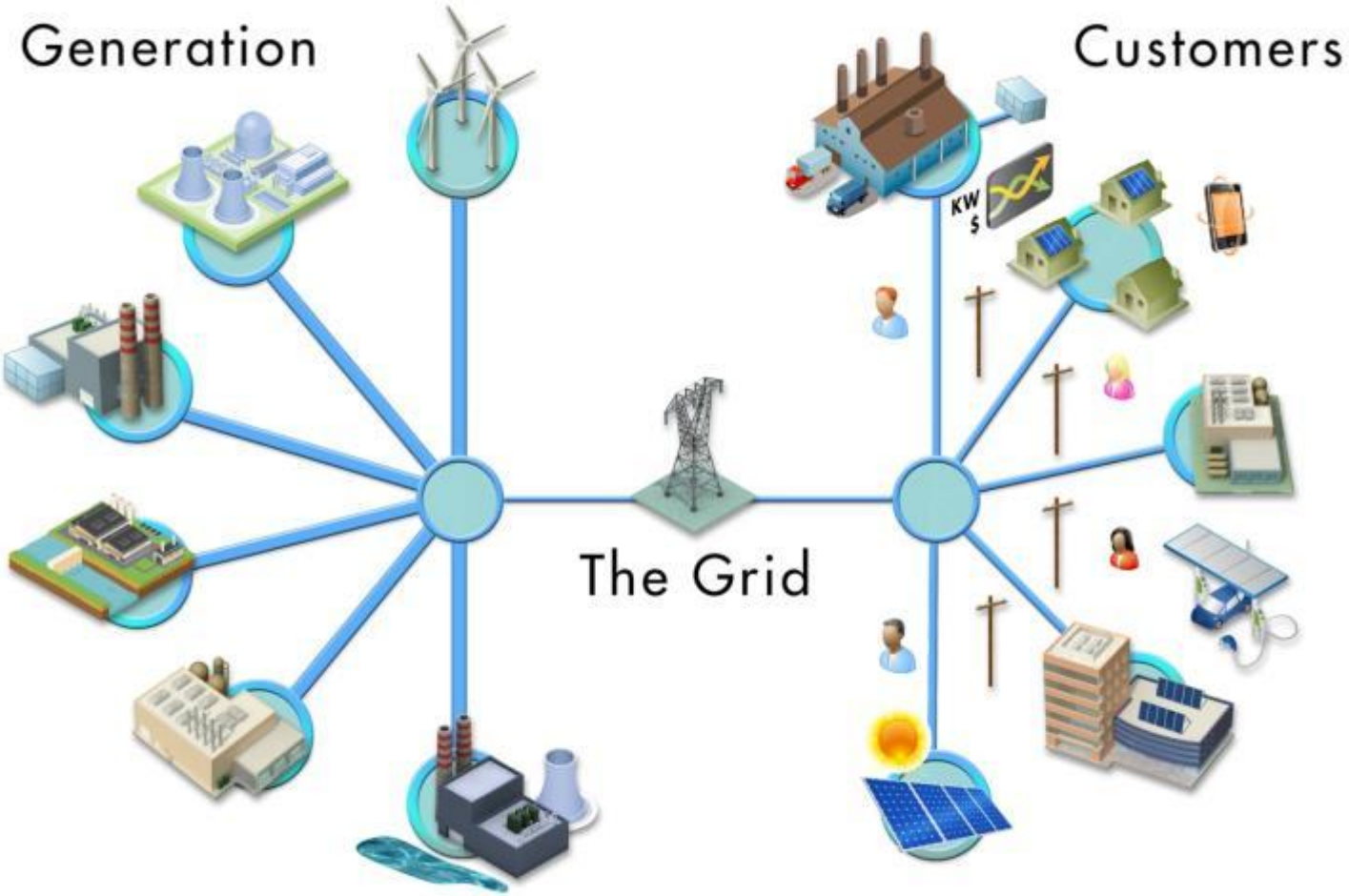
The Electric Power System



Looking Forward



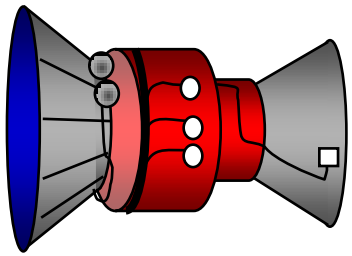
Distributed Energy Resources

Photovoltaics

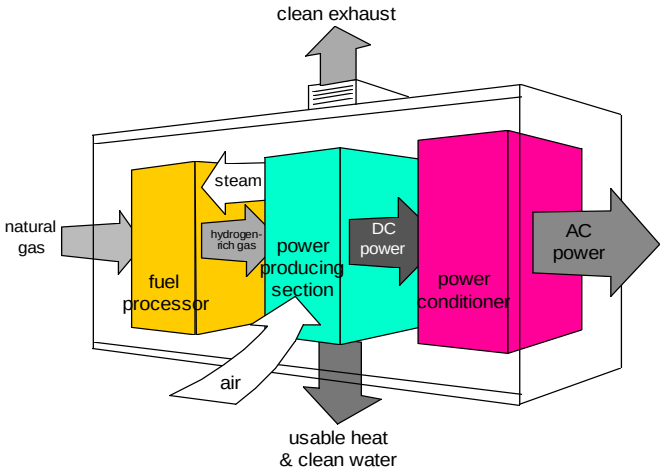
Storage

Photo courtesy of NREL

Micro-generation



Fuel Cells



Plug-In Electric Vehicles

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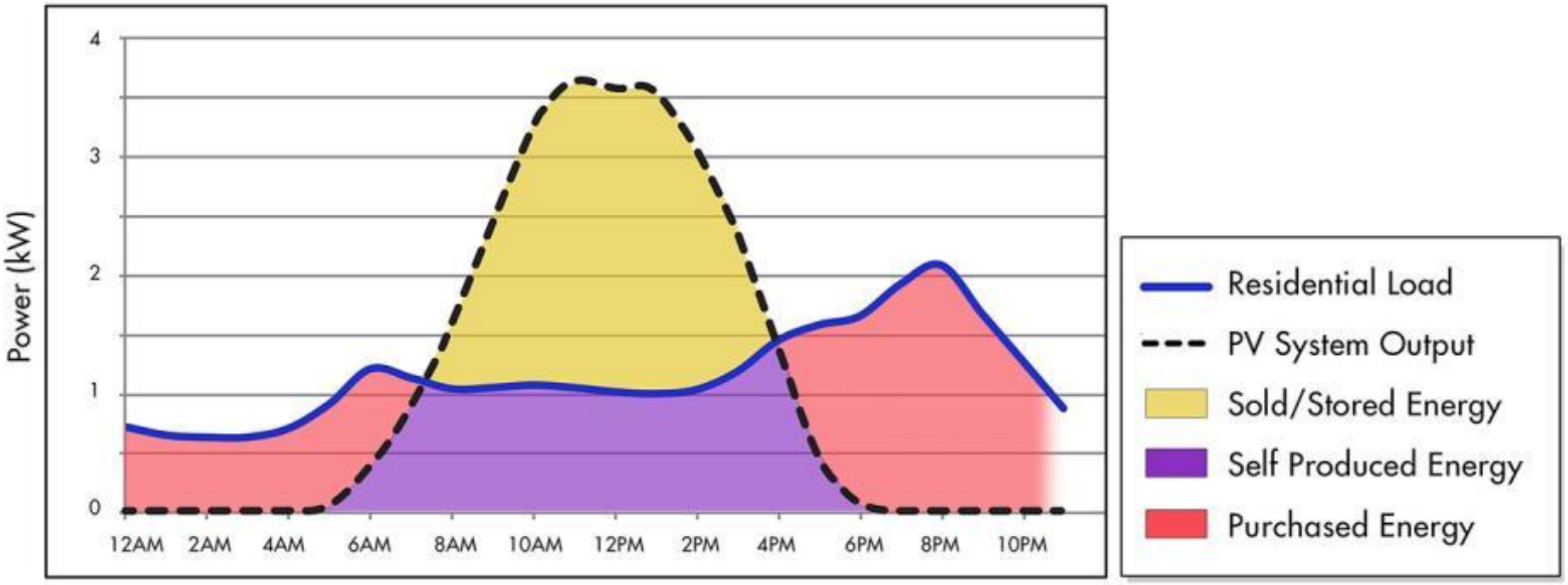
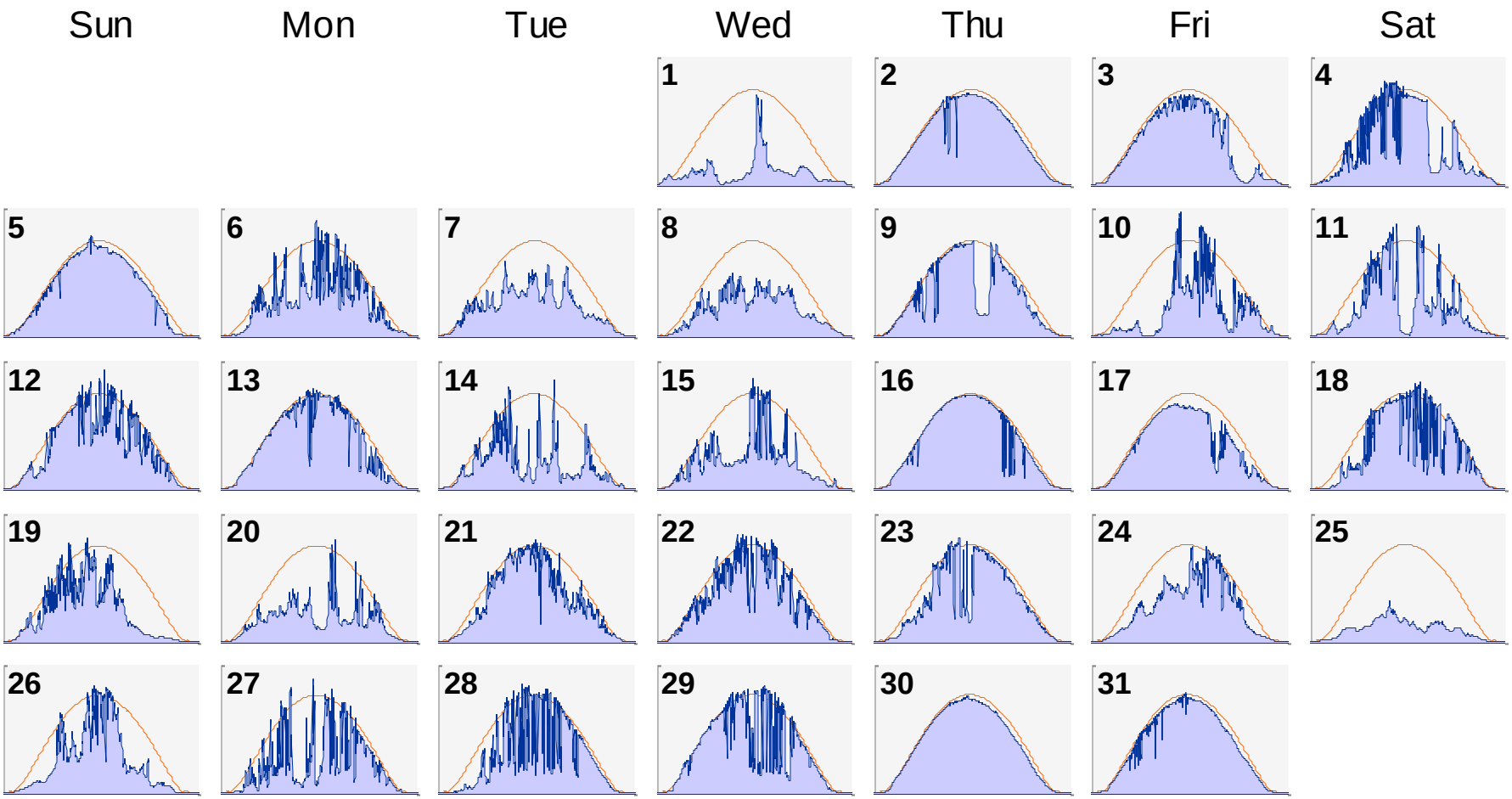
The Grid Provides Transactional Value



Grid Delivers Balancing Resource

Solar resource calendar for August 2012 shows irradiance profiles in NJ



Blue area: measured irradiance

Orange line: calculated clear sky irradiance

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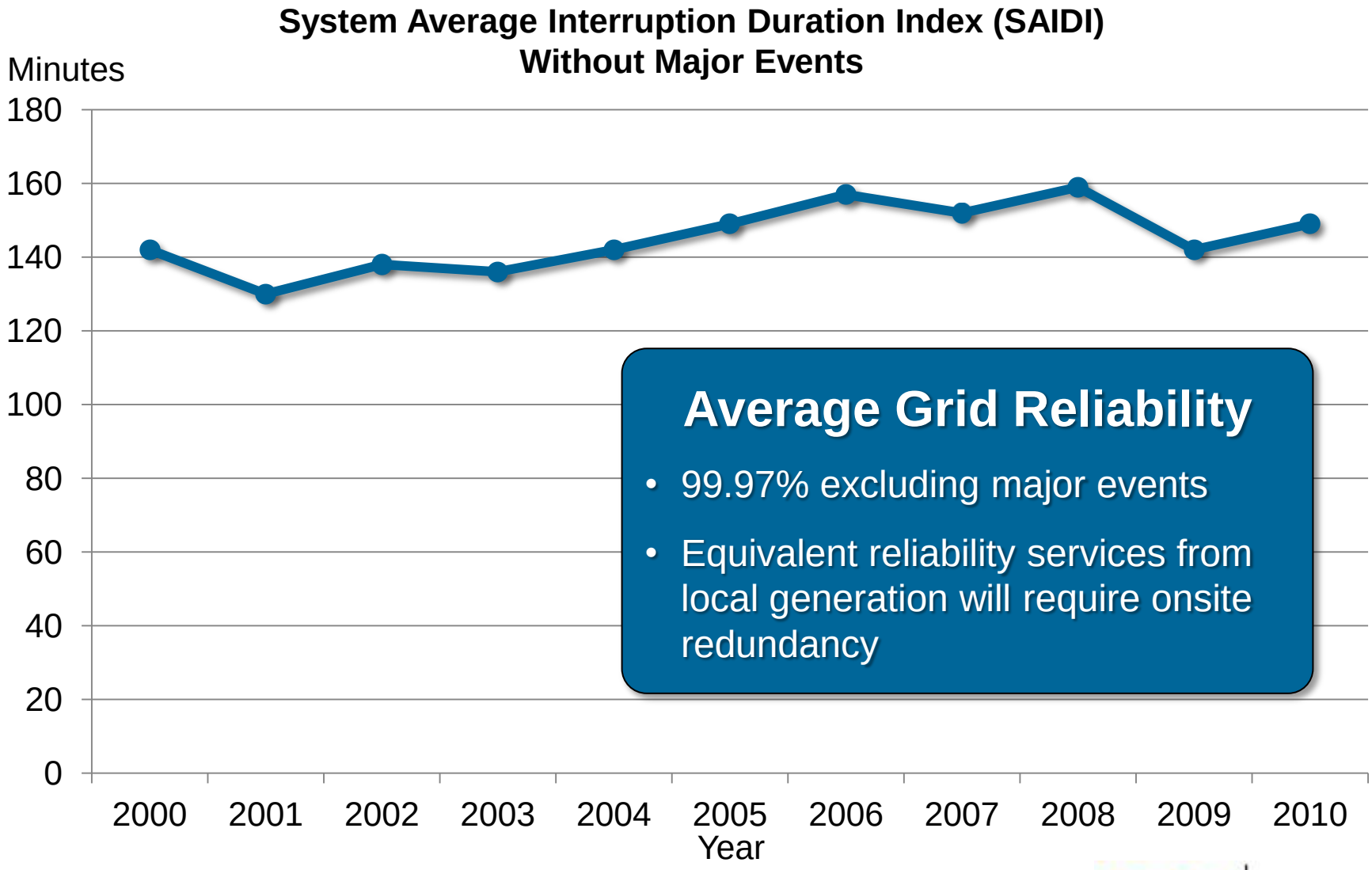
Grid Provides Reliability Service



Average Grid Reliability

- 99.97% excluding major events
- Equivalent reliability services from local generation will require onsite redundancy

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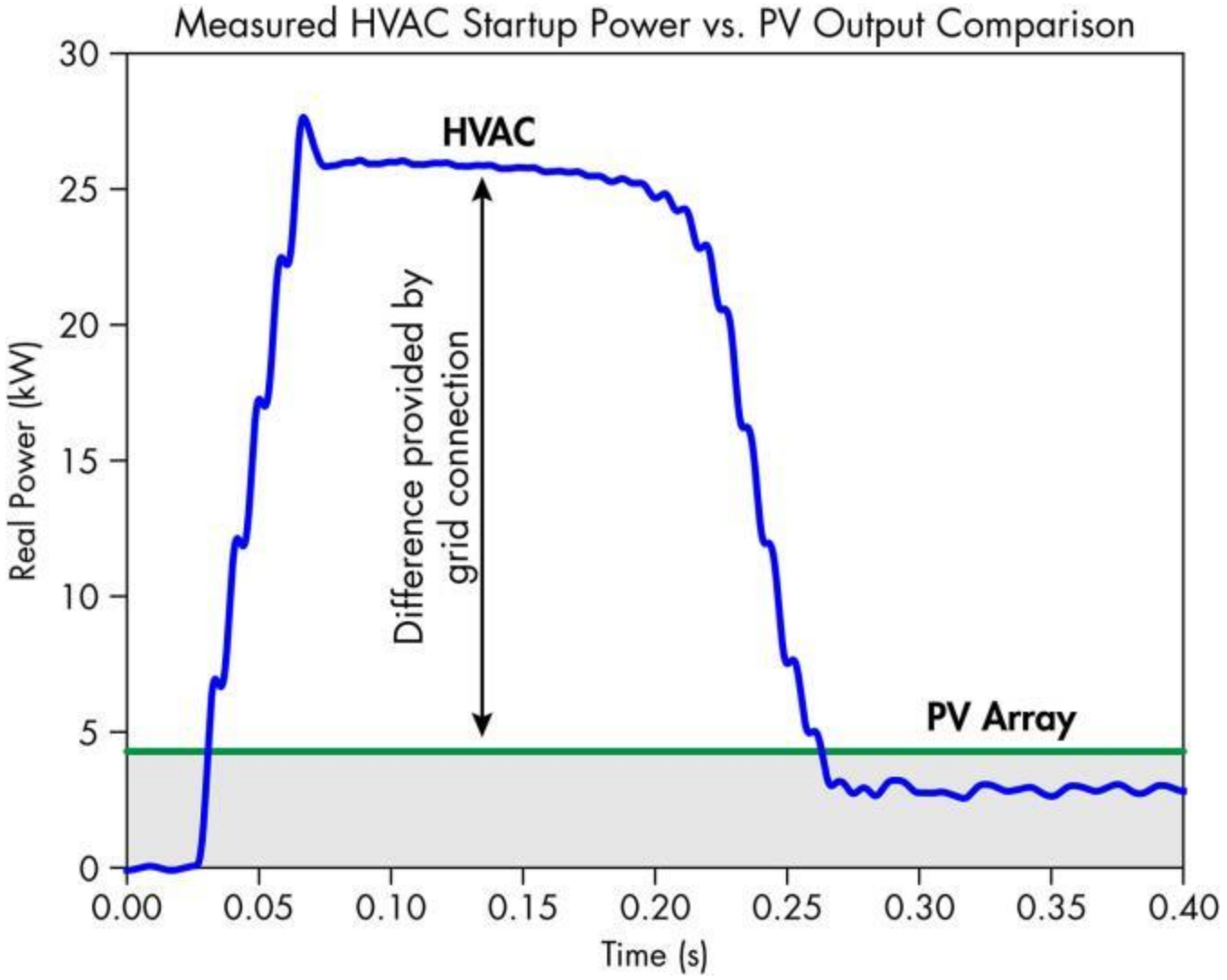
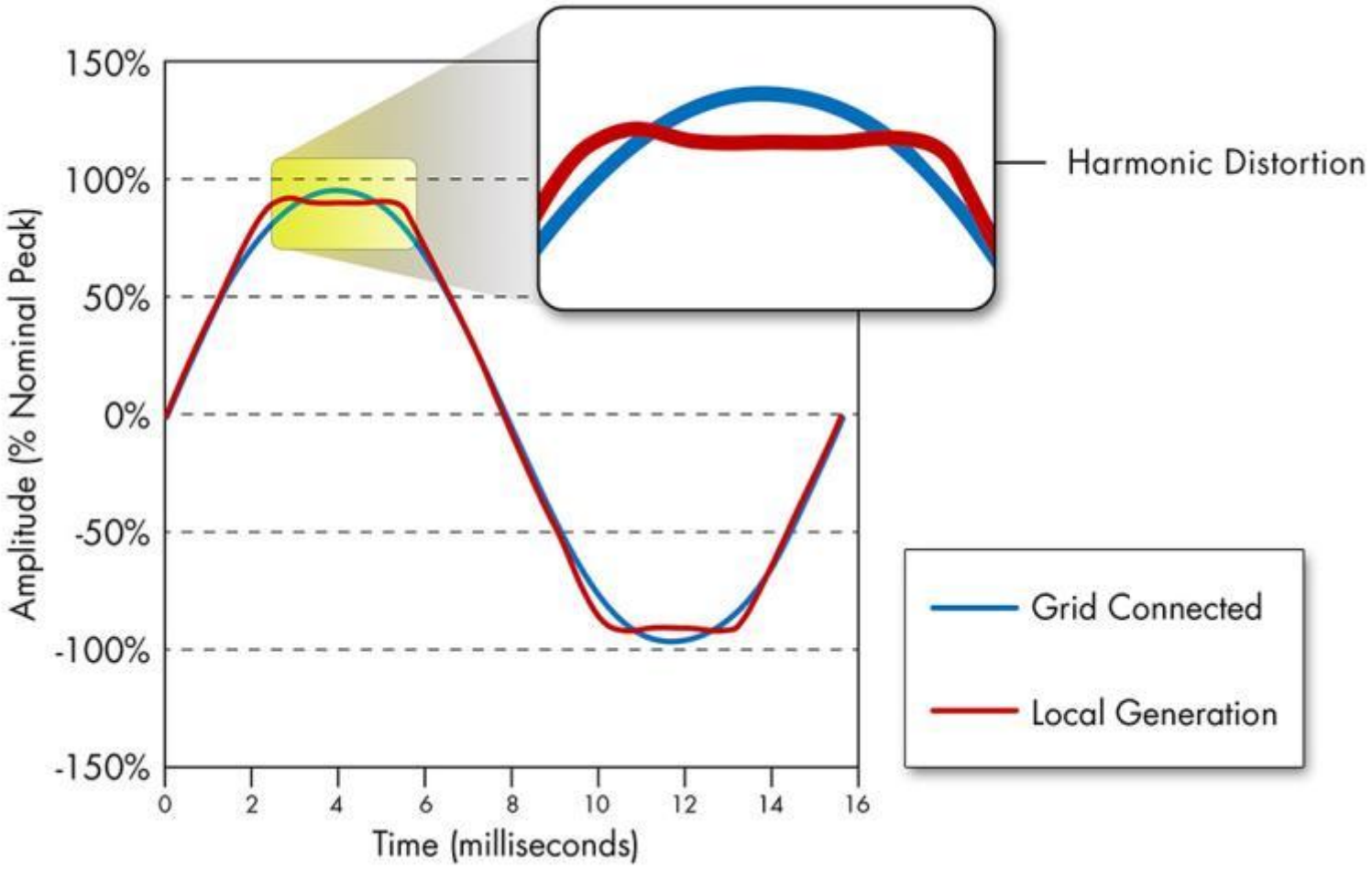
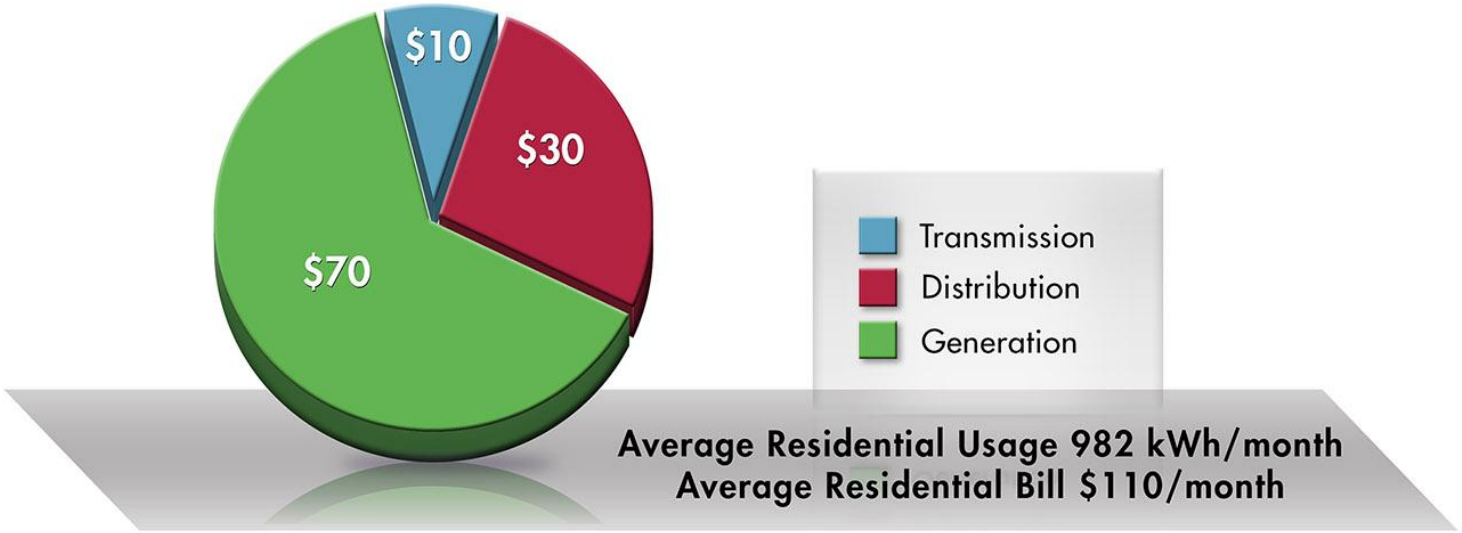
The Grid Provides Startup Power

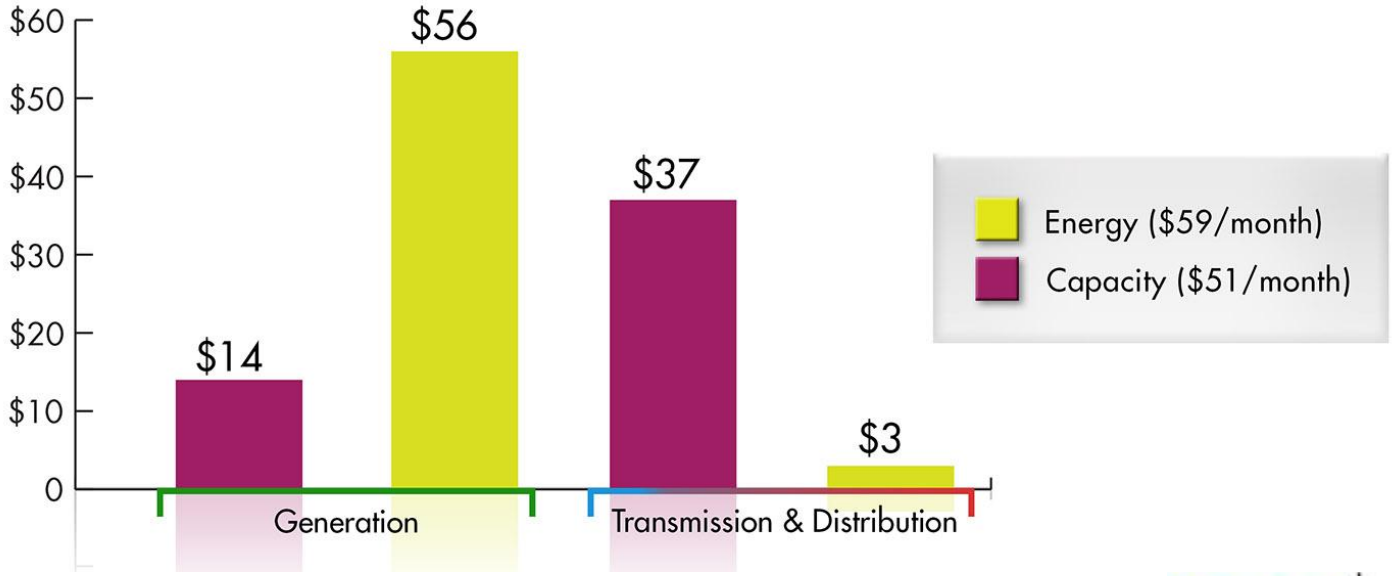


Grid Connectivity Reduces Harmonic Impact



U.S. Average Cost to Consumers





Cost Projection for Off-Grid Local Energy Resource

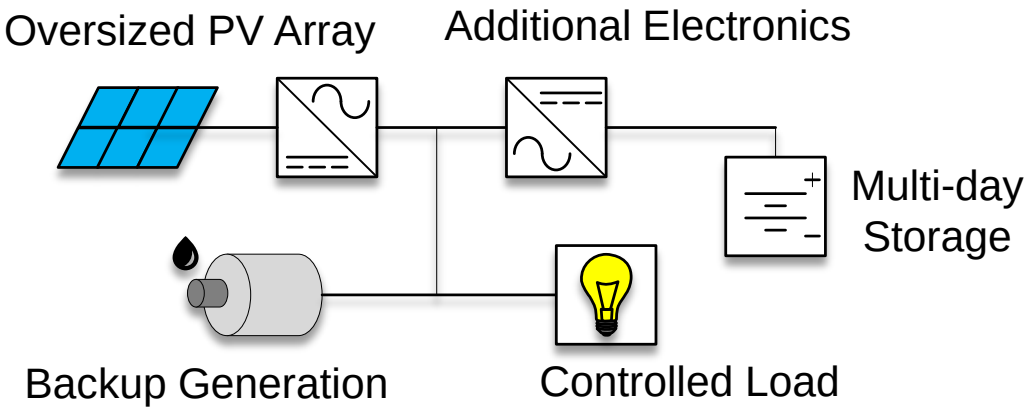
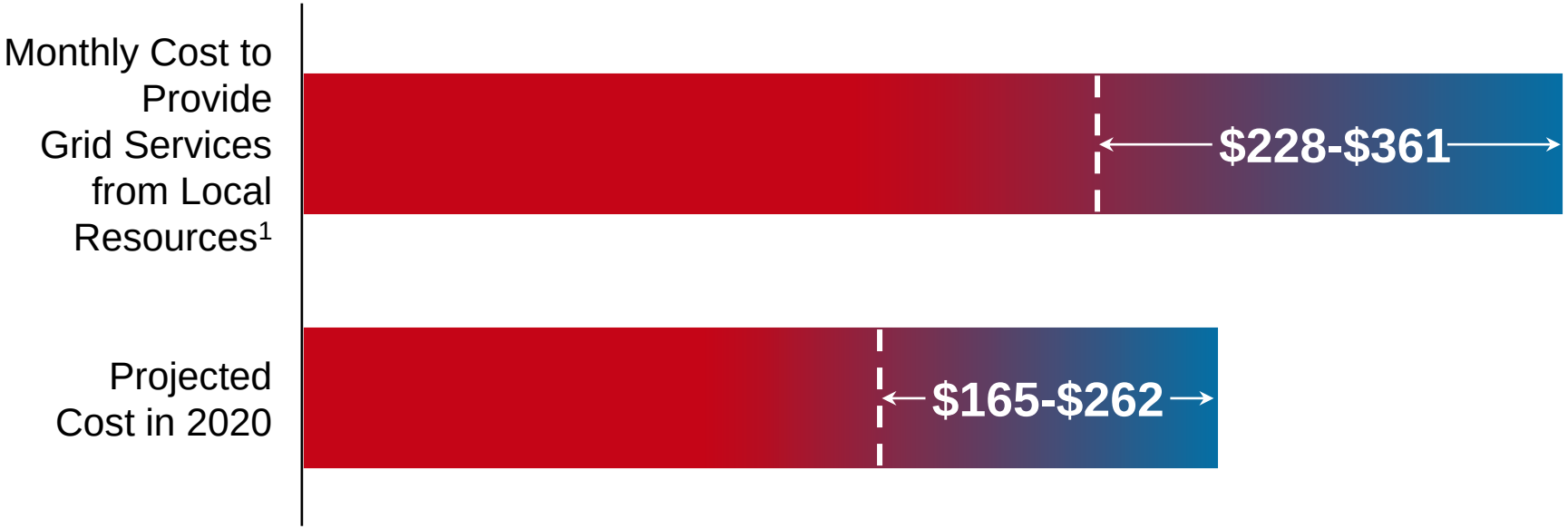


Photo courtesy of NREL

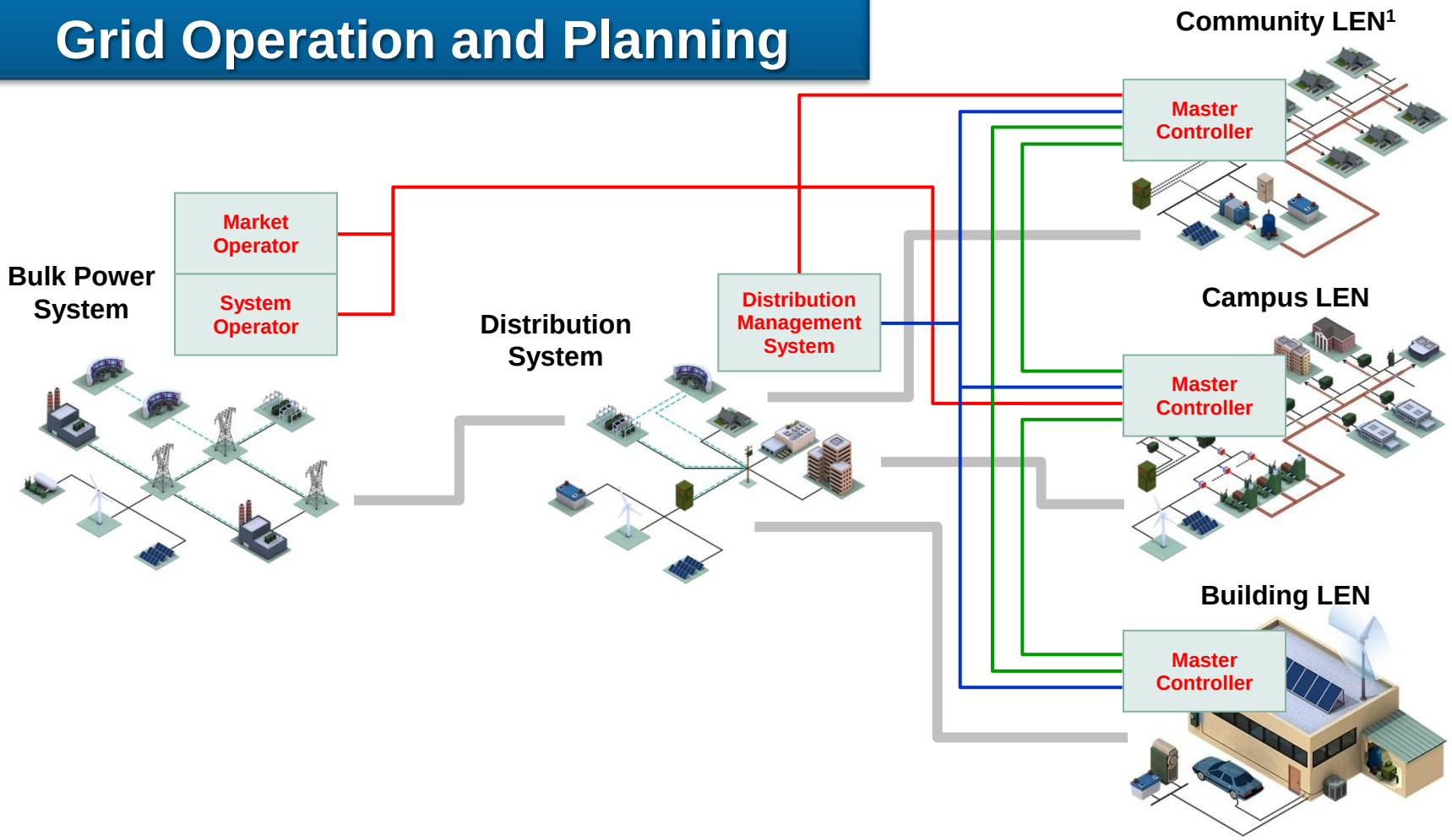


[1] *Does not include additional cost of energy from local resources*

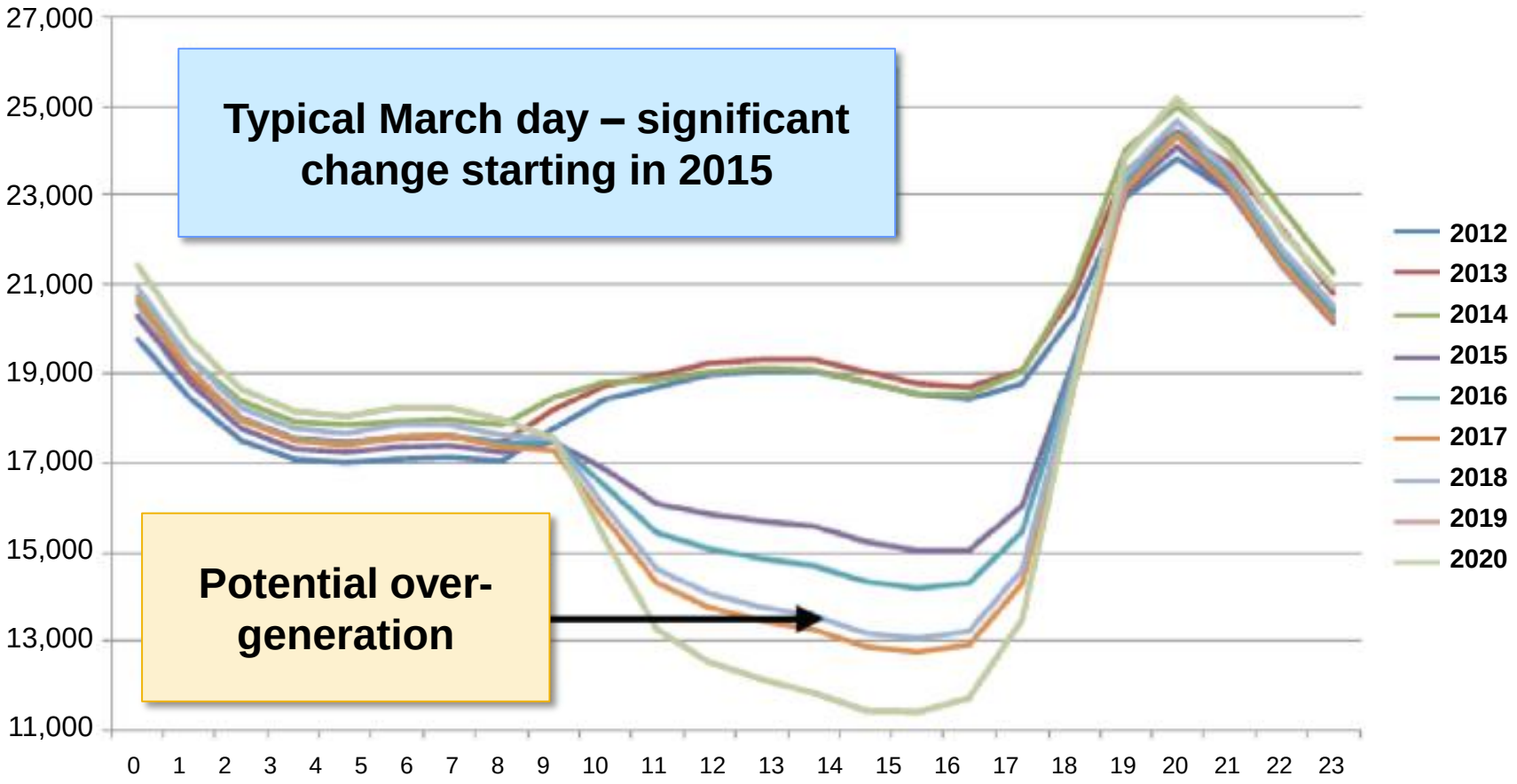
The Integrated Approach

Local Resources are Also Part of Grid Operation and Planning

[1]LEN: Local Energy Network



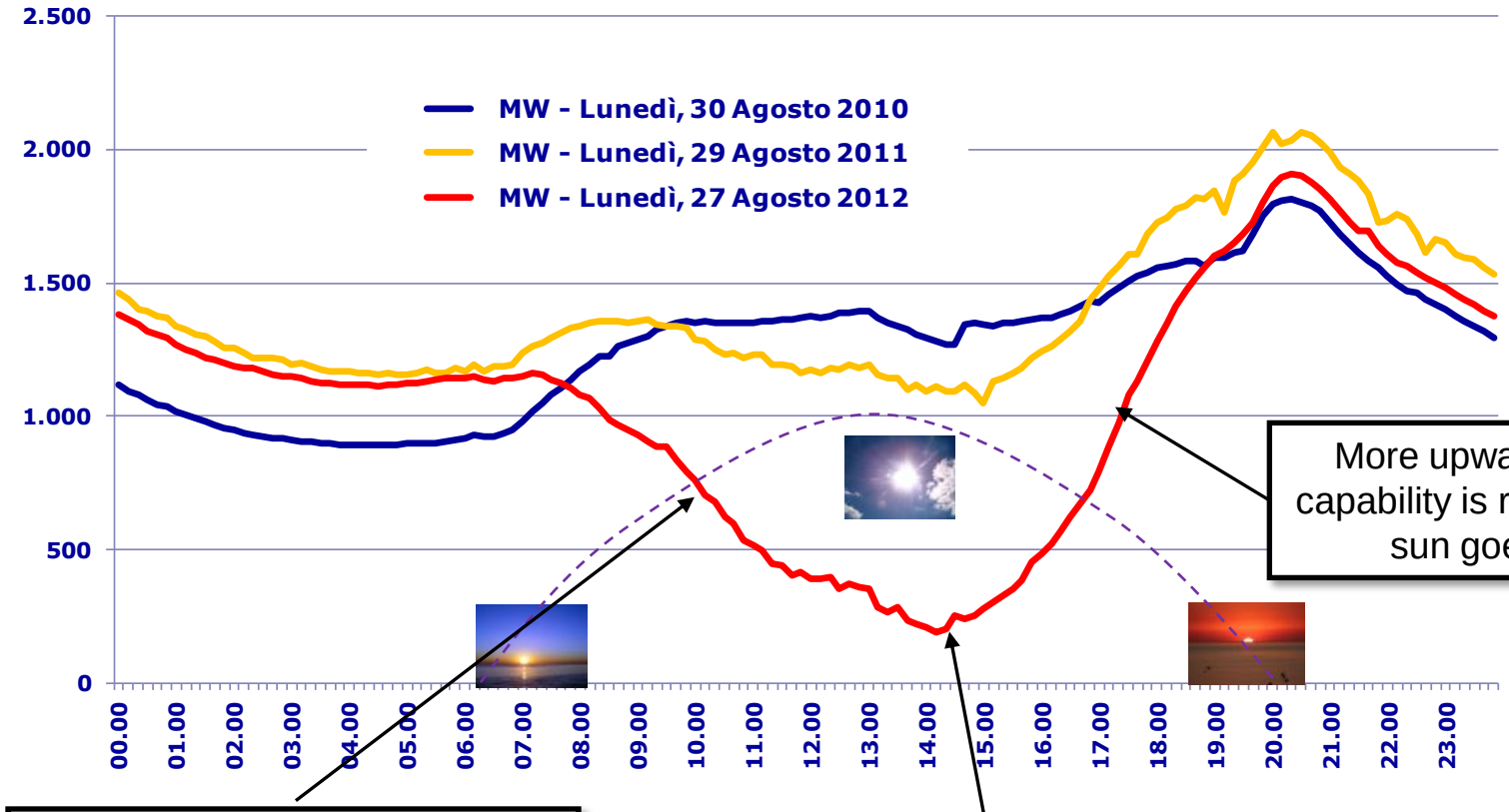
CAISO Net Load – 2012 Through 2020



Source: California ISO

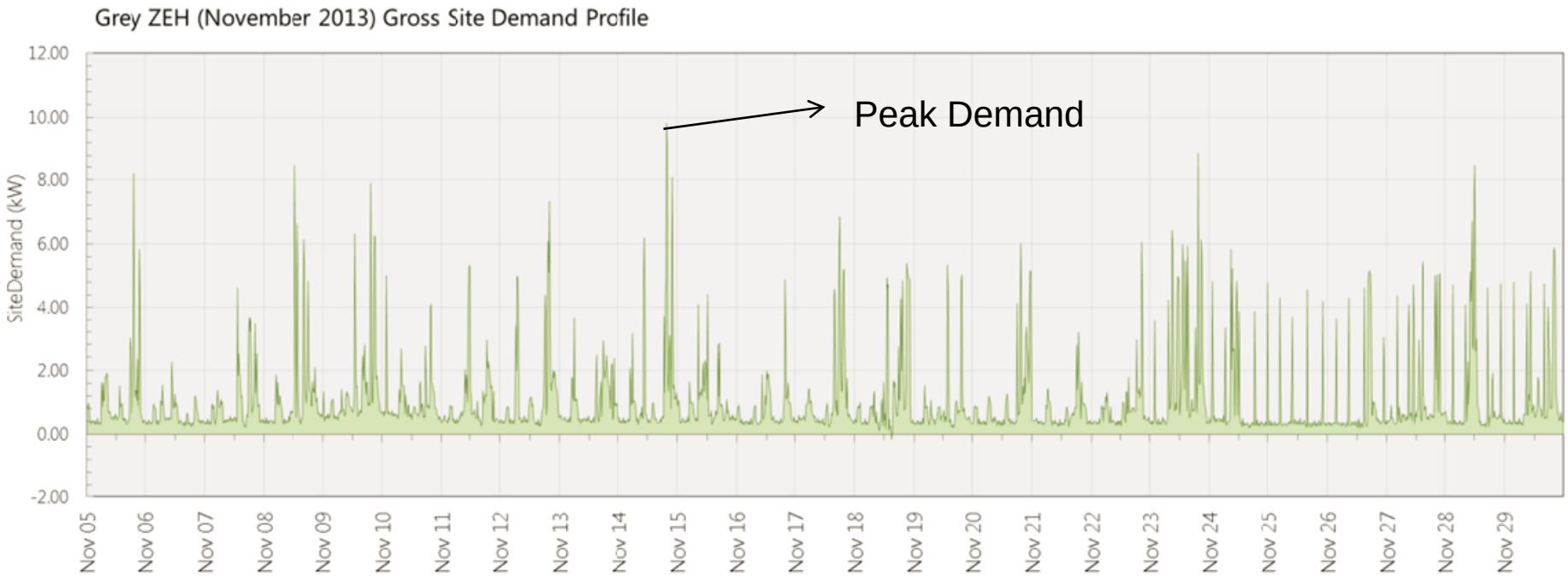
The “Duck” Curve is for Real

Not Just Resource Adequacy but the Adequacy of Resource of the Right Type



Source: *ENEL – Measured Data from Southern Italy and CAISO analysis*

Demand/Capacity versus Energy

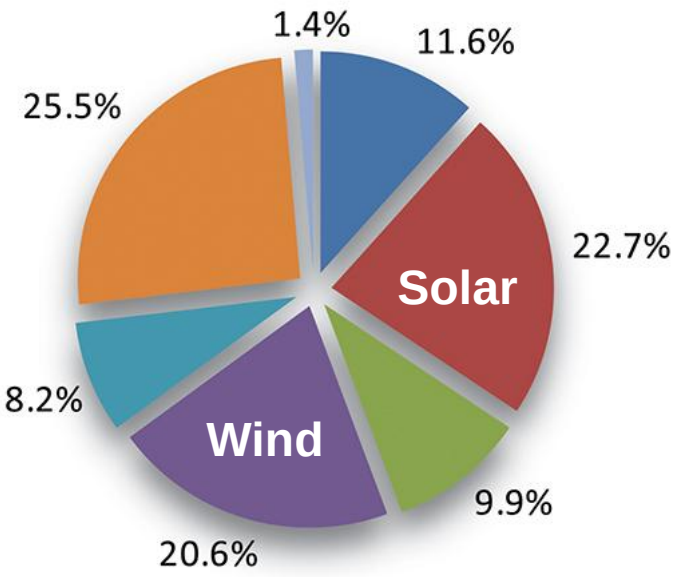


Measured Demand Profile from a *Zero Energy House*

Energy Rich but Capacity/Demand Poor

Germany: Higher Penetration of Local Generation Necessitates an Integrated Approach

Installed Capacity (2013)



~63GW of Installed Wind and PV – mostly connected to LV and MV grid

Interconnection Rules

- Grid frequency support

Grid Infrastructure Upgrade

- ~$27.5B-$42.5B upgrade

Two Way Communication

- Enabled by Advanced Distribution Management

Recent Changes in Germany to Address Concern of Grid Reliability

Source: Fraunhofer Institute, Germany

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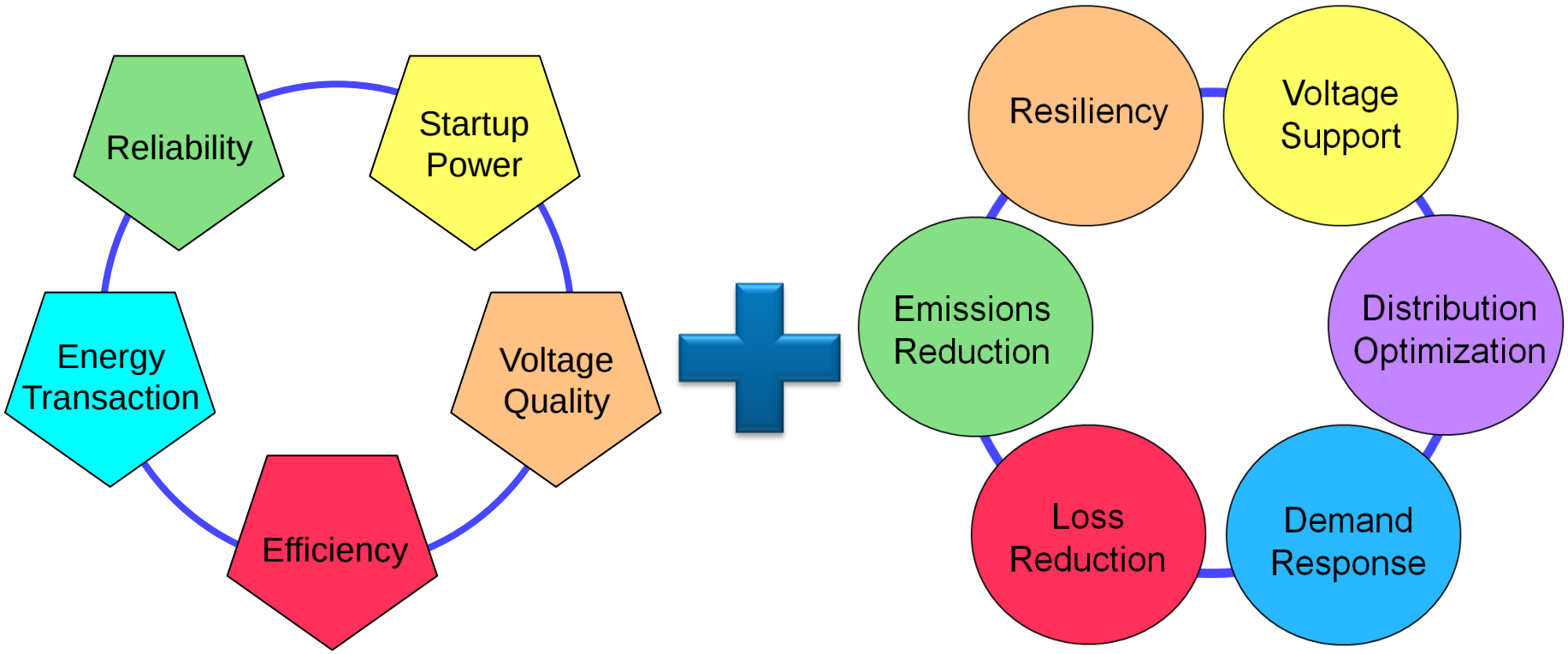
Interconnected but Not Integrated

Interconnected
Value of Grid Connectivity

Integrated
Value of DER and Grid



Integration Enables Values of all Resources

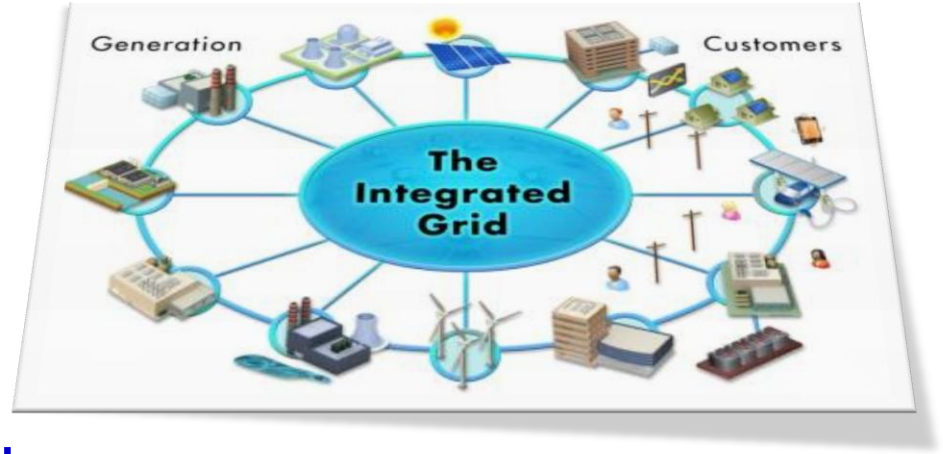
Foundation of An Integrated Grid

1. Grid Modernization

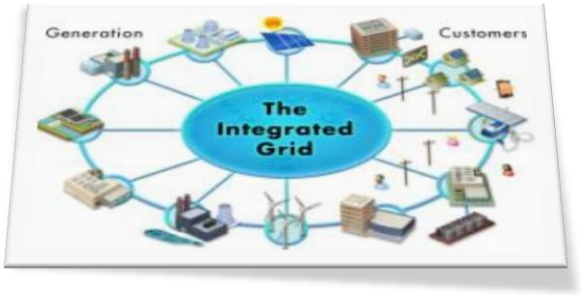
2. Communication Standards and Interconnection Rules

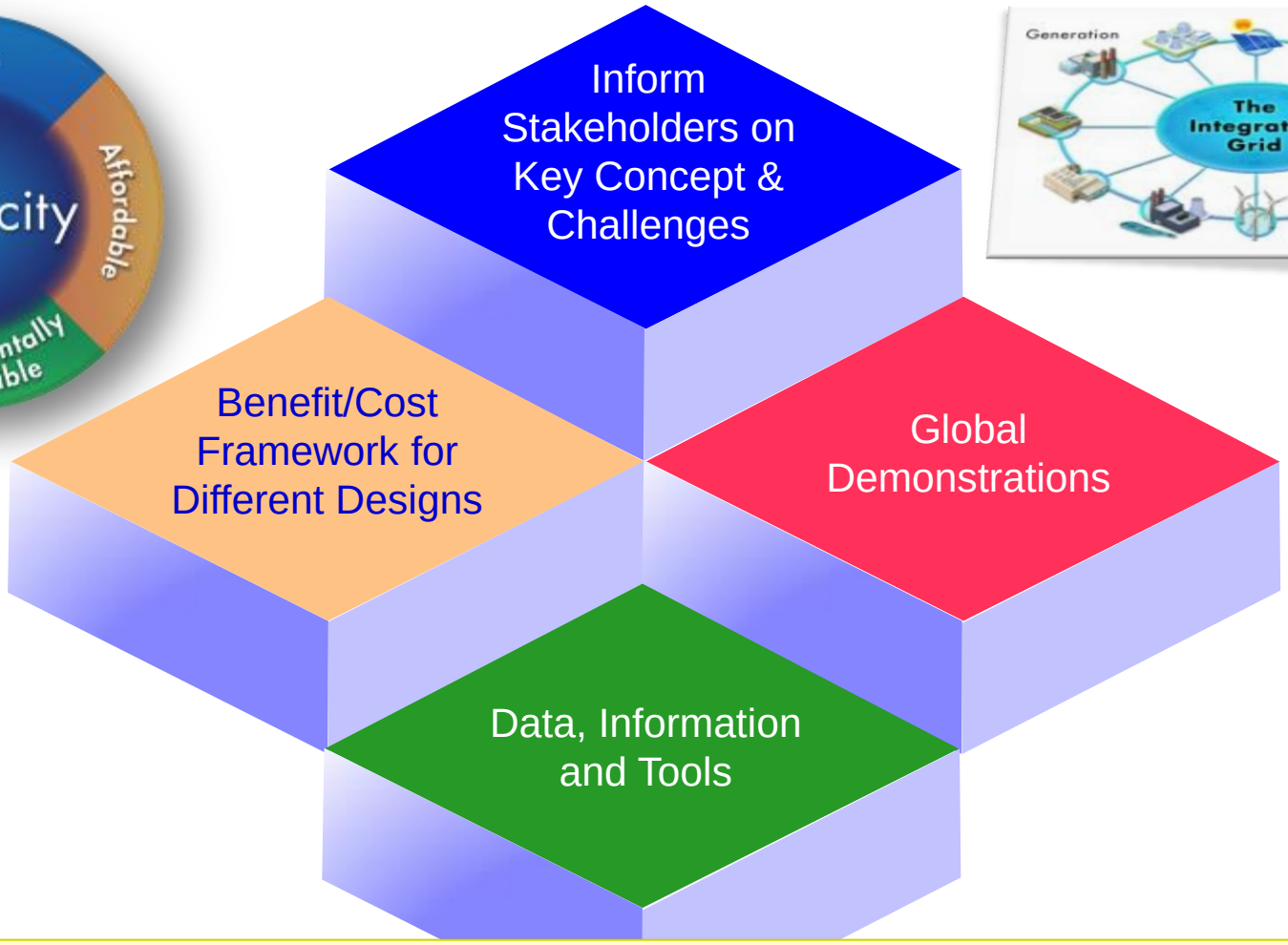
3. Integrated Planning and Operations

4. Informed Policy and Regulation



Action Plan





Global Collaboration to Establish the Science, Engineering and Economics

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Action Plan

3 Key Areas & Research Challenges

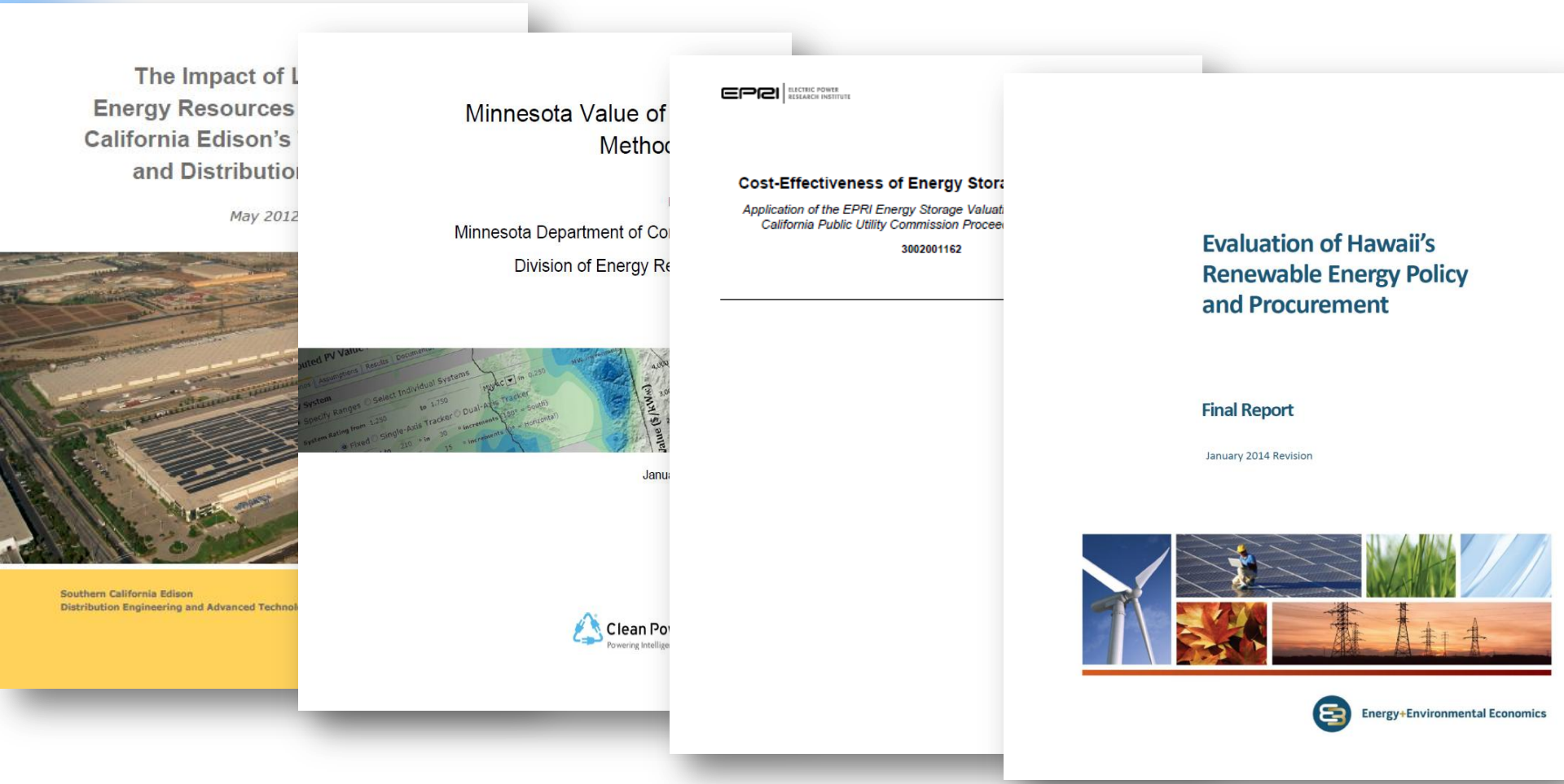
Benefit - Cost Framework

Interconnection Technical Guidelines

Grid Planning & Operations

Collaboration with All Stakeholders

Building Upon Prior Efforts



Many have contributed to specific aspects of the framework
Need comprehensive approach: connecting all puzzle pieces

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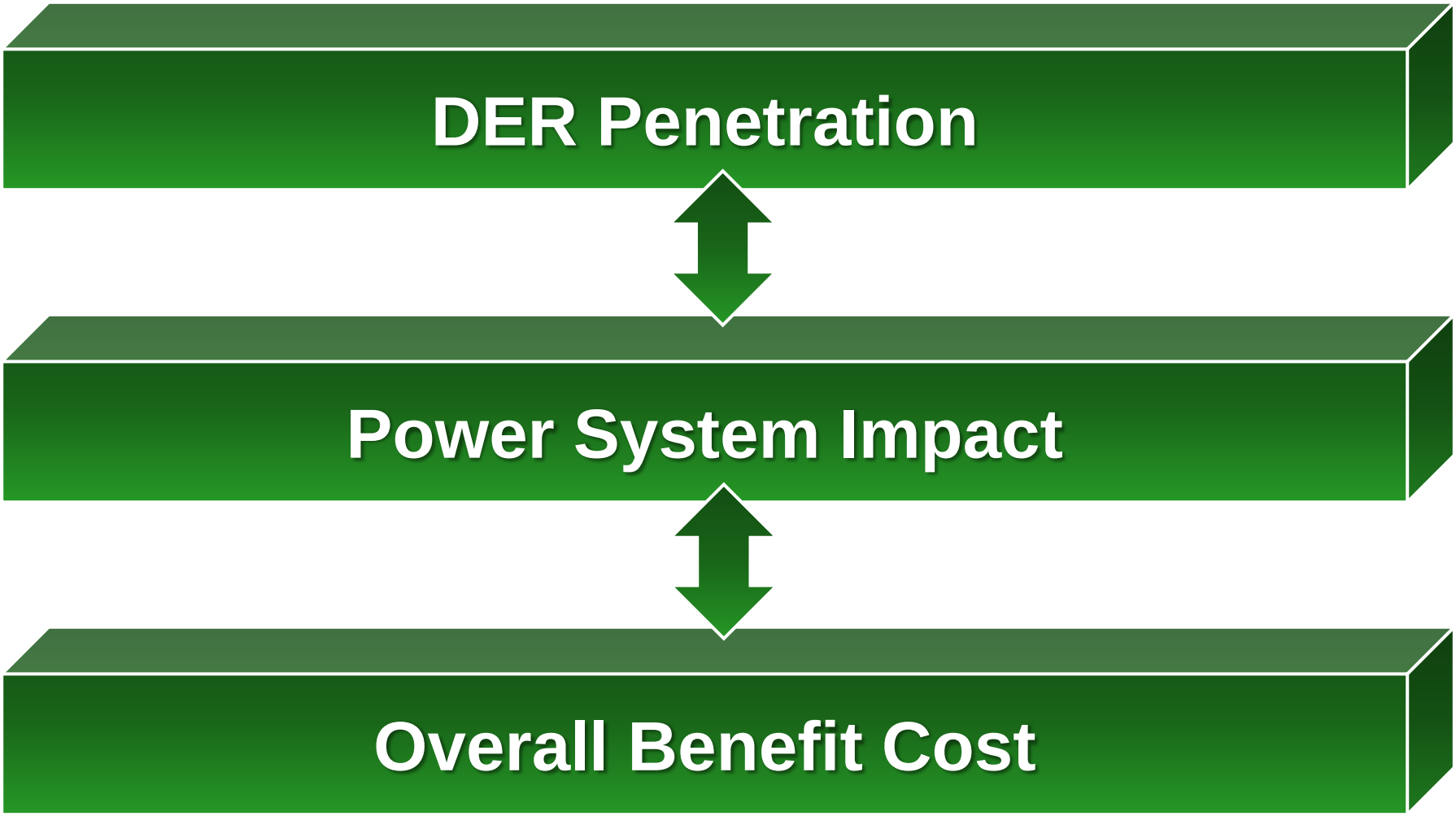
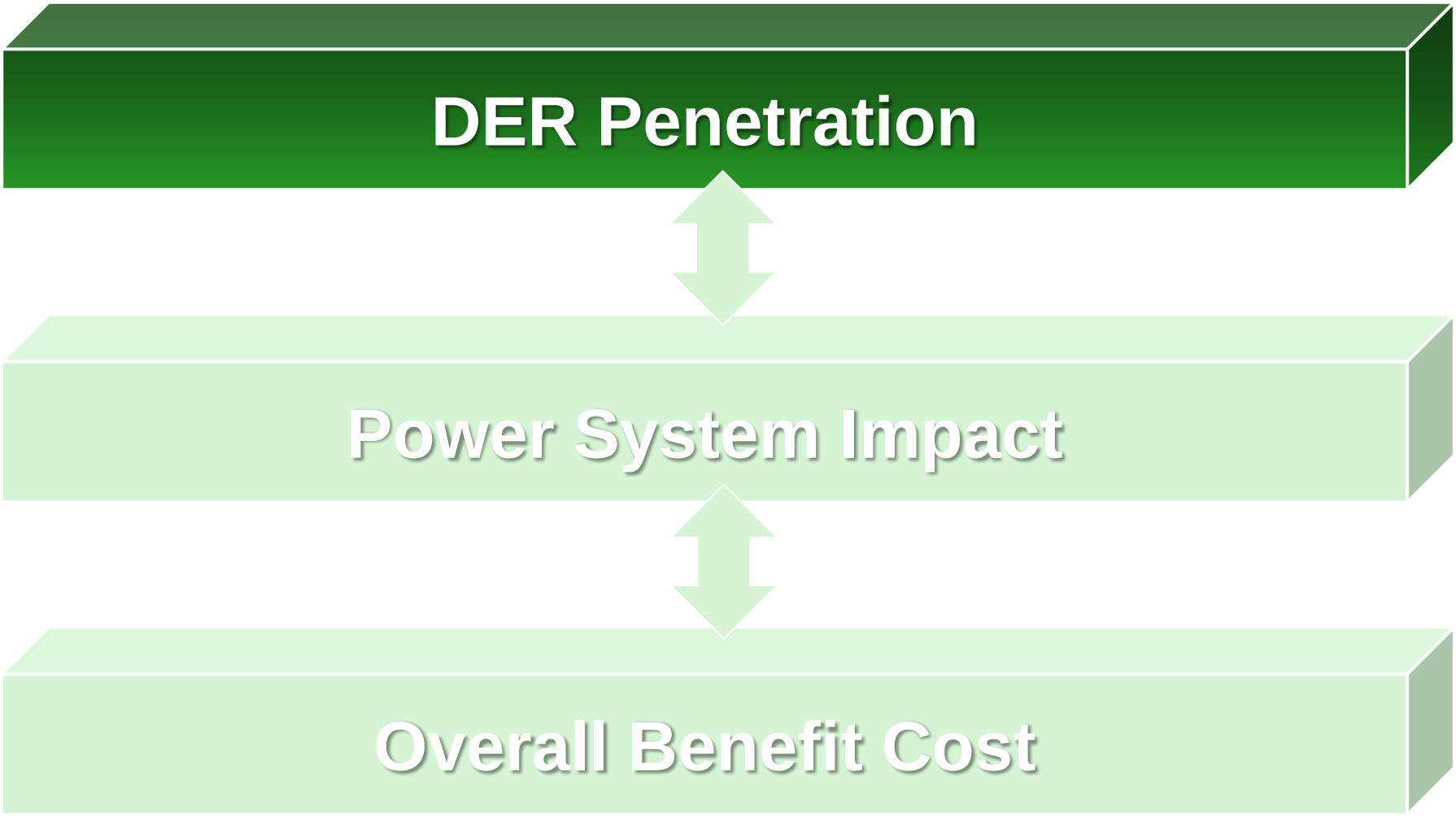
Integrated Grid Framework

Three Major Components



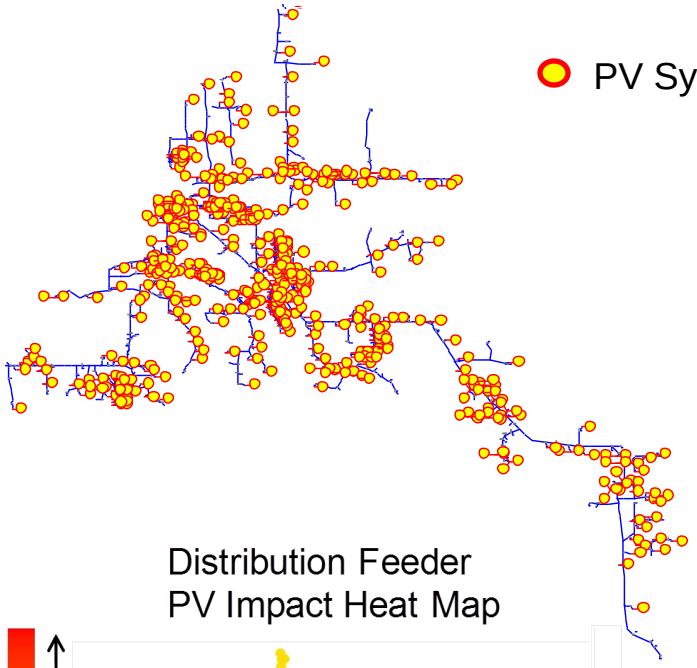
Integrated Grid Framework

Three Major Components

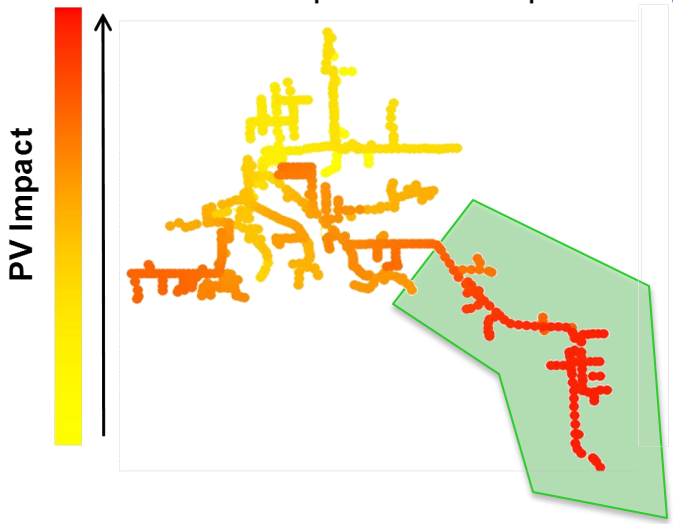


DER Penetration

Feeder Hosting Capacity: A Brief Primer



Distribution Feeder
PV Impact Heat Map



- Baseline – No PV
- PV Penetration 1
- PV Penetration 2
- PV Penetration 3
- Beyond…

Process is repeated 100's of times to capture many possible scenarios

Increase Penetration Levels Until Violations Occur

- voltage
- protection
- power quality
- thermal

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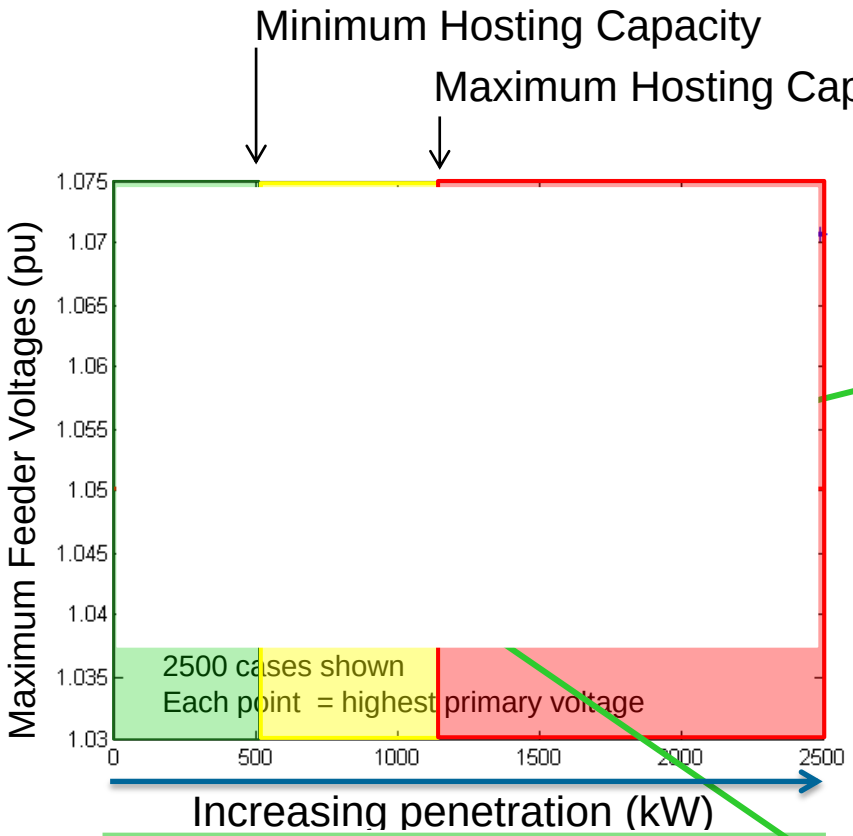
DER Penetration

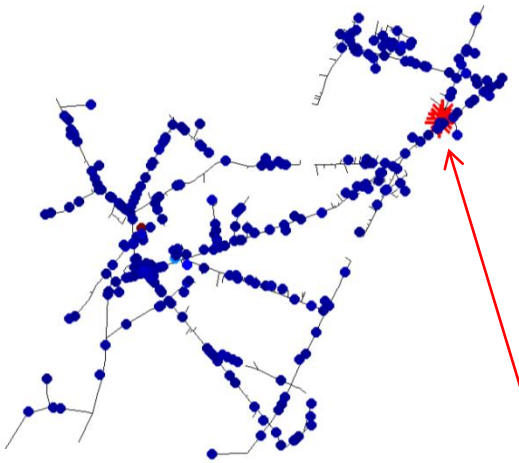
Hosting Capacity: Sample Results



No observable violations regardless of size/location

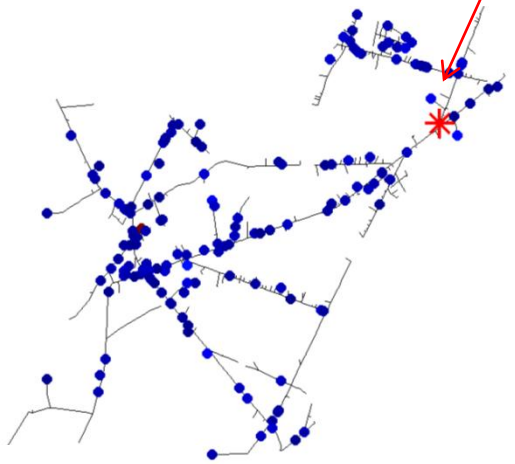
Possible violations based upon size/location

Observable violations occur regardless of size/location



Total PV:
1173 kW

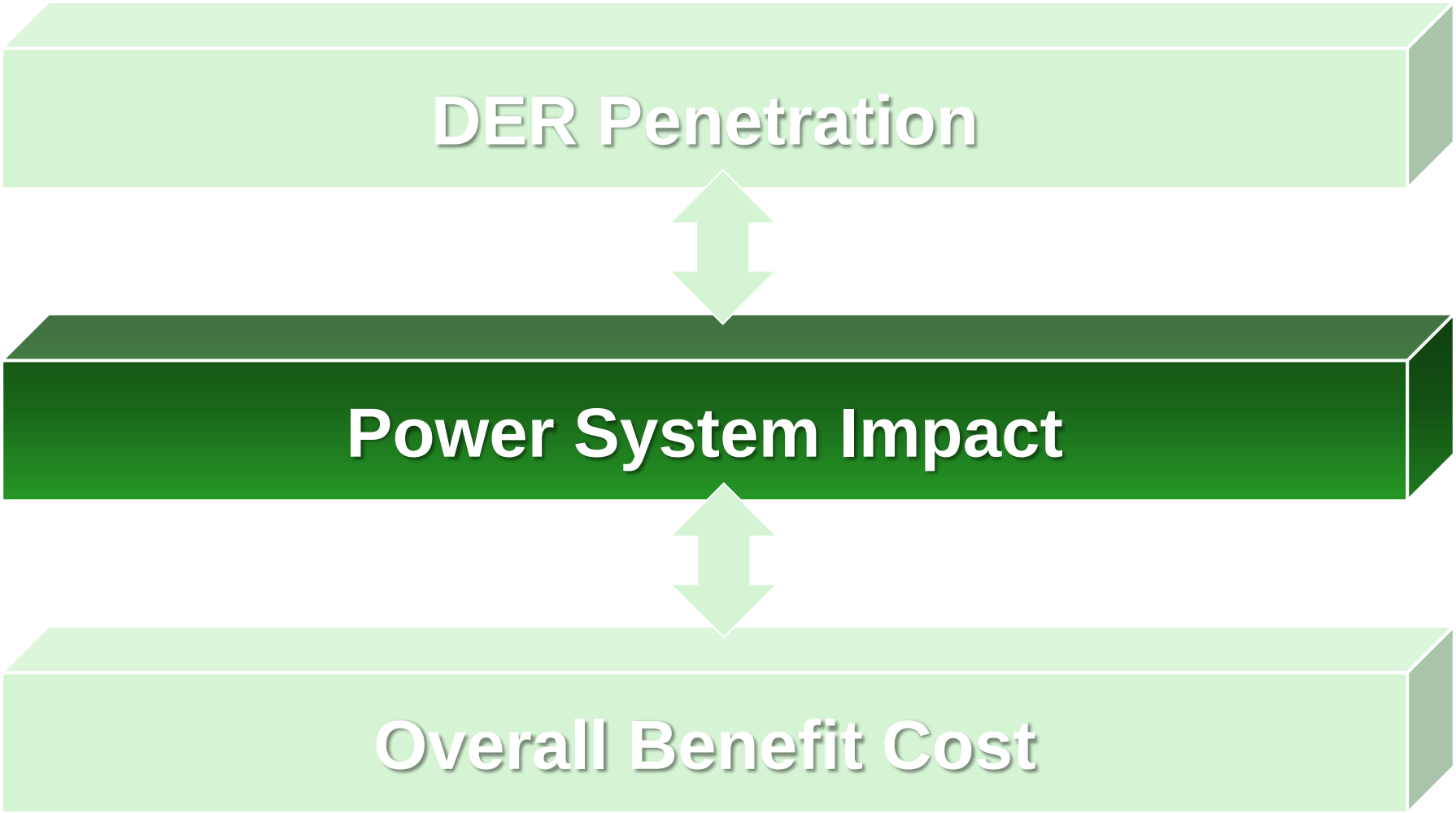
Voltage violation



Total PV:
540 kW

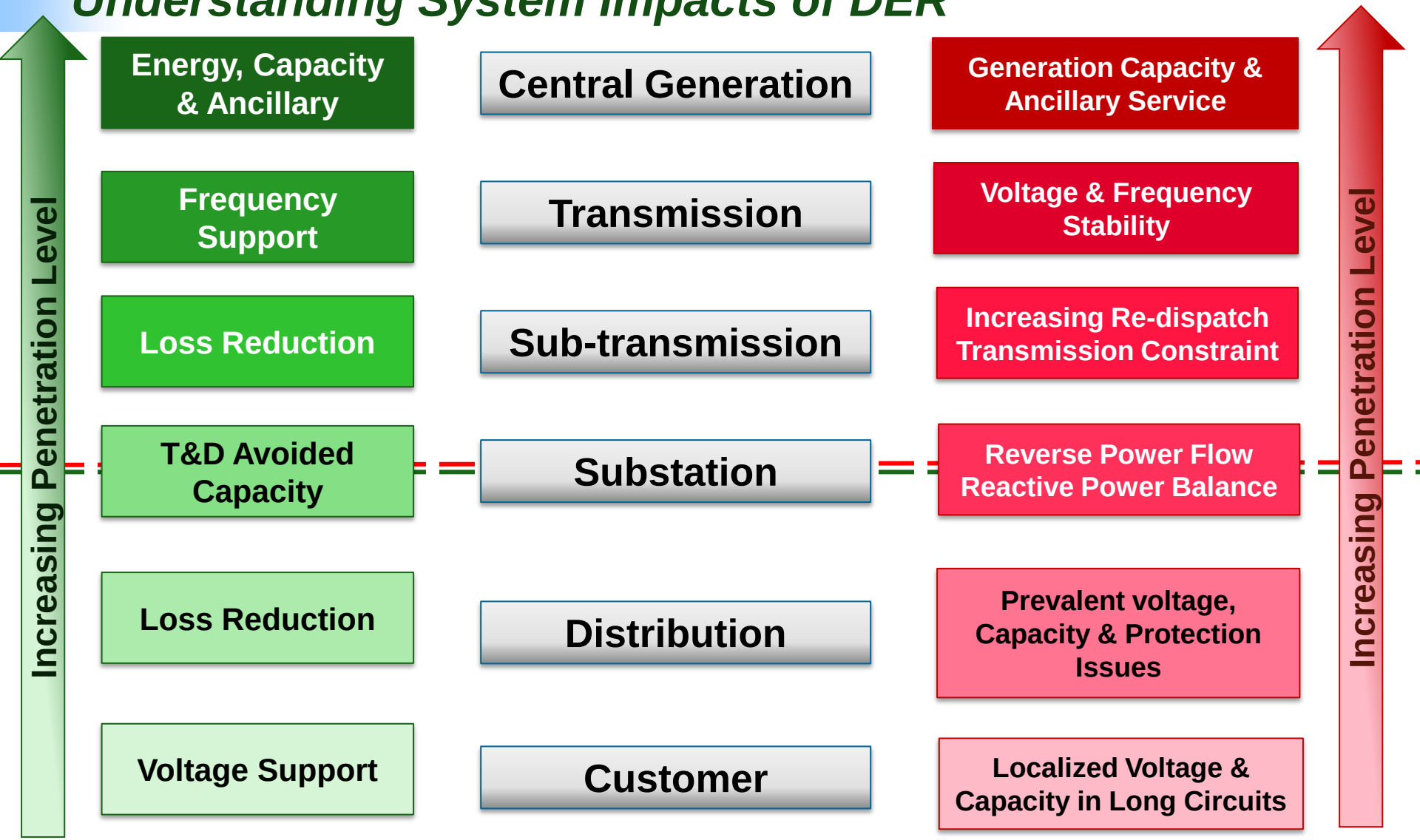
Integrated Grid Framework

Three Major Components



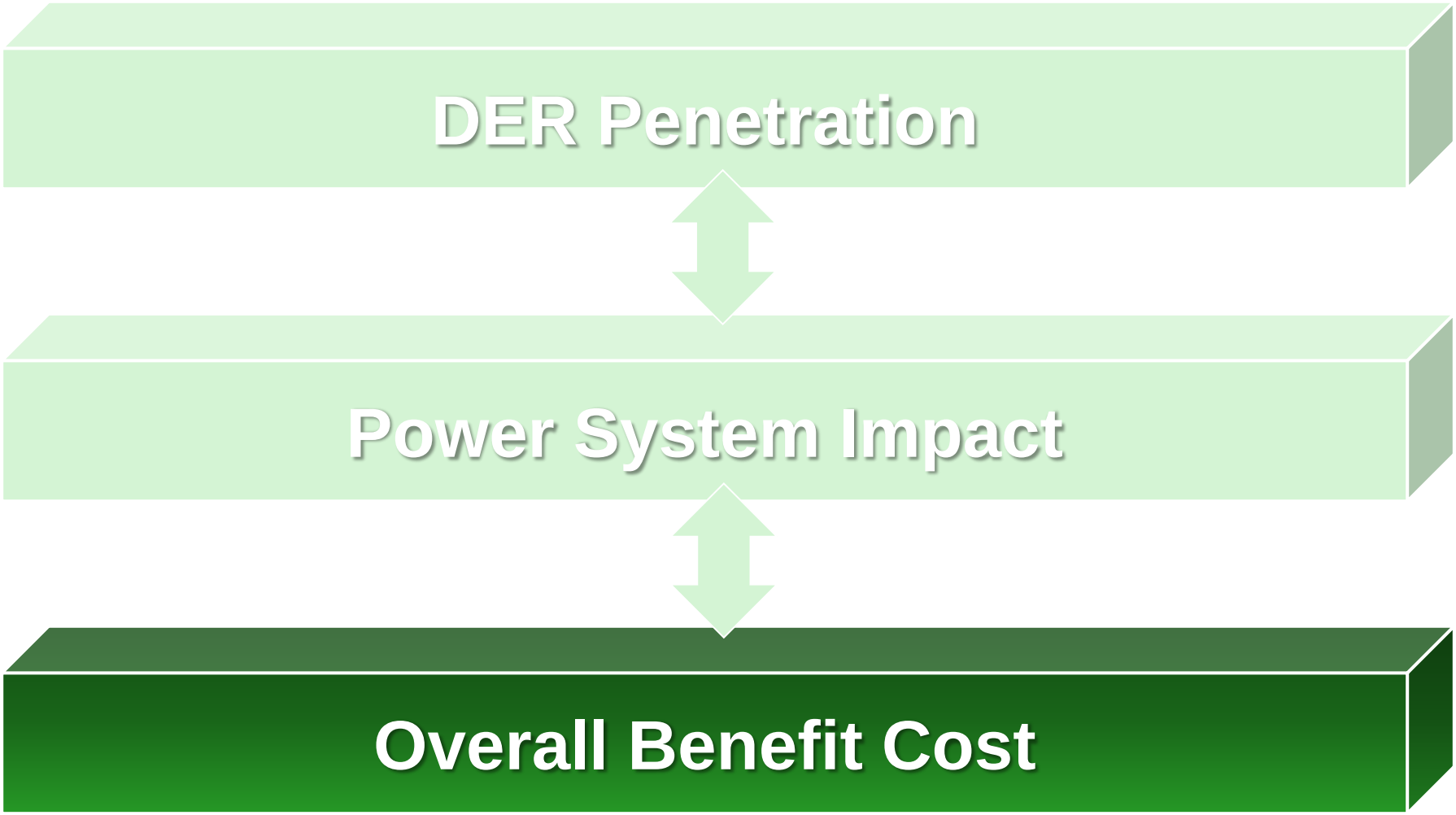
Power System Impact

Understanding System Impacts of DER



Integrated Grid Framework

Three Major Components



Overall Benefit Cost

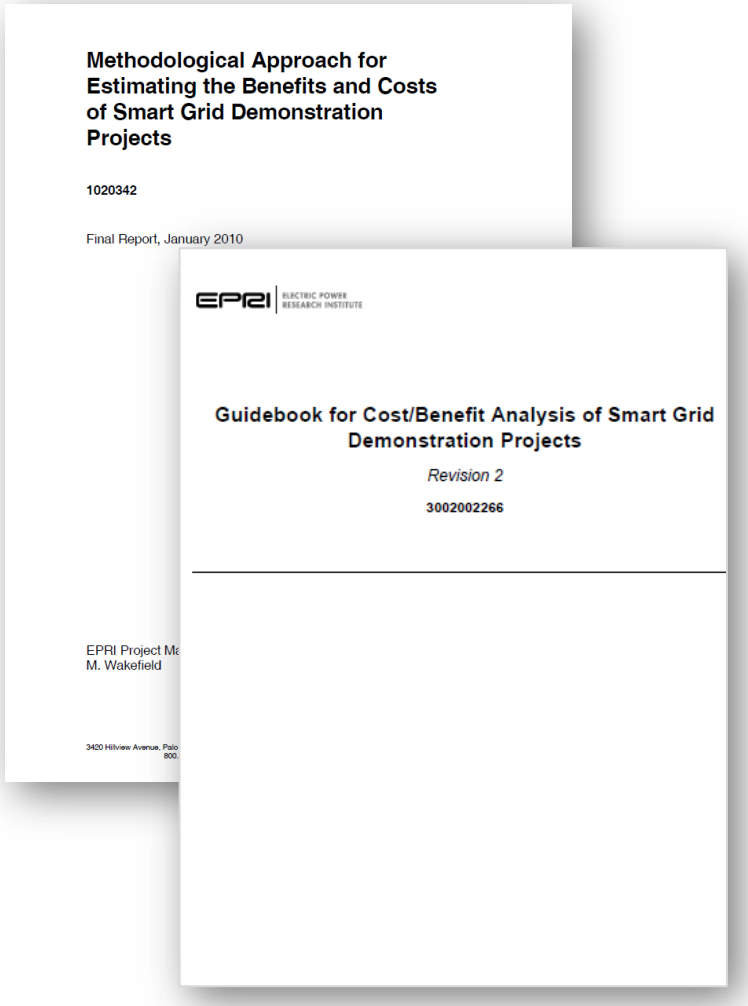
Leveraging Prior Work (CBA)

"Methodological Approach"

- Jointly funded by EPRI the US Department of Energy and provides framework for estimating benefits and costs, Jan 2010

CBA Guidebook, Rev 2

- Provides a manual for practical application, with step by step instruction, Rev. Dec 2013



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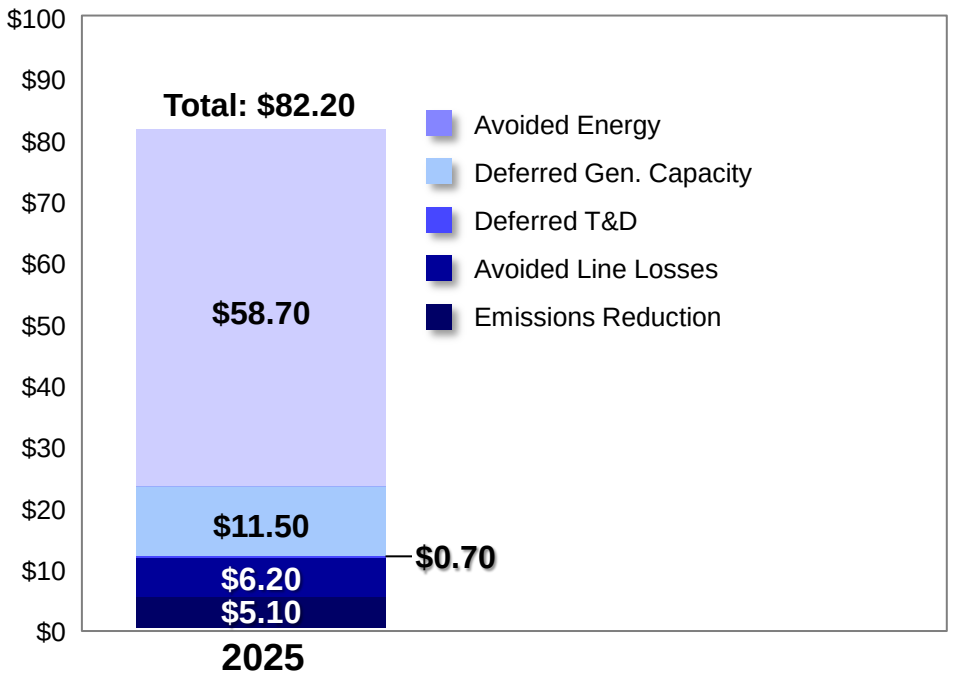
Overall Benefit Cost

From System Impact to Benefit/Cost

- Energy, Capacity & Ancillary
- Frequency Support
- Loss Reduction
- T&D Avoided Capacity



Xcel Energy Avoided Cost for 59MW of PV Deployment ($/MWh)

Source: "Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado System," Xcel Energy Services, Denver, May, 2013.

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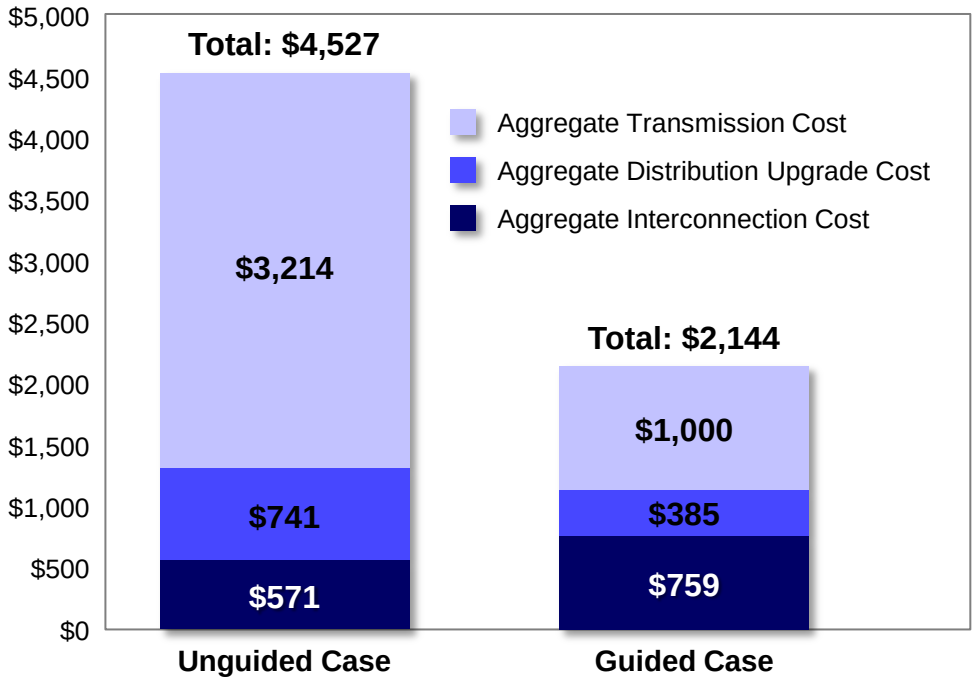
Overall Benefit Cost

From System Impacts to Benefits/Cost



Total SCE T&D System Costs for 4200MW of DER Deployment (Million USD)

Increasing Re-dispatch Transmission Constraint

Reverse Power Flow Reactive Power Balance

Prevalent Voltage, Capacity & Protection Issues

Localized Voltage & Capacity in Long Circuits

Source: "The Impact of Localized Energy Resources on Southern California Edison's Transmission and Distribution System," Southern California Edison (SCE), Rosemead, CA, May 2012.

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Overall Benefit Cost

What is Included & What is Not

- **Utility Operations**
  (people and how they do their jobs: non-fuel O&M, non-production assets, safety)
- **System Operations**
  (the power system and its efficiency: losses, combustion, dispatch optimization, emissions)
- **Utility Assets**
  (production assets required: GT&D)

Utility-Cost Function

Customer Perspective

- **Reliability & Power Quality**
  (frequency and duration of customer interruptions, harmonics, sags/swells, voltage violations)
- **Customer**
  (equipment & other direct customer costs)

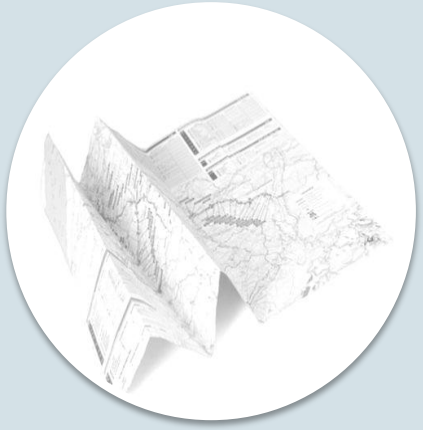
- **Society**
  (jobs, security, environmental and other economic costs and benefits

Included EPRI's Methodology based on Power System Analysis and Economics

Not in scope of EPRI's Methodology

Action Plan

Interconnection Technical Guidelines



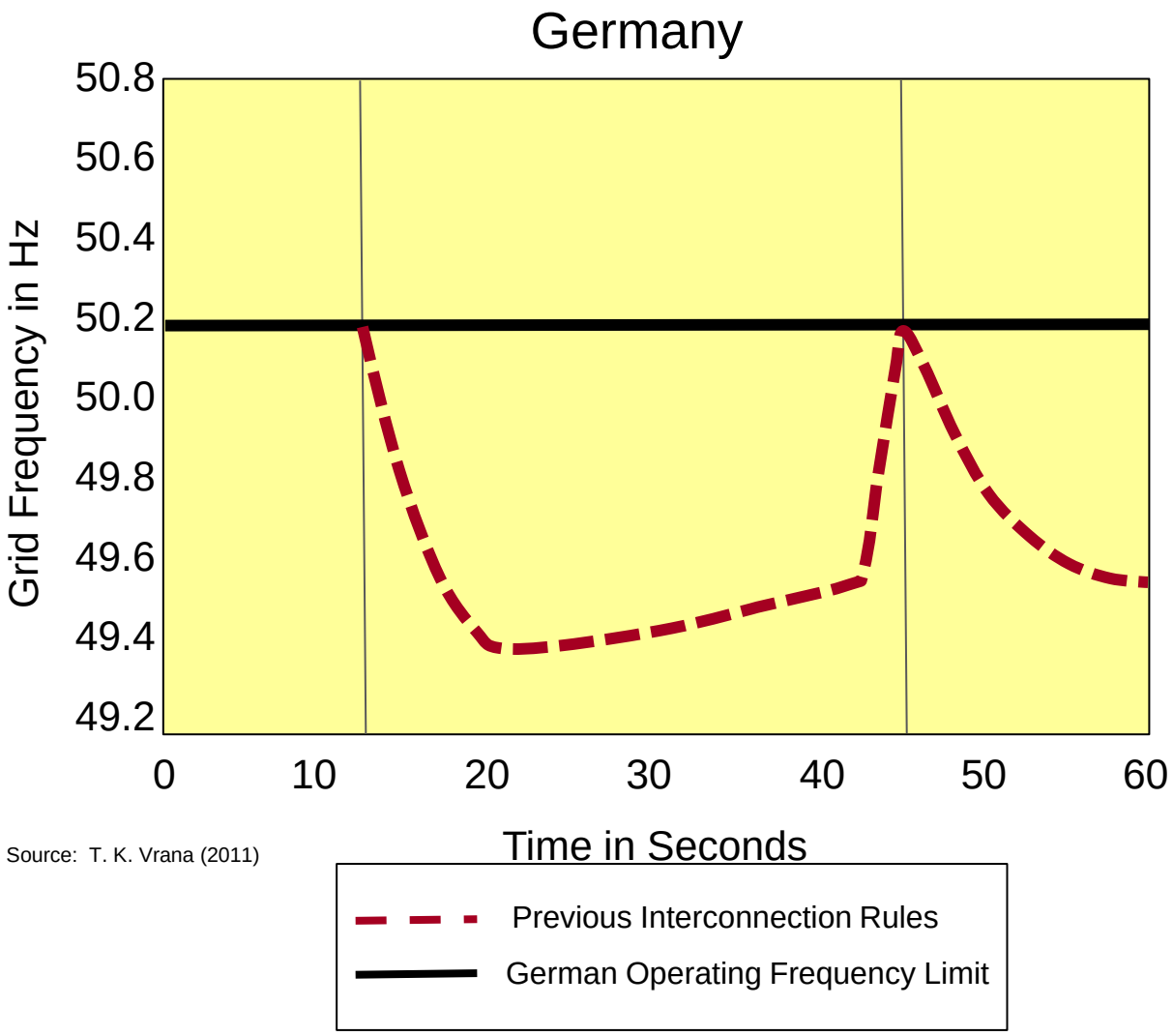
Benefit - Cost Framework

Interconnection Technical Guidelines

Grid Planning & Operations

Why Interconnection Guidelines Needed

Risk of Wide-Spread PV Disconnection



Source: T. K. Vrana (2011)

As of 2012 PV Inverters were not required to provide frequency support and disconnect from the grid if the frequency reaches 50.2 Hz

This is similar to all current interconnection requirements in US as per IEEE 1547-2003

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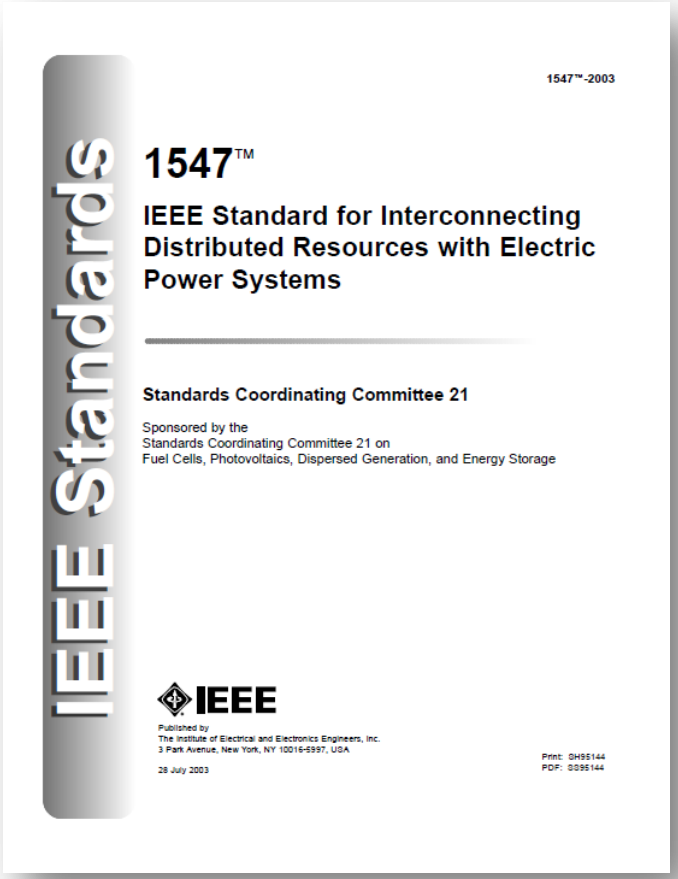
Interconnection Guidelines

New Technical Considerations



Future Interconnection Standards Should Consider

- **Voltage Support**
- **Frequency Support**
- **Fault Ride-Through**
- **DER/DSO Communication**

EPRI working on recommended technical guidelines for voltage and frequency ride through capability for DG based on new IEEE 1547a

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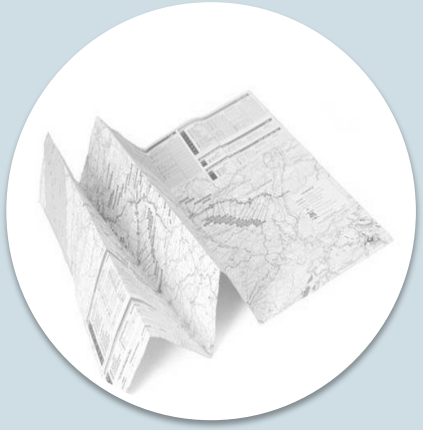
Action Plan

Grid Planning & Operations



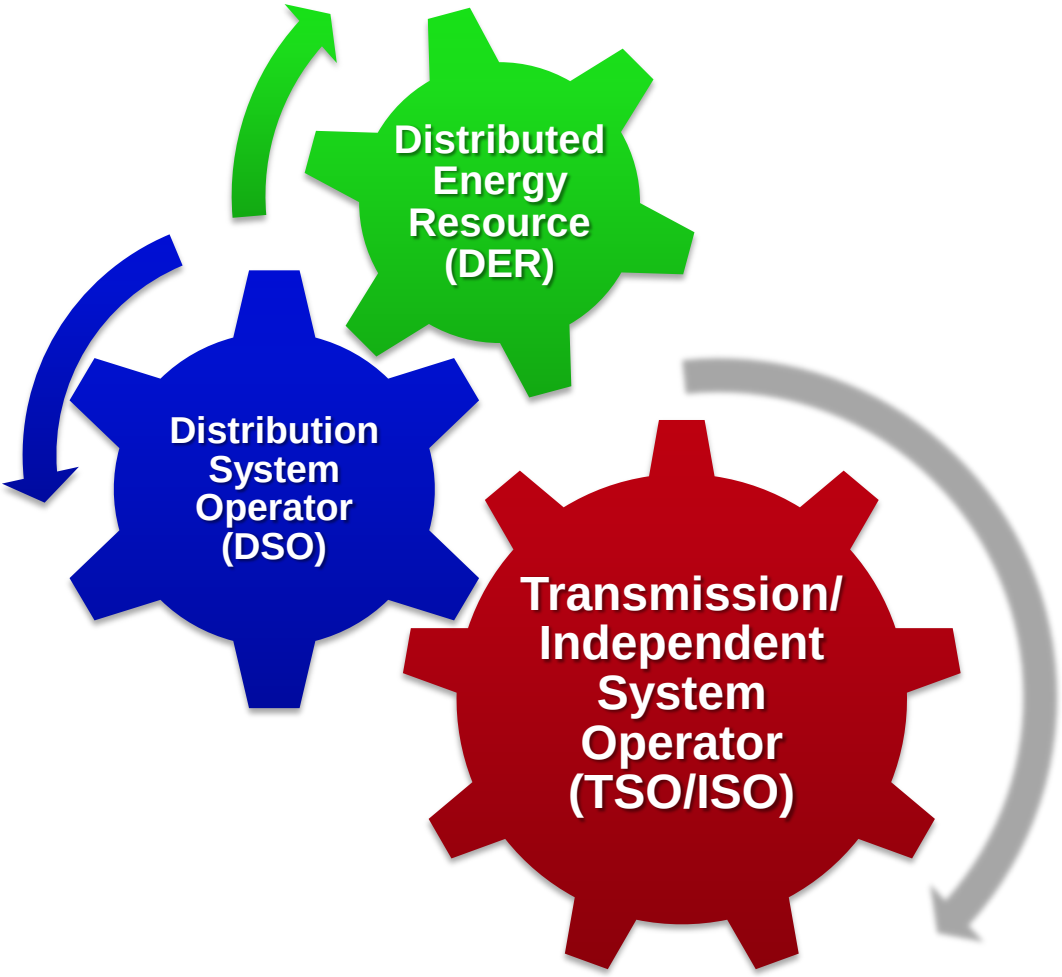
Benefit - Cost Framework

Interconnection Technical Guidelines

Grid Planning & Operations

Grid Planning and Operation

Transmission/Distribution Interface Needed



Establish technical requirements for transmission-distribution interface in a DER future

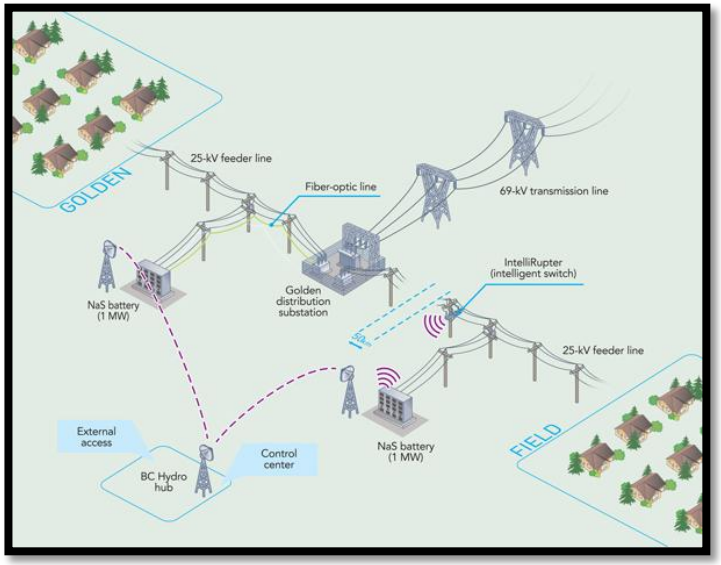
- Scheduling
- Real-time balancing
- Integrated markets
- Planning
- T&D operation
- Integrated System Modeling

Requires a coordinated effort among all stakeholders

Global Demonstrations & Modeling

Preparing for Two Types of Demonstrations

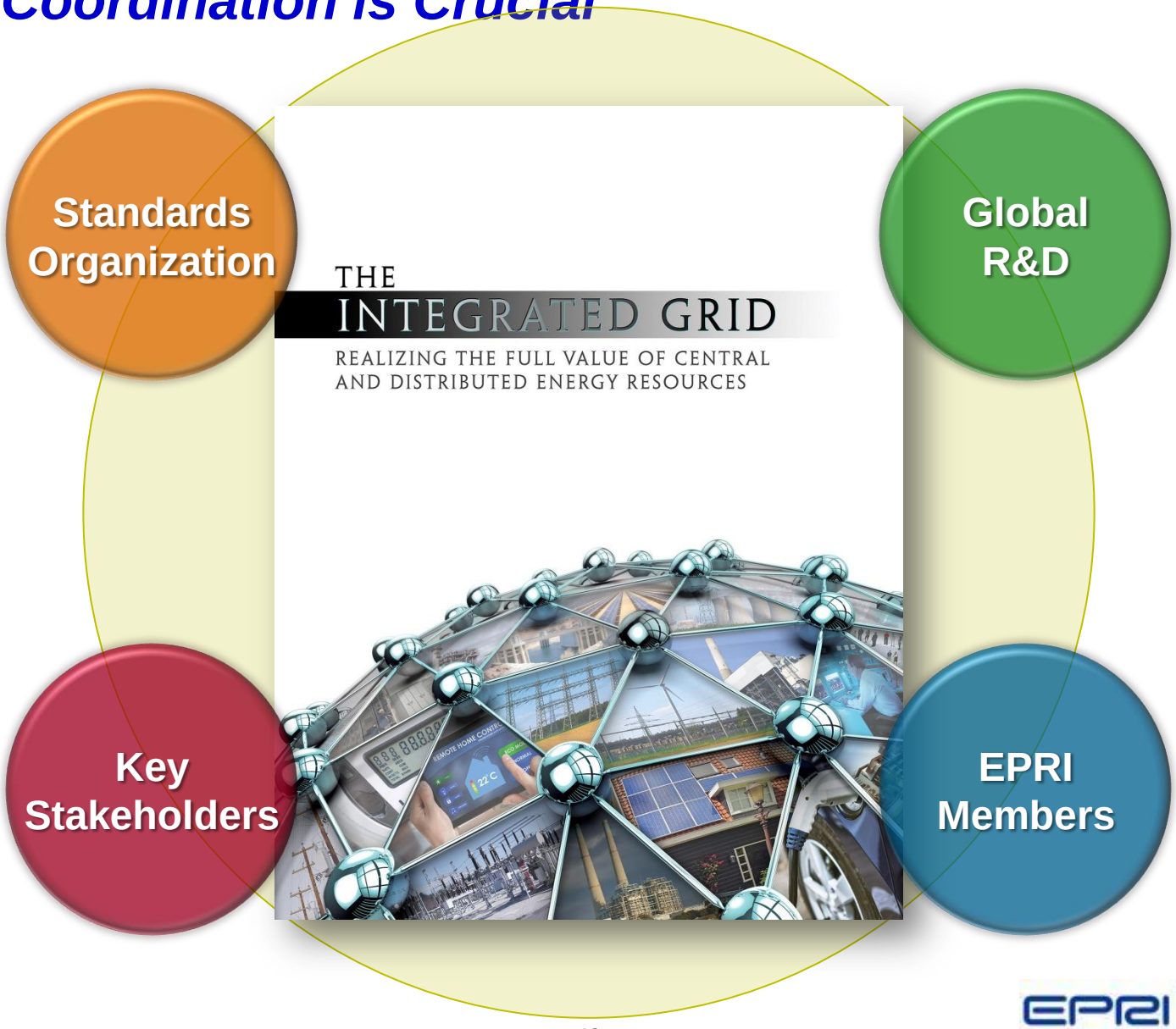
Methodology Demonstration:
System wide application of the Phase II methodology for a particular power system to assess the feasibility of an integrated benefit/cost methodology



Technology Demonstration:
One or more combination of technology demonstration for a specific part of a power system to assess the performance and benefit/cost of the technology

Integrated Grid Success

Wide Coordination is Crucial



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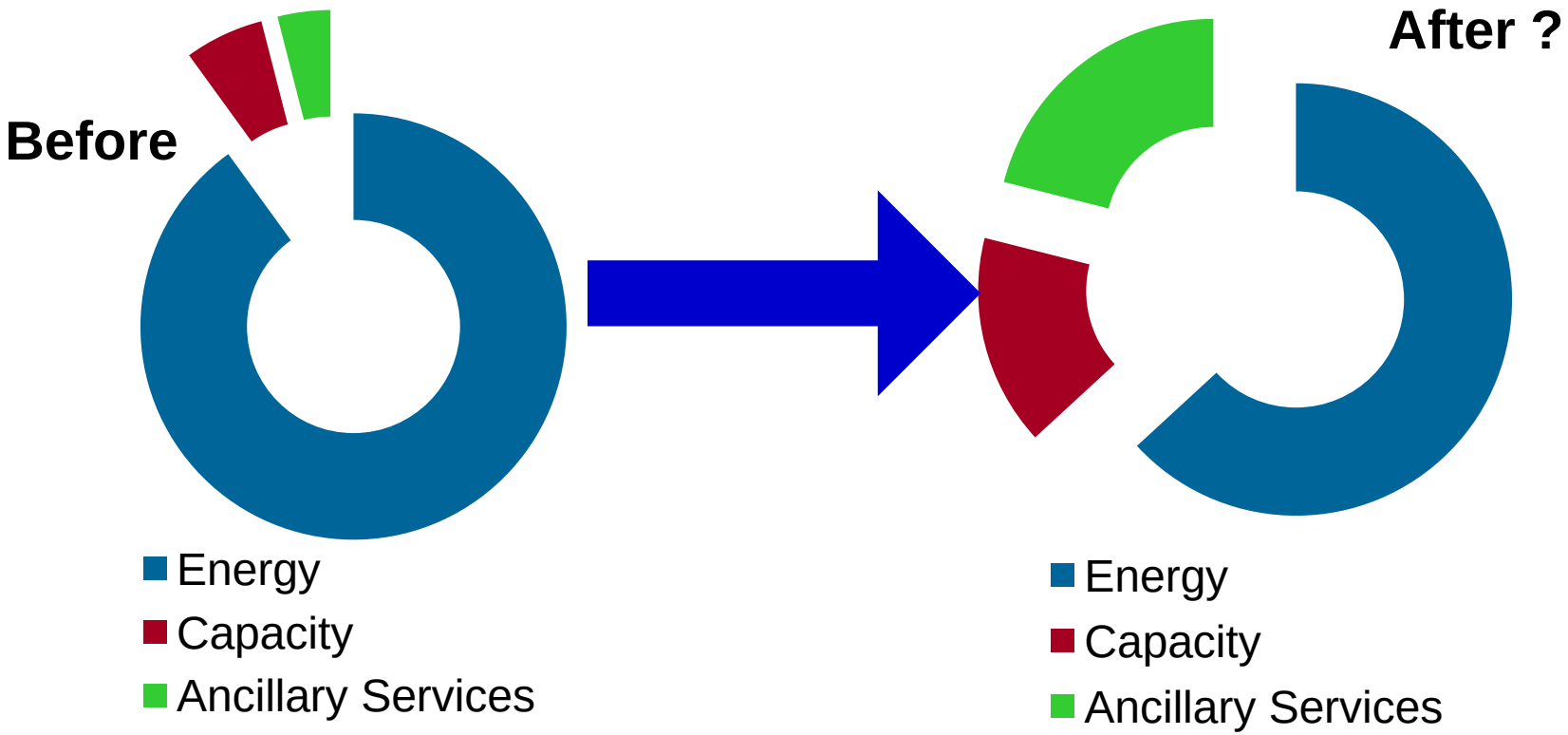
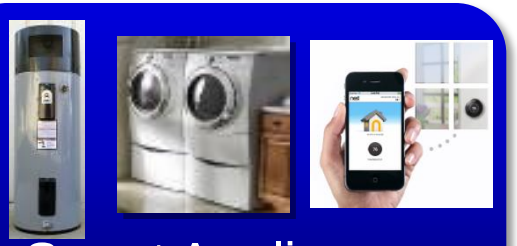
Can Change Create Opportunities?




Smart Appliances

Distributed Energy Storage


Electric Vehicles

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Together…Shaping the Future of Electricity

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