Emerging Technologies Summit

MAKING THE CONNECTION:

From Energy Efficiency Innovation to Delivery

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Making It Personal: Building a Peer-to-Peer Grid

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Transactive Energy Systems: Enabling Peer to Peer Grids

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Outline

- Brief Transactive Energy System Introduction
  - TES Framework and key characteristics
- Distributed Transactive Energy implementation example
  - Pacific Northwest Smart Grid Demonstration
- Use Case: Pooling DER resources for System benefits
  - Vermont Electric Company (VELCO) and Vermont distribution utilities

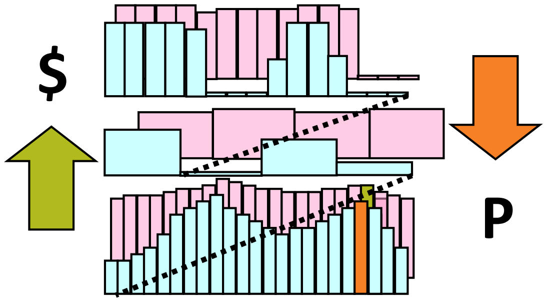
Definition of Transactive Energy

“A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter.”

– *GridWise® Architecture Council Transactive Energy Framework*

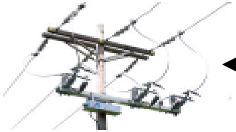
All *business* and *operational* objectives and constraints can be assigned value and thereby incorporated in these signals.

Signals forecast several days



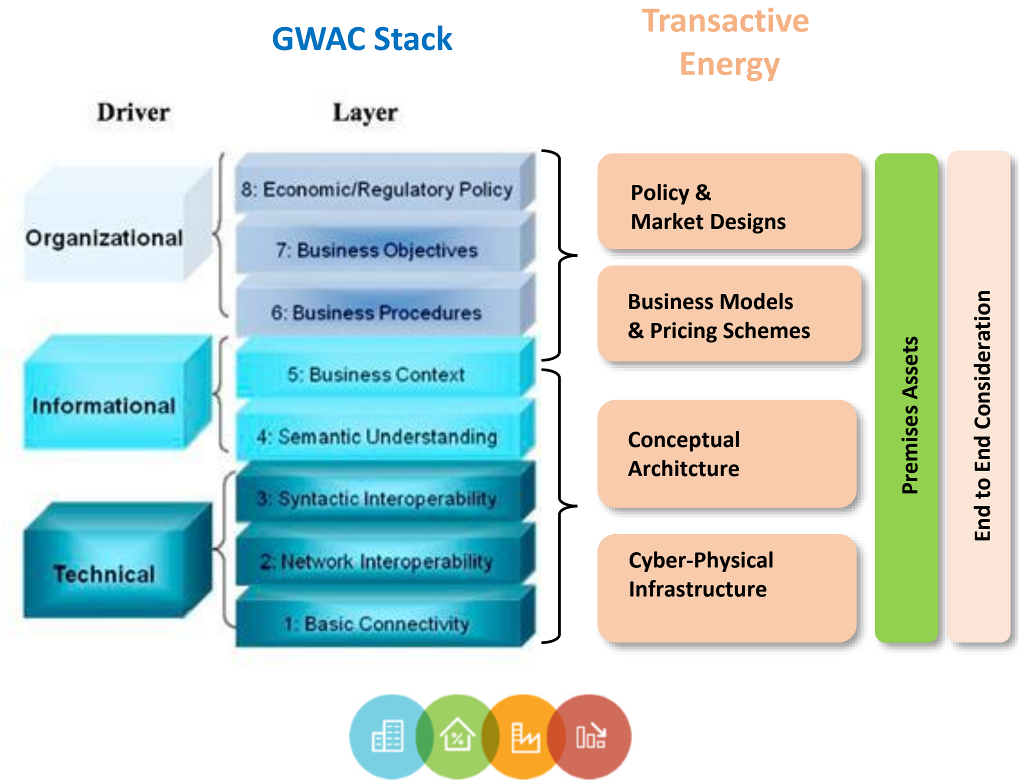
Transactive Incentive Signal (TIS): reflects true cost of electricity at any given point

Generation **Transmission** **Distribution** **Customers**

 e⁻ →  ← e⁻ →  ← e⁻ → 

Transactive Feedback Signal (TFS): reflects anticipated consumption in time

Transactive Energy Framework in the GWAC Stack Context



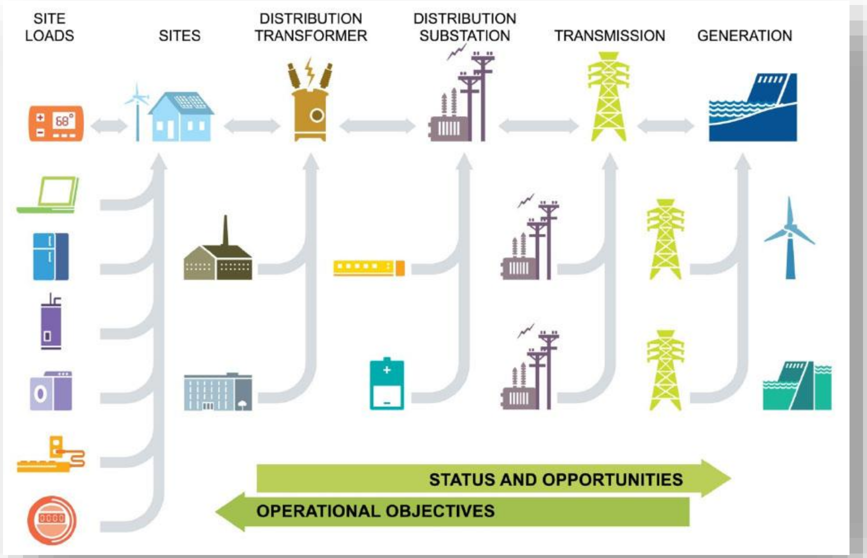
Transactive Energy (System) Attributes

- Architecture
- Extent
- Transacting parties
- Transactions
- Temporal variability
- Interoperability
- Value discovery mechanism
- Assignment of value
- Alignment of objectives
- Assuring stability

Pacific Northwest Smart Grid Project Basics

Operational objectives

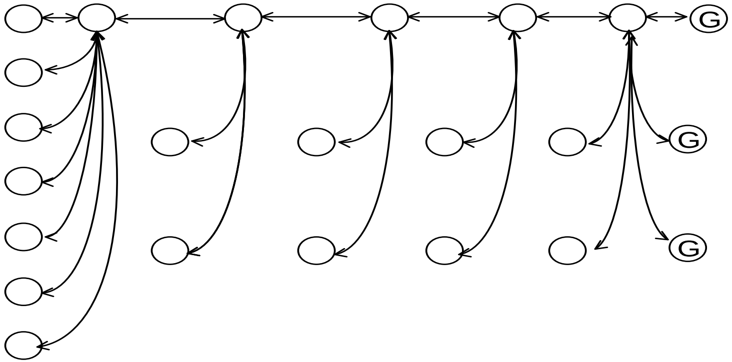
- Manage peak demand
- Facilitate renewable resources
- Address constrained resources
- Improve system reliability and efficiency
- Select economical resources (optimize the system)



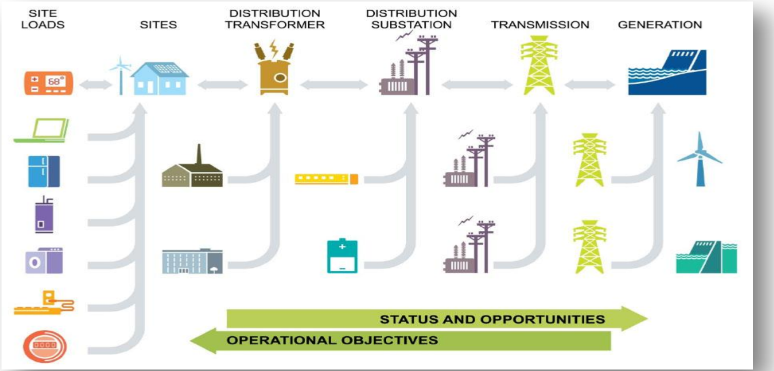
Aggregation of Power and Signals Occurs Through a Hierarchy of Interfaces

Propagation of the incentive and feedback signals

Incentive and feedback signals propagate through an information network (the Transactive Energy System) that overlays the electrical network; the signals are modified by Transactive Control Nodes (software agents)



Information Network

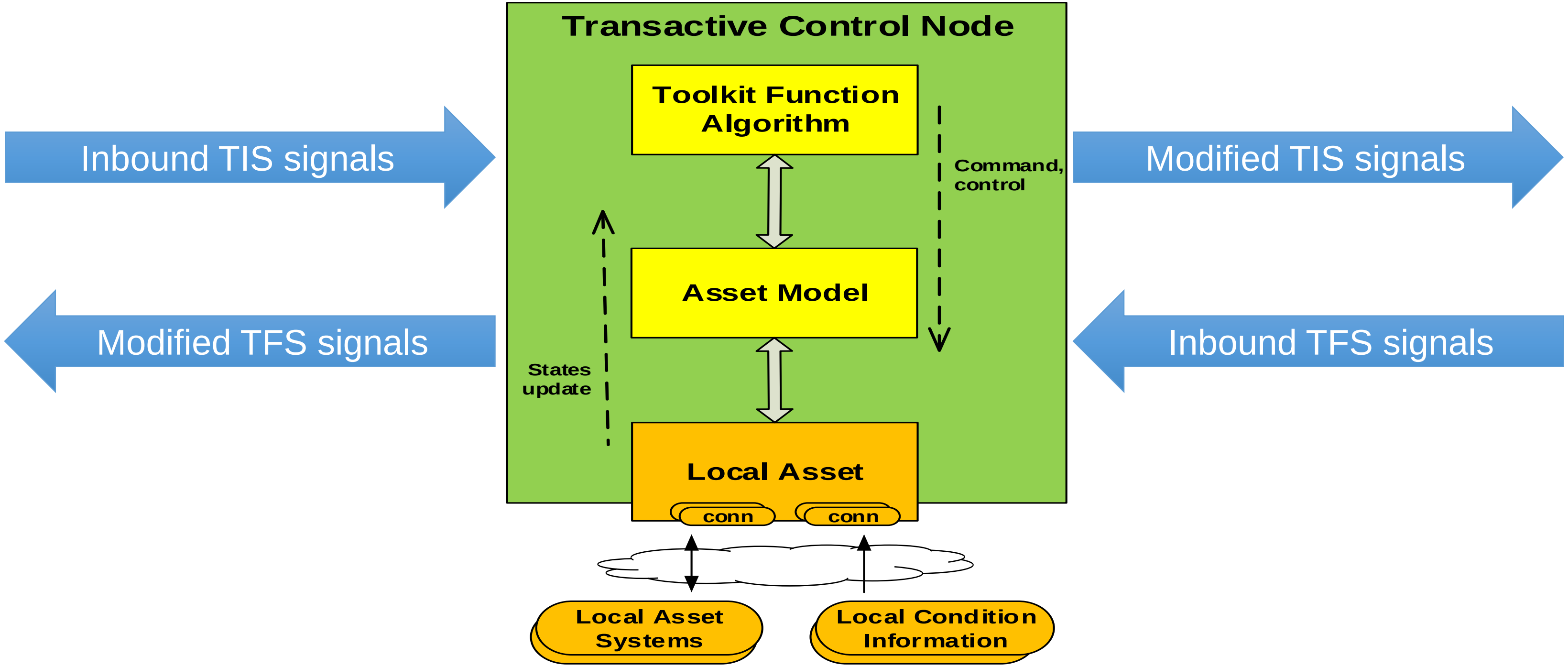


Physical Network

Role of a Transactive Control Node

- Respond to system conditions as represented by incoming Transactive Incentive Signals and Transactive Feedback Signals through
  - Decisions about behavior of local assets
  - Incorporation of local asset and other information
  - Updating both transactive incentive and feedback signals

Basic Design of a Transactive Control Node



Interoperability

- Formal transactive control node object model defined
- Reference implementation of ISO/IEC 18012 used to implement transactive control toolkit
- Transactive signals standardized for all participants, including interoperability / conformance test harness, using XML schema – suitable for inclusion in one or more future standards

Value Discovery Mechanism

- A primary responsibility of a transactive control node
- Accomplished through the exchange of transactive signals (TIS and TFS) with all neighbors
- The exchange of signals stimulates a “negotiation” like process
- The negotiation ends when the change in values is lower than a threshold
- The resulting TIS and TFS represent delivered cost of energy, and average rate of energy flow between the two transactive nodes, respectively
- Value is discovered throughout the distributed system – value is dependent on location

Value Assignment

- Another primary responsibility of a transactive control node
- Accomplished via local functions matched to the assets associated with the node
  - Resource function for supply assets
  - Load functions for consumption assets
- The functions translate local information such as weather, load history, engineering parameters, and business drivers into future cost for the TIS (and future consumption plans for the TFS)

Alignment of Objectives

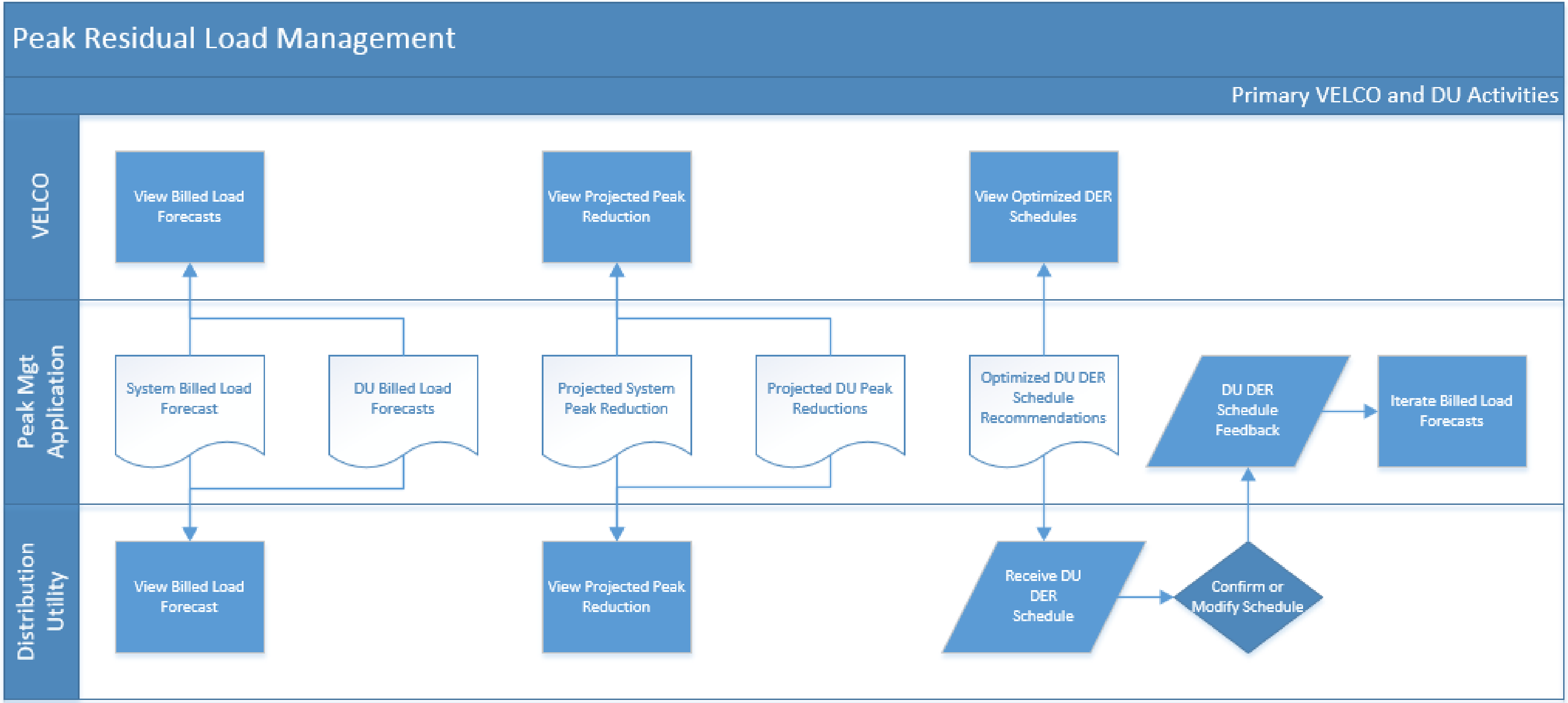
- Alignment of transactive control topology with power system topology supports natural alignment of objectives
- Asset owner-operators may affect the cost or consumption of power according to their operational and business objectives through the toolkit functions
- For the PNWSG Demo the bulk power system “needs” were represented in the TIS – the local utility added their “needs”, for example avoiding demand charges, and then acted to dispatch demand or other resources according to the resulting TIS.

Stability Assurance

- The Transactive Energy System implements a form of closed loop control and is expected to be stable
- Stability is not guaranteed by this form – but can be reliably achieved
- The specific analysis and/or modeling is required to determine the parameters that will provide this assurance

Vermont DER Pooling Use Case

- Objective: Manage System peaks by optimizing a pool of DER assets
  - The assets are a combination of utility-owned and customer-owned
- Value
  - Economic: Minimize charges keyed off monthly and yearly System peak loads
  - Operational: Reduce System max peak stress; defer transmission buildout; reduce power import



Peak Residual Load Management
Primary VELCO and DU Activities
VELCO
Peak Mgt Application
Distribution Utility
View Billed Load Forecasts
View Projected Peak Reduction
View Optimized DER Schedules
System Billed Load Forecast
DU Billed Load Forecasts
Projected System Peak Reduction
Projected DU Peak Reductions
Optimized DU DER Schedule Recommendations
DU DER Schedule Feedback
Iterate Billed Load Forecasts
View Billed Load Forecast
View Projected Peak Reduction
Receive DU DER Schedule
Confirm or Modify Schedule

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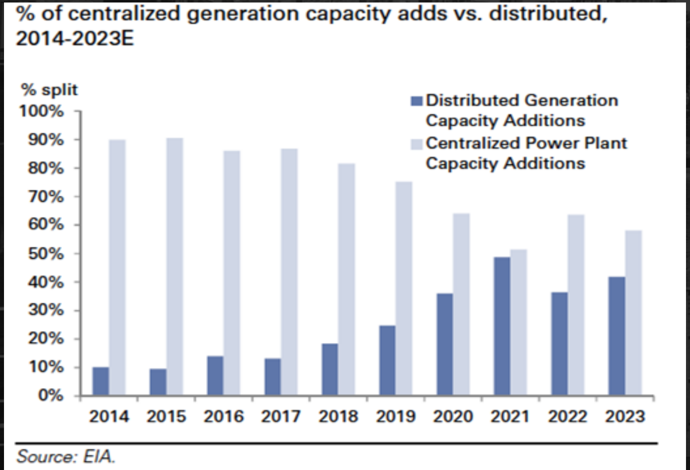
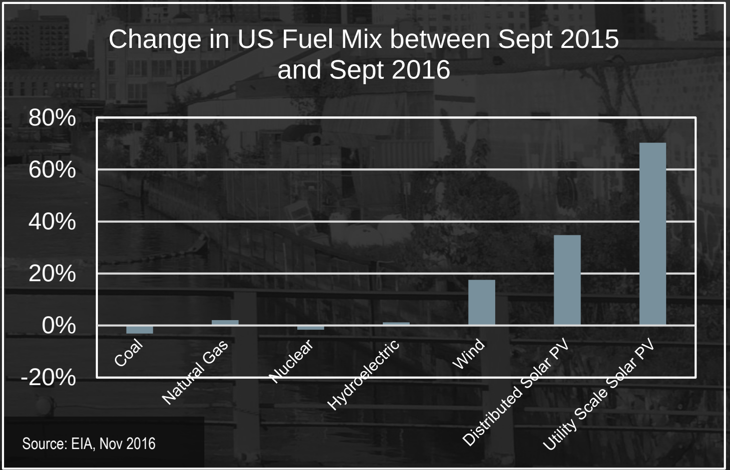
Distributed grid solutions that bring people, utilities and technology together

New Energy Resources are Renewable and Distributed





More than half of the estimated additional solar generation will be distributed, not utility scale

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Problem

Utility Grid Faces Structural Issues

- Utility Grid is unidirectional and brittle while future calls for fast-acting platform that can enable 2 way flow and is resilient and adaptive
- Current utility operating models do not encourage Distributed Energy Resources (DERs)
- Major market changes underway, unprecedented shifts by utilities and market actors
- “Prosumer” movement creating pressure on existing business models
- Broad, coordinated control of small scale DERs is uneconomic
- Consumer participation in energy markets limited by regulatory barriers and solutions to facilitate secure, efficient transactions

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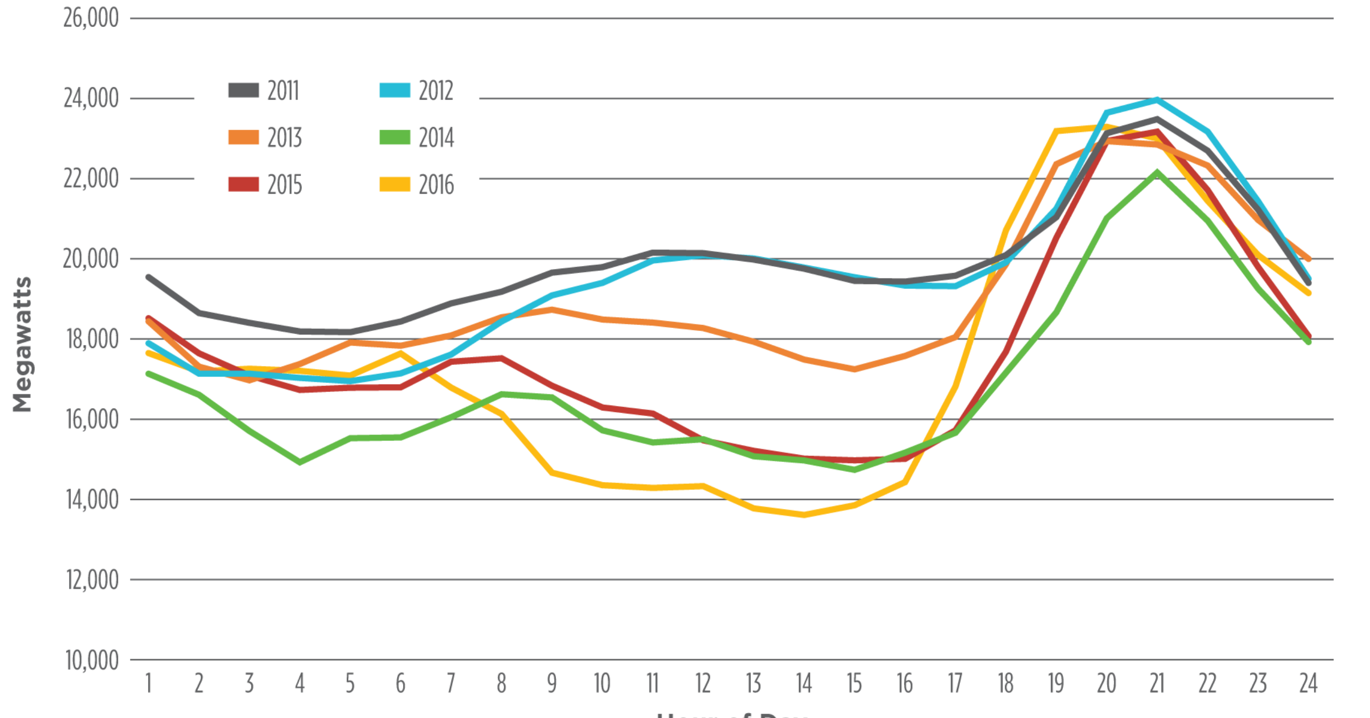
Impact of DERs

Lowest March Daytime Net Load for CA 2011-2016



Source: CAISO, Oct 2016

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Community Microgrids

Benefits of community microgrids

- Development of real Locational Value
- Energy supply based on values and economics
- Resiliency
- Circular benefits


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TRANSACTIVEGRID

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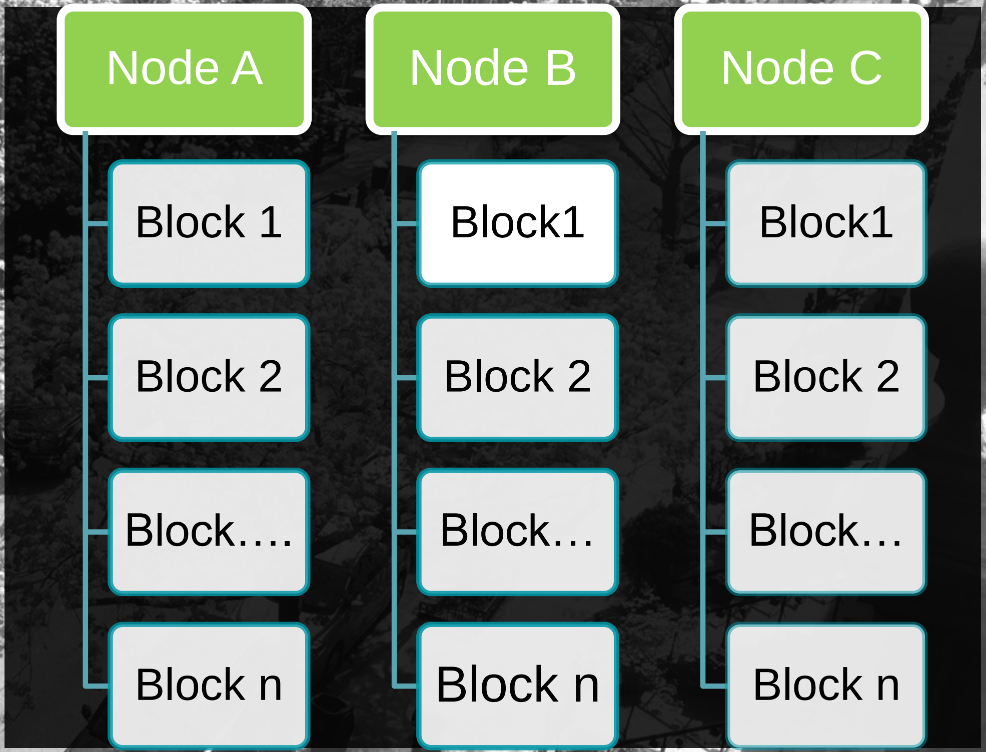
What is a Blockchain?

- Cryptographically secured, distributed ledger
- Transactions on the blockchain are kept permanently and are signed using public-key cryptography then ordered in blocks
- Every block is reviewed by network participants or nodes. A block is written when the nodes agree via a consensus algorithm that the data inside is accurate without a central authority
- Blocks are not easily produced. Nodes on a public blockchain perform complex cryptographic calculations to earn the right to publish a block.



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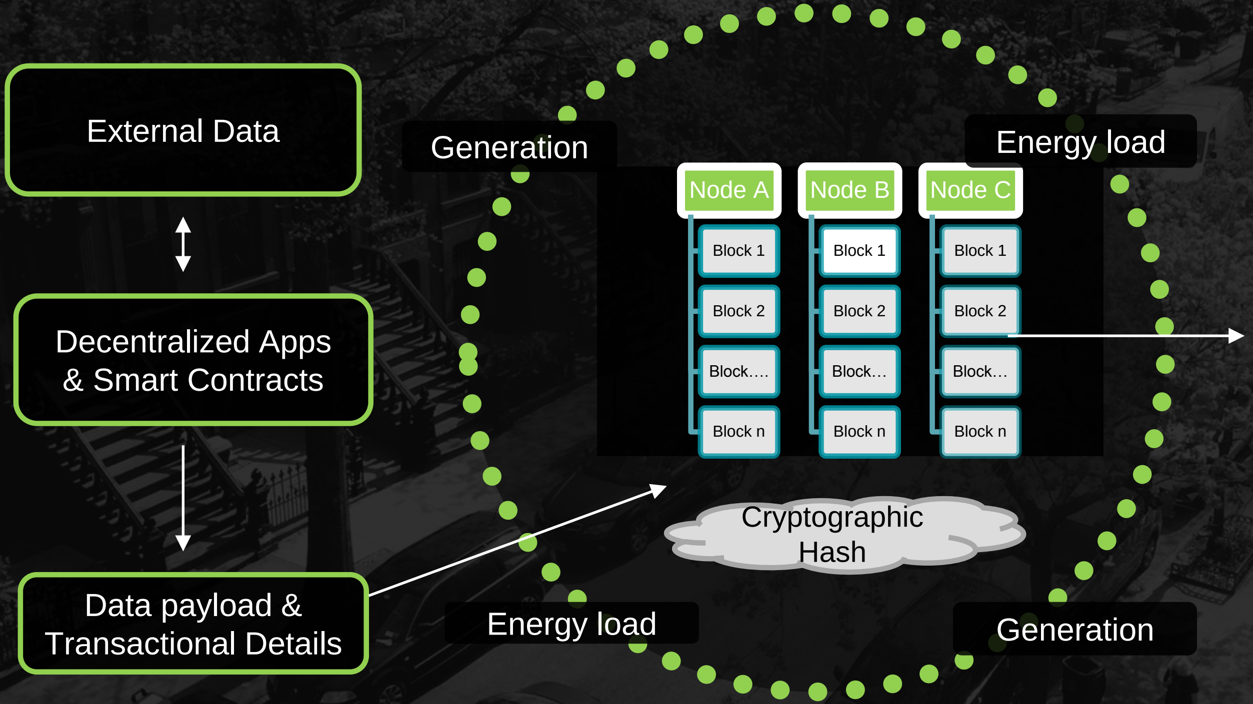
How is an energy blockchain different?



Each block contains:

- Time stamp
- Ownership status
- Reference to the previous block
- List of transactions

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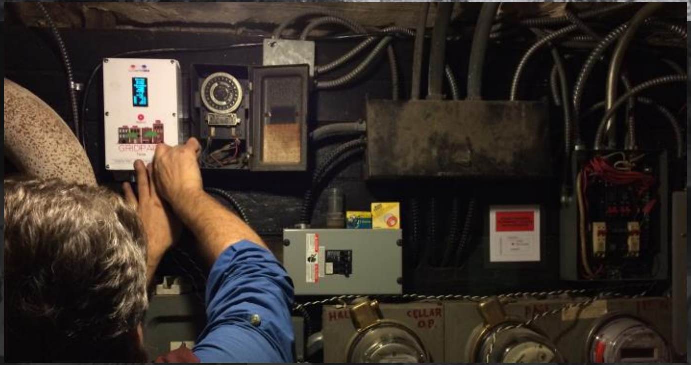
Blockchain-based meters

- Measure energy flows and hash information to blockchain
- Patented, proprietary and UL-listed
- Next generation AMI
- Network through a variety of communication protocols and write smart contracts within the network



Community Energy – Sharing Economy

Tokenization

Tokenization of energy production, storage and consumption creates efficient **local markets**

P2P Markets

Efficient Local Markets attract investment, increase impacts and create **local value** for energy, environment and community

Prosumers

Rise of the **Prosumers** neighbor-to-neighbor, neighbor-to-business community transactions reward **local markets and return community value**

Community Microgrids

Reward efficiency and resiliency allowing participants to optimize **existing energy spend** according to individual **values, priorities and outcomes**

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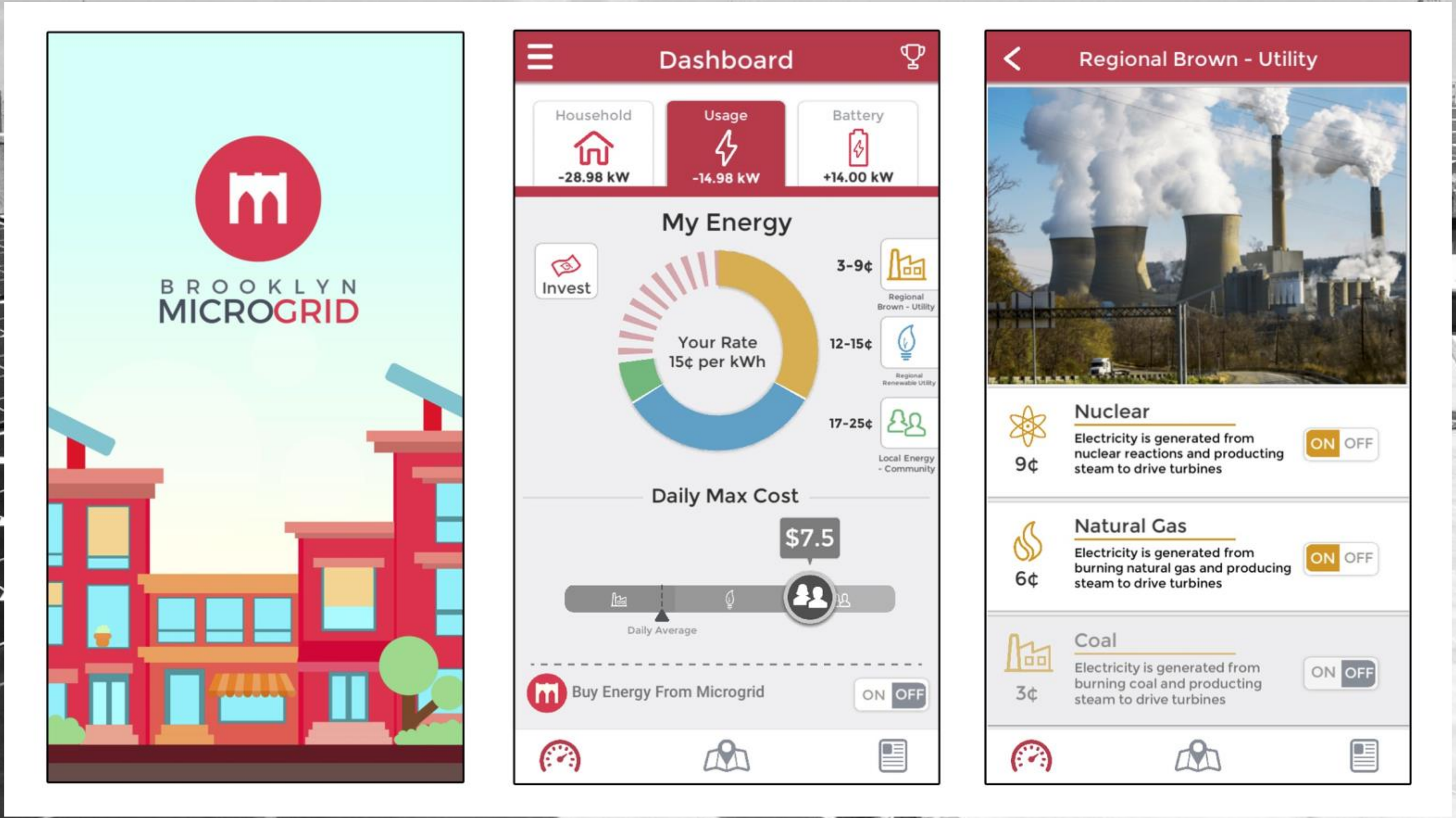
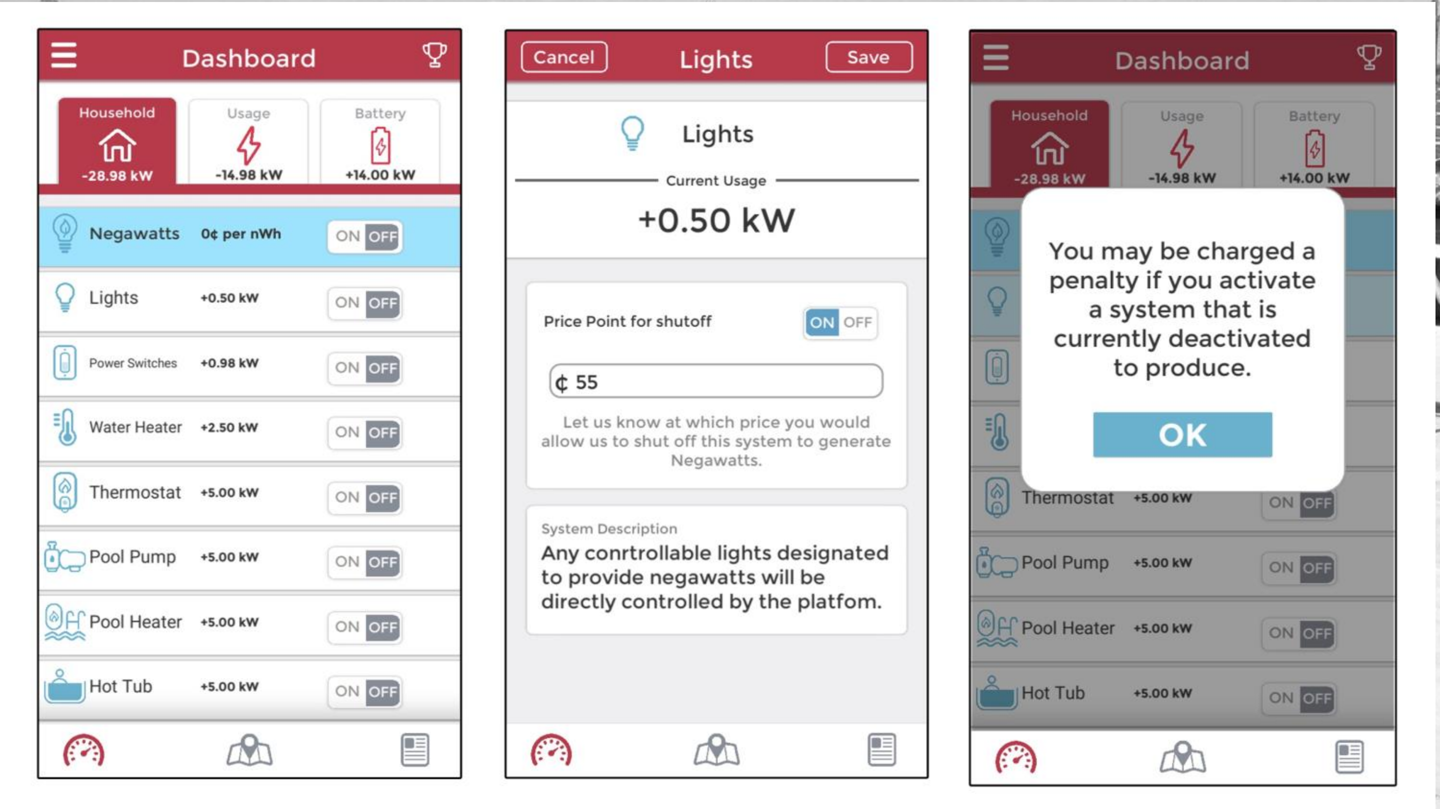
BMG Case Study



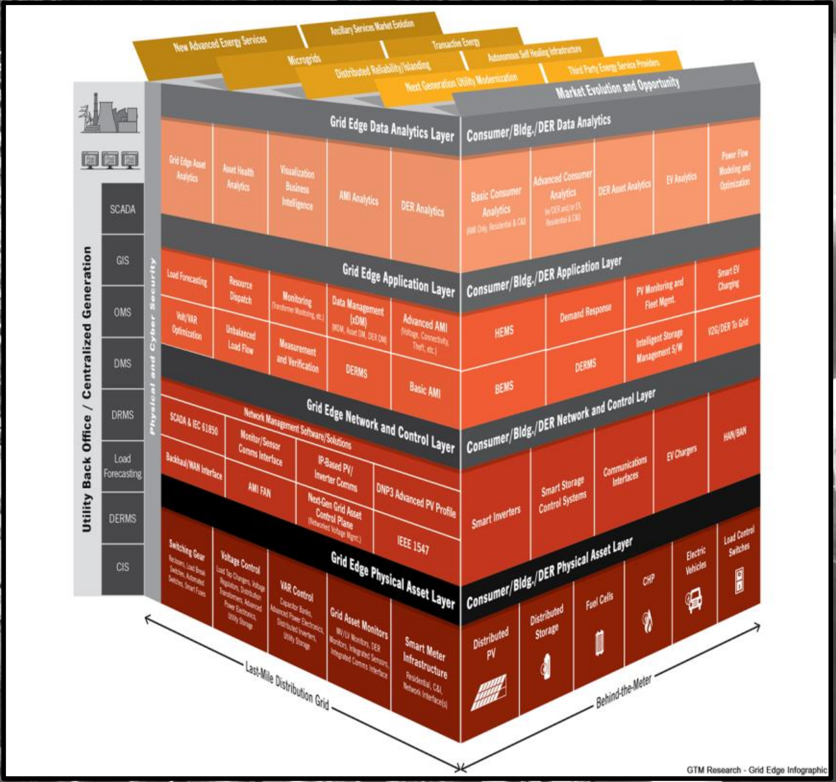
BMG Case Study



TransActive Grid

Blockchain-based Microgrid Intelligence System

- Transactive, distributed intelligence system to control microgrids
- Based on open-source, cryptographically-secure protocol layer delivering military-grade cybersecurity and real-time data
- Auditable, immutable, secure device control



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Drivers

Energy Consumers Demand New Choice and Services

69% of consumers are interested in having an energy trading marketplace

47% of consumers plan to sign up for a community solar program managed by a 3rd party and one that allows them to benefit from solar even if they do not have solar panels on their property within the next 5 years

Source: Accenture multi-year New Energy Consumer Research program: surveyed over 13,000 consumers from 26 countries from 2010 - 2016

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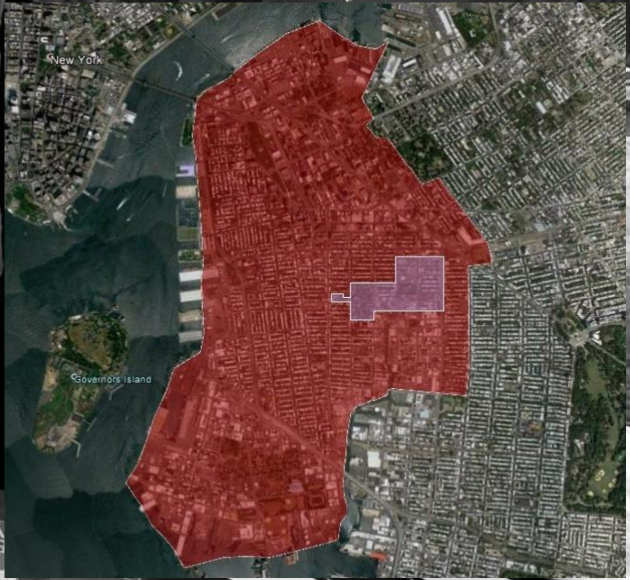
LO3 and Industry Status

- First peer-to-peer energy transactions executed
- Pilot and use case discussions underway
- Testing new business models
- Brooklyn Microgrid pilot in development
  - Over 40 meters installed and 130 sites registered
- Partners
  - Production partners lined up, incl. Siemens
  - Controls software development underway



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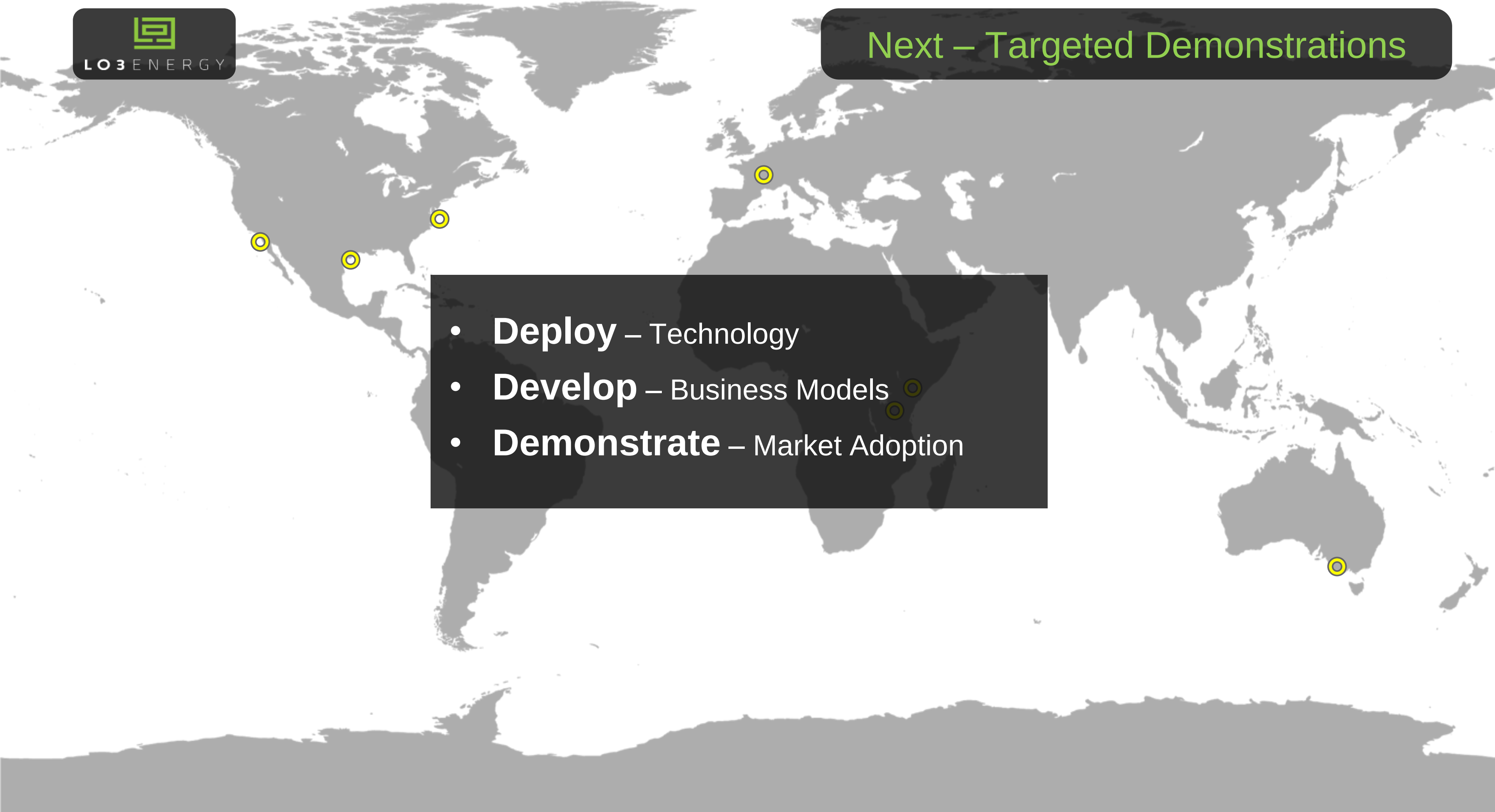
Next – Targeted Demonstrations



- **Deploy** – Technology
- **Develop** – Business Models
- **Demonstrate** – Market Adoption

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New Technology – New Choices – New Deal

They are your electrons, right?
Don’t forget that.

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THE LOCATIONAL VALUE OF DERs

Haider Khan, ICF

OUTLINE

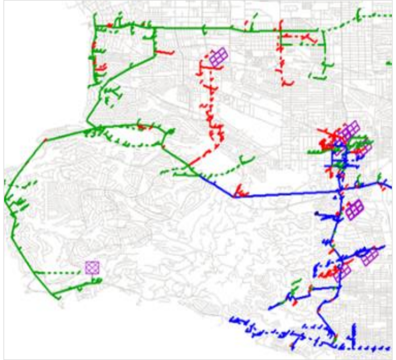
- Why value of DER matters, now and in the future
- Valuing DER up to now
- Valuing DER today—Best Practices
- Case Study: pioneering new methods for a utility
- Benefits and next steps for DER portfolio development
- Conclusions and key lessons

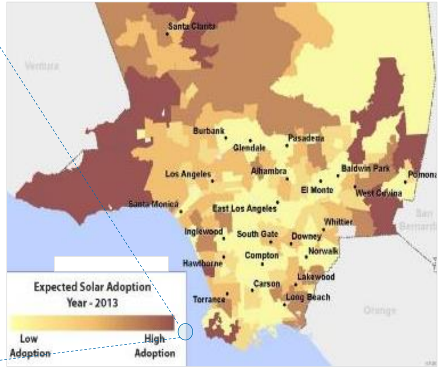
Distributed Energy Resource

- Other Distributed Energy Resources may include:
  - Energy Efficiency
  - Energy Storage
  - PV
  - Demand Response
  - Combined Heat and Power (CHP)
  - Electric Vehicles
  - Etc.
- All DERs interact locationally and temporally to affect T&D operations

DERS CAN BE **BOTH A THREAT AND AN OPPORTUNITY : SOLAR EXAMPLE**

- Residential solar grew by over 50% for the 4th consecutive year
- 14 states and D.C. hold policies now authorizing community solar programs
- Increasing solar penetration has ability to cause system violations or add potential system value





Operational Challenges

- Variability in net load
- Managing distribution voltage
- Integration costs
- Cost allocations

Potential Benefits

- Lower system costs
- Increased resiliency
- Savings for customers
- Emissions reductions

Number of low and high voltage violations are observed at 1:00 pm

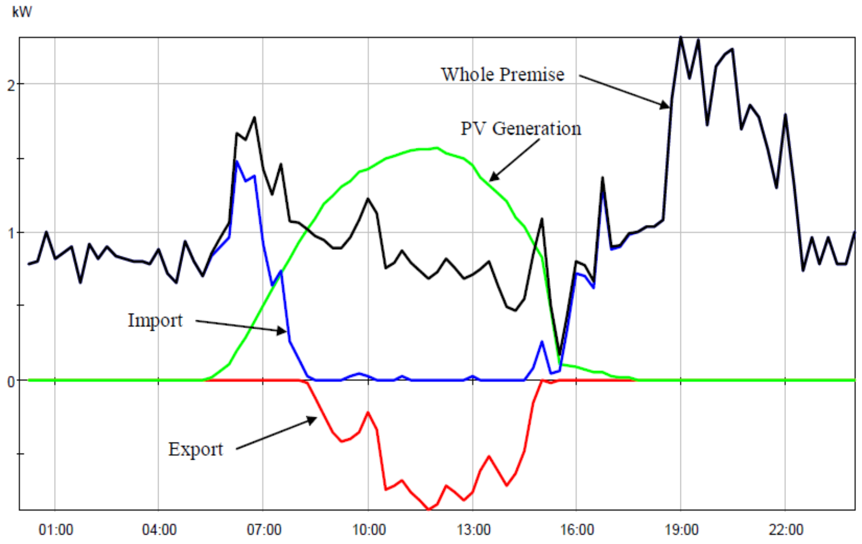
Legend

- Low Voltage Violation (<95%)
- Normal Voltage (95% - 105%)
- High Voltage Violation (>105%)
- Source or Substation
- Rooftop Solar PV Arrays

[1]30% measured at 5pm.
Source: ICF DEEP Analysis.

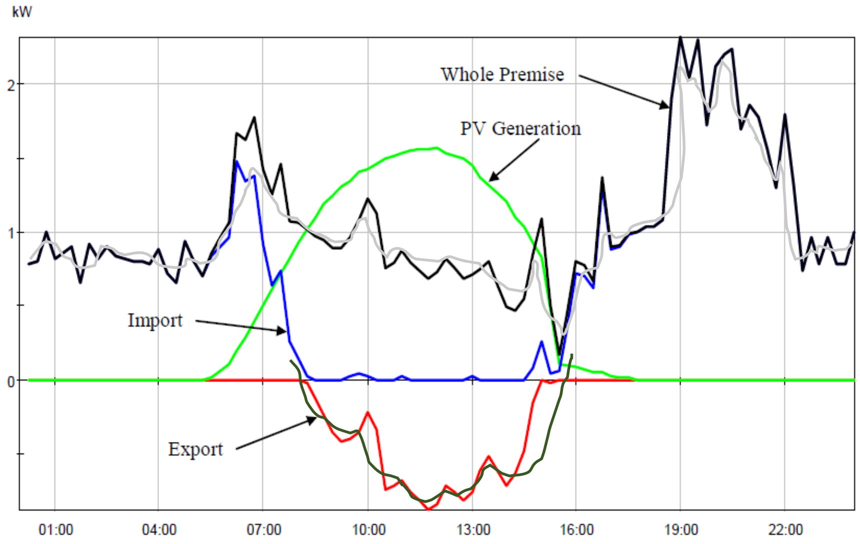
Distributed Solar Generation Profile vs. Customer Load

- DERS have a temporal value in addition to a locational value

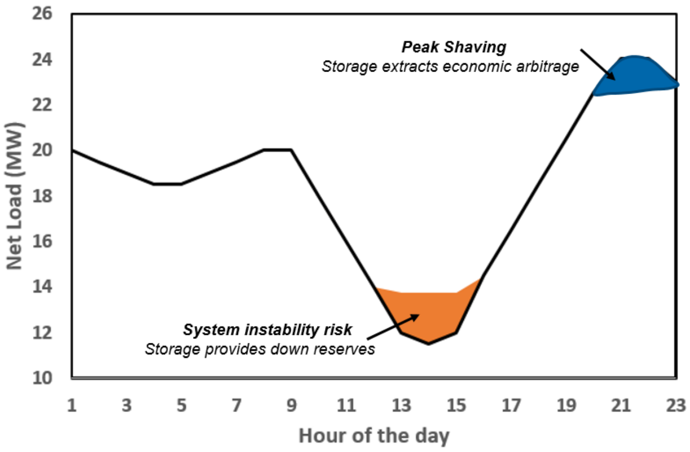


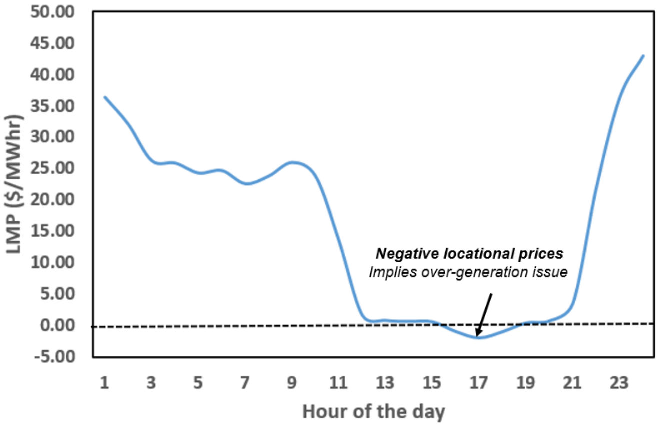
Distributed Solar Generation Profile vs. Customer Load

- DERS have a temporal value in addition to a locational value
- Energy efficiency affects the load shapes when interacting with other DERs



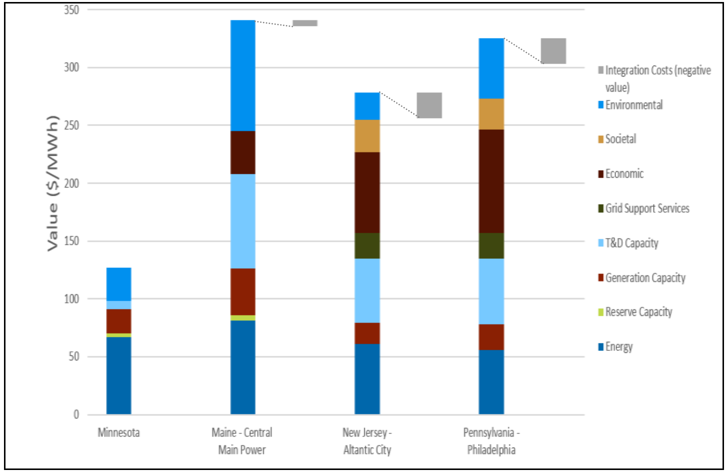
EXAMPLE: STORAGE PROVIDES DOWN RESERVES, BUT EE MAY COUNTERACT THESE DOWN RESERVES





Valuing DER up to now

- EE traditionally valued as a system resource using the California Manual tests
- Beyond EE, early valuation methods based on “Value of Solar”
- Early VOS studies have not applied consistent methodologies, and have resulted in significant variation in results
- A consistent methodology is needed that reasonably values all DERs on a locational and temporal net value basis



DER Value Framework

- **Valuation Frameworks are evolving:**
  - Moving from prescriptive to market based approaches
  - New valuation is dependent on quantifying the value that DER brings to the grid **(LMP + D + E)**
  - This requires greater grid modernization for higher situational awareness

Traditional DER valuation methods attempt to reflect associated benefits

- Distribution capacity
- Voltage
- Reliability
- Resilience
- Environment/Society

Key Obstacles

- Smart technologies deployment speed
- Common data standards
- Methodology framework

BENEFITS
Bulk System
Avoided Generation Capacity (ICAP), including Reserve Margin
Avoided Energy (LBMP)
Avoided Transmission Capacity Infrastructure and related O&M
Avoided Transmission Losses
Avoided Ancillary Services (e.g. operating reserves, regulation, etc.)
Wholesale Market Price Impacts
Distribution System
Avoided Distribution Capacity Infrastructure
Avoided O&M
Avoided Distribution Losses
Reliability / Resiliency
Net Avoided Restoration Costs
Net Avoided Outage Costs
External
Net Avoided Green House Gases
Net Avoided Criteria Air Pollutants
Avoided Water Impacts
Avoided Land Impacts
Net Non-Energy Benefits (e.g. avoided service terminations, avoided uncollectible bills, health impacts, employee productivity, property values, to the extent not already included above)**
COSTS
Program Administration Costs (including rebates, costs of market interventions, and measurement & verification Costs)
Added Ancillary Service Costs
Incremental Transmission & Distribution and DSP Costs (including incremental metering and communications)
Participant DER Cost (reduced by rebates, if included above)
Lost Utility Revenue
Shareholder Incentives
Net Non-Energy Costs (e.g. indoor emissions, noise disturbance)

Required BCA Categories from NY BCA Handbook

Benefits of Accurate DER Valuation

- Smarter Investments
- Better Rate Design
- Optimized Programs
- Adaptive Planning
- Greater Reliability and Resiliency
- Better Forecasts of Customer Adoption Rates

DEPLOYING A SYSTEMATIC, 5-STEP DISTRIBUTION PLANNING FRAMEWORK IS FAR SUPERIOR TO "WINGING IT"

Scenario based distribution planning

- Uncertainty of the types, amount and pace of DER make singular forecasts ineffective

Hosting capacity

- Must determine amount of DER a feeder can accommodate within three principal constraints: thermal, voltage/power quality and relay protection limits.

Locational value of DER

- Sourcing locational infrastructure or operational requirements from DER may result in positive or negative costs and benefits

Probabilistic-based engineering analysis

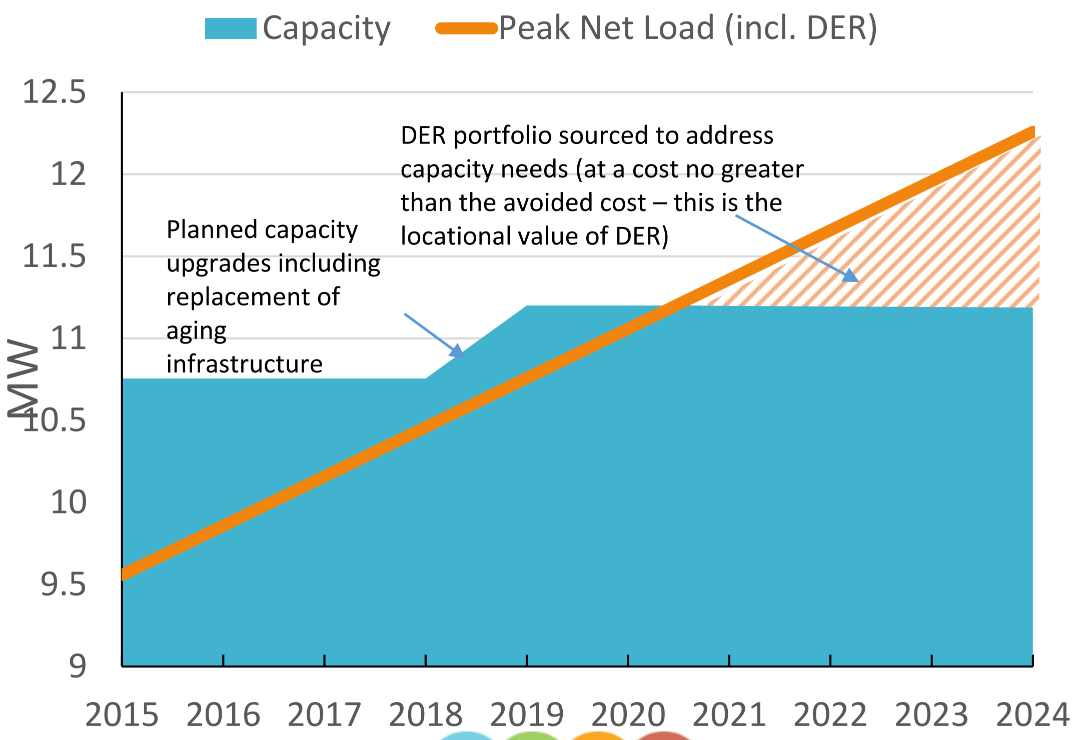
- Issues from increased DER penetration – variability of loading, voltage — require probabilistic analysis.

Integrated T&D planning

- At high DER, net load characteristics have impacts on transmission system / bulk power system operation, requiring transmission-distribution interaction analysis

Results: Better Planning, Greater Cost Avoidance, Smarter Investments, New Revenue & Service Capture, New Regulator Requirements Response

Deficiency in Feeder Capacity can be Addressed by Effective DER Portfolios

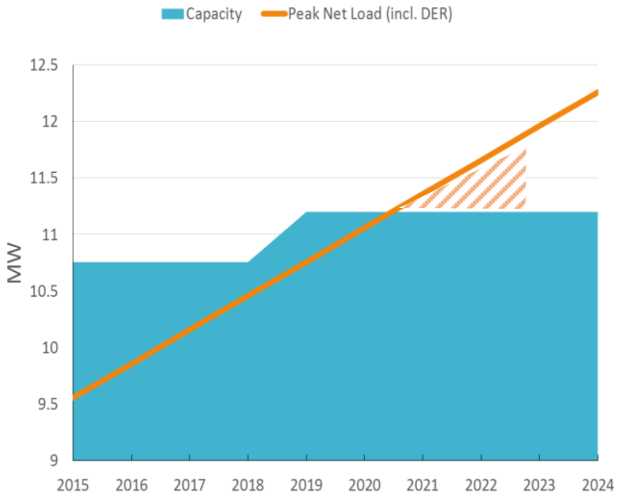


DER EXPANSION MAY REQUIRE CONSIDERABLE INVESTMENT, BUT PROVIDE EARNINGS OPPORTUNITIES FOR UTILITIES

Electric Reliability Investments

- Targeted feeder-substation upgrades to address DER penetration and reliability/safety
- ICF conducted a locational benefits analysis looking at 3,200 feeders on the PG&E system
- Assess the threshold at which DER penetration exceeds hosting capability
- T&D scale energy storage solutions
- Install Volt/Var Controls; Expand CVR Program

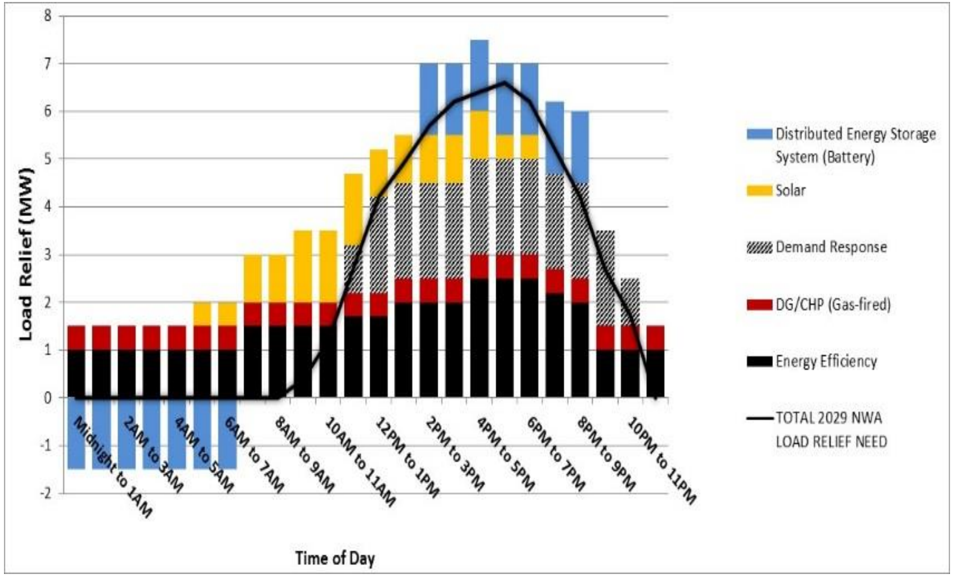
PG&E Example



FEEDER DEFICIENCY ASSESSMENT INFORMS FULL SYSTEM-WIDE LOCATIONAL BENEFIT ANALYSIS

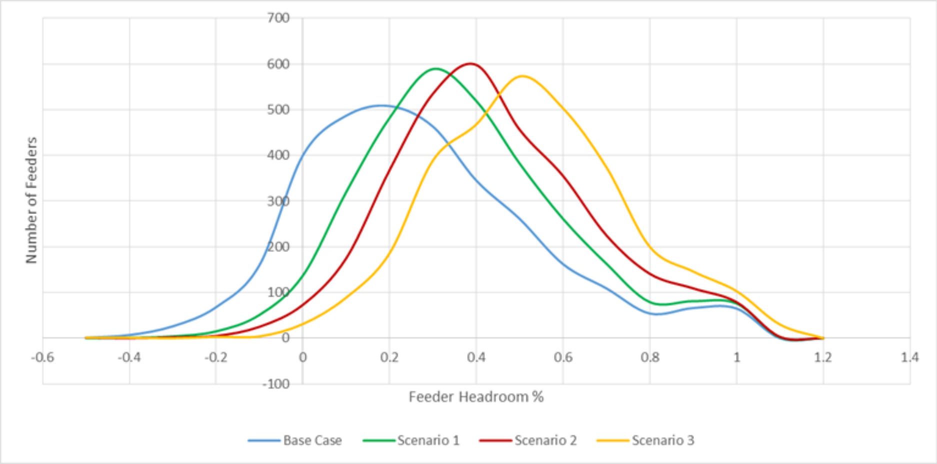
IT'S CRITICAL TO ANTICIPATE DER PORTFOLIO CONTRIBUTIONS AT THE FEEDER AND SYSTEM LEVELS

- Seamless, full cycle support for utility analysis & management of DER on utility's system
- Technology assessments & potential studies to designing, deploying & managing integrated portfolios
- Full spectrum of technology along with grid impacts & optimization to assess & develop tailored solutions
- Portfolio design & management, efficiency & capacity deferral



SCENARIO BASED PLANNING CAN LEAD TO MORE OPTIMIZED DER PORTFOLIOS CONSIDERING FEEDER HEADROOM AND HOSTING CAPACITY

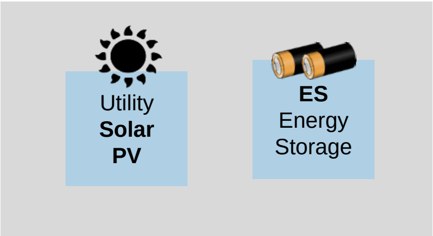
Shifting feeder headroom distribution to the right

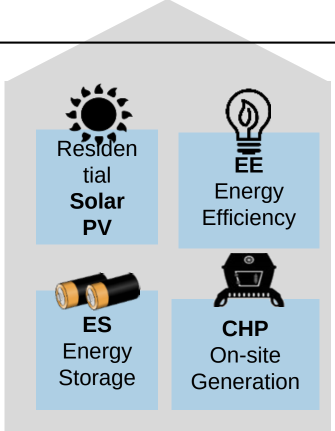


Integrated Analysis Components – Distribution System Model

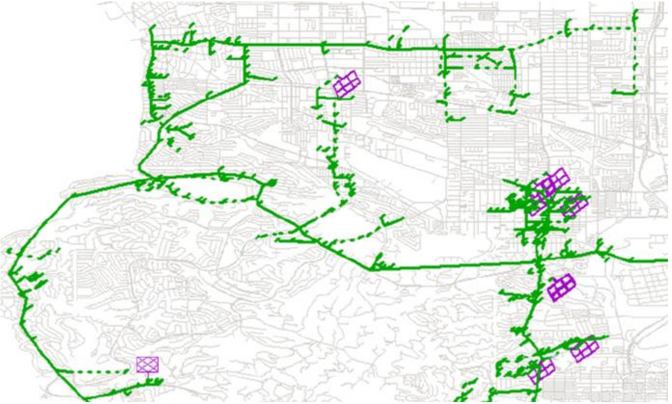
- Phase 1: **Distribution System** Impacts Scenario Analysis
- Phase 2: **Community level** optimization of DER solutions
- Phase 3: **Premises level** optimization of DER solutions

Community level DERs





Premises level DERs



Distribution System

TODAY: DER SOURCING THROUGH THE 3Ps

- As developing in CA & NY, each P sourcing method requires proper valuation of DER for a specific grid need and by time and location

Pricing	NEM 2.0 Time/location varying rates Tariff based standard offers for services like VVO
Programs	• Energy Efficiency • Demand Response • DG/DS Incentive Programs • NWA
Procurement	• Request for Proposals/Offers • PPAs • Grid support services

Overall Conclusions

- Locational net value is key
  - Must also factor in temporal value
- Aligning pricing, programs, and procurement to hosting capacity and locational value is essential
- Analysis needs to improve
- This is hard, but achievable
- Methodologies must be scalable
- Regulatory structures must keep pace

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