City of Hartford: An example of a Real-world Microgrid

Plenary Session 1

Quantifying the Power of Distributed Energy Resources

NIST Workshop

New York City; December 6, 2016

Mats Bergquist

Constellation Distributed Energy

Constellation. An Exelon Company

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America's energy choice.℠

Constellation: Who We Are

#1 C&I Power provider in the US

8th largest Gas provider in the US

Approximately
2 million
customers served

Continually investing in emerging energy **technologies**

Headquarters:
Baltimore, MD

Investing over **$1 billion** in **distributed energy assets** since 2010

Delivering RECs for customers enabling them to avoid **1.2 million metric tons** of **GHG in 2015**

Dedicated team of Regulatory, Market & Wholesale Experts

*2015 data

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The Constellation Distributed Energy Approach

Value for Customers

Management and operation services for complex energy assets from experienced generation operator and wholesale market expert

Attractive financials: no upfront capital requirements, long-term contract backed by Fortune 500 company, and increased budget predictability

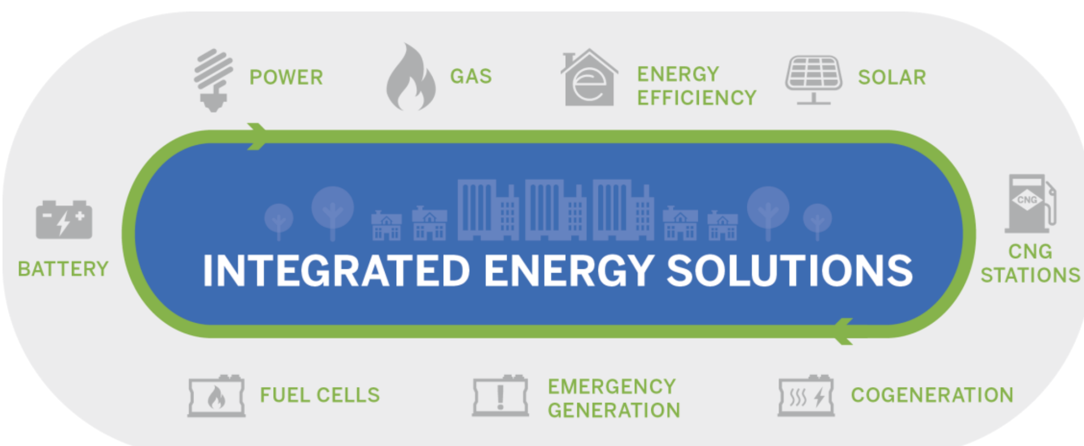
"**One stop shop**" for energy management expertise

Operational and revenue-stream efficiencies to alleviate customers' financial burden for needed infrastructure

Scalable assets with customizable **turnkey solutions**

Support of corporate **sustainability and emissions reduction goals**

Connecting Energy Users to Energy Choices



Constellation is a leader in developing behind-the-meter energy solutions, and has invested over $1 billion in distributed energy assets since 2010

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City of Hartford: An example of a Real-world Microgrid in Parkville

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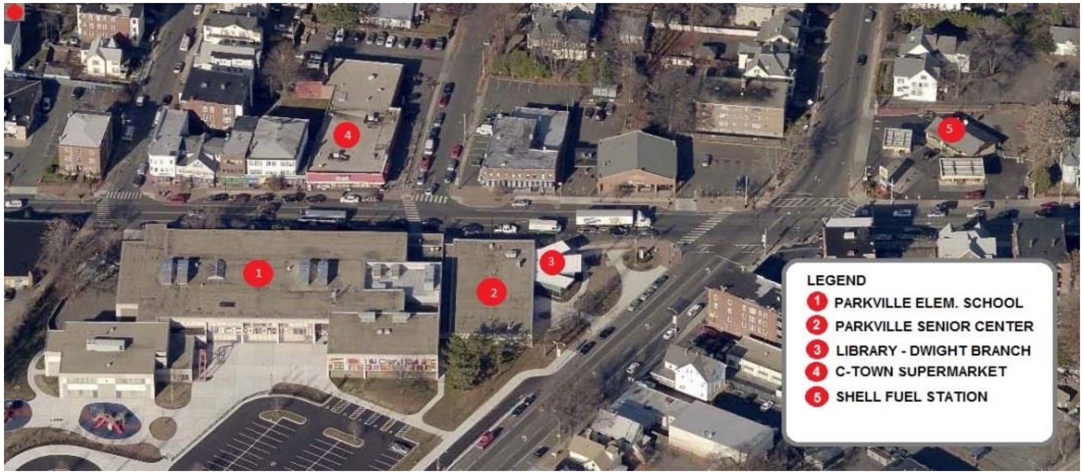
Parkville Microgrid: Summary

Size	800 kW grid parallel / 600kW microgrid-mode
Power Generation Technology	Bloom Energy Servers (4 ES5 fuel cells x 200kW) + 1 Uninterruptible Power Module (UPM)
Microgrid Equipment	Switchgear and Cabling
Microgrid Owner	Eversource
Fuel Cell Owner	Constellation / Bloom Energy
EPC Provider	Constellation
Developer / Construction Manager	Constellation/GI Energy
Utilities	Eversource; Connecticut Natural Gas
Interconnection	Parallel Grid Connection + Critical Load (microgrid mode)
Contracts	• EPC Agreement between Constellation and Hartford • O&M Agreement between Constellation and Hartford • Power Purchase Agreement between Bloom/Constellation “ProjectCo” and City of Hartford
Target COD	12/30/16



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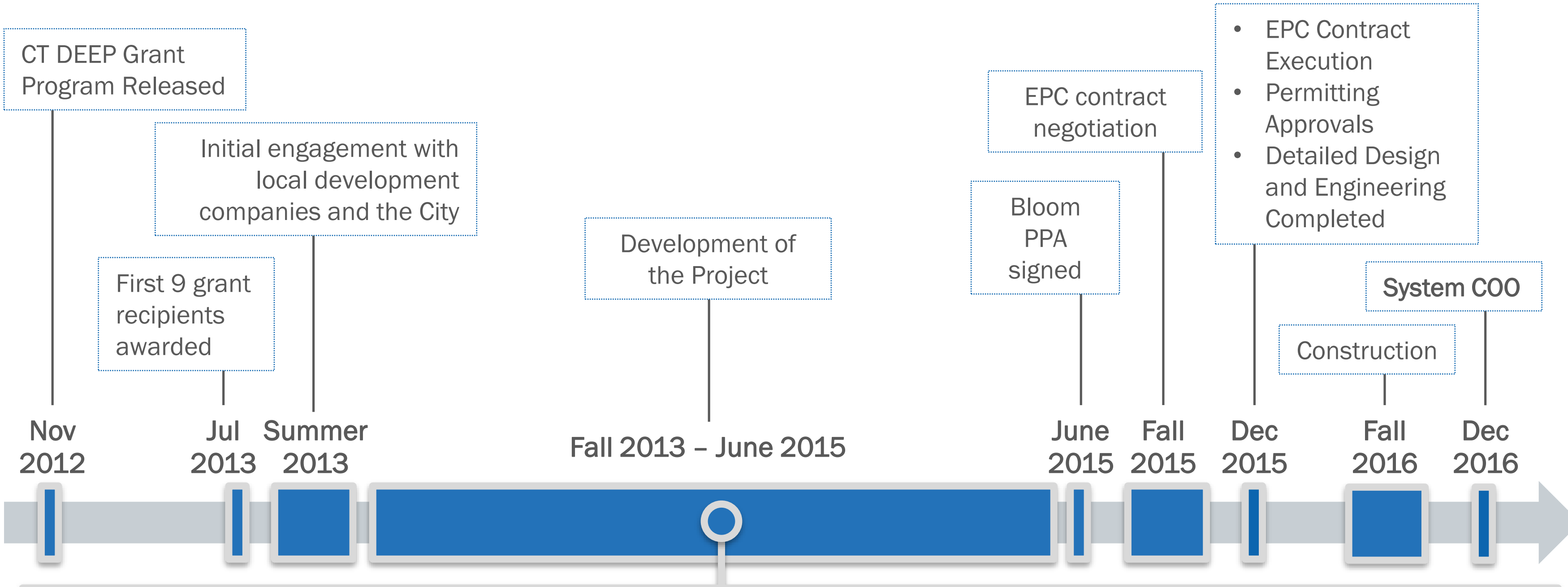
Parkville Microgrid: Life of the Deal



Key Development Activities

- **Selection of generator technology**: Initially CHP but lack of onsite heat load led to use of a Bloom fuel cell
- **CT LREC bid submission and award:** Bidding strategy required to ensure you are “picked up” while protecting project economics
- **Virtual Net Metering:** Site load under normal conditions @ 20% of fuel cell output required a structure to export excess energy that is only used by the microgrid during grid outages
- **Optimal ownership structure:** SPE ownership structure necessary for economics but not standard for Constellation-owned business model or microgrids in general
- **Securing Eversource engagement and sign-off**: New model for all parties requiring a collaborative effort
- **Ensure adequate pipeline gas pressure:** Dedicated high pressure gas line for Bloom fuel cell provides extra reliability but greater upfront cost

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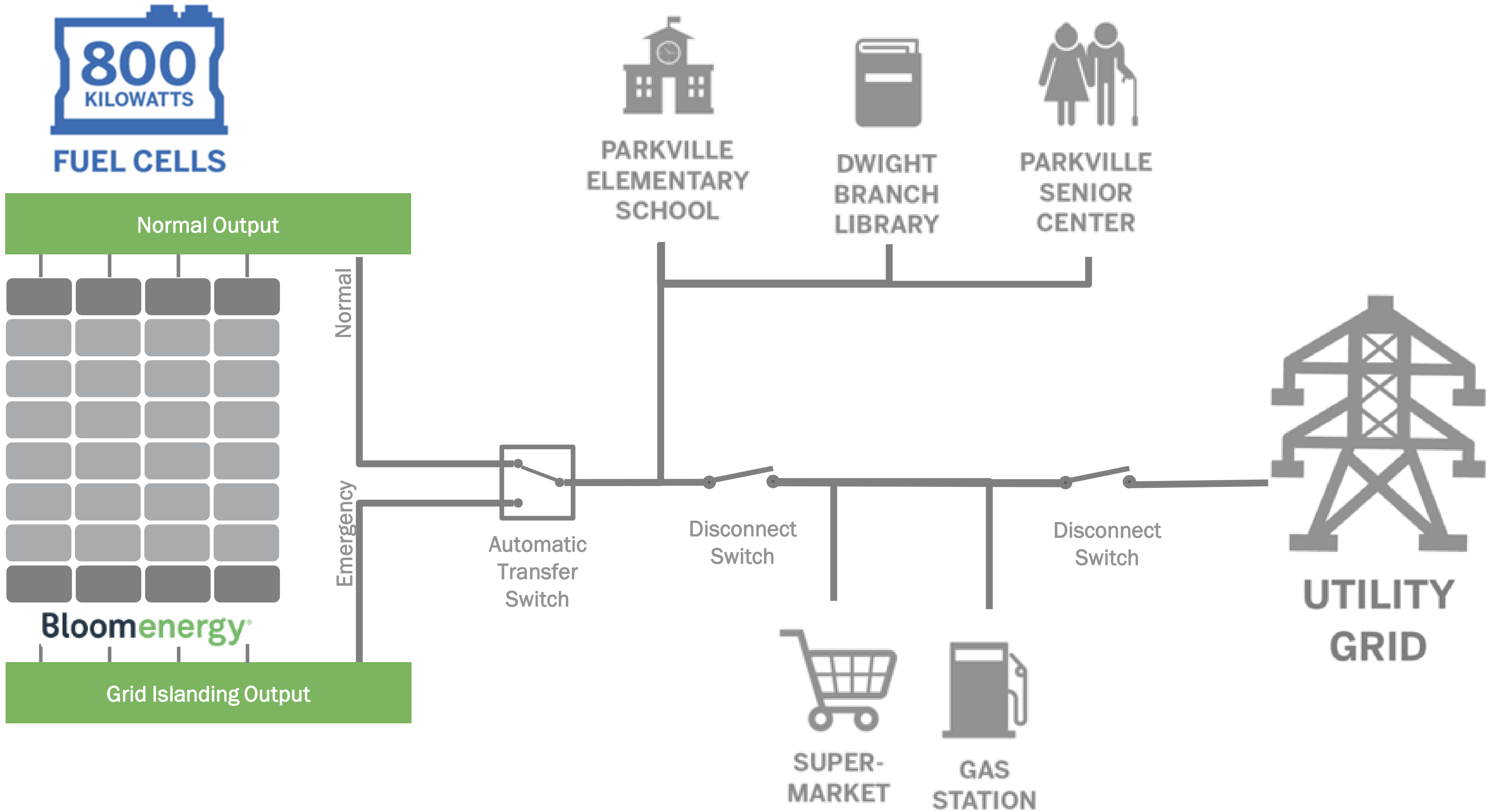
Parkville Microgrid: Configuration



Excess electricity generated by the system reduces electricity costs at four Hartford schools.

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Results

- A microgrid system that will help manage electricity costs and supply emergency power to a portion of the city's Parkville neighborhood

- Connecticut's first microgrid to be developed thorough a public-private effort

- One of the first microgrids to be developed under Connecticut's Department of Energy & Environmental Protection (DEEP) Microgrid Grant Program

- **Proof that utilities, project developers, manufacturers, state and local government, and project owners CAN work together to make fuel cell projects happen …**

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Challenges

- ❑ **Economically viable (at or below current cost of electricity)**
  - LREC (Low Renewable Energy Credit)
  - DEEP Grant
  - Ability to use tax assets (ITC and depreciation)
  - Virtual net-metering legislation
- ❑ **Technology selection**
  - Very little thermal load resulted in switch from a traditional CHP utilizing a reciprocating engine to a Bloom fuel cell
- ❑ **Technical hurdles**
  - Interconnection
  - Gas pressure
  - Fuel cell system working as a micro grid, including spare UPM
- ❑ **Complexity of the Transaction**
  - Many players involved in the Micro Grid – Eversource, Constellation, Bloom, Bloom/Constellation SPE, City and other facilities. Coordination and ability to migrate through varied complexities (VNM, DEEP…)
  - Non-standard Commercial arrangements resulting in uniquely crafted contracts and agreements
- ❑ **"Dumb Grid" Configuration**
  - No tangible financial benefit to a "smart-grid" configuration resulting in a manual operation
- ❑ **Microgrid Ownership**
  - Utility maintains ownership and responsibility of the Microgrid even when segregated from the Utility Grid

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In Closing

Thank you for your time…

Q&A

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LO3 ENERGY

Distributed grid solutions that bring people, utilities and technology together

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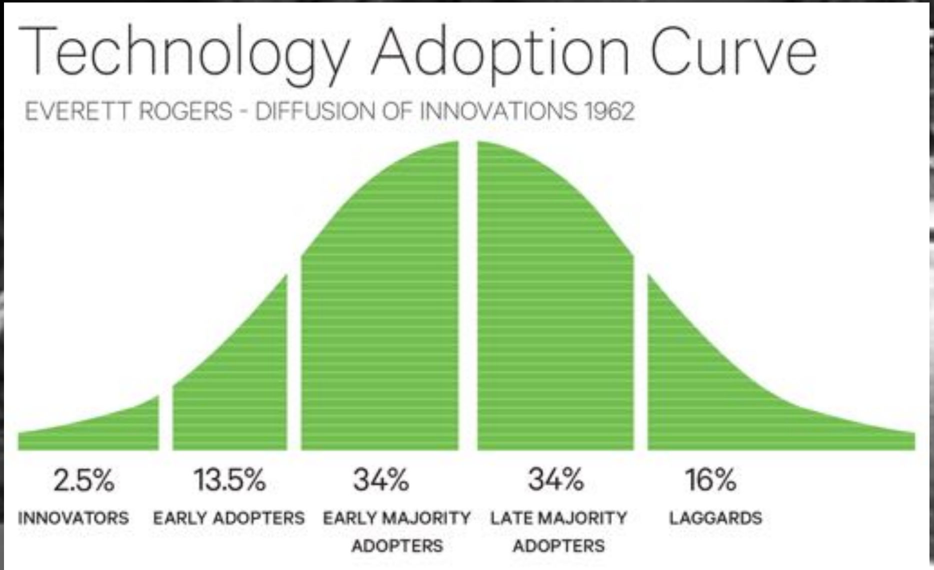
LO3 Energy Background

- An energy company applying well-developed strategies for market transformation and adoption of new tech
- Founded in 2012
- Company background in:
  - Energy Program Design
  - Community Engagement
  - EM&V
  - Codes and Standards
  - REC and Green Power Markets
  - Blockchain
  - Advanced Meters
  - System Architecture
  - Computation



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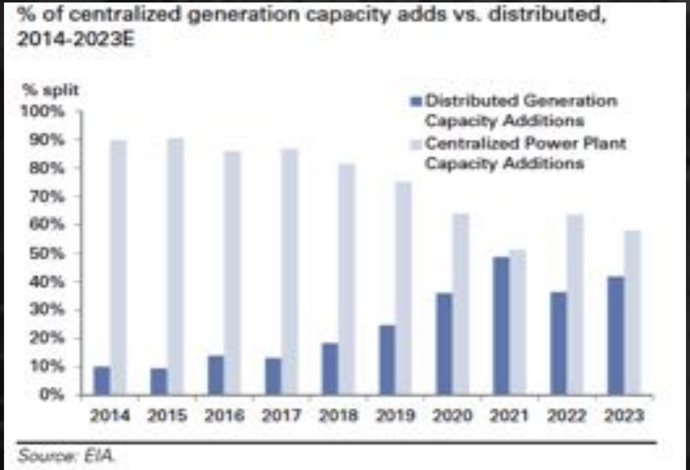
LO3 Energy Tech

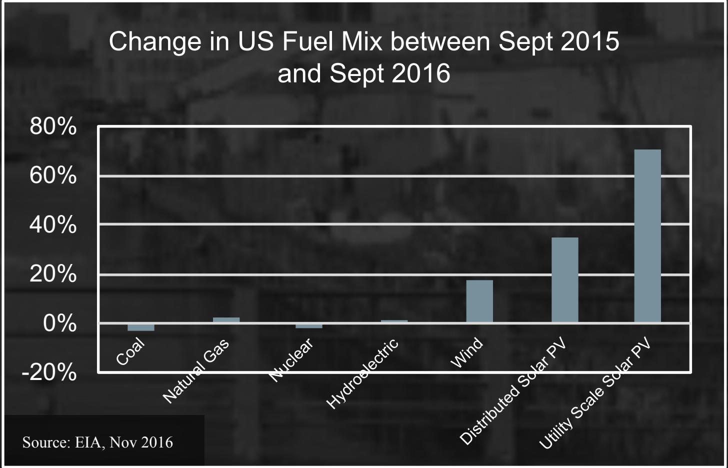
- Measure energy flows and hash information to blockchain
- Patented, proprietary and UL-listed
- Next generation AMI
- Network through a variety of communication protocols and write smart contracts within the network

LO3 ENERGY

Background

New Energy Resources are Renewable and Distributed





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

LO3 ENERGY

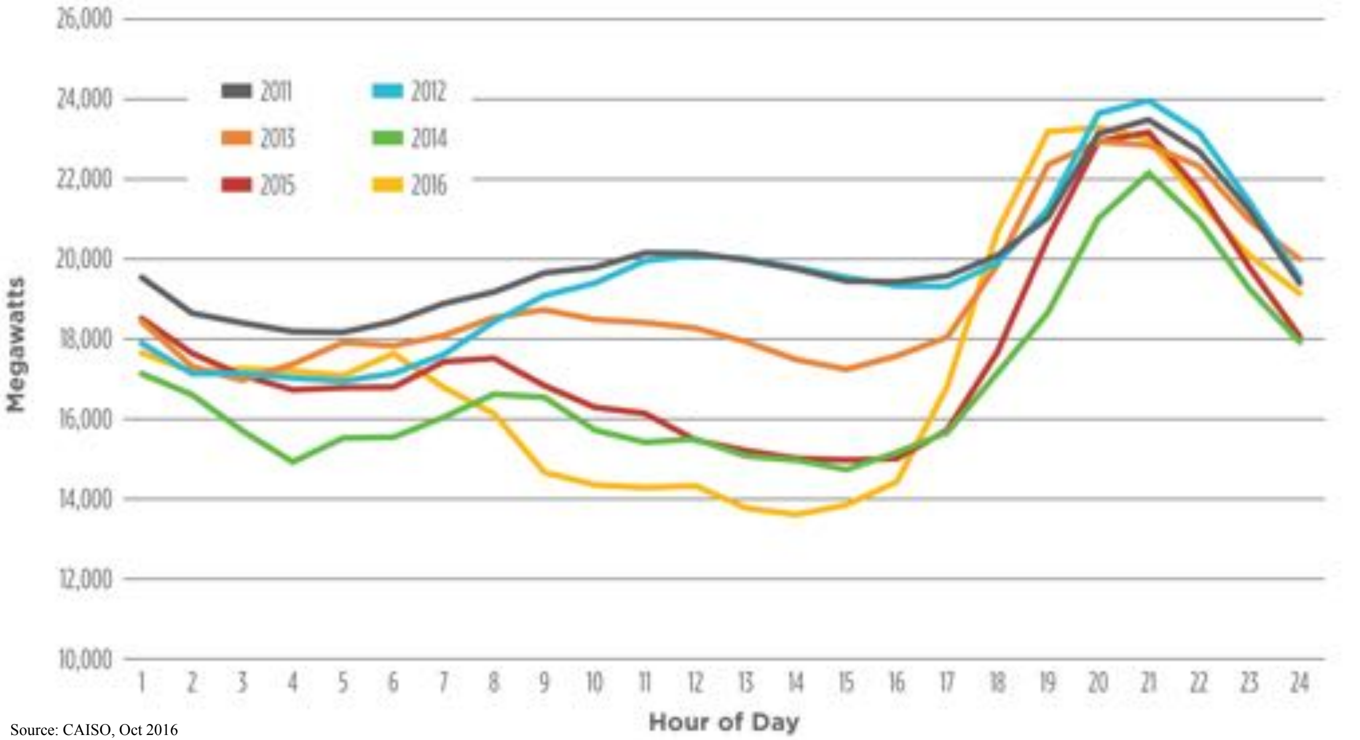
Problem

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

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 LBMP + D
- Energy supply based on values and economics
- Resiliency
- Circular benefits

TransActive Grid

LO3 ENERGY

Prosumer (Energy Surplus)

Smart Meter

Consumer (Buyer of energy surplus)

Regular Meter

Microgrid Energy Market

Community and Utility DERs

Regional Renewable Provider

Community Renewable Energy

Community Non - Renewable Energy

Regional Renewable (REC)

Regional Non-Renewable

Consumers have much more choice and can create personalized energy sourcing profiles

- Example: 80% from regional renewables and 20% from local microgrid

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TransActive Grid

Milestones

Smart Meter Proliferation

- Price discovery & Energy Transaction with microgrid members
- Real-time, location based energy market

Transact on consumer values

- Price, green energy, clean signals, social good
- Multi-factor tokens to encourage what you want to see in the market

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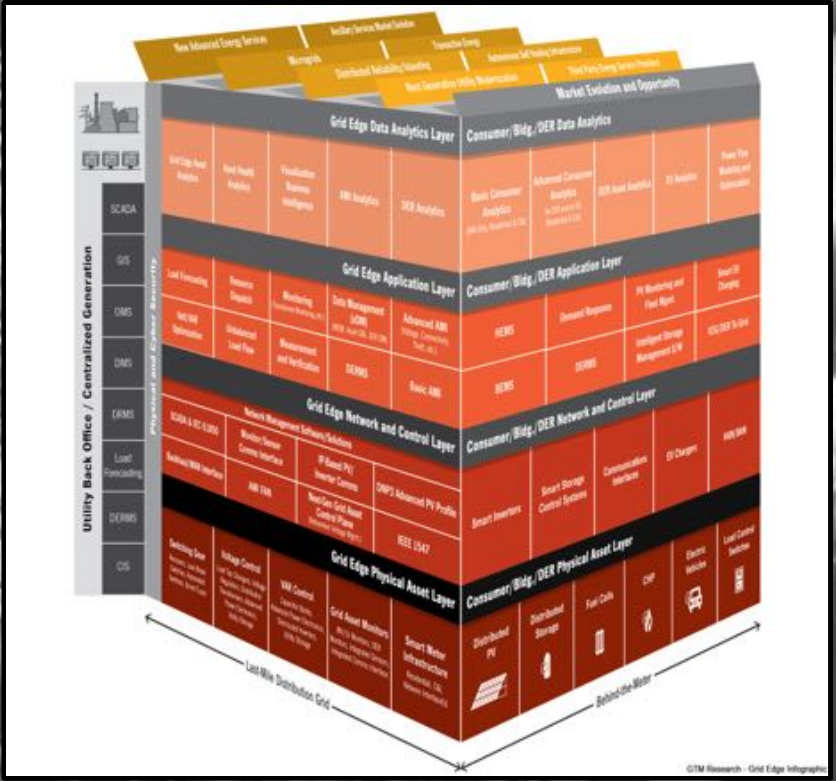
TransActive Grid

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



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**

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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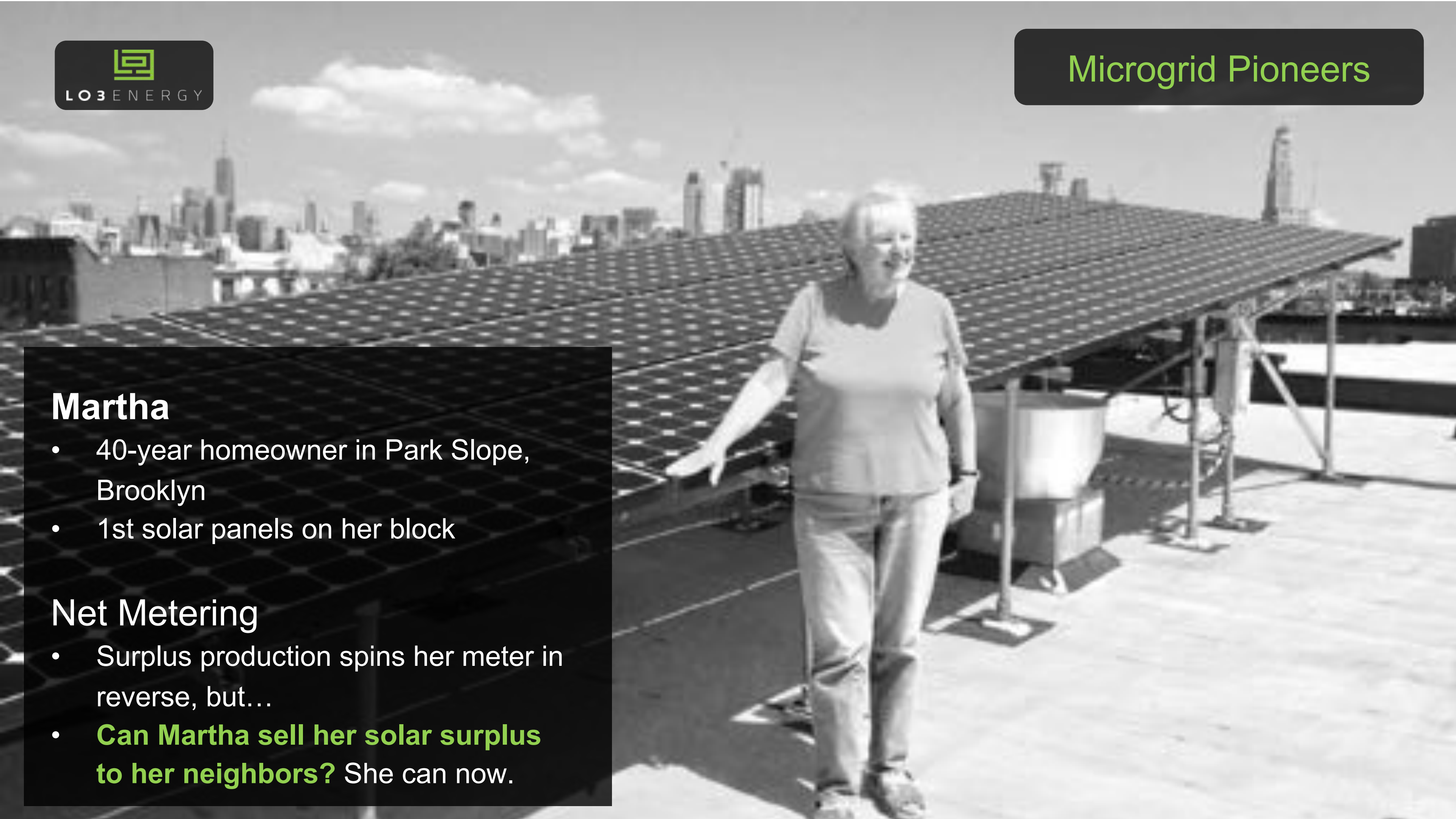
BROOKLYN
MICROGRID



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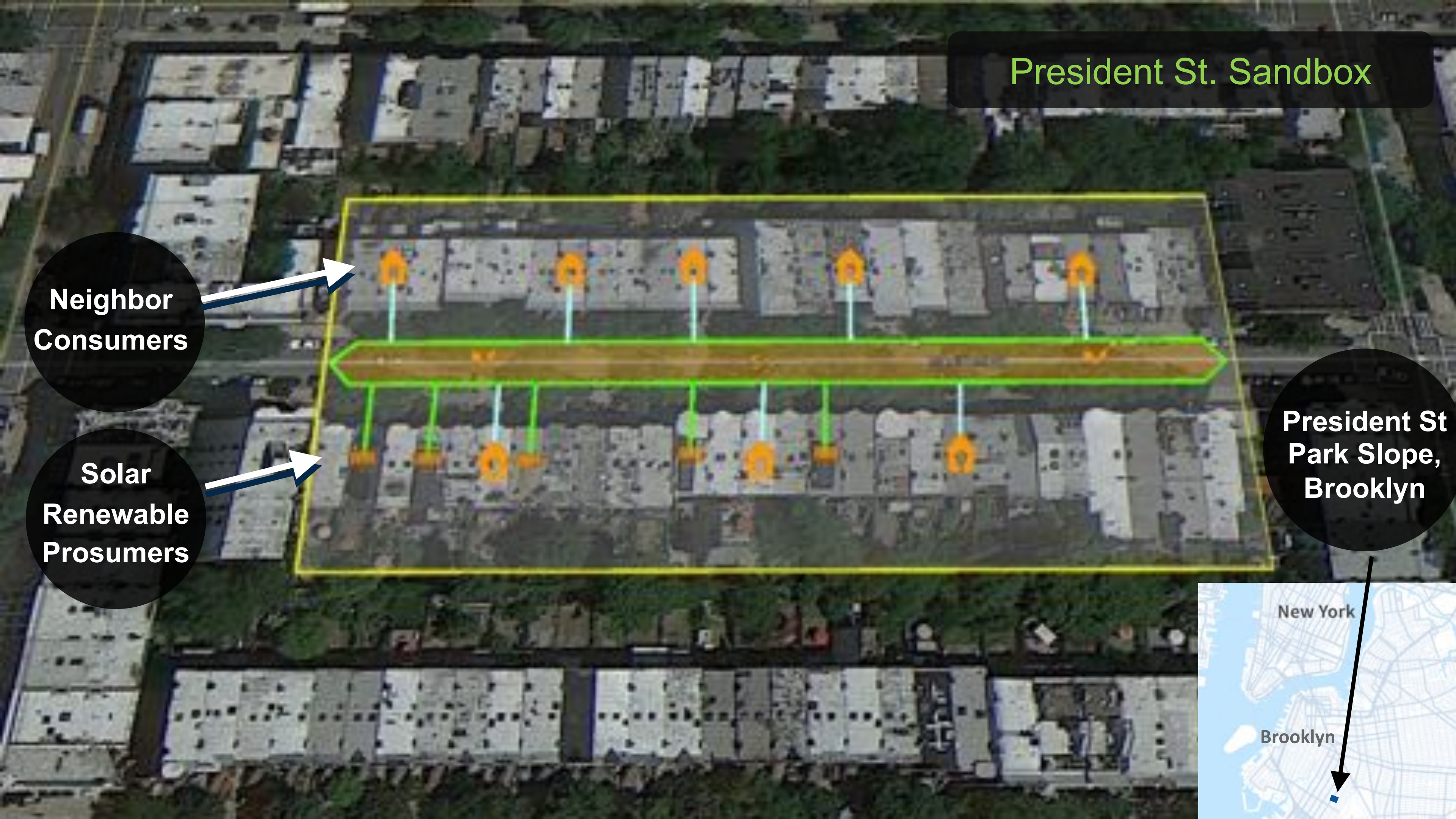
Microgrid Pioneers

Martha

- 40-year homeowner in Park Slope, Brooklyn
- 1st solar panels on her block

Net Metering

- Surplus production spins her meter in reverse, but…
- **Can Martha sell her solar surplus to her neighbors?** She can now.


President St. Sandbox
Neighbor Consumers
Solar Renewable Prosumers
President St Park Slope, Brooklyn
New York
Brooklyn

We Choose Local Green Energy

Community Energy

locally generated with community assets

Microgrid Markets

local energy market, revenues and increased system resilience

TransActive Grid

secure platform for peer-2-peer transactive energy and markets

Current Status & Next Steps

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

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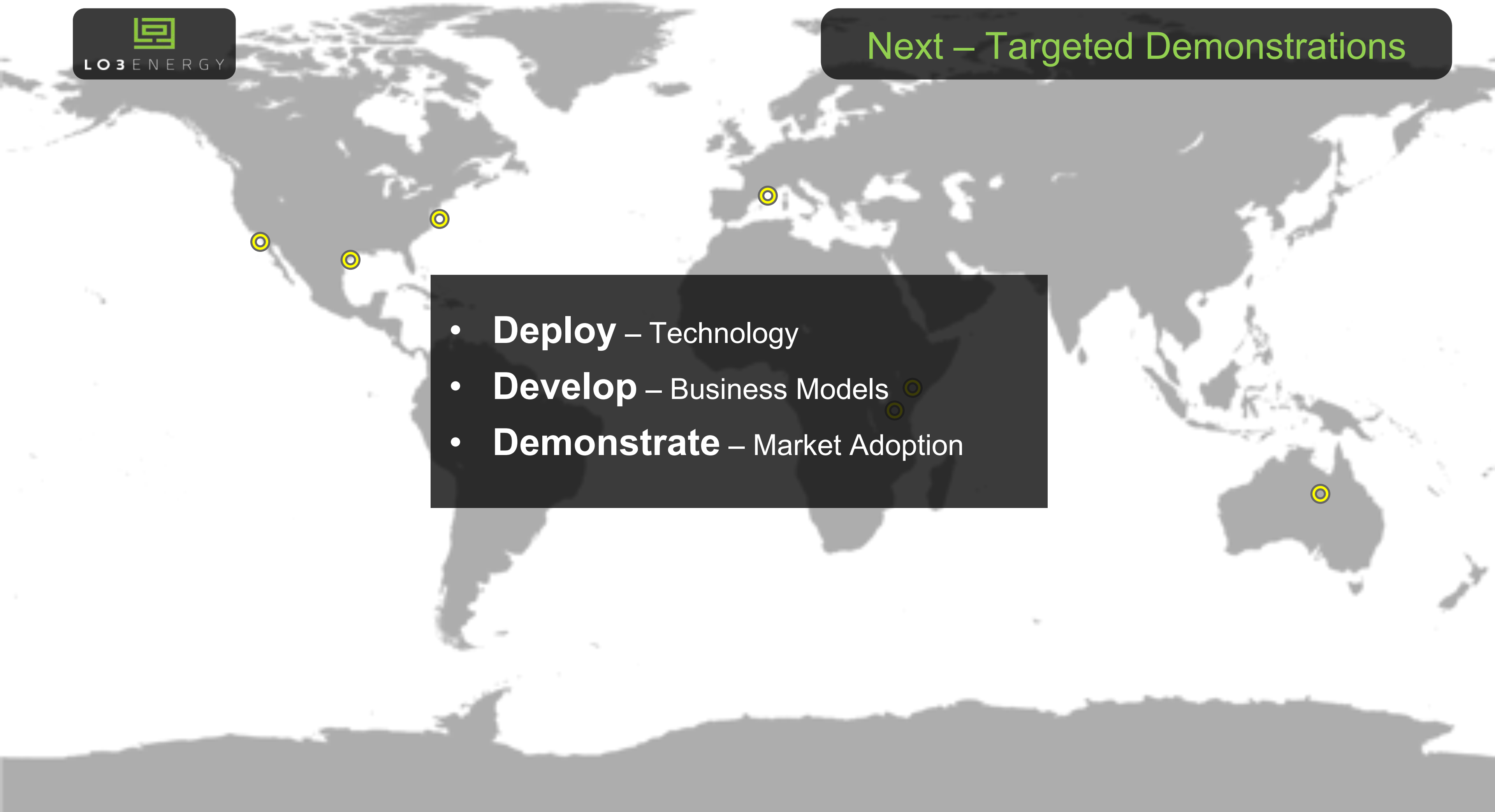
Next – Targeted Demonstrations



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

New Technology – New Choices – New Deal

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

LO3 ENERGY

Buildings and the Smart Grid

Steven T. Bushby
Group Leader, Engineering Laboratory
NIST Embedded Intelligence in Buildings Program

Quantifying the Power of Distributed Energy Resources
December 6, 2016

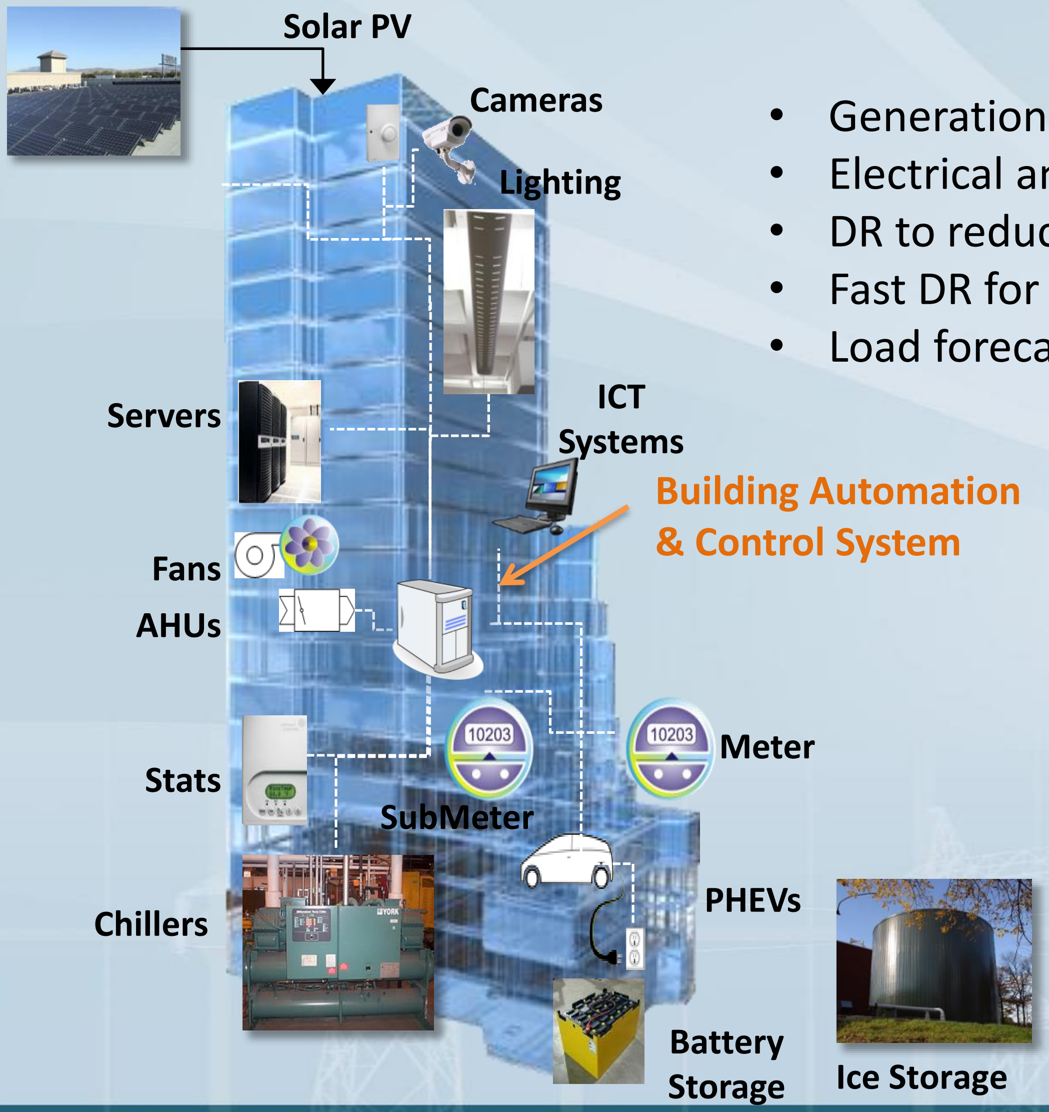
National Institute of Standards and Technology
U.S. Department of Commerce

There is no Smart Grid without Smart Buildings!

- 72% of electricity is consumed in buildings (40% commercial, 32% residential)
- As we approach national goals of net-zero energy buildings, renewable generation sources connected to buildings will become increasingly important
- As the nation migrates to electric vehicles, they will be plugged in to buildings

Buildings will no longer be a dumb load at the end of the wire. They will become an integral part of the grid.

Building Resources Potentially Available to the Grid

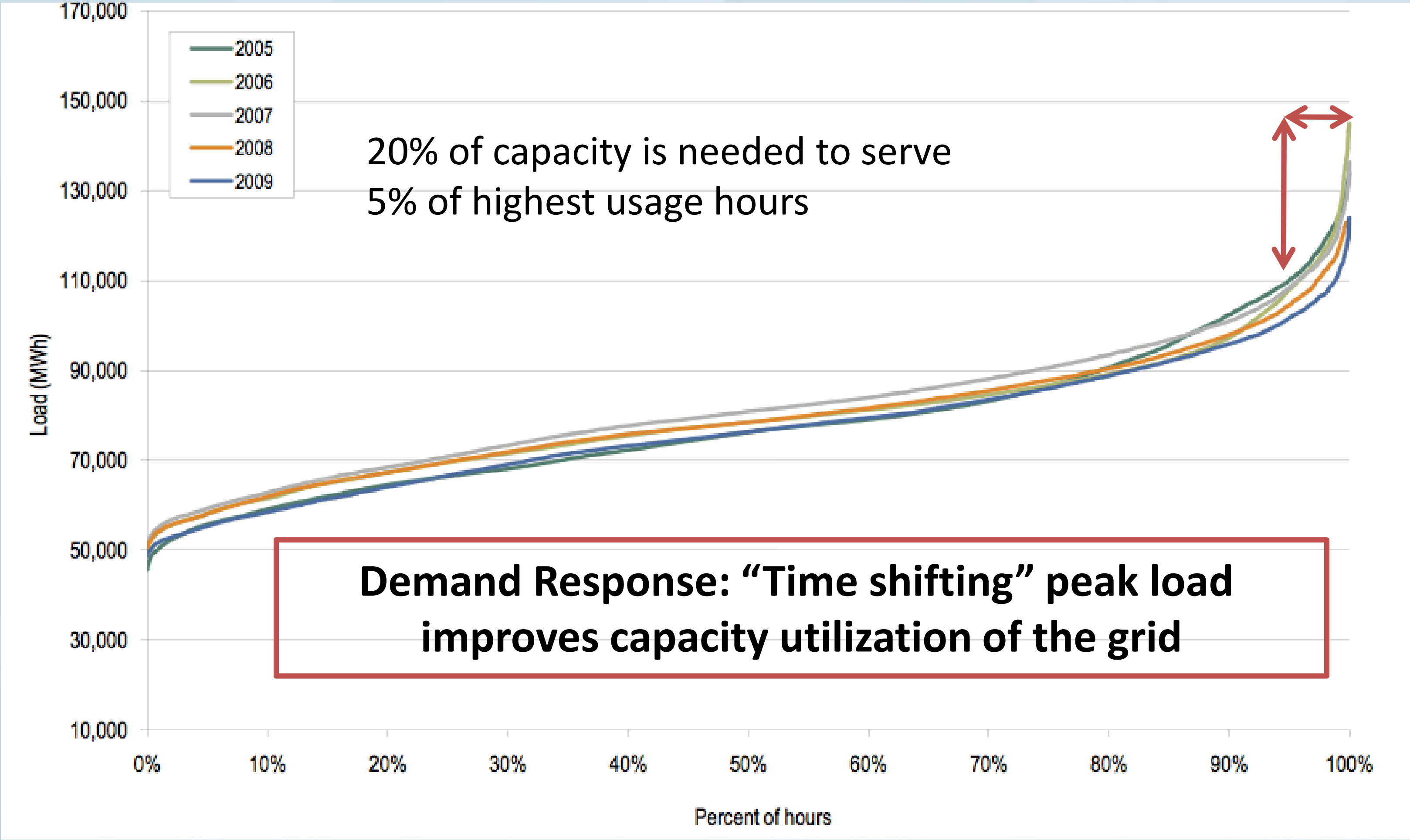


- Generation
- Electrical and thermal storage
- DR to reduce peaks
- Fast DR for some ancillary services
- Load forecasts to improve planning

The scale in homes is much smaller but there are many of them.

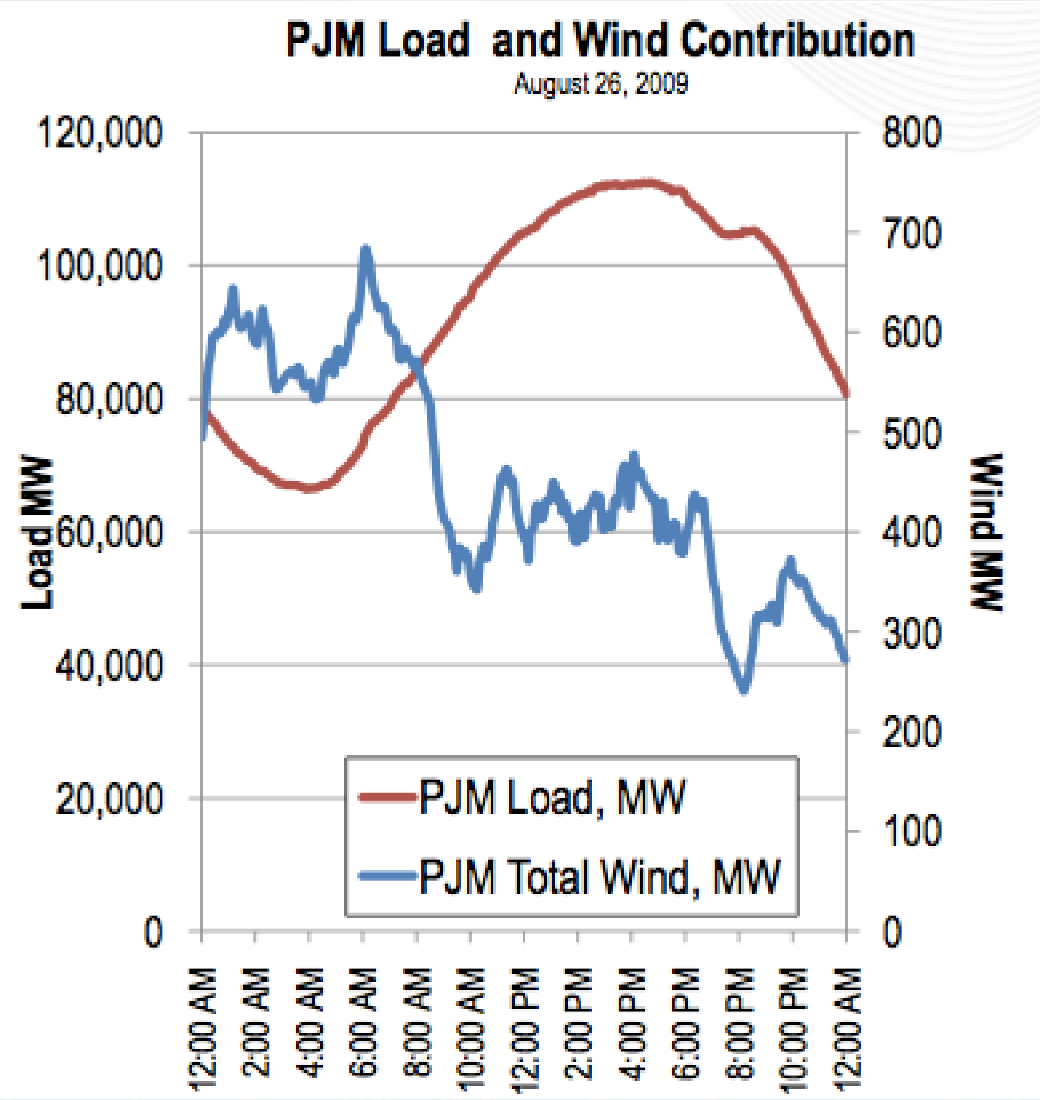
Buildings Can Improve Capacity Utilization

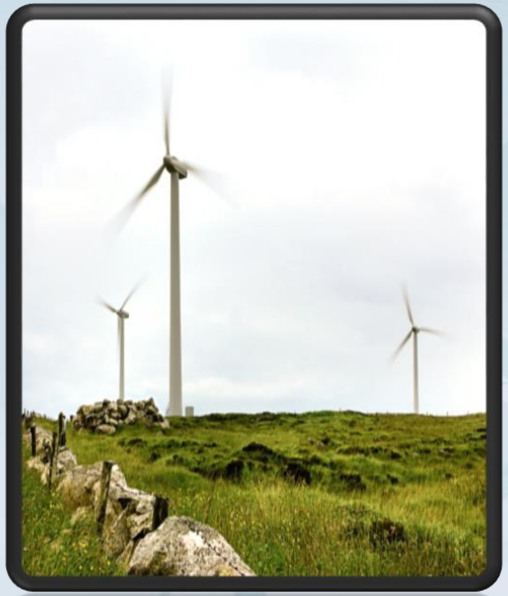
PJM Real Time Load Duration



Source: PJM (a Regional Transmission Organization part of the Eastern Interconnection grid)

Buildings Can Help Integrate Renewables





Renewable sources have their own challenges

- Intermittency
- Need for storage
- Need for power conditioning, quality, conversion systems
- Not all renewables are equally "green"

Today’s Automation and Control Technology

- Industrial – Ubiquitous, mature, capable but generally not configured to support grid needs
- Large Commercial –
  - Installed base slow to change (20 year life)
  - BACnet the dominant technology being installed today
  - Strong trend towards greater system integration and more sophisticated control strategies
- Small Commercial
  - Limited automation and control – mostly thermostats
- Residential
  - Limited automation and control – mostly thermostats

Control System Trends

ASHRAE NEMA
FSGIM
Facility Smart Grid Information Model
Standard 201

PURPOSE: The purpose of this standard is to define an abstract, object-oriented information model to enable appliances and control systems in homes, buildings, and industrial facilities to manage electrical loads and generation sources in response to communication with a “smart” electrical grid and to communicate information about those electrical loads to utility and other electrical service providers.

ASHRAE NEMA

FSGIM

Facility Smart Grid Information Model

Standard 201

The model will support a wide range of energy management applications and electrical service provider interactions including:

(a) on-site generation,
(b) demand response,
(c) electrical storage,
(d) peak demand management,
(e) forward power usage estimation,
(f) load shedding capability estimation,
(g) end load monitoring (sub metering),
(h) power quality of service monitoring,
(i) utilization of historical energy consumption data, and
(j) direct load control.

How Do You Model Device Energy Management?

Imagine modeling all devices behind the ESI as either an energy manager, energy meter, energy generator, or energy load.

Generator

Load

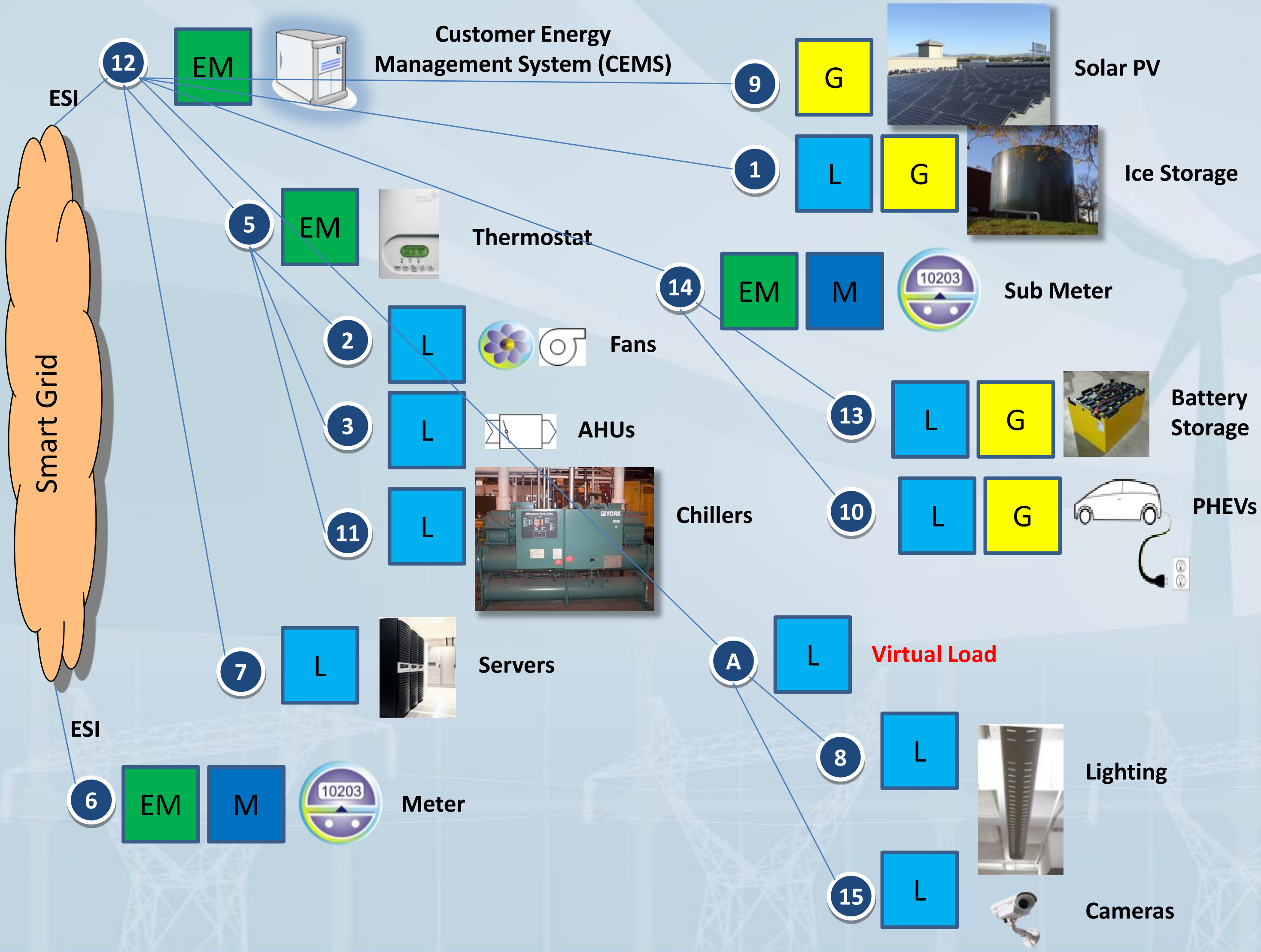
Meter

Energy Manager

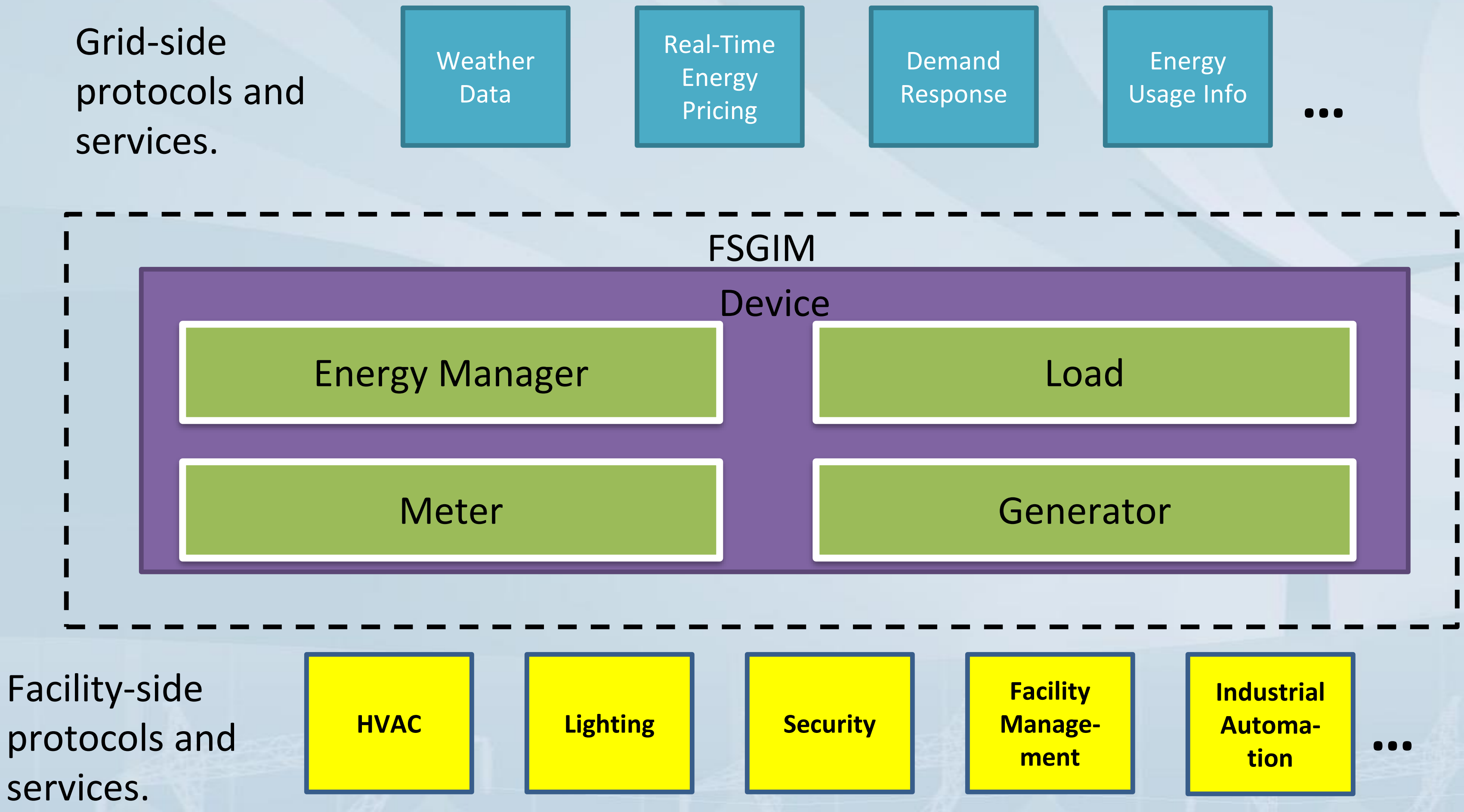
Examples might be:

EMS = Energy Manager
Smart Appliance = Energy Manager + Load
Battery = Generator + Load
Premise sub-meter = Meter

Composition of Devices from Components



FSGIM Overview

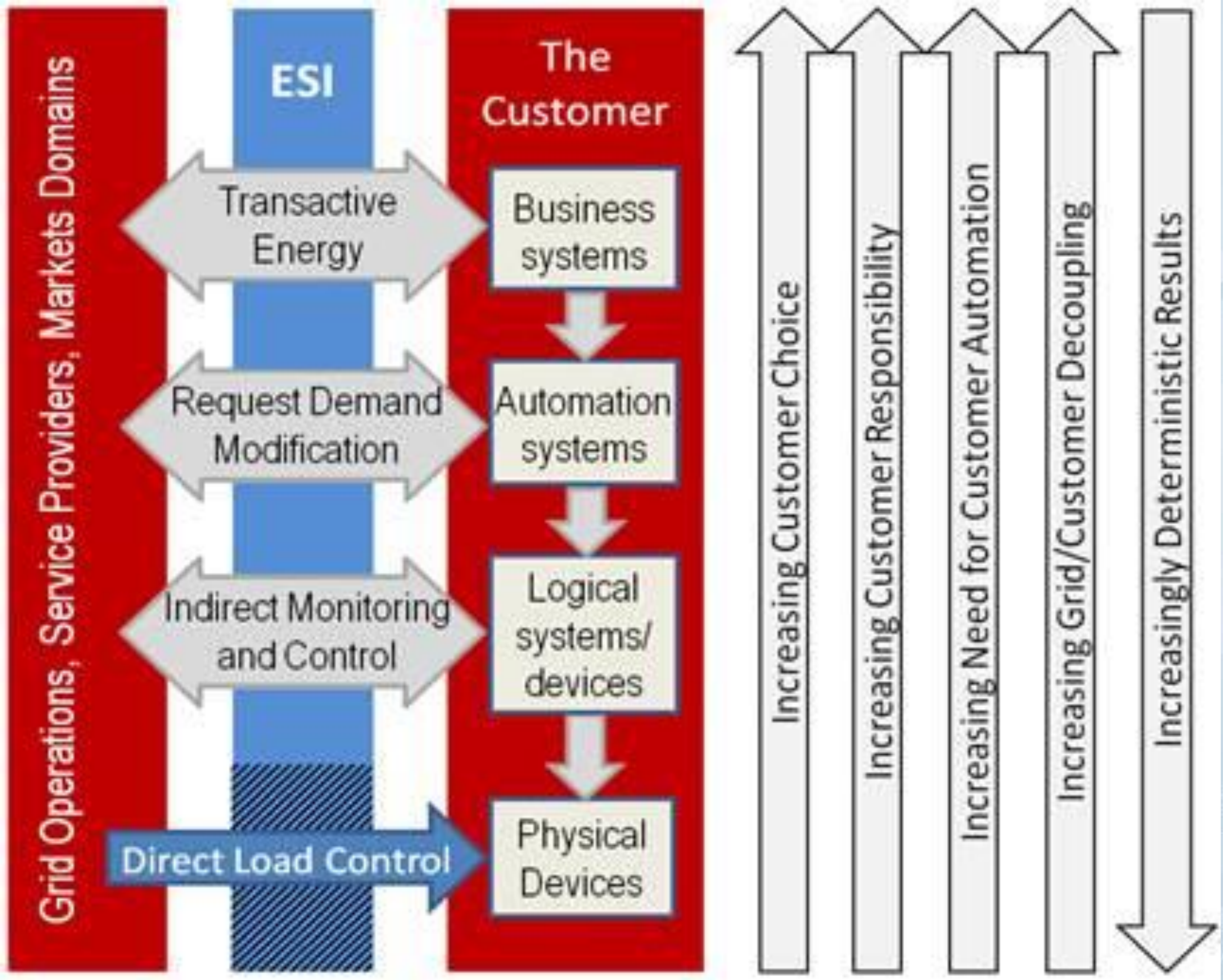


Impact of the FSGIM

- Compatible with Green Button, OpenADR and weather information services
- Provides standard aggregations that will work in a multi-vendor environment
- Can represent load curves for predicting energy and power consumption or selecting control points

Control technology standards groups are beginning to develop technology specific implementations of the FSGIM

Spectrum of Possibilities for Delivering TE Services to the Grid



The Evolution of Control Technologies and TE Services Will be Driven by Market Forces

Focus Questions Part 1:

What services & technologies will customers and aggregators bring to the grid today and in the future?

How do/will you get paid for these services?

How can this transaction be improved?

NIST Transactive Energy Challenge

Modeling and simulation for the transactive Smart Grid

David Holmberg

TE Challenge Lead, Engineering Laboratory
NIST Smart Grid Program

New York City Workshop

December 6, 2016

TRANSACTIVE ENERGY CHALLENGE
Modeling and Simulation for Grid Challenges

TE Challenge Goals

1. **Simulation tools and platforms**
    1. Demonstrate how different TE approaches can improve reliability and efficiency of the electric grid to address today's grid challenges
    2. Make use of Phase I-developed co-simulation platform, reference grid, scenarios and metrics to allow comparable results.
    3. Develop a repository of co-simulation platform components.
2. **Collaboration**—promote collaboration among industry stakeholders.
3. **Progress**—work toward implementation of TE applications.
4. **Communication**—provide a stage for teams to present the exciting work they've accomplished.

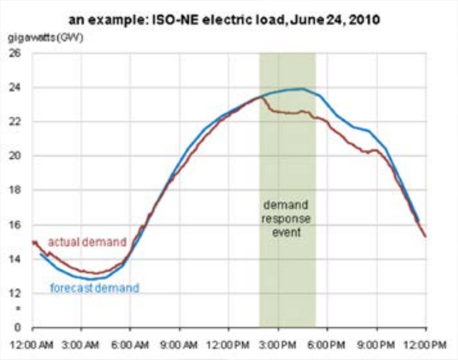
→ Deliver value to utilities, regulators, policy makers and other stakeholders in understanding, testing, and applying TE to meet today's grid challenges.

Timeline

- September 2015: Launch of Phase I and formation of 7 teams
- Summer 2016: Completion of Phase I team efforts, development of Co-simulation platform architecture
- September 20: Phase I Capstone meeting
- Fall 2016
  - Implementation of basic components of a co-simulation platform tool set.
  - Outreach meetings in San Jose, and NYC
- Early 2017 TE Simulation Challenge Phase II Launch.
  - Focus on TE simulation based on co-simulation platform tools, in addition to
  - Collaboration, demonstration, understanding and communication
- Collaboration site: https://pages.nist.gov/TEChallenge/ gives access to the latest documents
  - JOIN US!

TE Application Landscape Scenarios

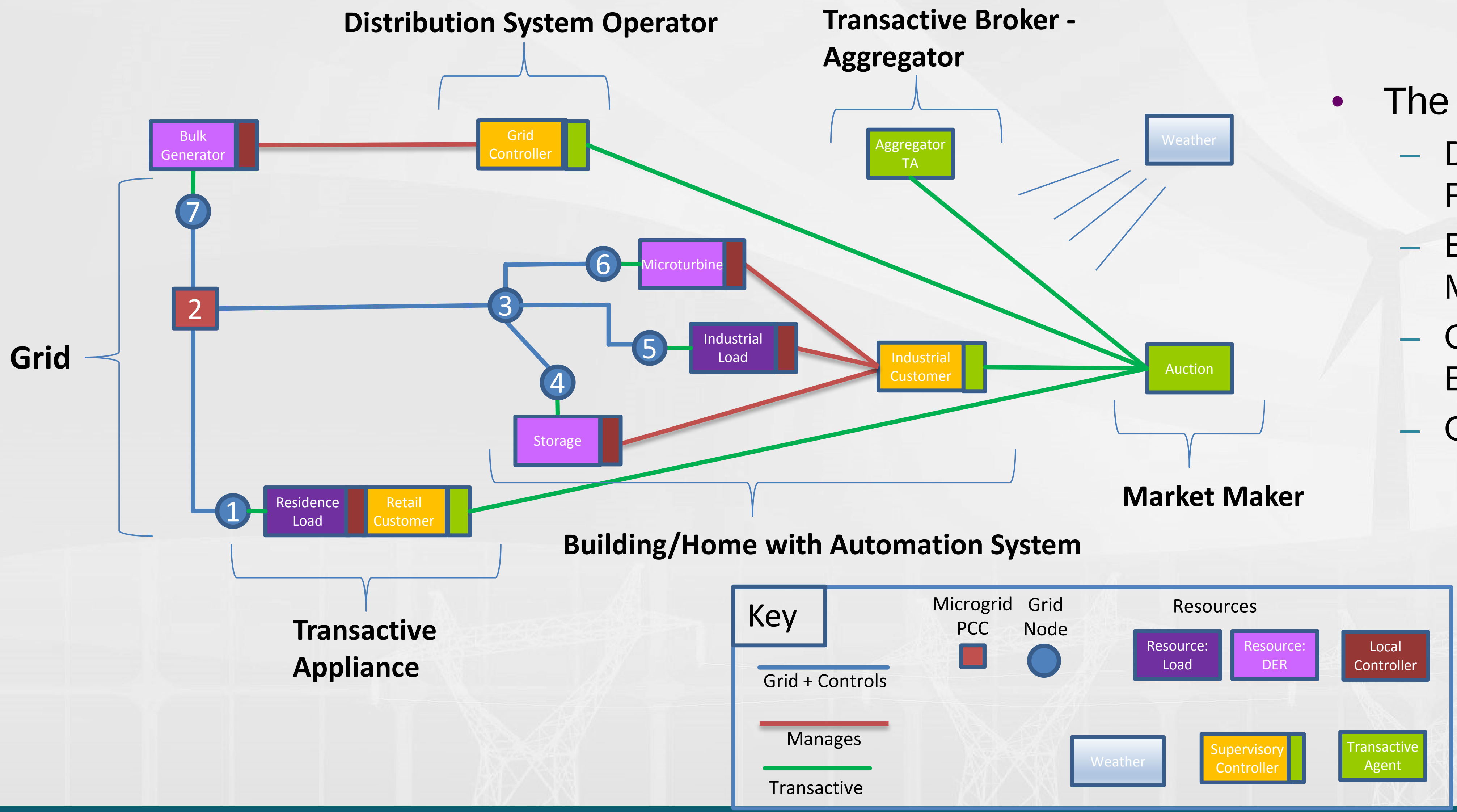
- TE use cases (in pre-read)
  - Cover the landscape of TE applications—how we think TE can support grid operations.
  - To be combined with reference grids, environmental conditions, analytics.
  - 6 use cases:
    1. Peak-day DR
    2. Wind energy balancing reserves
    3. Voltage control for high-penetration distribution circuits
    4. Concentrated EVs
    5. Islanded microgrid energy balancing
    6. System constraint resulting in sudden loss of supply



TE Landscape Scenarios paper abstract

- This paper presents an analysis of the transactive energy (TE) application landscape, specifically examining the ***transactive process***, ***business functions***, ***actors*** in different smart grid (SG) application domains, and ***time scales*** as dimensions of the landscape.
- Six high-level, operational scenarios are presented which cover the TE dimensions, and which can collectively be used to explore TE interactions.
- The paper also reviews the process that was used to analyze the TE landscape, including use case analyses, TE mind map, and a transactive agent interaction model.
- Paper is available on the SGIP.org website (white papers).

Summer progress on Co-simulation Framework



- The Results
  - Draft Technical Framework
  - Extensible Component Model
  - Canonical Experiment/Simulation
  - Core Analytics

Phase I work as input to Phase II simulations

- **Phase I was about foundational elements** in preparation for a more **simulation based research focus in Phase II**.
  - 2 of the Phase I teams were focused on modeling and simulation framework and reference components to allow comparison of simulations.
- Phase I teams also included "**what's working**":
  - Business and Regulatory Models team looking at what is being done or considered today in CA, NY and elsewhere.
  - Common Transactive Services (CTS) team examining minimal set of TE services based on what's used in for established financial markets.
    - TransactiveADR team looking to add these transactive services to the industry standard OpenADR.
  - 2 TE implementations: Microgrids and Virtual PowerMatcher demo teams.
- 11 Background questions are about what works for the customer and how we measure and validate performance of systems.
  - We discover the answers to these questions by examining what has worked and is working
  - Also by modeling and simulation

Connect with the TE Challenge

Go to the TE Challenge collaboration website to get more information on the team efforts and participants, and to get access to work products

Consider joining/forming a team to participate in our TE Challenge Phase II. Let us know how you want to be involved – techallenge-info@nist.gov

Thank you.

ProsumerGrid's Distribution System Operator (DSO) Simulation Studio: Project Update

Jim Gallagher
Executive Director,
NYS Smart Grid Consortium.

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Chairman,
ProsumerGrid, Inc.

Quantifying the Power of Distributed Energy Resources

December 6, 2016

ProsumerGrid, Inc.

- Startup company from Georgia Tech.
- Team performed ARPA-E GENI ***Distributed Control Architectures*** project (2012-2015).
  - Developed theoretical basis and simulated massive decentralized operation of the grid (decentralized algorithms for PF, OPF, UC, frequency regulation, SE, ATC).
- ProsumerGrid, Inc. formed in 2014 to develop and commercialize ***next generation software to simulate and coordinate systems with potentially billions of DERs and millions of decision-makers.***

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DSO/DSO Simulation Studio

Overview

- $3 million award from Advanced Research Projects Agency-Energy (ARPA-E) - 2.5 years
- Develop software tool to simulate DSO and microgrid physical and market operations
- Team: Prosumer Grid, the New York State Smart Grid Consortium, Southern California Edison, NRECA, and Georgia Tech Research Corporation

Team

- Strategically designed team to address the complexity of DSO/DSP activities.
  - Major DSO/DSP efforts in NY and CA
  - Realistic data, use cases, rules.

- NRECA's Open Modeling Framework (OMF) allows us to leverage existing engineering models and solvers: Milsoft, CYMDIST, GridLab-D, etc.

- Integrate strong expertise in decentralized architectures for control and optimization, federated co-simulation, visualization, analytics, economics, and cloud computing.

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DSO/DSO Simulation Studio

Simulation Capabilities

- Decentralized energy scheduling of DER-rich systems
- Modeling of DER services transacted in the DSO market
- Locational and time sensitive pricing of power, ancillary, and security services
- Analysis and valuation of DER services, DSO rules and utility business models
- Simulation of DSO interactions with upstream ISO, same level DSOs, and downstream subsystems (prosumers, microgrids)
- Web based, with interactive visualization

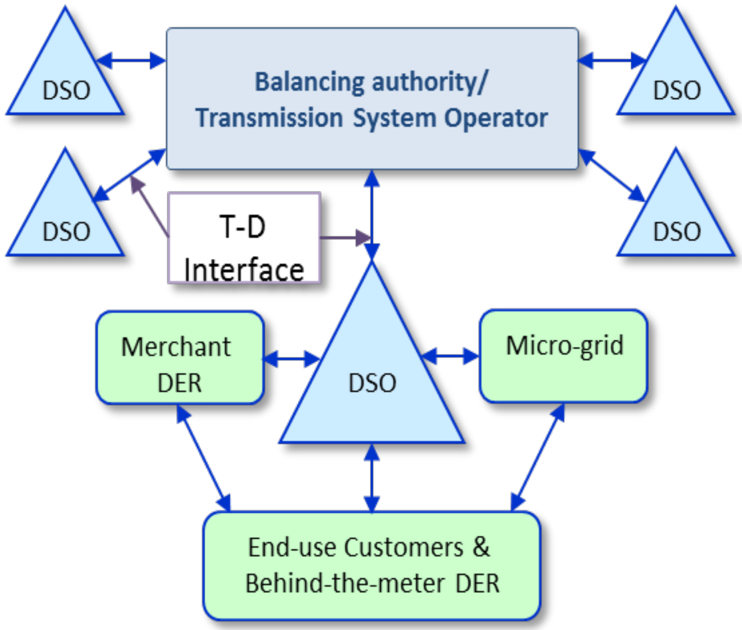
DSO/DSO Simulation Studio

Role of Consortium

- Establish and facilitate working group of NY stakeholders
- Identify existing distribution grid modeling tools, approaches and capabilities / DSP objectives under REV
- Provide NY input regarding simulator needs, features and capabilities – workshop and working group
- Coordinate simulator beta testing using NY case studies

Motivation for DSO Simulation

- The electricity industry has identified ***Distribution System Operators (DSOs)*** and ***Distributed System Platforms (DSPs)*** as critical to realize an electricity grid based on distributed energy resources (DERs), energy services, and active customers.



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Motivation for DSO Simulation

- It is very important to simulate DSOs and DSPs ***before*** they are broadly implemented.
- While there are many great propositions regarding DSOs, a tool that can be used to test those ideas does not exist.
- High-fidelity simulations are needed to ensure robust design.

- DSO/DSP operations will be ***very complex*** and simulation has the following ***challenges***:
  - Underlying decentralized decision making
  - Massive number of DERs and decision makers.
  - New physical behavior in space and time
  - New information, economic, and management elements

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DSO Project Objectives

- This project is developing ***an interactive software tool capable of simulating the operation of emerging DSOs and DSPs at the physical, information, and market levels***.
  - The software extends state-of-the-art distribution grid solvers with detailed DER models, decentralized optimization, DSO pricing rules, and interactive analytics features.

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DSO Simulation Studio

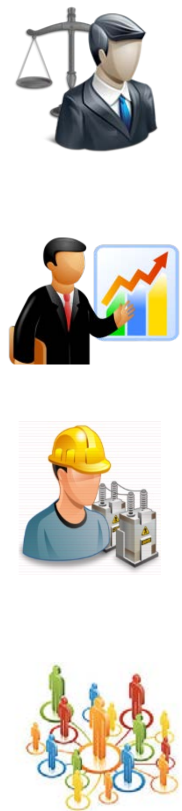
- A Multi-Layer Simulator

Regulators

Market Participants

Utility Engineers

Developers



DSO Simulation Studio

Market
- DSO Design and Policy Engine
- DER Services Valuation | DSO Rules
- DER Services | Locational-Temporal Pricing Module

System
- Decentralized Energy Scheduling
- Forecasting | Multi-Agent Prosumer Model
- Security Modeling | Time Series DER Quasi-Steady State Solver

Devices Controllers: Intelligent Controllers
Power Electronics, Protections, Sensors

Power Grid: Wires, Transformers, Capacitors, etc.
DER: Flexible Load, Solar PV, Storage, CHP, Wind, EV

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DSO Simulation System Requirements

- The team conducted interviews and gathered inputs from about 20 industry partners in leading DER regions.
- Identified major challenges/gaps/needs to support analysis, simulation and operations planning of DER-based power systems and to provide insights for DSO/DSP simulation.
- The team adopted a framework to address the questions & issues in a manageable, logical sequence that considers different levels of DER adoption and growth and corresponding functions.

- Priorities and pain points are:
  - DER hosting capacity and interconnection analysis
  - DER locational value analysis
  - Optimal scheduling of DER provided distribution grid services
  - Aggregation of DER for wholesale market participation

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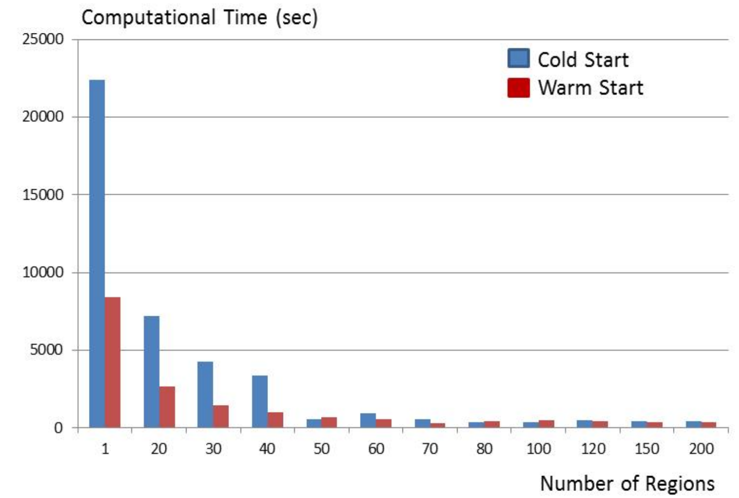
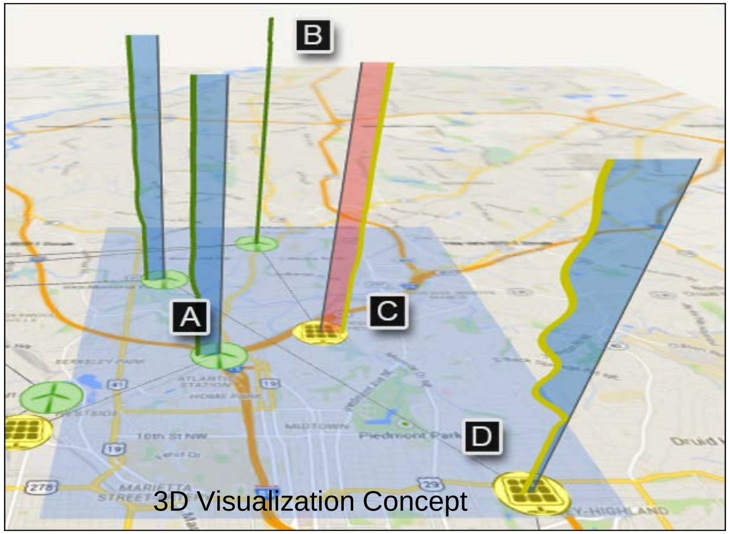
DER Modeling in DSO Simulator

- Separate DER modules from Open Modeling Framework (OMF) and power flow solvers.
  - Solar, Wind, DR, EV, Storage, CHP
- Steady State Modules at minutes to hour time-scales
- Control models at sub-second to seconds.
  - Control models using interfaces to MATLAB.
  - Quasi-static models (e.g. 1 year @ 1 sec granularity PV hosting capacity)
- Prosumer-based decentralized optimization of arbitrary DER subsystems (prosumers).
- Market Layer:
  - Service Definition Language (SDL)
  - DSO, Integration Rules

DSO Simulation Studio Unique Features

- Decentralized energy scheduling of DER-rich systems of arbitrary size.
- Explicit modeling of energy services transacted in the DSO.
- Locational and time-vector pricing of P/Q, ancillary, and security services.
- 3D Interactive Visualization
- Analytics and valuation of DER services, DSO rules, and business models.
- Simulation of multi-scale interactions of DSO with up-stream ISO, same level DSOs, and downstream (microgrid, building, and home) prosumer subsystems.





3D Visualization Concept

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Conclusions

- A DSO Simulation Studio would represent a quantum leap in the industry's ability to simulate and manage the complexity of emerging DER-based distribution grids.
- It will support decisions of great criticality and impact, as various states implement DSO/DSPs in the quest to realize a highly distributed, reliable, optimized, and sustainable electricity industry.

Thanks

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Validating the Models for Transactive Energy

Dr. Martin J. Burns

Electronic Engineer, Engineering Laboratory
NIST Smart Grid Program

Quantifying the Power of Distributed Energy Resources

December 6th 2016

TE Challenge Co-Simulation Framework

- Reason for Tiger Team Effort
- The Participants:
  - PNNL
  - Vanderbilt
  - CMU/MIT
- The Results
  - Draft Technical Framework
  - Extensible Component Model
  - Canonical Experiment/Simulation
  - Core Analytics

Why do we need a "Common Platform" for TE Simulations?

Platform Goal: *to be able to understand, evaluate, compare and validate transactive energy approaches, grid operations and controls.*

- Design a common platform that has well-defined interfaces and semantics such that stakeholders can use it to evaluate in their own contexts and may even plug-in their own [proprietary/confidential] models and components.
- As part of the platform we envision a library of tools & models that will be available for users to leverage existing great work from the open-source domain.
- Three collaborators may implement the common specification providing three equivalent testbeds for TE evaluations

Progression of Simulation Platform Usage

Baseline Reference Scenario Demonstrates the Model

- Simple Grid Model
- 30 Houses
- Simple market based on price curve bidding

What scale / type of grid model will meaningfully demonstrate your technology?

- Scale to achieve meaningful analysis
- Radial vs Mesh grid
- How many nodes/customers

How might you use the common platform to distinguish your capabilities?

- Compare different grids
- Compare different market models
- Compare discrete event physics and ODEs

What significant timescales should be studied?

- Capitalization impacts
- Grid stability
- Market stability/complexity -- time of use ... dynamic bidding ... aggregation pools

TE Challenge Common Platform Specification

- A detailed technical specification that can be faithfully implemented on one or more simulation platforms comprising:
  - A set of model components with specific minimum interfaces
    - Any interface can be extended as needed for any TE Challenge Case
    - Core components can be combined and hide internal interfaces
  - A canonical simulation that allows the set of components to be orchestrated in a simulation
    - Minimal or extended models can be substituted for any component(s) and can simulated by the same experiment controller
  - A reference grid and scenario
    - A defined set of grid nodes, resources, controllers, and transactive agents and market simulation to provide a baseline for comparison
  - A minimum core set of analytics based on the data provided through the canonical simulation

Baseline Reference Scenario

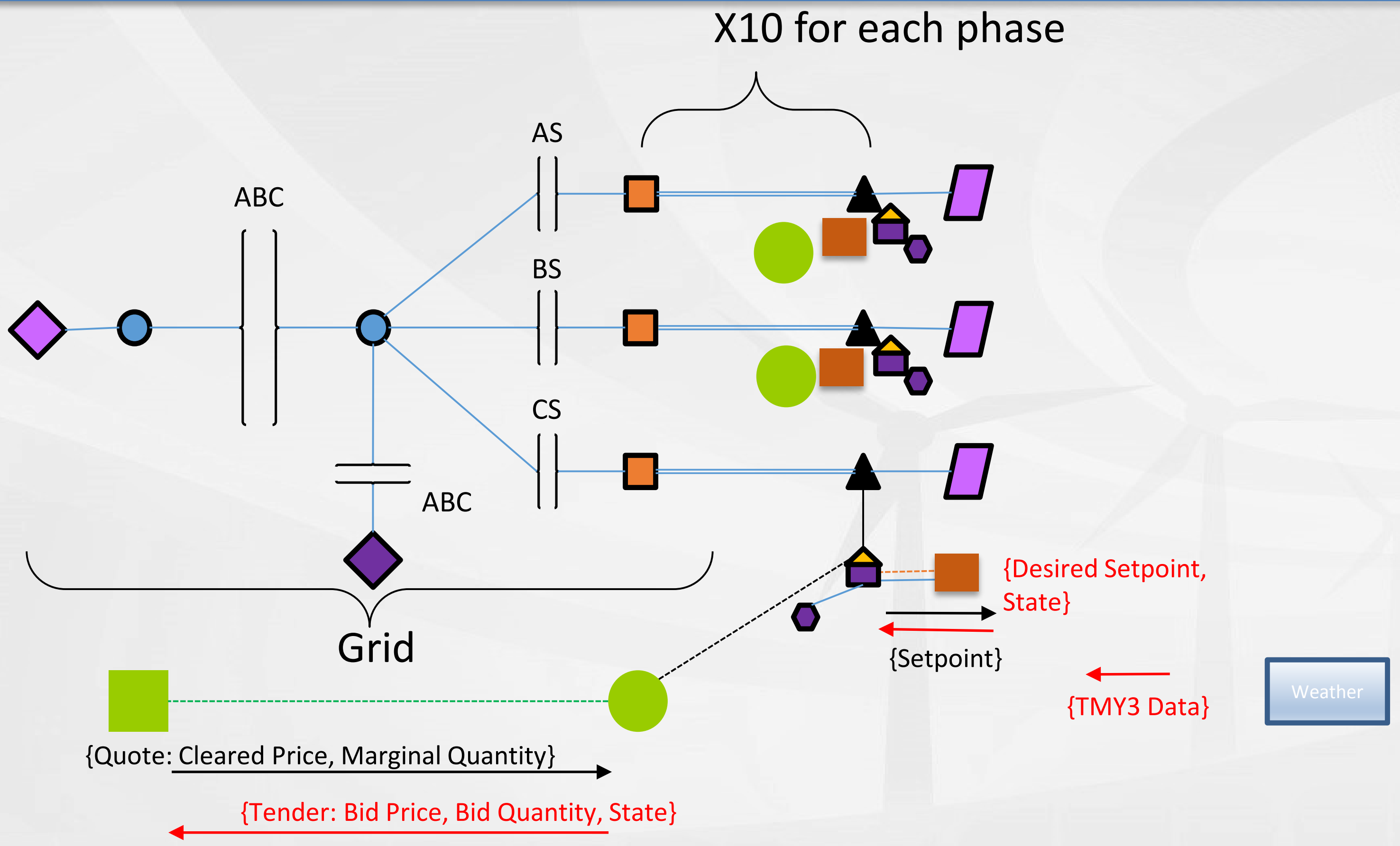
30 houses divided among three phases on one distribution transformer.

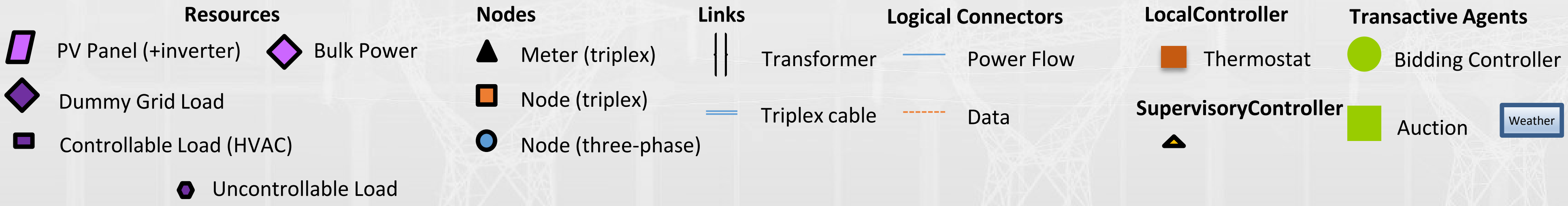
The distribution system has one uncontrollable load (Resource) and one source of bulk power (Resource).

There is a weather feed of TMY3 Data for a single locale (Weather).

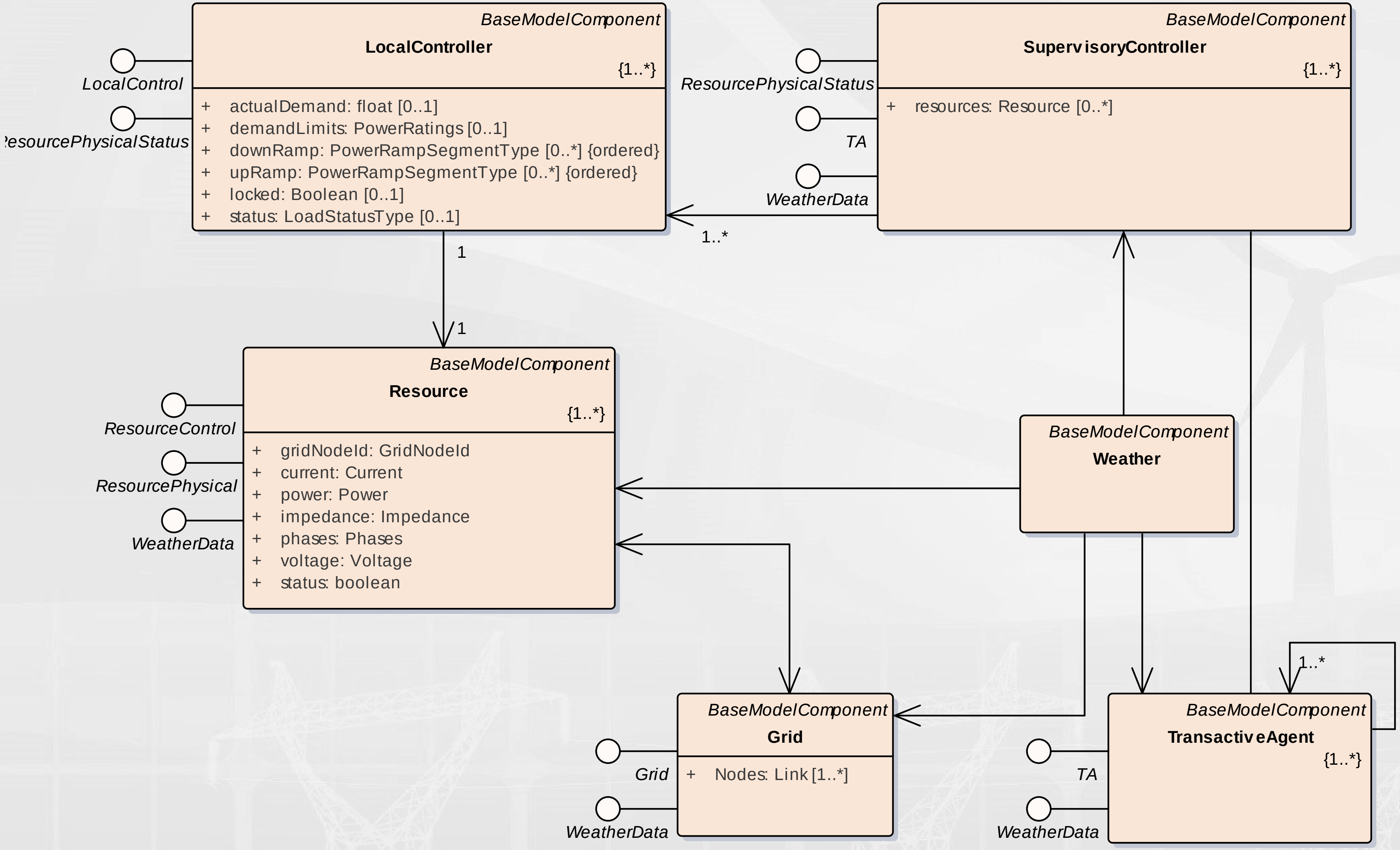
Each house has:

- A solar panel (Resource)
- A controllable load – HVAC (Resource)
- A non-controllable load (Resource)
- A home automation system (SupervisoryController)
- A thermostat (LocalController)
- A transactive agent (TransactiveAgent)





Core Modeling Components of Common Platform



Common Platform Canonical Simulation

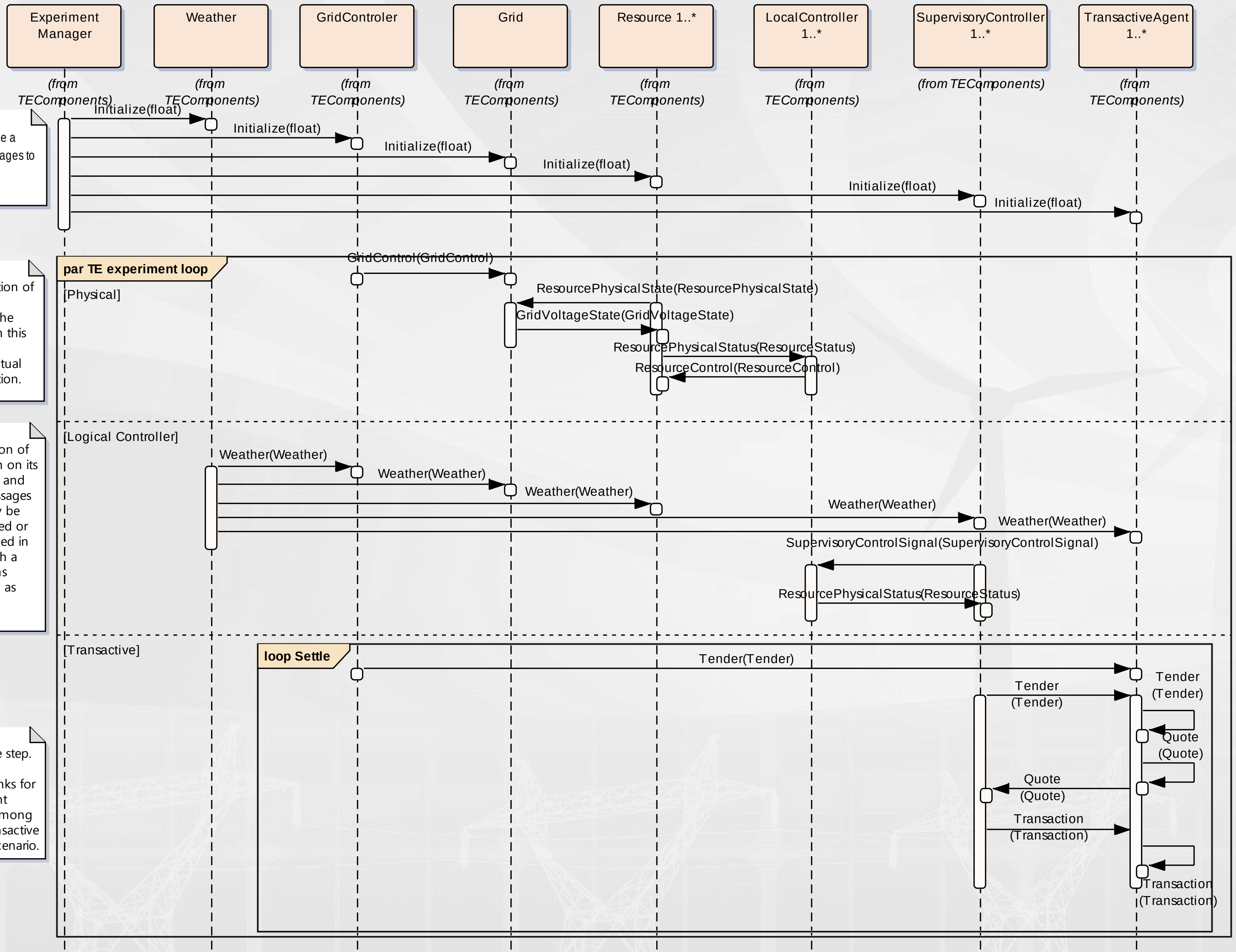
Initialization may be a sequence of messages to each object.

Physical simulation of load/generator attached grid. The message lines in this case may be messaged or actual physical simulation.

Logical simulation of controller action on its managed loads and generators. Messages in this case may be directly messaged or may be messaged in conjunction with a communications simulation such as NS3 or Omnet.

Transactive time step.

Note that self-links for TransactiveAgent imply sharing among the various Transactive Agents in the scenario.



Metrics that can be Extracted by Analytics Component

Through the course of the experiment/simulation the following data can be extracted from the message exchange:

- Grid power flow and voltage states
- Load profile as consumed by all loads
- Generation profiles as produced by all solar panels
- Aggregated loads by household
- Price negotiations and exchanges
- Realized pricing coordinated by loads and generators

Focus Question

- *Focus Question: Describe the characteristics of a model that would assess your technology or service best?*