Transactive Controls R&D (Tx-R&D)

Holistic Thinking with Control of Sources to Loads…

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Joseph Hagerman
Building Technologies Office

Building to Grid (B2G) is one facet of Tx-R&D

Transactive Controls R&D funding represents an opportunity for BTO's B2G program to…

- Fully **realize** ~~that both~~ whole buildings & Connected Equipment are assets that can benefit the grid but that will scale at different rates and through different drivers (and to contribute to GMLC where applicable);
- **Extend** applicable outcomes from a comprehensive Building Sensors & Controls Roadmap, AOP funding, & merit review
- **Maintain** "no regrets," but **focus** BTO activities beyond the meter
  - New and existing EE funds are part of but not the entire integrated solution – focus on system efficiency, operational efficiency and energy market services th benefit the owner/operator.
  - GMLC focuses on grid & energy service apps.

BTO Tx-R&D projects must...

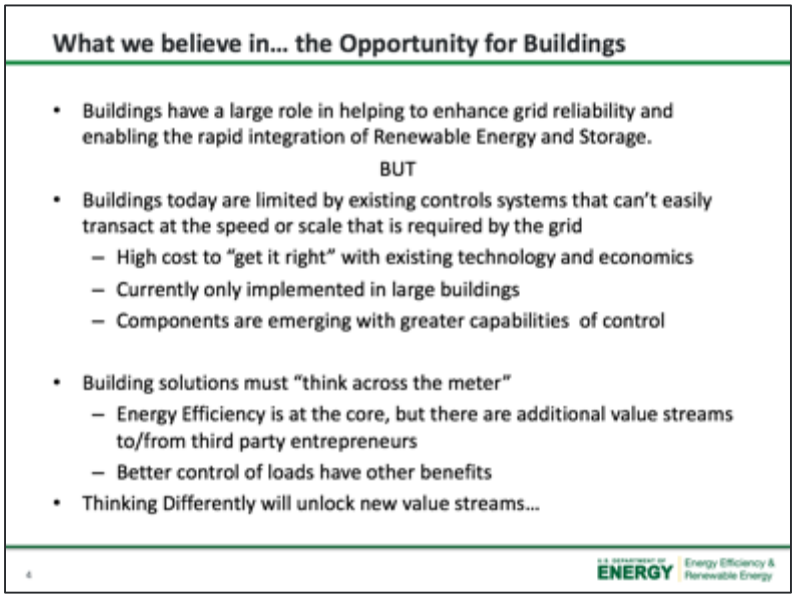
- Understand, evaluate, & unlock the characteristics of whole buildings & Connected Equipment that provide all services/benefits/functionalities.
- Balance these B2G characteristics with other EE & RE technologies.
- Always be mindful that Connected Equipment can impact ongoing regulatory issues.

B2G Definitions (1)

These B2G terms have been established in BTO's public meetings & reference documents (through review and comment):

- **Transaction** – The negotiated exchange of products, services, and rights within a structured or unstructured market that enables allocation of value among all parties involved (known as settlement). Transaction require the exchange of the …
  - Physical (in our case, Energy + Information)
  - Logical (in our case, controls or control systems that act on information)
  - Financial (in our case, a price to determine value to users)

"Value" is allocated & can be based on non-energy criteria expressed as price (i.e. "green-ness" of the power, asset valuation, comfort, etc).

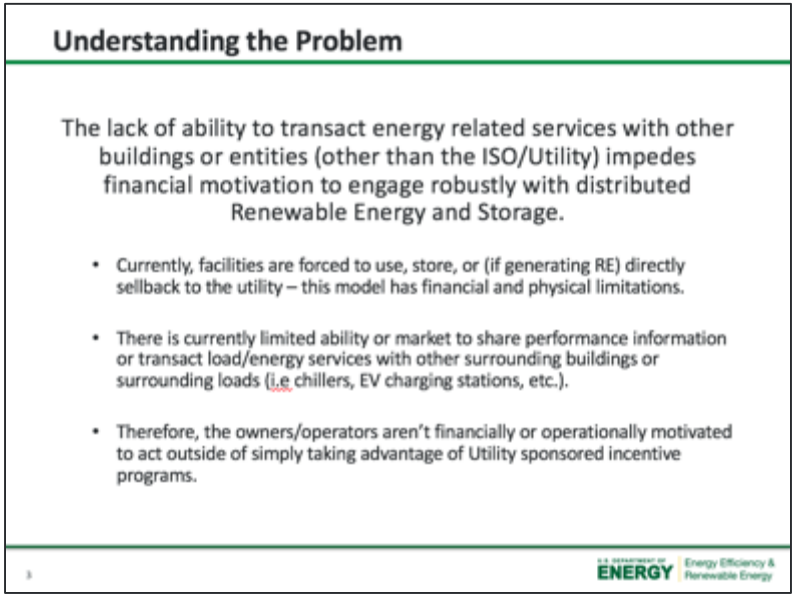


What we believe in… the Opportunity for Buildings

- Buildings have a large role in helping to enhance grid reliability and enabling the rapid integration of Renewable Energy and Storage.

BUT

- Buildings today are limited by existing controls systems that can't easily transact at the speed or scale that is required by the grid
  - High cost to "get it right" with existing technology and economics
  - Currently only implemented in large buildings
  - Components are emerging with greater capabilities of control
- Building solutions must "think across the meter"
  - Energy Efficiency is at the core, but there are additional value streams to/from third party entrepreneurs
  - Better control of loads have other benefits
- Thinking Differently will unlock new value streams…



Understanding the Problem

The lack of ability to transact energy related services with other buildings or entities (other than the ISO/Utility) impedes financial motivation to engage robustly with distributed Renewable Energy and Storage.

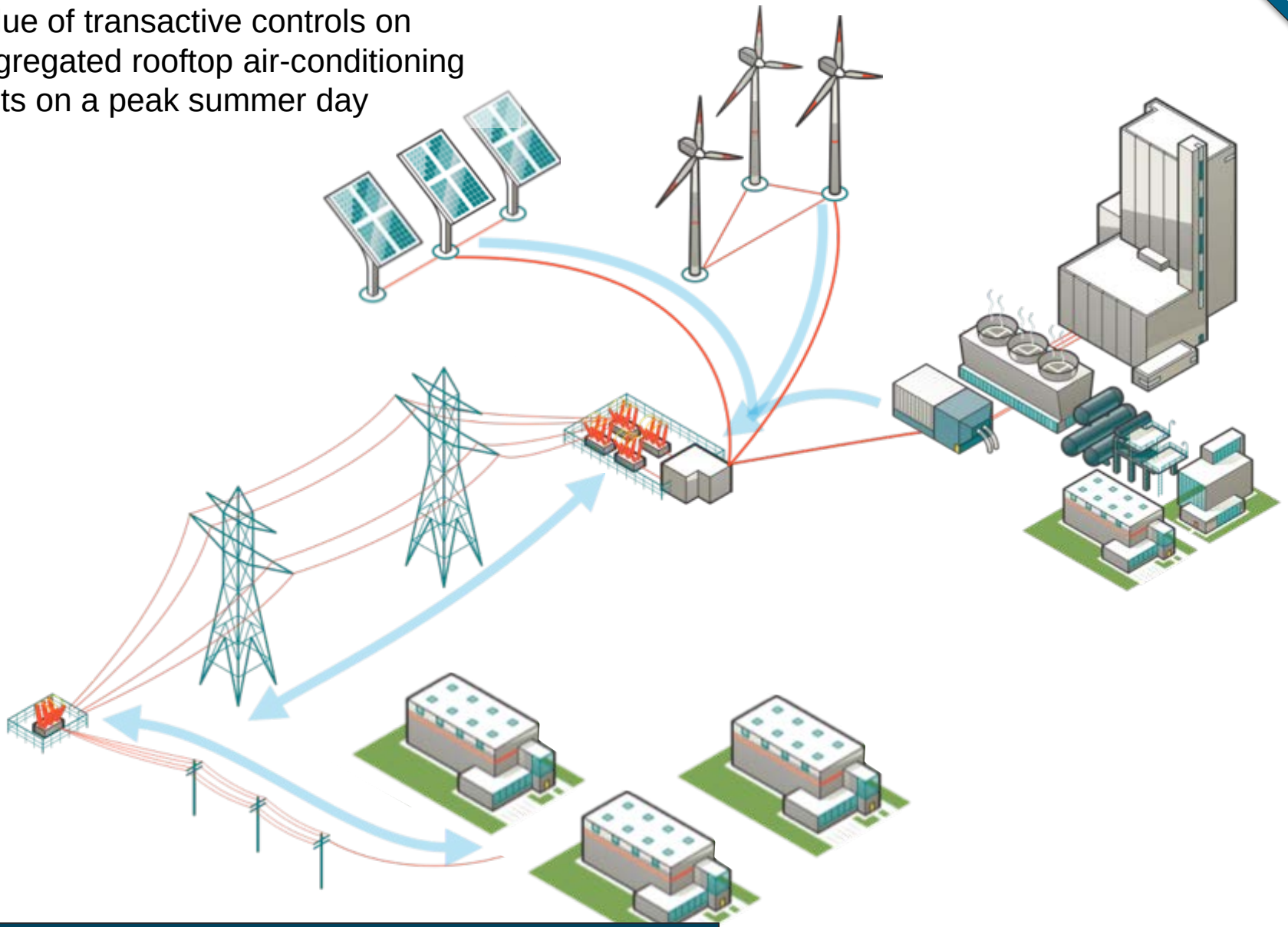
- Currently, facilities are forced to use, store, or (if generating RE) directly sellback to the utility – this model has financial and physical limitations.
- There is currently limited ability or market to share performance information or transact load/energy services with other surrounding buildings or surrounding loads (i.e chillers, EV charging stations, etc.).
- Therefore, the owners/operators aren't financially or operationally motivated to act outside of simply taking advantage of Utility sponsored incentive programs.

Fundamentally, to enable transactions we must commingle energy + information and assign value.

Example Opportunity:

- Value of transactive controls on aggregated rooftop air-conditioning units on a peak summer day

illustrative



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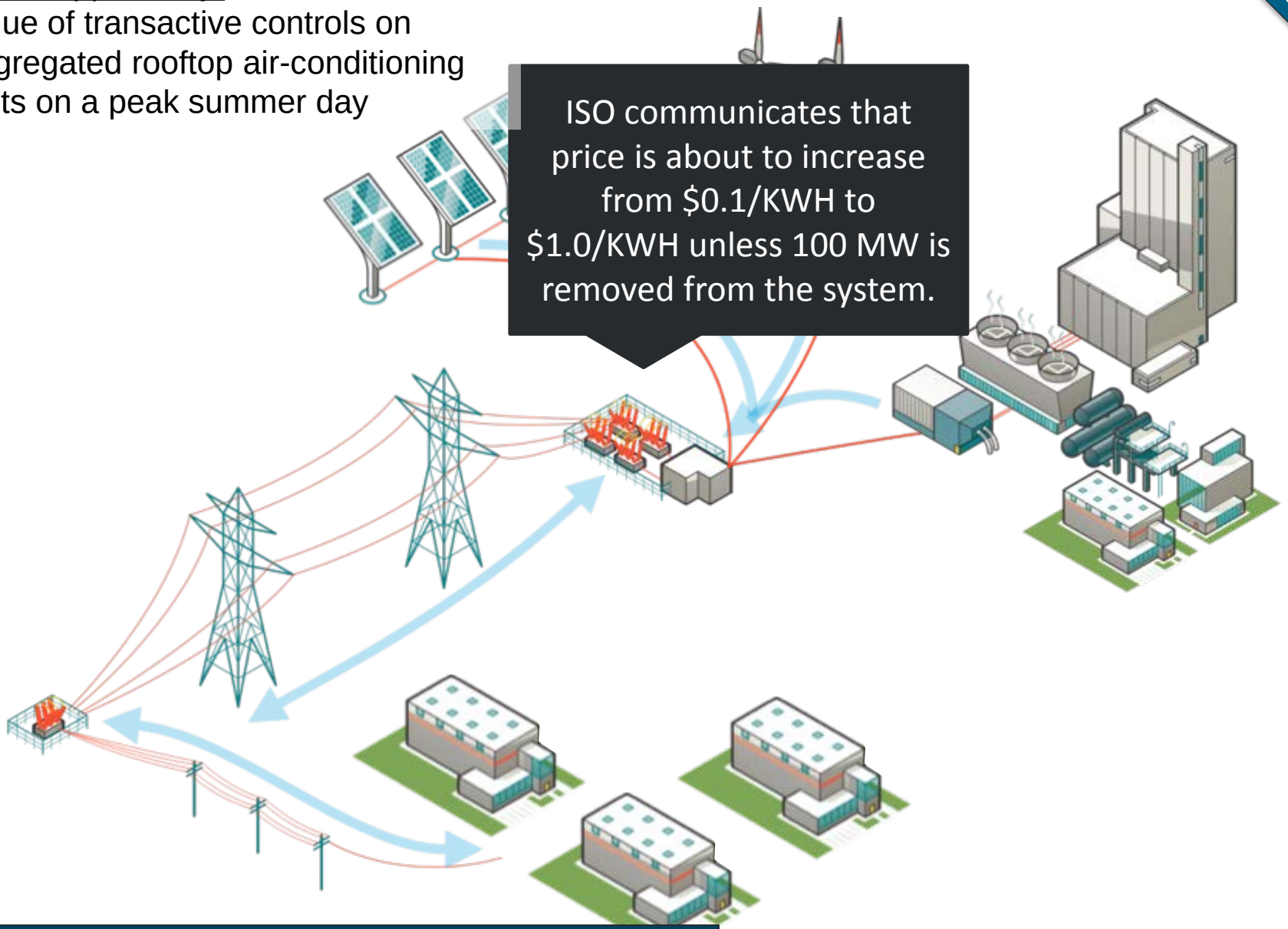

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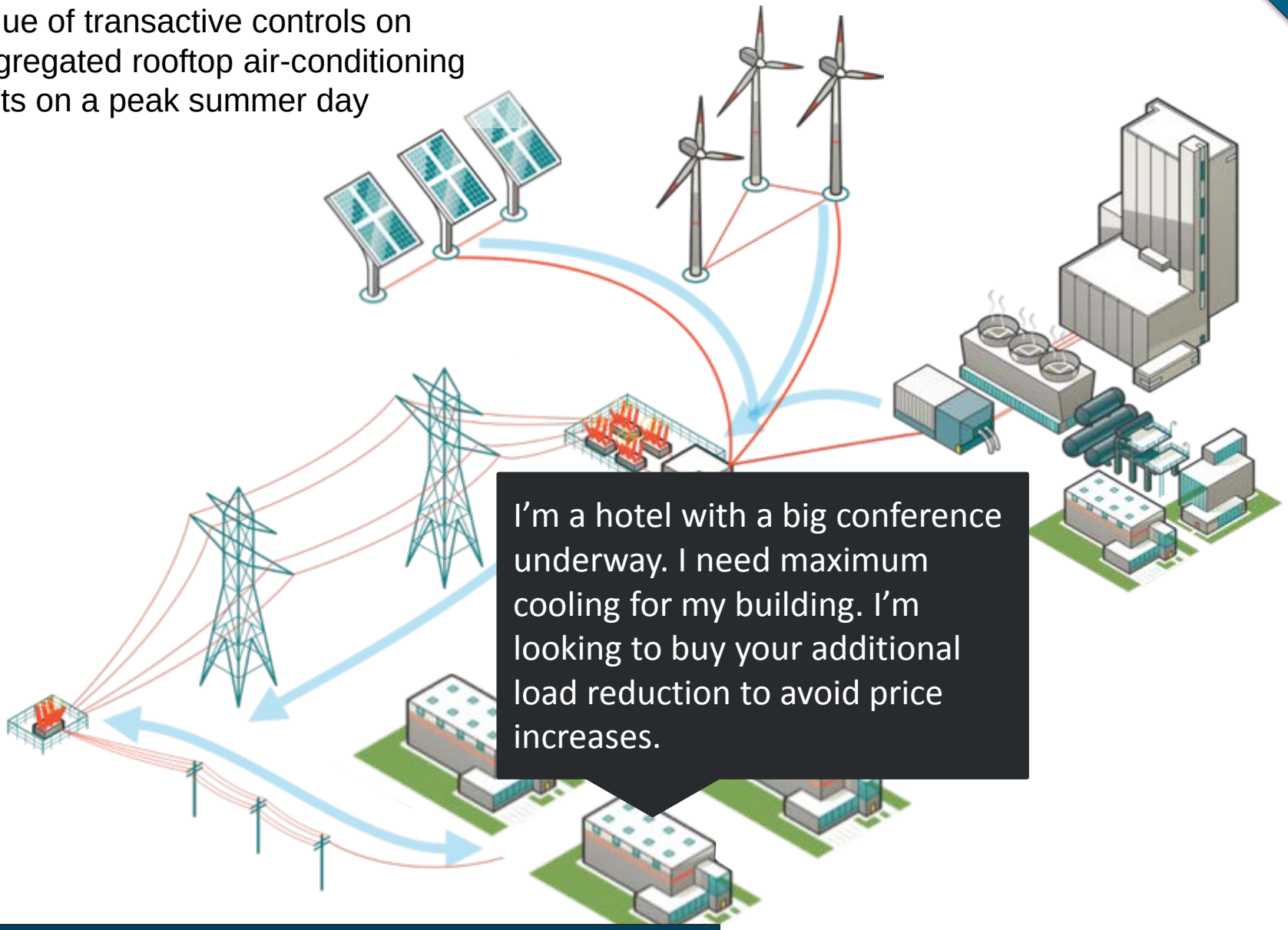

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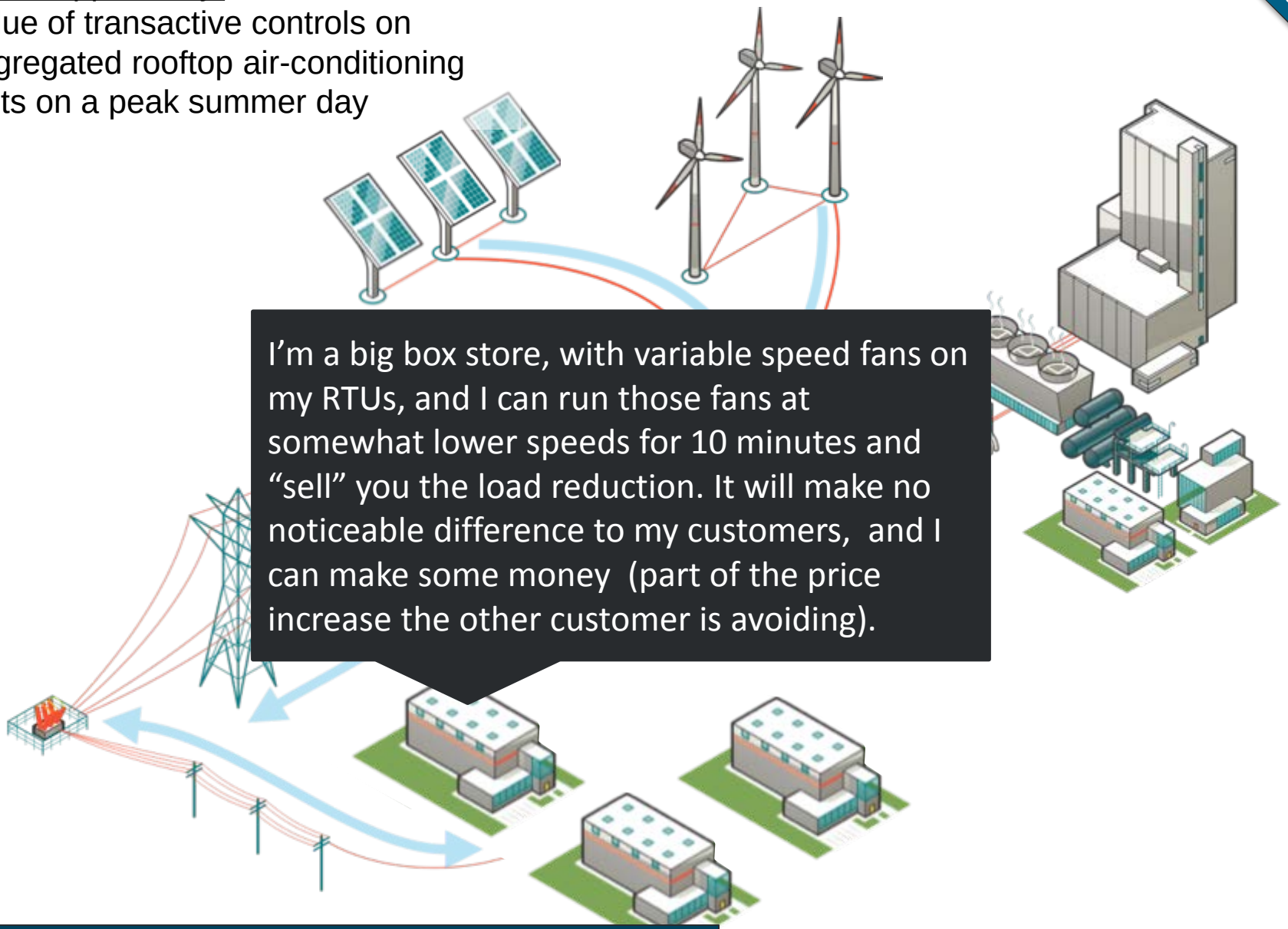

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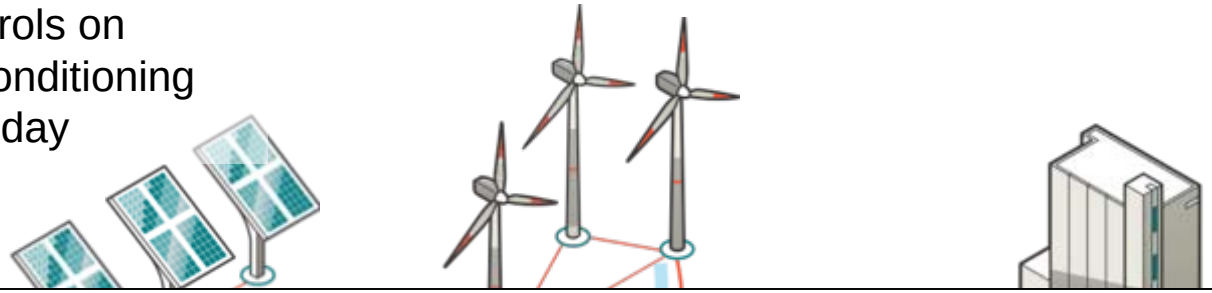
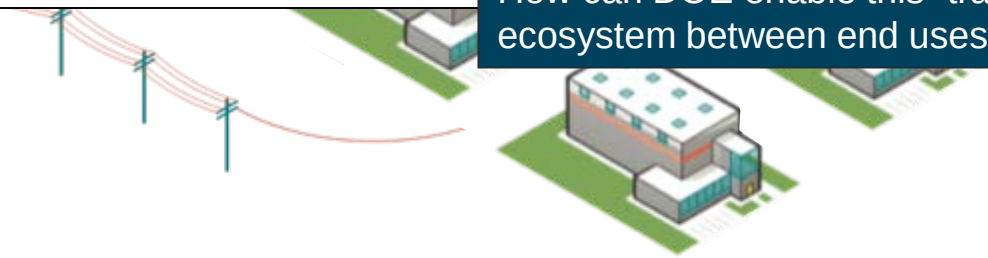


But to reach 100MW, negotiating and controlling across a few RTUs in a few buildings won't realize an impact.

However, if all the RTUs in a service territory -- across the national accounts AND the independents -- could autonomously and automatically aggregate to deliver a solution for the utility, the system would be optimized and building owners/operators would realize energy and cost savings.

If only the controllers could systematically communicate, transact, and settle amongst themselves. These solutions are beyond simple Demand Response because they inherently understand, value, and can act for the owner's operational needs while simultaneously optimizing to help the grid.

How can DOE enable this "transaction"-based ecosystem between end uses and utilities?



B2G Definitions (2)

These B2G terms have been established in BTO's public meetings & reference documents (through review and comment):

- **Transaction** – an exchange or interaction between entities.
- **Transaction Based Controls** – controls that exchange, negotiate, & respond to information through information and communication technologies (ICT).
  - Most common signal is economics based: "price."
  - Needs advancements in fundamental sensors & controls – like plug-n-play, FDD, auto-mapping, etc.
- **Transactional Platform** – a software platform (e.g. ICT & related physical hardware) that allow applications to be programmed and negotiate/act on the exchange of information.
  - VOLTTRON is fully supported throughout DOE (OE, EERE, others) & is open source.
- **Transactive Energy** - techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic (or market-based) constructs while considering grid reliability constraints. (GWAC)
  - The term "transactive" comes from considering that decisions are made based on a value to the parties involved. The decisions may be analogous to (or literally) economic transactions.
- **Transactive Devices** or **Connected Equipment** – consumer products with ICT that enable them to be exercised through transactions – without boundaries.
  - Available technologies are typically proprietary (e.g. vendor specific ICT)

Fundamental concepts – typically bound within buildings to take advantage of the closed ecosystem. "No Regrets to EE."

Core Controls platform that supports whole buildings, appliances & devices. Can be applied anywhere.

Fundamentally supports grid & energy market service benefits. May opt out of "No Regrets to EE" to benefit "System Efficiency."

B2G Definitions (3)

- **Transactive Buildings** – buildings that can dynamically respond to signals or messages from entities outside the building.
  - Can provide a measurable response to entities outside the building through the utilization of building located loads.
  - Self-aware (continuously aware of building state such that availability can be quantified) and continuously interacting with the larger systems they are a part (e.g. campuses, grid, etc.)
    - through ICT, negotiations, etc.

Transactive Equipment and Transactive Buildings are assets to the grid but will scale at different rates and through different drivers thereby presenting a range of solutions:

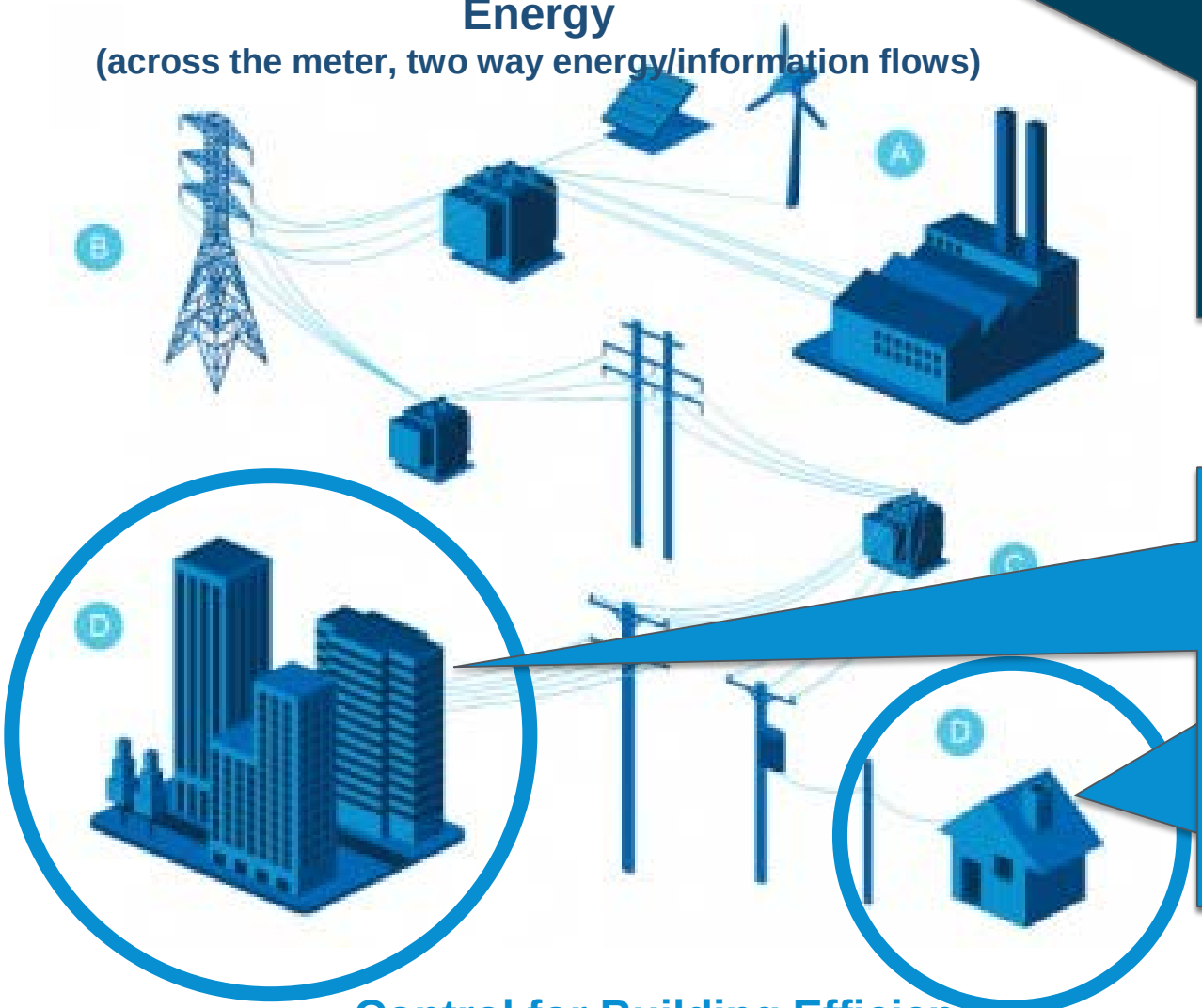
- ✓ Existing building transactions include Demand Response (DR) triggered through Automated-DR messaging;
- ✓ "Clunky," limited transactions could be in the form of existing Building Automation Systems (BAS) control (until transaction based controls proliferate into whole buildings);
- ✓ Portfolio-based control of transactive equipment located throughout distribution feeder (distributed devices across time and spatial boundaries);

- **Transactive Campuses** are the physical locations of fully integrated collections of transactive equipment, buildings, and other EERE.
  - Transactive locations can deliver energy market and grid services through the management/ interactions of installed assets, devices, and loads.

Building Controls & Transactive Controls/Energy

B2G: Transactive Controls & Transactive Energy

(across the meter, two way energy/information flows)



Control for Building Efficiency
(within the customer side of the fence)

Control for Transactive Energy need…

- Cyber Secure Transactional Platform,
- Applications that Transact services (Grid, Energy Market, Consumer & Societal)
- Valuation for Utility to Consumer spectrum
- Have ties to External Nodes to Affect System Efficiency

ET Transactive Controls R&D (FY16 line item), GMLC EERE Specific Funds (EERE FY17)

Controls for Building Efficiency need…

- Inter Building Communication Mechanism & Interoperability
- Algorithm to optimize energy use for the consumer only
- Valuation from the owner, operate to recoup the investment to realize energy system
- Have ties to Internal Systems drive building Efficiency

ET Sensors & Controls subprogram, RBI and CBI R&D/T2M

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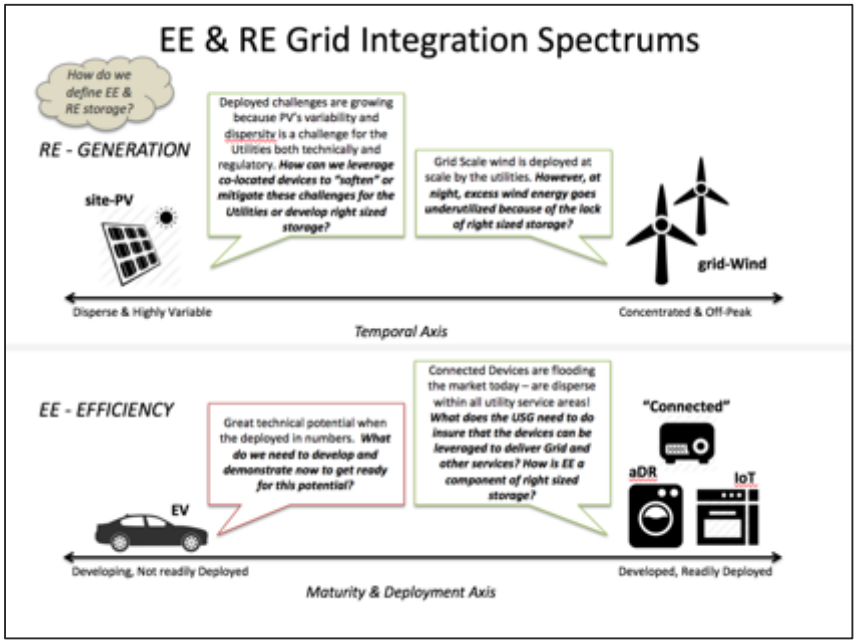
Buildings as an Energy System Asset: Principles (1)

Connected Equipment performs **primary functions** as we holistically think "from sources to loads:"

- **SUPPLY (+)** - generate power to avoid, minimize, or shift larger system distortions → FC, PV, Wind, etc.
- **CONSUME (-)** – regulate, change, or alternate operation to optimize or reduce large system distortions → End use loads
- **REGULATE (rate)** - transfers loads between two or more devices to optimize the larger electricity system → Transformers, economic dispatch, dynamic management of loads and generation, etc.
- **STORE (time)** – applications of those functions necessary to store or stage energy → Batteries, Virtual Batteries, and thermal storage.



Note: Fundamentally this coordination is beyond one building, and per building implementation will be custom without fundamental Sensor & Control (S&C) solution development (e.g. plug-n-play, auto-mapping, auto-tuning, auto-Cx, auto-etc).

Buildings as an Energy System Asset: Principles (2)

- Connected Equipment must perform those functions while understanding/monetizing performance losses, lifetime, maintenance, and service levels potentially over vast time- and spatial-considerations (similar in concept to “locational marginal pricing”).
  - BTO must identify core transactive functions.
  - BTO must support the development of transactive energy apps that demonstrate the transactive functions.
  - BTO must work with industry or with stakeholders identify, monetize, and demonstrate value of transactive energy.

- Concurrently, BTO must develop the financial energy components in coordination with OE & GMLC to scale the transactive energy market:
  - Financial Settlement Reference Document (ANL funded in FY14-15)
  - Valuation of Transactive Energy (OE-BTO PNNL funded in FY15-16)
  - Market Structures (GMLC?)

Buildings as an Energy System Asset: Foundational Items

- BTO must integrate the Connected Equipment cross cut initiatives into the GMLC so that the BTO defined methods can be scaled across all EE & RE technologies – as well as be better recognized by OE & their stakeholders.
  - **Interoperability** – EERE should roll up their activities in terms of defining a roadmap & action plan.
    - DOE must collaborate with utilities, other agencies (e.g. NIST, ANSI), and manufacturers to define a unified plan that can realize results.
  - **Characterization** – from defining frameworks to writing protocols this work must be scaled across the diversity of EE & RE technologies and with the representative stakeholders.
    - DOE must also understand that each technology is at a different stage with different stakeholder structures – this diversity must be mapped across DOE.
    - DOE must also consider its role in terms of working with utilities to define unified models that align with the characterization results.
  - **Cyber Security** – buildings and end-uses must be incorporated into OE's cyber activities.

Transactive Controls R&D FY16 Portfolio

PNNL and ORNL are BTO's core labs with nationally recognized capabilities in sensors, controls, and transactive controls/energy.

- Tx-R&D at PNNL:
  - Virtual Batteries
  - Economic Dispatch
  - Transformers
  - Volttron Support to GMLC (and NW Connected Accelerator)
- Tx-R&D at ORNL:
  - Connected Loads
  - Hybrid Inverters
  - Connected Homes
- Enabling Tx-R&D:
  - Universal Message Bus (SLAC)
  - CE 2045 Connector (ORNL)
  - Mini-split Controller (ORNL, DOE International)
  - Microgrid controller (LBNL)
- Tx-R&D-Campus Project
  - WA State (OE, BTO, PNNL)
  - WA State extension at CWU (FY16 Q4) & UTSA (FY16 Q4) (OE, BTO, PNNL)
  - Connected Neighborhood with Southern (BTO, ORNL)

- Foundational/Cross Cutting
  - Cyber Security → BS-C2M2, Integration into FEDs, Cyber Security BS-Framework, DOD, DOS
  - Interoperability → BTO Vision
  - Characterization → ASRAC Grid Connected Equipment, Maturity Model, Assistance to other trade groups

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