GEB Webinar Series:
Distributed Energy Resources (DER) Integration

Building Technologies Office

June 30, 2020

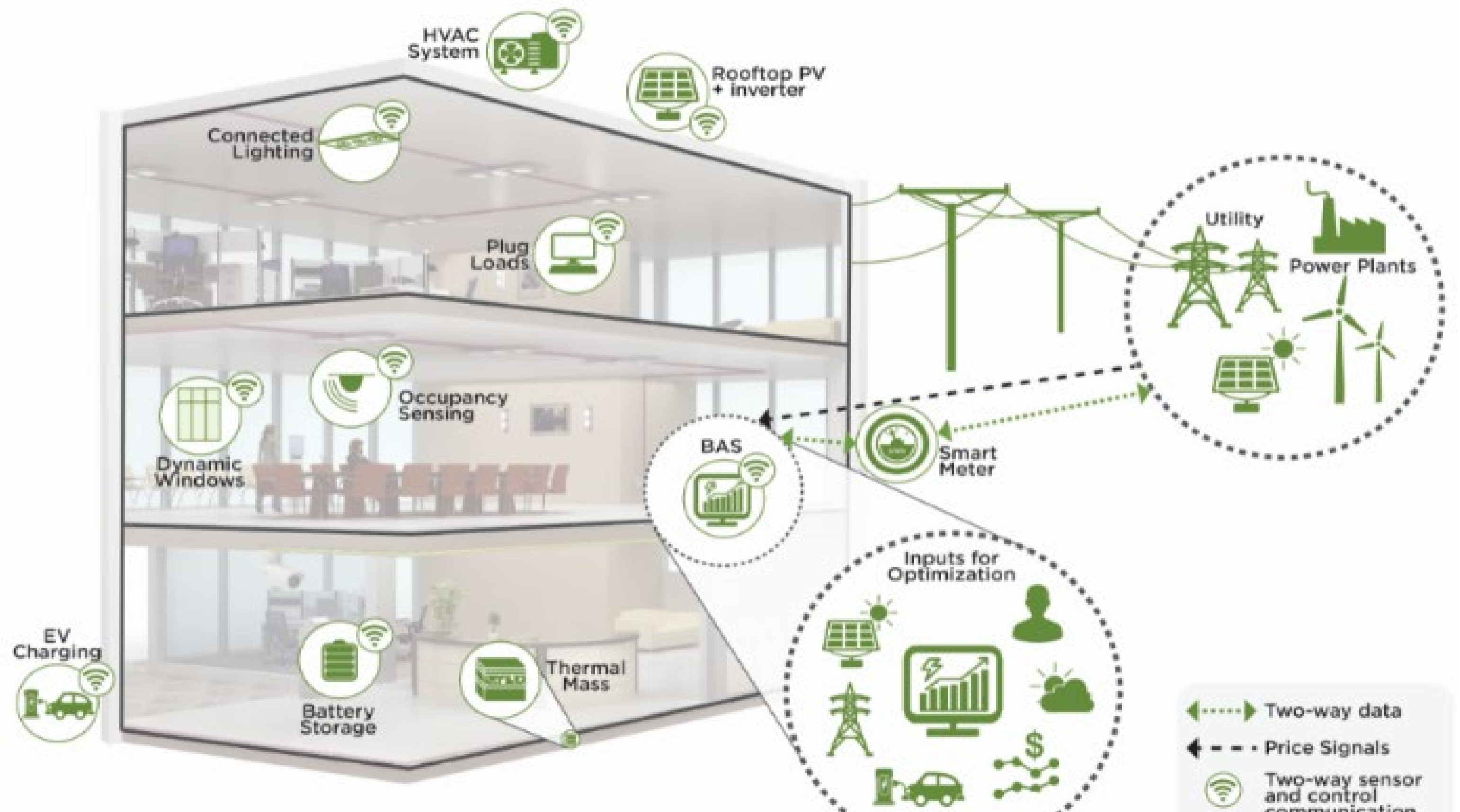
GEB Technical Report Series Overview

The GEB Technical Report Series outlines key demand flexibility opportunities across BTO’s R&D portfolio:

http://energy.gov/eere/buildings/grid-interactive-efficient-buildings

Technical Report Series

- Overview of Research Challenges
- Heating, Ventilation, & Air Conditioning (HVAC); Water Heating; and Appliances
- Lighting & Electronics
- Building Envelope & Windows
- Sensors & Controls, Data Analytics, and Modeling



GEB Technical Report Webinar Series

Topic	Date	Time
Whole-building Control, Sensing, Modeling & Analytics	May 19	2:00pm - 3:30pm ET
Lighting & Electronics	May 26	2:00pm - 3:00pm ET
Heating, Ventilation & Air Conditioning (HVAC)	June 2	2:00pm - 3:30pm ET
Water Heating & Appliances	June 9	2:00pm - 3:00pm ET
Envelope & Windows	June 16	2:00pm - 3:30pm ET
Integration - Building Equipment	June 23	2:00pm - 3:00pm ET
Integration –Distributed Energy Resources (DERs)	June 30	2:00pm - 3:00pm ET

Webinar Agenda

I. GEB Overview

– Nikitha Radhakrishnan, Pacific Northwest National Laboratory (PNNL)

II. DER Integration Project Examples

– Cindy Regnier, Lawrence Berkeley National Laboratory (LBNL)

III. Georgia Tech Campus Energy

– Scott Duncan, Georgia institute of Technology

IV. Challenges to DER adoption/integration

– Hayden Reeve, Pacific Northwest National Laboratory (PNNL)

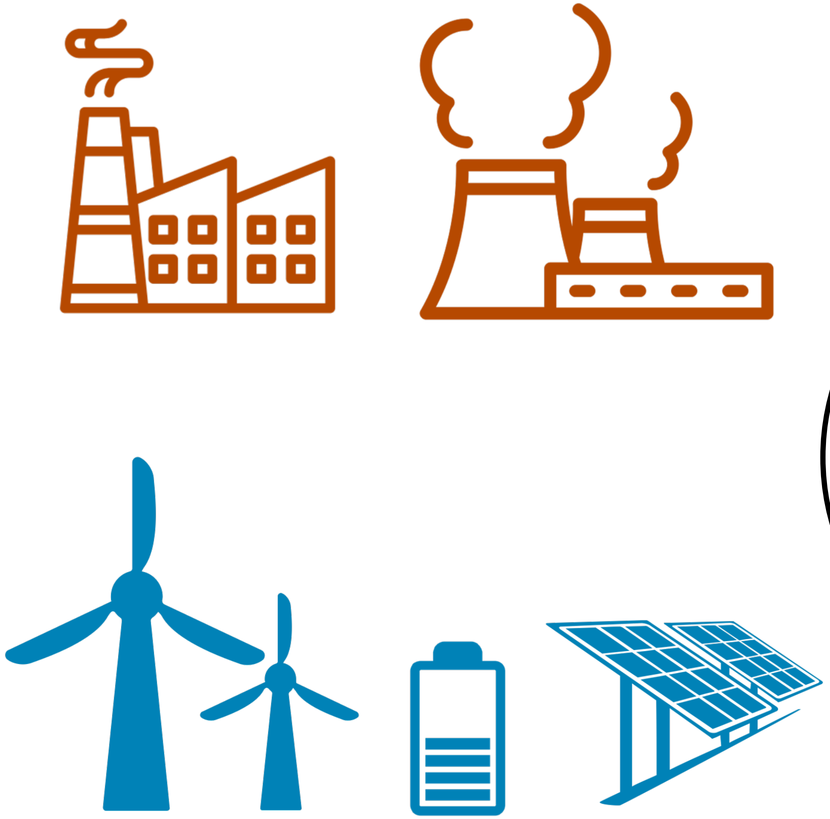
– Michael Starke, Oak Ridge National Laboratory (ORNL)

– Cindy Regnier, Lawrence Berkeley National Laboratory (LBNL)

V. Q&A Session

– Monica Neukomm, Building Technologies Office

GEB is about enabling buildings to provide flexibility in energy use and grid operation



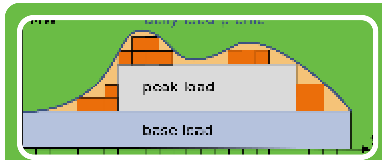
~75% of electricity generation is used in buildings

Supply

Demand

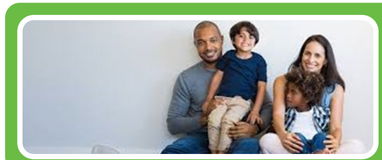
Potential Benefits of Flexible Building Loads

- ✓ Energy affordability



- ✓ Improved reliability & resiliency

- ✓ Reduced grid congestion



- ✓ Enhanced services

- ✓ Environmental benefits

- ✓ Customer choice

Key Characteristics of GEBs

A GEB is an energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.

EFFICIENT

Persistent low energy use minimizes demand on grid resources and infrastructure

CONNECTED

Two-way communication with flexible technologies, the grid, and occupants

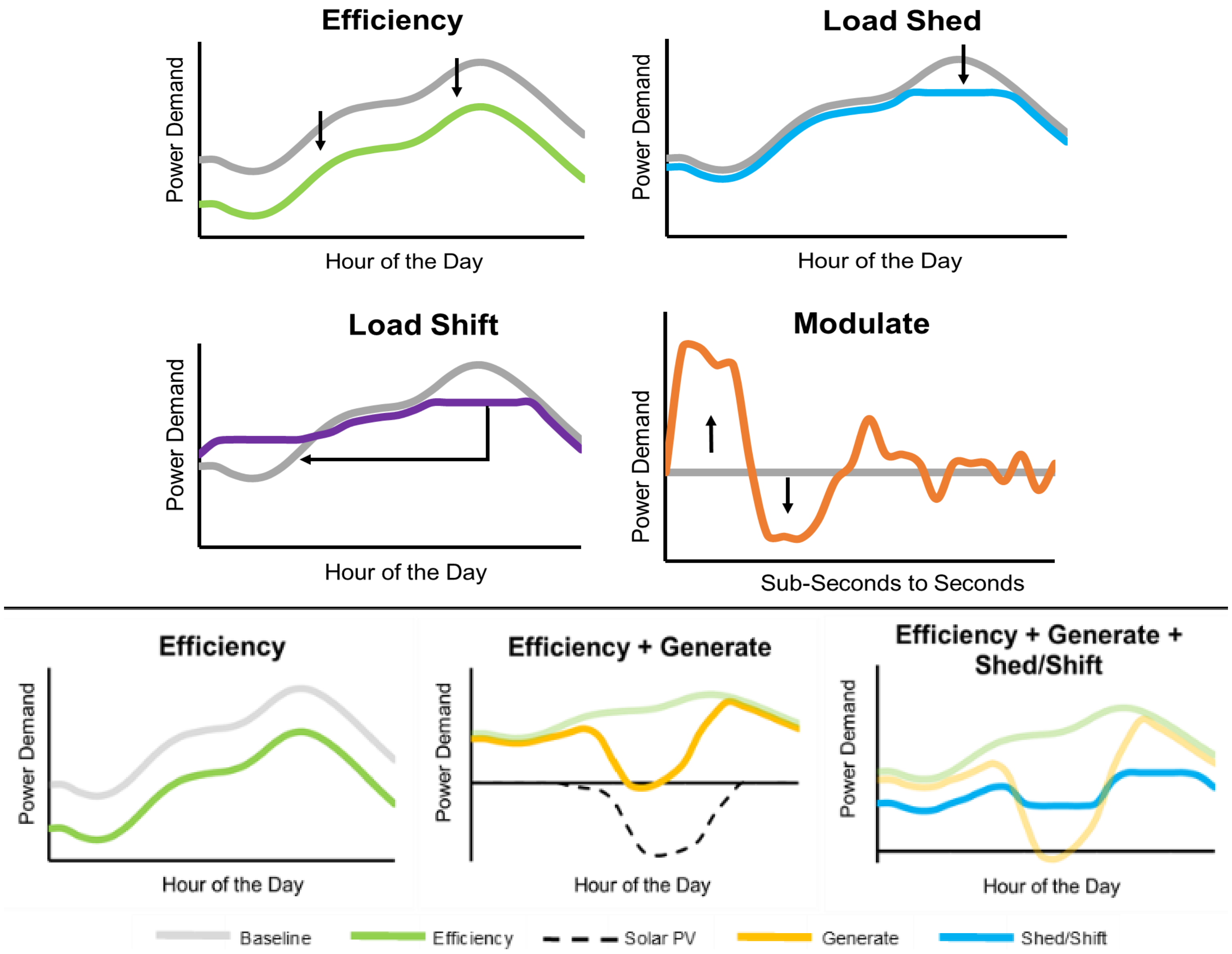
SMART

Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences

FLEXIBLE

Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use

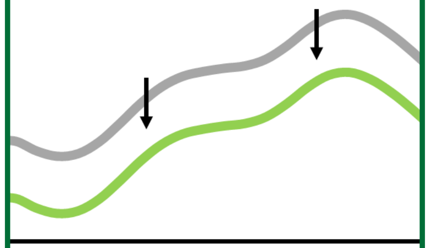
Demand Management Provided by GEB



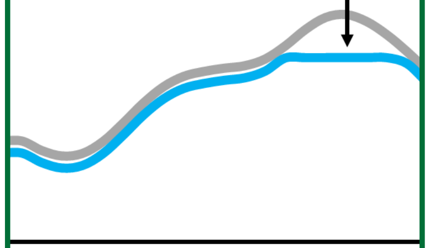
Mapping Flexibility Modes and Grid Services

Buildings can provide grid services through 4 demand management modes.

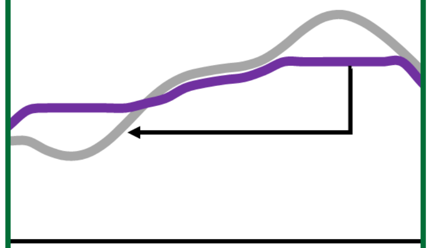
Efficiency



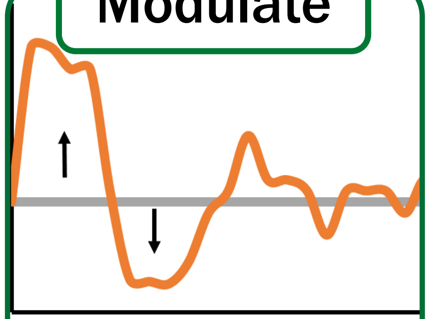
Load Shed



Load Shift



Modulate



Grid Services Provided

Efficiency	Load Shed	Load Shift	Modulate
• Generation: Energy & Capacity • Non-Wires Solutions	• Contingency Reserves • Generation: Energy & Capacity • Non-Wires Solutions	• Generation: Capacity • Non-Wires Solutions	• Frequency Regulation • Ramping

Examples

Efficiency	Load Shed	Load Shift	Modulate
• Daylighting with sensors & controls	• Reduce plug loads	• Precool with T-stat; preheat water heater	• Rapid dimming of lighting

DER Aggregation

- **Device level**
  - Individual devices interact directly with grid/aggregator
- **Building level**
  - Coordinate devices within building
  - Interact with grid as a unit
- **Campus/Community level**
  - Co-located buildings and devices coordinate
  - Package services at the district/neighborhood level
- **End-use level**
  - Coordinate fleets of similar devices

Considerations: performance, complexity, latency, scalability

Poll#1

Which of the following is the right level of aggregation for DERs behind-the-meter? [select one]

- ❑ Device level (individual devices interact with utility/aggregator)
- ❑ Building level (building interacts with grid as a unit)
- ❑ Community/Campus level (Coordinate co-located buildings)
- ❑ End-use level – (Coordinate fleets of similar devices)

Poll#2

What is the most significant barrier to integration of building technologies with other distributed energy resources (DER)? [select one]

- ❑ Usability (ease of installation, operation, and maintenance)
- ❑ Cost (including manufacturing, capital, O&M)
- ❑ Value proposition (M&V, customer perception and participation)
- ❑ Incentives/Tariffs (utility program, retail rates, policies, regulation)
- ❑ Technology (control and coordination algorithms, communication protocols)

DER Integration Project Examples

Cindy Regnier, LBNL

Post House: Evansville, IN

Source: CenterPoint Energy

52 multifamily units in two mixed-use buildings (2nd building is control)

EE measures: Cold-climate heat pumps, Advanced air sealing, Connected water heater and appliances, LED lighting

DERs: Rooftop solar, EV chargers

GEB Controls

- Apartment units aggregated for load-shed DR program
- Response is optimized using HVAC, connected lighting, water heating, and smart appliance loads

Goals and Metrics

- Energy: Savings per unit and by measure type
- Load: Average and peak load reduction, DR snapback
- Occupant experience: Comfort, opt-out rate, satisfaction, and experience with smart home devices
- DER: PV/smart inverter performance
- Cost-effectiveness

DER Integration Challenges

- Fire department approvals for battery installation.
- Data access – equipment APIs can change without notice, can disrupt controls. Data privacy concerns.

AI-Driven Smart Community: Basalt, CO

Source: NREL

27 new-construction townhomes

EE measures: High-efficiency homes, Cold-climate heat pumps, Heat pump water heater, Connected thermostats

DERs: Rooftop PV, Battery storage, EV chargers, Virtual microgrid

GEB Controls

- Home energy management system (HEMS) uses model-predictive control of home load, responds to aggregator signals
- Community Aggregator module coordinates all the homes collectively; interacts with utility to get requests such as demand response

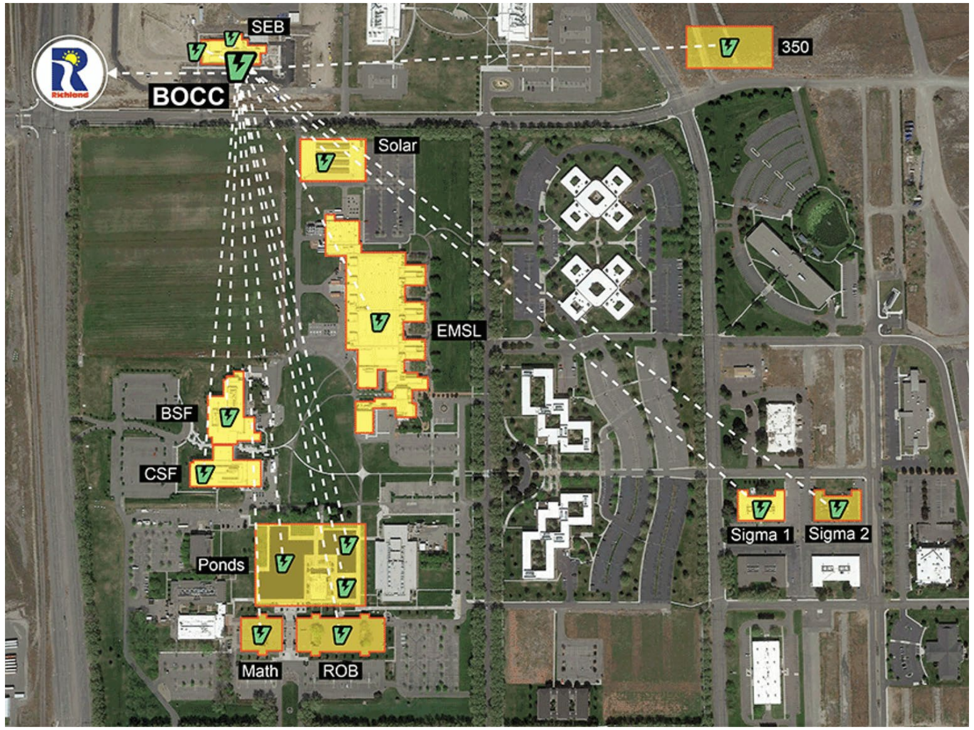
Goals and Metrics

- Energy: 35% better than code
- Load: Distribution feeder over-voltage reduction, 10% peak demand reduction, daily load shift
- Resilience: Days of operation with no net grid exchange
- Occupant comfort and experience: Indoor temperatures, satisfaction survey

DER Integration Challenges

- Ongoing O&M of optimization controls – what architecture is easiest to maintain, and which parties are responsible
- Battery system controls – currently owned by utility, not clear if they will be available for resiliency usage

Transactive Campus: Richland, Spokane WA; Toledo, OH



Source: PNNL

4-8 existing commercial buildings on each of 2 campuses; Future Pilot: tens of buildings in new EcoDistrict Spokane, WA

EE measures: Agent-based transactive controls for existing HVAC, lighting

DERs: PV, battery and thermal storage, EV chargers

Goals and Metrics

- Energy: Consumption and bill savings, per building and for campus
- Load: Coincident and non-coincident peak load reduction, distribution feeder congestion reduction
- Indoor environmental quality: indoor temperature and illuminance
- Occupant satisfaction survey
- Scalability: Deployment and integration time and effort

GEB Controls

- Efficiency optimization and fault diagnostics at individual building
- Transactive controls respond to grid prices and signals at campus or feeder level

DER Integration Challenges

- BACNET integration relatively straightforward, any vendor proprietary integration much more challenging

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Georgia Tech Campus Energy

Presenter: Dr. Scott Duncan, Research Engineer

Chief Engineer: Dr. Jung-ho Lewe, Research Engineer

GT Aerospace Systems Design Lab

"GT Flex": Georgia Tech Main Campus, Atlanta, GA, USA

Source: Georgia Tech

GEB Controls

- Efficiency optimization for individual buildings and two district energy thermal plants
- Pre-programmed strategies for optimal response to provide grid services (real-time pricing or demand response)

12-18 existing campus buildings of varying typology, age

EE measures: Optimized controls for existing HVAC systems, central plant upgrades (future)

DERs: Battery, PV, and thermal energy storage (future)

Technical Goals and Metrics

- Energy: Consumption and utility bill savings, greenhouse gas reductions
- Load: Peak load reduction, load shift energy for individual buildings, aggregation of campus flexibility to provide grid services, e.g., contingency reserve
- Cost-effectiveness: return on investment
- Minimized impact to thermal comfort, maintenance

Programmatic Goals

- Inform upcoming GT Campus Energy Master Planning
- Precursor to campus testbed / demonstrator
- Focal point for education and research

“GT Flex”: Georgia Tech Main Campus, Atlanta, GA, USA

Source: Georgia Tech

Technical Features of GT Flex Initiative

Premise: Pilot how to increase the number of buildings that can operate as GEBs on a legacy campus

Approach (Mar-Oct 2020):

- Baseline energy modeling
- Model ECMs and flexibility tactics
- Pilot via tests on buildings (currently unoccupied)
  - Newer, higher-performing buildings
  - Older legacy buildings
- Gain on-the-ground understanding of current campus BAS controls and implication for harnessing flexibility
- Define a roadmap for
  - Increasing GEB participation
  - Co-planning increased penetration of DERs
  - Aggregating DER/GEB flexibility
  - Designing grid services in coordination with utility companies

"GT Flex": Georgia Tech Main Campus, Atlanta, GA, USA

DER/GEB Integration Challenges

- **Heterogeneity of buildings on a legacy campus**
  - Wide variety of mechanical systems make standardized modeling approaches a challenge
  - Mixed opportunities for rooftop DERs
  - Some research labs hesitant to participating in DR
- **Interoperability of systems, e.g., DERMS, BAS, even with a central campus controls vendor**
  - Utilities data standardization, cleaning, maintenance, etc.
- **Uncertain fiscal climate due to pandemic**

Commercialization and Deployment Challenges

Hayden Reeve, PNNL

Commercialization and Deployment Challenges

- **Customer Acceptance and Adoption:**
  - Ensuring privacy
  - Enabling customer agency while combating engagement fatigue
  - Avoiding getting ‘turned-off’

- **Value Proposition and Alignment:**
  - Limits of “single-purpose” programs
  - Highly Balkanized market and regulatory environment
  - Grid service transformation timeline and incentive uncertainty
  - Market elasticity and saturation
  - How to align investment and value (avoiding the split incentive problem)

Commercialization and Deployment Challenges

- **Delivery Challenges:**
  - How to qualify and acquire devices and customers?
  - Navigating a fragmented life-cycle (design, specification, installation, commissioning, & maintenance)
  - Role of Cx and other EE solutions in delivering grid services
  - Can system solutions and savings be delivered incrementally?
  - What happens at transfer of ownership?
- **Business Model and Deployment Led Innovation:**
  - Adjacent opportunity for utilities, OEM/vendors, ESCOs, and service providers to bundle EE and Grid Services?
  - How to target soft costs with similar success as solar industry?

Optimization, Cyber, and Interoperability Challenges

Michael Starke, ORNL

DER Optimization, Cyber, and Interoperability Challenges

- **Timing:**
  - The periodicity of device updates based on control requests issued or data measurement postings
  - Timestamping
- **Unique Functionality/Semantics :**
  - Device modes of operation and naming are not always consistent
  - Available modes may not directly align with needs or objectives
  - Standards are working on these challenges, but have not yet been fully adopted by industry
  - Still significant proprietary development with NDA protection

DER Optimization, Cyber, and Interoperability Challenges

- **Communications:**
  - Standards are being developed to support challenges: IEC61850/Sunspec/IEEE1547
    - Not all encompassing or can be complicated
  - Not plug-and-play require integration into SCADA systems
  - Firewall implementation is typical approach to cyber protection
  - Keys sharing as a protective measure
    - must be updated periodically to ensure
  - Some protocols are not able to be protected and are expected to be physically secured.

DER Optimization, Cyber, and Interoperability Challenges

- **Multi-objective optimization and strategies:**
  - Establishing the overall objective in relationship to other objectives can be challenging.
  - Multiple ownership models
- **Unique mode representations**
  - Including new modes or capabilities into an optimization formulation
- **Objectives and Constraints may be non-linear**
  - Loss of accuracy to linearize problem
  - May be more time consuming to solve (need more computational open-solvers)
- **Performance versus Maximal Usage**
  - PV shed to maintain grid against maximum profits PV

Measurement & Verification, and Equity Challenges

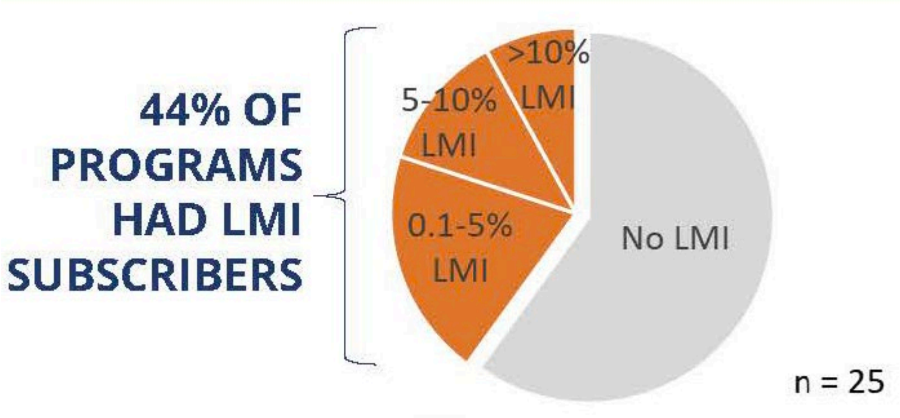
Cindy Regnier, LBNL

DER Measurement & Verification Considerations

- Descriptive information – e.g.
    - DER Characteristics – capacity, quantity etc.
    - Information on pricing structure, demand charges
- Data collected –
    - DER energy use, power production, building net energy consumption
    - Change of value data – recorded at irregular intervals, whenever the value changes
    - Time series data - recorded at regular intervals, metadata
    - Customer energy bills
- User/Installer Experience – survey responses (quantitative, quality), ease of deployment
- Performance metrics – computed from some 'base' set of data for the grid services provided, for example, annual avoided energy use, or average whole-building load shed
- Other considerations
    - DER ownership - who owns the data, who owns operations, who benefits
        - Change of ownership, ownership model influences on operations/optimization
    - Baseline comparison – include controls baseline, possibly different utility rate structure, other
- Cost-effectiveness

Equity – PV

- Nearly half of U.S. households (154 million people) don’t have access to PV installations due to lack of suitable roof space, or being in a rental condition
- Low-income households on average spend over 8% of their income on utility bills, about three times more than moderate- to high-income households.[1]
- **PV ownership in communities of color – for the same median household income, black- and Hispanic- majority census tracts have installed 69 and 30% less PV than non-majority census tracts[3]**
- Many financial barriers to PV ownership – credit scores, capital cost, high interest rates
- Community solar can be a resource for Low- to Moderate- Income (LMI) households[2]
    - Offered by 228 utilities in 36 states, 734 MW total (~ 1% of U.S. total)
    - **Less than half of U.S. community solar programs have any participation from LMI households. Only about 5 percent of programs involve a sizable share(more than 10 percent)**
- To be successful solar subscription costs need to be lower than the



Source: Smart Electric Power Alliance Program Administer Survey Data, 2018

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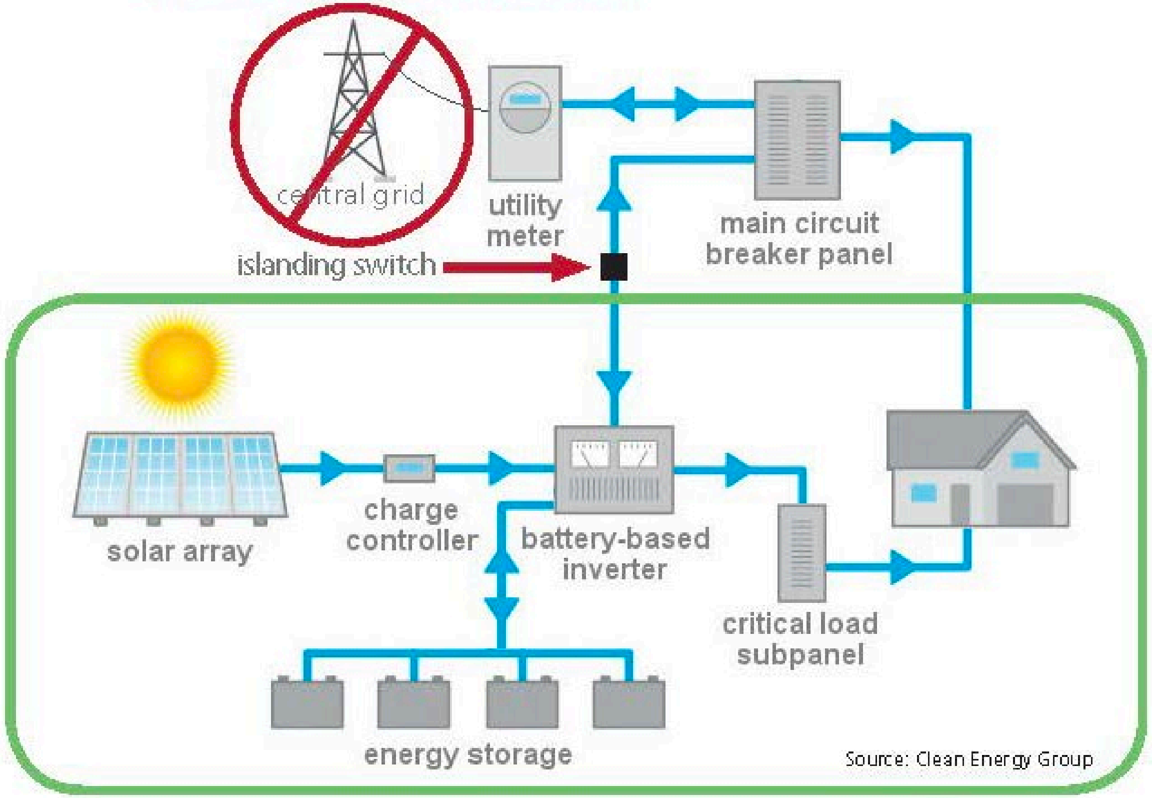
1. Earthwiseradio.org, 2020. ‘Solar Equity for Low Income Communities’
2. SEPA, 2018. ‘Community Solar Program Design Models’
3. Sunter, D., Castellanos, S., Kammen., D. 2019. ‘Disparities in Rooftop PV Deployment in the United States by Race and Ethnicity’. Nature Sustainability.

Equity - Storage

- Batteries have further economic barriers to LMI deployment
- Growth and interest in resiliency in public policy and programs may support further development in LMI households
- Some innovations in public policy and programs starting to address this:
  - The California Public Utilities Commission (CPUC) on Sept 12th approved a $100M equity resiliency budget within the Self-Generation Incentive Program (SGIP). Targets deployment in high wildfire risk areas (where power outages possible). (Also targets vulnerable households and critical services facilities)[1]
- State, municipalities and utilities can support further deployment through grants, rebates, incorporating solar+storage into existing programs, utility mandates, tax incentives, alternative ownership structures, financing, and more[2]

FIGURE 1: Islanded Resilient Power System



Source: Clean Energy Group

1. https://www.utilitydive.com/news/california-calls-for-100m-to-incentivize-ders-in-high-risk-wildfire-areas/561563
2. SunShot U.S. Dept of Energy and Clean Energy States Alliance, 2017. 'Solar+Storage for Low-and Moderate-Income Communities. A Guide for States and Municipalities'

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