GEB Webinar Series: Distributed Energy Resources (DER) Integration

Building Technologies Office
June 30, 2020
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

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# GEB Technical Report Webinar Series

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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.
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 to 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

- **Efficiency**: Reducing power demand at specific hours.
- **Load Shed**: Temporarily reducing power demand during high demand periods.
- **Load Shift**: Shifting power demand to off-peak hours.
- **Modulate**: Adjusting power demand in real-time for substations and microgrids.

- **Efficiency + Generate**: Combining efficiency improvements with renewable energy generation.
- **Efficiency + Generate + Shed/Shift**: Integrating energy storage and demand response to optimize power use.
Mapping Flexibility Modes and Grid Services

Buildings can provide grid services through 4 demand management modes.

**Efficiency**
- Generation: Energy & Capacity
- Non-Wires Solutions

**Load Shed**
- Contingency Reserves
- Generation: Energy & Capacity
- Non-Wires Solutions

**Load Shift**
- Generation: Capacity
- Non-Wires Solutions

**Modulate**
- Frequency Regulation
- Ramping

### Grid Services Provided

#### Load Shed
- Contingency Reserves
- Generation: Energy & Capacity
- Non-Wires Solutions

#### Load Shift
- Generation: Capacity
- Non-Wires Solutions

#### Modulate
- Frequency Regulation
- Ramping

### Examples

- 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

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

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

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

**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

Source: CenterPoint Energy
AI-Driven Smart Community: Basalt, CO

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

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

Source: PNNL
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

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**

### 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)

### Programmatic Goals
- Inform upcoming GT Campus Energy Master Planning
- Precursor to campus testbed / demonstrator
- Focal point for education and research
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
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.
  o DER Characteristics – capacity, quantity etc.
  o Information on pricing structure, demand charges

• Data collected –
  o DER energy use, power production, building net energy consumption
  o Change of value data – recorded at irregular intervals, whenever the value changes
  o Time series data - recorded at regular intervals, metadata
  o 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
  o DER ownership - who owns the data, who owns operations, who benefits
    – Change of ownership, ownership model influences on operations/optimization
  o 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 tracts³
- 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) households²
  - 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) of LMI subscribers.

¹ Earthwiseradio.org. 2020. 'Solar Equity for Low Income Communities'.
² SEPA, 2018. ‘Community Solar Program Design Models’
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 more²

². Clean Energy States Alliance, 2017. ‘Solar+Storage for Low-and Moderate-Income Communities: AFeasibility Study for States’