Grid-Interactive Efficient Buildings (GEB)

The objective of this challenge is to develop conceptual designs that support BTO's overall GEB strategy in the areas of 1) intelligent algorithms that optimize the operation of building's active and passive systems to maximize energy efficiency, and 2) whole-building-level interoperable and low cost automation systems that enable communication with building equipment and appliance to optimize operation to provide grid services.

Background

Buildings are the nation's primary users of electricity with 75% of all U.S. electricity is consumed within buildings.[1] Perhaps more importantly, building energy use drives a comparable share of peak power demand. The electricity demand from buildings result from a variety of electrical loads that are operated to serve the needs of occupants. These loads are heating, cooling, water heating, appliances, lighting, and miscellaneous electric loads. The electric grid is traditionally "load following," wherein the generation is controlled, often times centrally, to increase or decrease based on the demand. However, with proper coordination and controls, building loads can be intelligently managed to consume electricity at specific times and at different levels, while still meeting occupant productivity and comfort requirements. This increased demand flexibility can benefit the grid by balancing supply and demand while providing value to owners through reduced utility bills and increased resilience, among other benefits. The demand flexibility can also enable higher penetration of renewable generation sources.

Demand response (DR) programs and Demand-side management programs currently offer an opportunity for consumers to play a role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of incentives. Existing programs are limited in scope both in number of buildings' loads engaged and also amount of demand flexibility engaged in a given utility. A significant opportunity exists in engaging this demand flexibility to provide grid services such as load shifting, load shedding, reduction in peak demand, and integration of renewables. Additionally, onsite distributed energy resources (DERs)—such as rooftop photo voltaic (PV), electric vehicle charging, and batteries —can be co-optimized with building electrical loads through demand-side management. Electric grid needs vary significantly by location, time of day, day of week, and season; aligning building load shapes with renewable generation profiles is critical to maximizing the benefit of building load flexibility and higher utilization of renewables. Accordingly, a building may need to manage its electricity load in different ways during these times by reducing load through year-round energy efficiency, shifting load to different times of the day, and/or pre-charging/storing for later use. These methods allow buildings to provide demand flexibility and are a significant focus area of US Department of Energy (DOE).[2] Additionally, passive technologies (e.g., envelopes, windows, daylighting) increase the efficacy of these strategies by lowering energy intensity.

The ability to take an integrated approach to demand-side management and demand flexibility requires smart technologies, including advanced sensors, controls, models, and data analytics that can meet occupant requirements and respond to changes in the grid, building usage, and weather conditions.

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[1] Annual Energy Outlook 2019. "Reference Case Projections Tables- https://www.eia.gov/outlooks/aeo/tables_ref.php

[2] Grid-interactive Efficient Buildings Technical Report Series: Overview of research challenges and gaps- https://www1.eere.energy.gov/buildings/pdfs/75470.pdf

Today, behind-the-meter DERs—including energy efficiency, demand response, distributed generation, electric vehicles, and storage—are typically valued, scheduled, implemented, and managed separately. The DOE Building Technologies Office's (BTO) grid-interactive energy efficient buildings (GEB) vision involves the integration and continuous optimization of these resources for the benefit of the buildings' owners, occupants, and the grid. BTO recognizes that this is a long-term vision and that there is continuum—from manual operation of buildings to fully automated energy management platforms—that allows for continuously improving integration and optimization.

GEBs are beneficial for both end-users and the grid. Operating an electricity grid is tantamount to balancing supply and demand for different timescales under the constraints of limited generation resources and transmission and distribution capacity. Demand must be met through matching services provided by supply-side entities: integrated utilities, grid operators, generators, and/or distributed generation resources. Demand-side entities such as buildings and electric vehicles may also contribute to balancing supply and demand. In this regard, demand-side contributions can be just as viable as supply-side counterparts. Building owners or occupants that use demand-side management strategies may do so for various motivations, including compensation through lower utility bills, lower rates, or negotiated payments. Additionally, building operating costs may be reduced by avoiding utility demand charges or time-of-use peaks, which may or may not align with the real-time grid needs. Furthermore, owners and occupants may be motivated by environmental or other nonfinancial considerations. These strategies also have the potential to provide grid services, some of which provide benefits to the grid by avoiding or deferring transmission and distribution upgrades and associated capital expenditures, which can prevent utility customer rate increases. Both the utility system and society can realize numerous benefits from using demand-side management strategies such as increased system reliability and resilience, increased DER integration, increased owner/occupant satisfaction, flexibility, choice, and so on.

The Challenge:

The JUMP into STEM competition is looking for conceptual designs that support BTO's overall GEB strategy in the areas of 1) intelligent algorithms that optimize the operation of building's active and passive systems to maximize energy efficiency, and 2) whole-building-level interoperable and low-cost automation systems that enable communication with building equipment and appliances to optimize operation to provide grid services.

Teams can explore solutions appropriate to any and all building uses and building types, including residential buildings, commercial buildings, and campuses and may choose to, but not limited to, work on some of the following research items and strategies:

- **Interoperability.** Innovative approaches to establish two-way connectivity and communications with the building equipment and appliances as well as the grid at low installation and commissioning costs.
- **Control Algorithm Development.** Intelligent algorithms for optimal scheduling of devices that can maintain user comfort while minimizing energy cost. They may also include automated uncertainty management and fault diagnosis capabilities for low operation and maintenance costs. Algorithms could use data-driven and machine learning approaches.

- **Building Load Shaping to Match Renewable Generation.** Control and coordination concepts that enable innovative load shapes to maximize utilization of renewable generation for optimizing occupant energy usage and changing conditions over multiple timescales
- **Ensuring Occupant Comfort.** User-friendly methods to obtain feedback on comfort from occupants while the building is providing grid services

Each team's solution should include:

- Description of the proposed solution. What problem or need does it address? How does the solution address that problem?
- Details about how the proposed solution will be integrated with and improve upon the existing approach of the building
- How the proposed solution will benefit both end-users and the grid (e.g., quantified potential energy and nonenergy benefits realized through increased automation and user interaction)
- A technology-to-market plan for how to scale-up this solution to make an impact on the building industry. The GEB ecosystem includes many different companies and organizations. Radical change does not come easily, so the technology-to-market plan should also address how to scale-up this solution such that an impact on the building industry and the grid can be made.