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This letter is in response to your U.S. General Services Administration (GSA) Freedom of Information Act (FOIA) request number (GSA-2020-000441), submitted on January 26, 2020 in which you requested the following:

> "A copy of the cost-benefit analysis, conducted by RMI, to examine the value of incorporating load flexibility, peak load reduction, and demand response capabilities at GSA buildings at 6 different parts of the country. This report identified the potential for savings of 180 GWh/y of energy and $50 million across the GSA's owned office portfolio. Year-round demand management and flexibility in most cases delivered greater value than demand response. Kevin Kampschroer and Ken Sandler have a copy of this cost benefit analysis."

Enclosed please find the document responsive to your request.

For future reference, this document is publically available and can be found at the following link: https://rmi.org/insight/value-potential-for-grid-interactive-efficient-buildings-in-the-gsa-portfolio-a-cost-benefit-analysis/.

This completes our action on this FOIA request. Should you have any questions, please contact Ms. Kinga Porst Hydras at (202) 501-0762 or by email at kinga.hydras@gsa.gov. If you need additional assistance, you may also contact Ms. Audrey Brooks, GSA's FOIA Public Liaison at (202) 205-5912 or via email at audrey.brooks@gsa.gov.

Sincerely,

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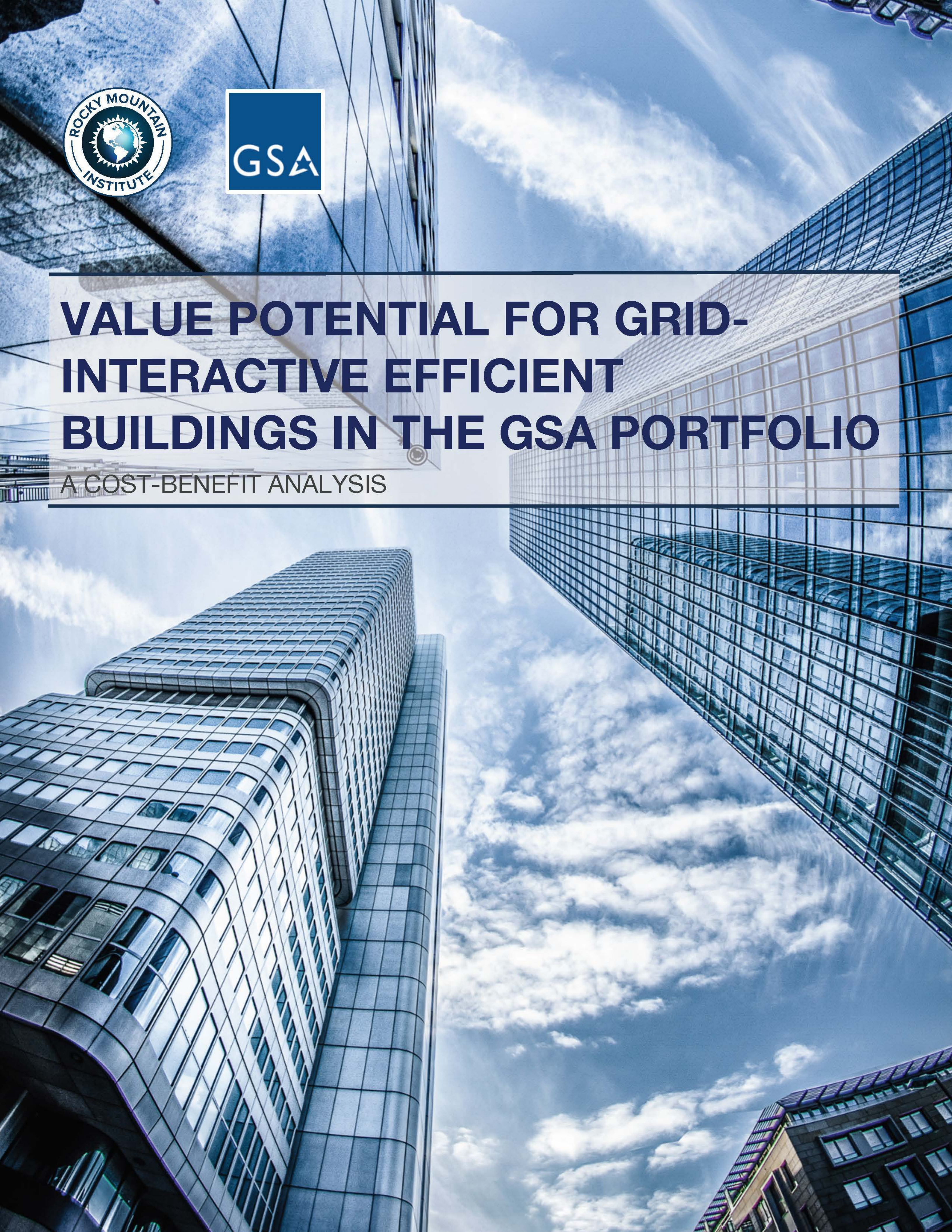

VALUE POTENTIAL FOR GRID-INTERACTIVE EFFICIENT BUILDINGS IN THE GSA PORTFOLIO

A COST-BENEFIT ANALYSIS

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ABOUT ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; the San Francisco Bay Area; Washington, D.C.; and Beijing.

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EXECUTIVE SUMMARY

This report quantifies the significant, untapped value that the General Services Administration (GSA) could unlock by investing in grid-interactive efficient buildings (GEBs). A GEB is an efficient building with smart technologies characterized by the active use of energy efficiency, solar, storage, and load flexibility to optimize energy use for grid services, occupant needs and preferences, and cost reductions. There is a great deal of interest in this topic from the GSA, the Department of Energy Building Technologies Office, ASHRAE, the National Renewable Energy Laboratory (NREL), and a number of state and local governments, utilities, nonprofits, and research institutions, proving that GEBs are a national priority.

GEB measures go far beyond today's energy management best practices. They focus on demand and the time value of energy via energy efficiency, renewable energy, storage, and load flexible technologies, thereby reducing grid constraints and enabling decarbonization. A focus on GEBs optimizes benefits like cost savings, grid services, resiliency, and carbon emissions reductions. A GEB requires control systems that enable interoperability between independent building systems (such as lighting and HVAC) and provides the ability to respond to grid signals for price, carbon, or other constraints.

The purpose of this report is to demonstrate the value of GEBs, to encourage deeper analysis for implementation of GEB strategies, and to launch a conversation around building-to-grid interactions. The report shows how GEBs can provide a great deal of untapped value to building owners, grid stakeholders, and society at large. The analysis leverages prototypical building models and extrapolated results to estimate the portfolio-wide savings potential and investment value of GEB measures in the GSA portfolio. The GEB value for specific buildings will vary given the complexity and diversity across the GSA's portfolio. This report is not intended to take the place of a detailed feasibility study for implementing GEBs at specific buildings, so before engaging in site-specific pilot projects, we recommend a deeper analysis of the existing capabilities of a building's control systems, cybersecurity concerns, impacts on occupant comfort, and impacts on equipment life.

The value of GEBs:

- **Proven measures**: HVAC, lighting, plug load, renewable energy, and storage measures define the cost-optimal strategy.
- **Substantial energy impacts**: These measures can generate 165 MW of peak load reduction and 180 GWh/y in energy savings across the GSA-owned office portfolio.
- **Cost-effective building-level economics**: Each modeled location shows paybacks of less than four years,[i] saving on average 30% of annual energy costs (depending on location-specific factors[ii]).
- **Sizable savings at scale**: The GSA could generate $50 million in annual cost savings, about 20% of the GSA's annual energy spend, by pursuing GEB measures for all of its owned office buildings. This would require a $184 million[iii] up-front investment that would in turn deliver $206 million in net present value (NPV) over eight years.[iv]
- **Potential to be price maker**: The GSA's building portfolio is large and concentrated enough to provide notable demand reduction within local utility territories and impact grid-level economics.
- **Persistent savings**: GEB measures enable load flexibility, which ensures savings even as rate structures change.

A GSA GEB strategy should prioritize:

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[i] With incentives included.

[ii] Annual cost savings by location vary between 7% and 60%.

[iii] This figure is based on RMI-researched upfront costs. Upfront costs can vary widely, but sensitivity analysis indicates that upfront costs could more than double and still provide NPV-positive investments in all locations.

[iv] Based on a 3% discount rate and eight-year analysis period, which represents the shortest duration/lifespan of the proposed measures, even though lifecycle savings would continue to accrue after eight years for some of the equipment.

- **Investment in fully controllable systems:** For example, fully controllable lighting fixtures can provide greater value than LEDs alone.
- **Staging of large building loads:** Staging loads such as electric heating, air handling unit (AHU) fan motors, and plug loads offer an untapped source of demand savings and require little to no new equipment.
- **Consistent demand management and peak shaving:** Year-round demand management delivers greater value than demand response in most scenarios.
- **Battery storage and solar photovoltaic (PV) panels:** These technologies make economic sense in most locations, but to varying degrees. Falling first costs make these technologies more important for future projects.
- **Occupant comfort and building operations:** The GEB measures have little to no discernable difference in occupant comfort.
- **Interoperable, intelligent building controls:** An ideal control system should balance available energy and demand flexibility, building operational needs, and grid price signals to provide grid benefit and reduce costs.

The value of GEBs will increase over time:

- GEBs could generate up to **$70 million per year in societal value to grid users** due to reduced generation capacity and reduced transmission and distribution costs, which could be monetized and benefit all ratepayers. GEBs also improve grid resilience, balance loads, and reduce grid carbon intensity.
- The GSA should **leverage its size and relationships with utilities and regulators** to pioneer opportunities to fully realize the societal value of GEBs (by integrating this value into grid planning) and to monetize where possible, through new rates and programs.
- Nationally, utilities are moving toward rate structures with higher demand charges, time-of-use rates, and seasonal variation—all of which make GEBs projects more cost-effective.

Recommended next steps:

1. **Fold GEB measures into current projects and pipeline:**
    a. GEB measures have a short payback and a high NPV; therefore, they should be implemented now to capture value. This makes them valuable for buying down longer-payback measures in energy savings performance contract (ESPC) and utility energy service contract (UESC) projects. And quick paybacks reduce the risk of uncertainty around future utility pricing, including demand charges.
    b. GEB measures should be evaluated in all upcoming projects, and this analysis should include demand charge savings.
    c. Controllable fixtures and building controls for reducing peak demand should be included in a standard specification and should be required when fixtures are changed and controls are reprogrammed.
    d. New construction and major renovation projects should have advanced specifications for GEB-capable control systems.
2. **Develop dedicated GEB pilots to generate proof points:**
    a. Prioritize locations with high demand rates or time-of-use rates, including NYC ($3.1 million NPV, 2.3-year payback), Fresno ($4.0 million NPV, 3.7-year payback)[v]
    b. Prioritize locations like Denver ($900,000 NPV, 1-year payback) due to GSA's sizeable local presence and high demand charges.
    c. Applying GEBs to all-electric buildings should be a top priority; they generate double the

[v] Based on a 3% discount rate.

NPV compared to dual-fuel buildings.

3. **Develop and/or adopt a building performance metric** that considers electric demand (e.g., demand load factor).

1. INTRODUCTION TO GEBS

Grid-interactive energy-efficient buildings (GEBs) are the next frontier for reducing energy consumption and demand, operating costs, and carbon emissions in the built environment. Integrating buildings with the electrical grid goes hand in hand with smart ongoing daily energy management practices to better control building energy loads. These practices also generate immense societal value by reducing the cost of electricity transmission and distribution and utility generation, which trickles down to all ratepayers. This space is evolving quickly, offering opportunities for building owners and operators to work with utilities to recognize the value of GEBs and ensure that value benefits all stakeholders. Many market players are working in this space, but **this is the first study focused on replicable solutions for an entire portfolio and the business case for building owners.**

The General Services Administration (GSA) is the nation's largest landlord, overseeing almost 9,000 buildings and over 350 million square feet of space. The GSA has long been a national leader in the high-performance building space—the agency was an early adopter of advanced standards like LEED, it led the federal government in delivering deep energy retrofits through its world-class National Deep Energy Retrofit program, and it is experienced with net-zero energy buildings. The GSA is leveraging a number of piecemeal GEB techniques today, yet has the opportunity to leverage a holistic approach to drive even greater returns from its buildings.

The GSA has an opportunity to deliver cost savings to all electricity users, including both the federal government and taxpayers. It boasts a large portfolio that would be of value to utilities, and its prominence will allow it to scale its impact through other federal agencies and the broader commercial real estate space. **The next frontier for GSA leadership is to leverage its size and relationships with utilities to pioneer opportunities to realize the full societal value of GEBs, helping all ratepayers to save on their utility bills.**

What Is a Grid-Interactive Efficient Building?

GEBs are buildings that leverage technologies and strategies to provide continuous demand management and load flexibility. GEBs include a holistic and optimized blend of energy efficiency, energy storage, distributed energy generation, and load-flexible technologies/controls. What makes them unique are their ability to optimize across these attributes (today such measures are individually optimized), provide load flexibility, and be continually optimized over time. GEBs result in a less peaky, more flexible energy load profile that reduces operational costs through demand charge savings.

Buildings drive up to 80% of the peak demand on the grid,[1] and thus are key to balancing the grid. GEBs reduce the number of power plants, increase grid performance, and better utilize the renewables that are on the grid. The traditionally centralized, one-way electrical grid does not provide the optimal environment for managing many of the new and emerging energy challenges and opportunities of the 21st century. A smart, two-way grid interacting with smart, responsive buildings can fortify the system to deal with economic, security, supply, and demand disruptions while leveraging new opportunities for efficiency, cost savings, resilience, and distributed energy generation.

Some technologies that support a GEB approach are in use today, including fully controllable LED fixtures, solar photovoltaics, and electric battery storage. However, there are a few key differences between GEBs and today's highly efficient buildings:

1. **Interoperability and intelligence from building to grid:** GEBs should receive utility price signals, and share the availability of flexible loads within the building to modulate loads and optimize for cost, carbon, reliability and other factors. Even buildings engaged in curtailment or demand response programs do not often have an automated process, and virtually no buildings automatically shift loads based on real-time changes in utility price signals.
2. **Interoperability and intelligence across building systems**: GEBs should have one overarching, intelligent system that controls HVAC, lighting, plug loads, thermal or electric storage, and other key building loads. Without cross-system interoperability and intelligence, buildings will fall short of their full potential to control electricity demand to save money and to interact positively with the grid. Many building loads (e.g., plug loads) are seldom controlled at all, let alone to optimize to utility price signals.

Existing control systems vary widely across building type, size, and vintage, but most building controls are not set up to coordinate across building systems.

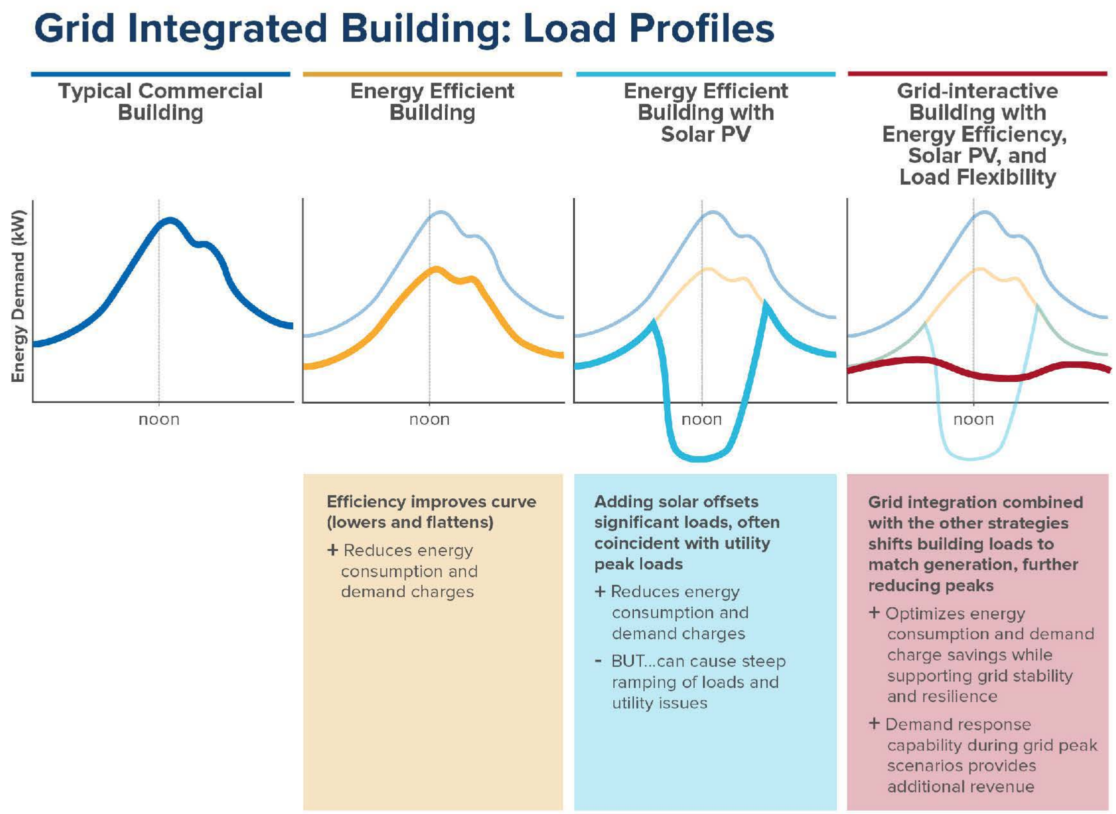
3. **Load flexibility and demand-focused optimization**: GEBs should have the intelligence to track building demand, predict patterns that can help limit peak demand, and shift or shed demand rapidly in response to grid or building events. Using the same functions to limit building billing peak is often more cost-effective than responding to narrow demand-response events. The ability to predict weather patterns, track renewable energy generation curves, or predict building operational needs can allow a GEB to limit monthly peaks and reduce costs more so than today's more traditional efficiency- and demand response-focused energy management practices.

This paper focuses largely on the economic case for GEBs. Additional research and industry demonstration projects are needed to better understand the challenges and potential solutions related to control interoperability and intelligence.

Understanding GEB Load Profiles

To illustrate this concept, the graphs in Exhibit 1 show representative daily building load profiles for a typical large office building. The first profile shows a generic commercial building load profile with a midday peak demand. The second profile shows the benefit that energy efficiency provides by lowering the load profile overall and reducing energy use and demand. The third scenario is an efficient building with on-site solar PV generation, which produces more energy than the building consumes during the middle of the day. The last scenario shows an optimized blend of energy efficiency, solar PV, energy storage, and load flexibility, which delivers a flexible, lower, and less peaky load profile.

EXHIBIT 1: DAILY BUILDING LOAD PROFILES FOR A TYPICAL LARGE OFFICE BUILDING



State of the Industry

Currently, buildings and utilities separately pursue high-performance energy innovations; however, these efforts are insufficiently integrated to take full advantage of the new range of opportunities. Building owners need to understand the value proposition to integrate their buildings with the needs of the grid. Utilities, operators, and others in the electricity space need to properly value the services that buildings can provide to the grid and align their pricing models with grid health and emissions intensity.

The GSA's size and relationships with utilities puts it in a unique position to lead demonstrations of GEB concepts, and to work with utilities to realize the full value of grid integration. This analysis recommends many straightforward GEB measures that any building owner could invest in today to see utility cost savings. It also provides the framework for a greater conversation that building owners need to have with utilities to realize the full societal value of building-grid integration. This will ultimately save building owners and operators and taxpayers money if that value can be properly attributed.

The Benefits of GEBs to the GSA

GEBs can provide substantial value to the GSA. This includes direct value in the form of cost savings, as well as a number of other benefits that support the GSA's Strategic Plan. The four strategic priorities for the GSA laid out in the GSA Strategic Plan for Fiscal Years 2018–2022 are:[2]

1. Save taxpayer money through better management of federal real estate;

2. Establish the GSA as the premier provider of efficiency and effective acquisition solutions across the federal government;
3. Improve the way federal agencies buy, build, and use technology; and
4. Design and deliver expanded shared services within the GSA and across the federal government to improve performance and save taxpayer money.

GEBs support these goals directly by reducing the cost of the federal inventory, advancing technology modernization initiatives, enabling services that yield measurable savings while aligning with changing market demands, and delivering integrated offerings. GEBs provide an opportunity to demonstrate federal leadership in advancing smart and economical building practices.

Additionally, the GSA's investment in GEBs will benefit taxpayers at large by:

- Improving energy affordability
- Increasing reliability and resilience
- Expanding opportunities in public/private partnerships
- Furthering industry transformation
- Reducing CO_2 emissions
- Maximizing current building interventions through improved project value

Three Value Drivers of GEBs

Our research has shown that GEBs drive three main types of benefits to the building owner and to the grid: direct value, indirect value, and societal value.

EXHIBIT 2: CORE VALUES OF GEBS TO THE GSA AND OTHER BUILDING OWNERS

Direct Value	Indirect Value	Societal Value
$50M in annual cost savings	Demonstrate federal and real estate industry leadership	Reduce grid-level generation, transmission, and distribution costs by up to $70M/y
$206M in NPV	Enable deeper savings in ESPCs and UESCs	Savings ultimately benefit federal government and taxpayers
Project-level payback under 4 years	Improve comfort, health, and productivity through better building controls	Future rate structures will more directly share grid-level savings
Flexibility to accommodate future rate structure changes		Reduce CO_2 emissions

Direct Value

GEB measures drive direct value to the GSA and other building owners through reducing energy and demand costs and leveraging revenue-generation opportunities. RMI identified five categories of direct value to the GSA:

1. **Demand charge reduction ($/kW savings):** GEB measures reduce billing peak demand, which reduces utility bills. Billing peak demand is typically the highest demand the building experiences throughout a full billing period, regardless of time of day. Reducing peak billing demand can dramatically reduce costs but will not always align with grid peak demand. Demand charge reduction is sometimes referred to as "peak shaving" or "peak demand reduction."
2. **Flexibility that addresses time of use ($/kW or $/kWh savings):** Utility bills are reduced by leveraging GEB measures to "flex" building energy loads from costly energy times to cheaper energy times. This benefit is only valuable when the building is signed up for a time-of-use (time-of-day) rate.
3. **Energy cost savings ($/kWh savings):** GEB measures include energy efficiency measures, as pure efficiency measures also reduce demand—either constantly or during peak times. For example, LED lighting retrofits reduce energy consumption and also reduce demand throughout their operating hours. It's also worth noting that some GEB measures could increase energy consumption. For example, electric battery storage consumes excess energy when charging and loses excess energy when discharging. This charging and discharging can lead to battery losses between 6% and 9% for standalone commercial Lithium batteries.[3]
4. **Demand response revenue ($/event or $/contract term):** Revenue is generated by enrolling in a demand response (DR) program through the utility, independent system operator (ISO), or regional transmission organization (RTO) (or by leveraging a third-party aggregator to maintain these enrollments). Demand response requires that a certain amount of building demand be reduced within a pre-established time period. For example: On a very hot day, a utility may engage its demand response participants to balance the high demand required by cooling systems in its operating region. Demand response and demand reduction can overlap, so often a building owner must decide between one strategy or the other to reduce costs. Our analysis shows that demand charge reduction (reducing demand charges on monthly utility bills) through consistent energy management is typically more lucrative than demand response (earned revenue for responding to DR events).
5. **Rebates and incentives ($/various metrics):** Many utilities offer rebates and incentives that reduce the first cost of investments that help them reduce loads. GEB measures have excellent paybacks even without these rebates and incentives, but these cost reductions can additionally cut payback periods from three years to less than one year in some scenarios.

Indirect Value

GEBs can also provide value to the GSA that is ancillary to the core implementation of GEB measures including:

1. **Federal and real estate industry leadership** as a result of being a first mover in the GEB space.
2. **Deeper savings in energy savings performance contracts (ESPCs) and utility energy savings contracts (UESCs),** which are financing mechanisms that the federal government leverages to pay for energy projects through reduced energy costs. Because the GEB measures studied have high net present values and low payback periods, they would help to pay down larger investments or reduce the financing term for ESPC and UESC projects.
3. **Better building control and occupant comfort**, as well as other values beyond energy cost savings. While these characteristics can enhance employee performance while lowering operations and maintenance costs for the space, they are often not monetized.
4. **Reduced CO_2 emissions,** which are an ancillary result of a cost-optimized GEB approach. Other GEB approaches could also be leveraged to target CO_2 reductions.

Societal Value

Additionally, GEBs can provide greater value to society at large—including all grid users (taxpayers). By focusing on reducing and shifting building peak loads, buildings can reduce the need to invest in grid transmission and distribution costs, generation costs, and other costly investments that can increase utility rates. Additionally, GEBs can reduce CO_2 emissions across the grid by focusing on reducing utility peaks that are coincident with grid carbon emissions. The societal value driven by GEBs is explored in more detail in Section 5.

2. FRAMEWORK FOR EVALUATING GEB MEASURES

The main objective of RMI's analysis is to assess the direct economic benefits of GEB measures in several locations where the GSA has substantial building footprints. A secondary objective is for the GSA to raise the national conversation about GEBs with utilities, ISOs, RTOs, regulators, and other key players, as described in Section 5.

To achieve the main objective, RMI developed a common framework that could map specific GEB measures to the direct value drivers listed above. Toward this end, RMI developed the following four categories of GEB measures:

EXHIBIT 3: THE FOUR CATEGORIES OF GEB MEASURES

Traditional Efficiency (reducing energy) Primarily $/kWh savings (e.g., LED fixture upgrades)	**Peak-Focused Reductions** (energy conservation measures that have an outsized impact during building peaks) Primarily $/kW savings (e.g., peak-focused LED dimming or staging AHU fan motors during peak heating or cooling))
Dynamic Demand Shifting (load flexibility) Primarily time-of-use or peak $/kW savings (e.g., batteries for peak reduction)	**Demand Response and Distribution-Level Grid Services** (point-in-time events) $/event, $/contract term, or $/custom (e.g., batteries for demand response)

Analysis Methodology

RMI used its proprietary Portfolio Energy Optimization (PEO) tool to analyze the technical and economic impact of GEB measures, which will help the GSA to prioritize investments in GEB measures across its portfolio. The PEO tool is an energy modeling tool that leverages the Department of Energy's (DOE's) EnergyPlus Simulation engine. The PEO tool was designed to more readily analyze energy upgrade projects across many similar buildings in one portfolio. For this study, the models are based on the DOE's reference model prototypes for office buildings. A small number of measures were analyzed outside of the PEO tool due to limitations of the EnergyPlus interface in addressing specific GEB measures.

The prototypical models were simulated in six locations chosen by RMI and GSA to represent a variety (rather than a representative sample) of utility rate structures, climate zones, GSA regions, and other factors. These models are *prototypes* rather than *actual buildings*, so the results should not be construed as formal recommendations for any single *actual* building in each of these locations. Rather, they are meant to guide decision-making and highlight opportunities in typical buildings. The technical and economic parameters of each building model were tuned to address each location's specific parameters. A few of those parameters are summarized in the following table:

EXHIBIT 4: TECHNICAL AND ECONOMIC PARAMETERS OF THE BUILDING MODELS

Location	Utility rate structure	Utility rates (approx.)	ASHRAE Climate Zone	GSA Region	Average Materials Cost Index[vi]	Average Labor Cost Index[vii]
College Park, MD	Moderate consumption charge, low demand charge	$0.085/kWh $3.75/kW	4A	11	1.031	0.916
New York, NY	High consumption charge, moderate demand charge Seasonal variation in rates	$0.12/kWh $20–$25/kW	4A	2	1.062	1.811
Atlanta, GA	Consumption only, moderate consumption charge	$0.10/kWh	3A	4	1.063	0.780
Denver, CO	Low consumption charge, moderate demand charge Seasonal variation in rates	$0.04/kWh $18–$23/kW	5B	8	1.095	0.766
Phoenix, AZ	Low consumption charge, moderate demand charge	$0.035–$0.055/kWh $17.6–$25.3/kW	2B	9	1.076	0.747
Fresno, CA	Moderate-to-high consumption charges, moderate-to-high demand charges Seasonal variation in rates and structure, time-of-use rates	$0.08–$0.15/kWh $19–$37/kW	3B	9	1.059	1.325

The utility rates used for this study are based on actual rate structures used in GSA buildings—including the separate energy supply bill and transmission and distribution bills present in deregulated energy markets. We cross-referenced actual GSA utility bills with the Genability utility rate database to ensure that our model incorporated all of the intricacies related to seasonal variations in supply or demand charges for some locations, as well as the nuances of other complex rate structures. In some deregulated markets and where data was not available, RMI made assumptions about utility energy supply charges based on publicly available data.

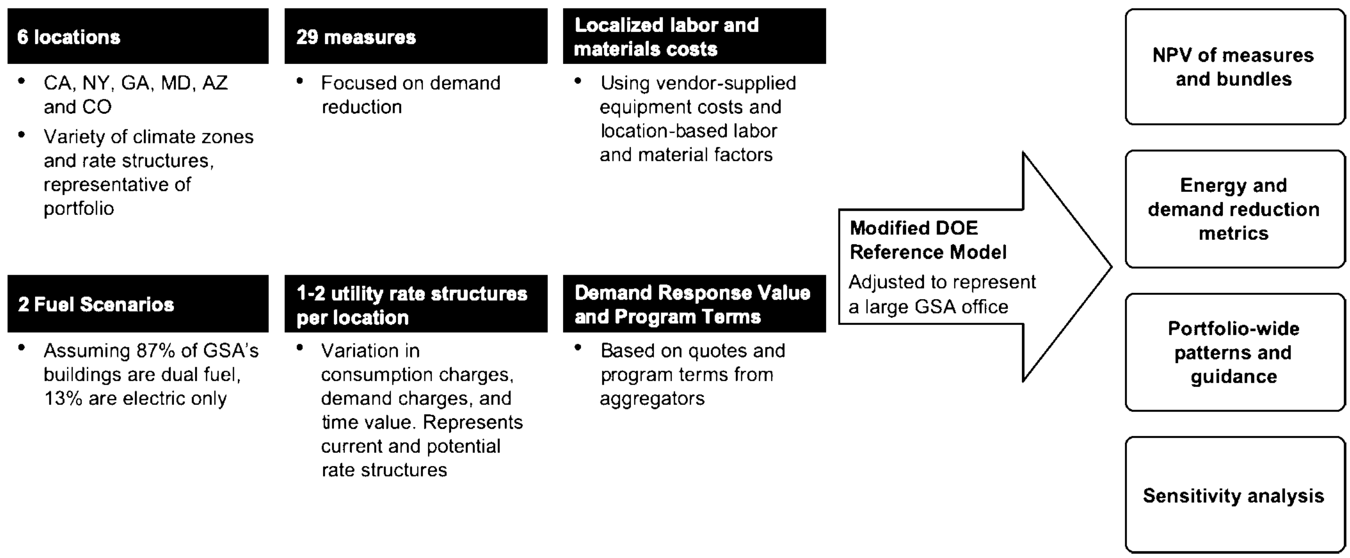
In addition to the six locations included above, RMI performed a site visit at the Harvey W. Wiley Federal Building in College Park, Maryland, to better understand the true operation of buildings in GSA's portfolio. The body of this report focuses on the prototypical locations listed above, and Appendix B includes some recommendations for the Wiley building's laboratory and office spaces.

The PEO tool takes a large number of inputs across multiple scenarios to deliver a detailed set of technical and economic outputs that help to prioritize investments in GEB measures. Exhibit 5 below shows a simplified flow chart of the key inputs to the PEO model (left) that generate the key economic outputs (right).

[vi] Based on RSMeans City Cost Indexes.

[vii] Ibid.

EXHIBIT 5: THE KEY INPUTS AND OUTPUTS OF THE ANALYSIS



GEB Measures

RMI developed a list of 29 GEB measures to evaluate across the six locations and two fuel scenarios studied. Some of those measures are common efficiency-focused measures that happen to have dramatic impacts on demand, while others are more nuanced demand-focused measures.

Exhibit 6 below includes the full list of measures studied, mapped to the four core values listed above. Appendix A describes these measures in further detail.

EXHIBIT 6: THE FULL LIST OF MEASURES STUDIED

	Traditional Efficiency	Peak-Focused Reductions	Dynamic Demand Shifting	Demand Response and Grid-Level Services
LED fixture with full control	X	X		X
LED fixture with occupancy controls	X			
LED tube retrofit	X			
***Electric resistance heating* staging**		X		X
Zone space temp setback	X	X		X
Window film	X	X		
Thermal storage			X	
Chilled water and hot water pumping pressure reset for demand response		X		X
AHU fan staging		X		X
Increased air filtration to reduce outside air (OA) needs	X	X		
Demand-control ventilation	X	X		
Energy/heat recovery systems	X	X		
Static pressure reset for demand response		X		X
Laptop battery charger staging		X		X
Solar PV array	X	X		
Electric battery storage		X	X	X

RMI created “bundles” of measures for each location studied, which included only the measures that had a positive net present value over their useful lifetimes. This bundle of NPV-positive measures for each location allowed RMI to account for interactive effects between the different energy measures studied, and for RMI to provide one set of economic and technical metrics for each location and fuel scenario. This results in 12 sets of metrics—one for each fuel scenario in each location. Sharing results for every measure in every location would be too complex and lengthy for this report.

3. KEY INSIGHTS

The GSA (and all building owners) have an immense opportunity to save direct costs and deliver societal value through GEBs. The GSA has the opportunity to drive about $50 million in annual cost savings—about 20% of the GSA's annual energy costs—by investing in GEB measures in its owned office and similar buildings. Investing in the GEB measures recommended below would deliver approximately $206 million in net present value over eight years, providing much more value than the payback period of less than four years.

Understanding and investing in GEB measures will help the GSA to future-proof its buildings against changes in utility rate structures, and will also enable the GSA to start a national conversation that could unlock additional value from GEBs.

The following insights are based on RMI's intensive analysis of six prototypical building locations, and are designed to help the GSA understand and prioritize key GEB value drivers.

A. There Is Likely Untapped Value from GEBs Across the GSA Portfolio

Buildings in every location that we studied can benefit from GEB investments. New York City and Fresno, California, showed the greatest net present value (NPV) and included the highest investments in GEB strategies.

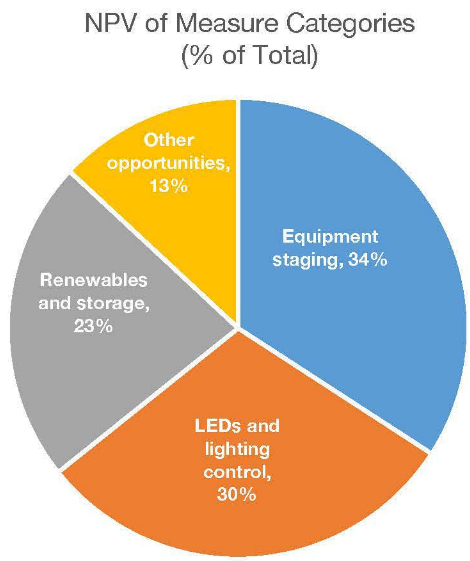
EXHIBIT 7: KEY ECONOMIC FACTORS FOR GEB MEASURE BUNDLES IN EACH OF THE SIX LOCATIONS STUDIED (DUAL FUEL SCENARIO ONLY)

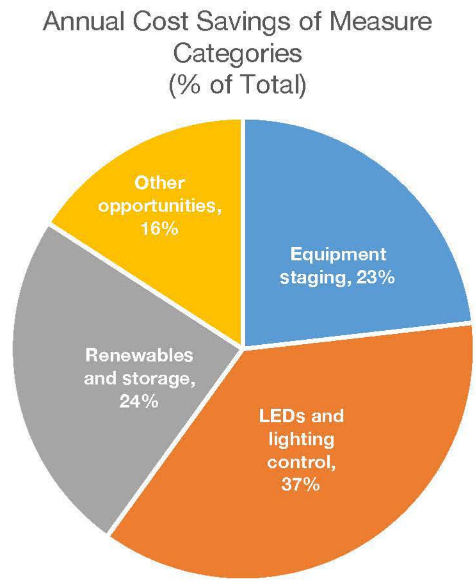
Location (sorted by NPV)	First Cost of GEB Measures	Annual Cost Savings	Payback with Incentives (years)	NPV with Incentives
Fresno, CA	$2,458,955	$612,178	3.7	$4,006,943
New York, NY	$2,013,386	$429,315	2.3	$3,084,392
Denver, CO	$282,357	$122,803	0.9	$894,312
Phoenix, AZ	$664,291	$207,468	3.2	$1,021,231
College Park, MD	$107,138	$48,251	2.2	$227,549
Atlanta, GA	$190,687	$59,072	2.9	$238,934
Average (unweighted)	**$952,802**	**$246,514**	**2.5**	**$1,578,894**

B. Three Categories of GEB Measures Drive the Most Value

RMI's analysis showed that a majority of the direct value generated by GEB measures comes from three categories of measures: equipment staging, LED lighting and lighting controls, and renewable energy/storage.

EXHIBIT 8: NET PRESENT VALUE AND ANNUAL COST SAVINGS GENERATED BY EACH CATEGORY OF GEB MEASURES ACROSS ALL LOCATIONS





NOTE: The "other opportunities" category includes zone space temperature setback, window film, thermal storage, increased air filtration to reduce OA needs, demand-control ventilation, and energy/heat recovery.

The difference between the NPV and the annual cost savings as shown in the two charts above tells us that **incremental investments in smarter controls and controllable devices often provide the greatest value.** This point is supported by each of these measures:

- Equipment staging is a low-cost, high-return GEB measure. The cost to implement controls to existing HVAC systems or banks of laptop battery chargers is relatively low and requires little to no new hardware. This unlocks immediate, untapped savings for any site with demand charges, and is supportive of future rate strucutre changes focused on demand charges or time of use.
- LED tube or fixture upgrades are a common retrofit measure, but the incremental cost of full controls enables significant additional value. In regions with higher demand charges and or more advanced peak pricing schedules, fully controllable LED fixtures offer more than three times more net present value at about two times the cost.[viii] Advanced lighting controls were not cost-effective in locations with low or non-existent demand charges.
- Renewable energy and energy storage are both relatively cost-intensive, hardware-focused installations. While both of these measures can add great value to any GEB project, the first costs should not be overlooked.

[viii] This assumes a fixture replacement rather than a tube retrofit. Tube retrofits can deliver value at a lower up-front cost but will not enable the level of control discussed in this report.

C. Staging Loads for Peak Shaving Drives Significant Value

Staged loads will drive substantial reductions in monthly peak demand charges. The staged load measures that we evaluated focus on programming high-load equipment to turn on in sequential stages, rather than all at once, in order to limit peak demand. We considered staging for air handling unit (AHU) fan motors, electric resistance heating systems (for all-electric buildings), and laptop battery chargers. Modest assumptions were used to limit peak demand, so as not to impact occupant thermal comfort or other core functions of the space. This measure could also be applied to chilled water or hot water pumps, condenser fans, and other equipment.

Staging can be used to reduce peak demand charges or for generating demand response revenue. Our analysis showed that staging loads is most cost-effective when utilized for reducing monthly billing peak, rather than focusing on demand response. Also, given that two of these measures focus on HVAC systems (AHU fan motor and electric resistance heating), they will produce variable reductions in peak demand based on the severity of the building's heating, cooling, and ventilation needs. So, the maximum amount of demand reduction for these measures will only be available when heating or cooling demands are highest, making it more difficult to respond to demand response events that may not align with peak heating or cooling days.

D. GEBs Can Support Resiliency While Decreasing Utility Costs

Solar PV and battery storage can reduce utility costs through peak shaving and demand response, or by allowing a building to optimize around time-of-use energy rates. These measures also enable buildings to operate mission-critical systems during power outages and to maintain some level of operation if sized correctly. In fact, some of the control strategies needed to enable GEBs are necessary for operating buildings in low power modes during power outages or other critical events.

E. Managing Peak Demand Is Typically More Cost-Effective Than Demand Response

We analyzed several of the GEB measures for peak demand reduction and for demand response, including equipment-staging measures and zone space temperature setback. In every location except for New York City, limiting peak demand (peak shaving) was more cost-effective than demand response for each of these measures. Peak shaving was cost-effective, but less cost-effective than demand response in Fresno and College Park, Maryland, as evidenced in Exhibit 9 below. Demand response was more cost-effective in New York City because the current demand response programs offered by NYISO offer substantially more revenue than the other markets that we researched. The other three cities either did not have demand response programs or had critical peak pricing programs that did not have clearly defined market values that we could use for this analysis.

EXHIBIT 9: VALUE OF PEAK MANAGEMENT COMPARED WITH DEMAND RESPONSE: ZONE TEMPERATURE SETBACK

	Peak Management ($ NPV)	Demand Response ($ NPV)
Fresno, CA	$339,630	$11,595
New York, NY	$89,598	$253,797
College Park, MD	$38,236	$3,301
Phoenix, AZ	$102,454	n/a
Atlanta, GA	$25,844	n/a
Denver, CO	$125,334	n/a

This confirms that ongoing energy management practices should be continually emphasized and refined as building use patterns and occupants change over time. Managing a building's energy loads consistently can drive significant economic value outside of operations and maintenance cost savings.

F. Flexibility Is Key to Long-Term Value

GEBs show us that there is immense value in flexing building energy demand and on focusing on *when* buildings are consuming energy, as opposed to the traditional focus on *how much* energy is being consumed. Demand charges can be up to 60% of a building's electricity costs in high demand charge locations like New York City or Fresno, CA, and a focus on GEB measures can drive almost a 60% savings in utility costs (through reducing both demand and consumption). Buildings with truly flexible loads have the opportunity to reduce costs today while supporting future changes to utility rate structures. Load flexibility will allow buildings to maximize the economic opportunity available in any utility rate structure by shifting loads from one time of day to another, based on the price signals provided by utilities. This not only delivers value from rate structures available today, but also supports the rate structure of the future, which will likely incorporate a more direct value to when energy is consumed and how much carbon is emitted.

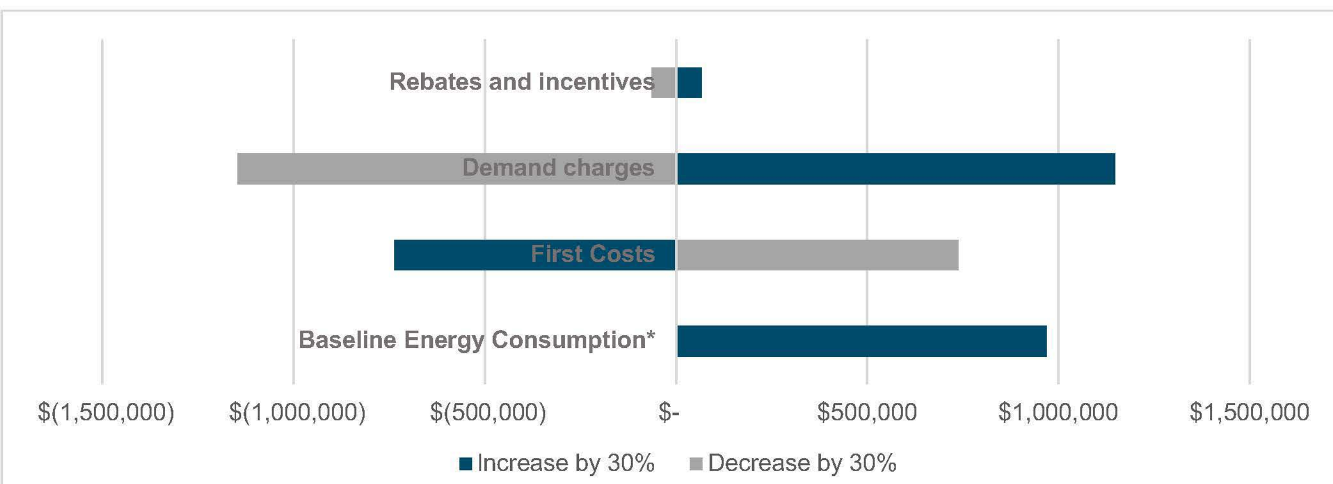
G. Sensitivity Analysis: Three Key Variables That Drive the Results

The cost-effectiveness of a GEB measure is driven by a location's **demand charges,** the **first cost** of the GEB measure, and the **baseline energy consumption** of the site. While this is obvious, it confirms that **GEB measures should be pursued first in locations with high demand charges and high baseline energy consumption.** Factors like rebate amounts, available incentives, and demand response revenues had little impact on GEB economics overall, with the exception of New York City.

The chart below shows the relative sensitivity of increasing or decreasing rebates and incentives, demand charges, first costs, and baseline energy consumption for the building model in Fresno, California. This trend is similar to the other building locations, with the exception of New York City, which was affected by larger-than-average rebates and incentives.

Exhibit 10 shows that if the first cost for the measures in the Fresno location bundle increases by 30% (for instance if the lighting upgrades take longer to install or are more expensive than modeled), it would reduce the NPV by $737,687, which would bring the total NPV down to $1,656,357. This is still an attractive investment.

EXHIBIT 10: NPV SENSITIVITY TO FIRST-COST CHANGES: FRESNO



One important finding from the sensitivity analysis is that **even if first costs were to double, almost all locations would still be NPV positive**. Exhibit 11 further emphasizes this point, by showing how much first costs could increase before the bundle of recommended measures for each location would be NPV neutral, or just barely cost-effective. This shows that first costs could double in most locations for the dual-fuel scenario, and first costs could increase by even more for the all-electric scenario before the proposed GEB investments were not considered cost-effective.

EXHIBIT 11: NPV SENSITIVITY TO FIRST COST CHANGES: ALL LOCATIONS

	Dual Fuel		All-Electric	
City	**First Cost of GEB Investment**	**NPV Neutral Increase in First Cost**	**First Cost of GEB Investment**	**NPV Neutral Increase in First Cost**
Phoenix, AZ	$664,291	2.1X	$764,411	2.2X
Atlanta, GA	$190,687	2.3X	$78,586	3.5X
Fresno, CA	$2,458,955	1.8X	$1,828,227	2.3X
College Park, MD	$107,138	3.1X	$107,138	7.4X
New York City, NY	$2,013,386	2.0X	$2,151,382	3.3X
Denver, CO	$282,357	3.6X	$887,094	3.1X

H. GEB Measures Should Be Closely Studied and Pursued Where Feasible

This analysis clearly shows that some GEB measures will be cost-effective across the GSA's portfolio. We would encourage the GSA and other building owners to evaluate all of the measures listed below across their entire portfolio. However, the group of measures that are cost-effective in almost every location could be pursued immediately, with no regrets.

EXHIBIT 12: GEB MEASURES SORTED BY THEIR APPLICABILITY ACROSS THE GSA PORTFOLIO

1. *Cost-effective in almost every location*	2. *Cost-effective in some locations*	3. *Limited cost-effectiveness; requires further study*

• LED lighting upgrades, including tube retrofits and fixture retrofits
• Staging to reduce peak demand:
  • Laptop battery charging
  • AHU fans
  • Electric resistance heaters (all-electric only)
• Space temperature setback to reduce peak demand
	• **Advanced lighting controls,** which enable peak shaving and DR
	• **Electric battery storage**[ix]
	• **Solar PV energy generation**[x]
	• **A solar + storage "bundle"** [xi] bundling enhances the value beyond investing in solar and storage individually
		Static measures with minor impact on peak demand
		• Increased air filtration to reduce OA needs
		• Low-E window films
		• Heat recovery (heat pipes)
		• New chilled water plant
		• Demand control ventilation
		Flexible measures that are location specific
		Advocate for, adopt, and respond to advanced rate structures

The locations that saw the greatest opportunity for GEBs had a few common characteristics, which made most of these GEB measures cost-effective:

- ***High demand charges***: At least $20/kW
- ***Moderate-to-high electricity consumption charges***: At least $0.08/kWh
- ***Advanced rate structures***: Including structures that define clear peak, part-peak, and off-peak pricing, with the ultimate rate structures including true time-of-use pricing.
- ***Some incentives:*** More than 5% of the total project cost

Locations with these characteristics were typically able to invest in measures that were within all three categories of exhibit 12. As expected, the locations with lower values in each of these categories warranted smaller investments in GEB measures, which were typically limited to the first two categories in exhibit 12.

A number of other factors can also indicate potential for GEB investment and would be worth considering for a future study that focuses on different buildings in more locations with a variety of building load profiles. Those factors are:

- ***Building equipment***: Different building process loads (e.g., data center computing versus personal computers), use types (e.g., lab versus office), or HVAC system types can drastically affect a building's load profile shape and magnitude
- ***Baseline building conditions***: Older buildings with more deferred maintenance likely have higher operating costs and more complexity, but also more opportunity for cost-effective retrofits.
- ***Real time pricing (future)***: Rate structures that move beyond time-of-use pricing and implement actual real-time pricing to value real-time grid constraints will result in greater GEB measures.
- ***Grid constraints (future):*** Locations with greater grid constraints—including limited generation capacity or costly transmission and distribution upgrade needs—will trend toward more advanced pricing

[ix] Solar PV and battery storage sizing assumptions can be found in Appendix E.
[x] Solar PV and battery storage sizing assumptions can be found in Appendix E.
[xi] Solar PV and battery storage sizing assumptions can be found in Appendix E.

structures that value demand flexibility and GEB measures to help them defer or eliminate some of their grid maintenance costs.

I. GEB Measures Can Improve the Economics of Performance Contracts

The combination of high net present value and short payback make GEB measures ideal investments for performance contracting projects (ESPCs and UESCs). The GSA relies on performance contracting to achieve its federal energy targets and to continue showing its leadership to deliver greater energy savings, cost savings, infrastructure renewal, and resilience than many other agencies. **Adding GEB measures to performance contracts will increase project cost savings, decrease contract terms (due to the low payback periods of GEB measures), and further support federal resilience goals by investing in flexible loads, energy storage, and renewable energy generation.**

Further, the short payback period of GEB measures mitigates the risk of unrealized savings due to changes in utility rate structures in two ways:

1. **Load flexibility enables GEBs to adjust to future utility rate uncertainty.** Flexible loads allow buildings to shave peak demand regardless of the time of day or time of year that peak is defined. Some measures will have greater impacts on demand during certain parts of the day (e.g., flexible heating or cooling loads), but will still have some level of impact throughout the day and year.
2. With sub-five-year payback periods, **GEB measures will likely pay back faster than large-scale utility rate structure changes can occur**.

Regardless of the contracting mechanism used, it is clear that some level of GEB investment is cost-effective in every location studied.

4. GEBS ANALYSIS RESULTS: NEW YORK CITY

This section highlights the results of the GEB analysis for the New York City prototypical building model, which shows the best opportunity for GEB investments across the GSA locations modeled in both the electric-plus-natural gas and all-electric scenarios. While the Fresno prototypical building measures had a higher net present value for the electric-plus-natural gas scenario, Fresno had limited opportunities in the all-electric scenario.

New York City had more favorable economics than most locations due to several factors:

- Moderate to high electric demand charges
- High electric consumption charges
- Alternative "time-of-day" rate structure that provides added value
- Substantial rebates and incentives
- Significant demand response program

Due to these factors, utility bills could be cut nearly in half with a payback under three years in the electric-plus-natural gas scenario, and under one year for the all-electric scenario.

The following tables demonstrate the key results of the GEB analysis for New York City (the results for all other locations are included in Appendix C).

EXHIBIT 13: KEY ECONOMIC METRICS: NEW YORK CITY

	Electric + Natural Gas	All-Electric
Baseline Annual Electricity Costs ($)	$947,743	$1,507,057
Annual Electricity Cost Savings ($)	$429,315	$741,186
% Reduction in Energy Costs	**45%**	**49%**
Electricity Savings (kWh)	1,508,636	922,548
Maximum Potential Demand Reduction (kW)	1,122	1,644
First Cost of GEB Investment ($)	$2,013,386	$2,151,382
Total Incentives ($)	$1,024,733	$1,920,865
Net Present Value of Bundle (including incentives) ($)	**$3,084,392**	**$7,892,077**
Payback (including incentives) (years)	**2.30**	**0.31**

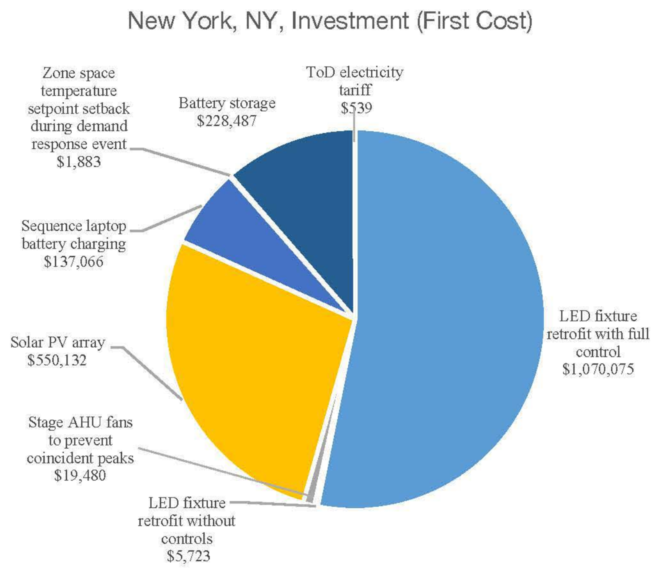
The cost-effective measures that are recommended for the New York City location include:

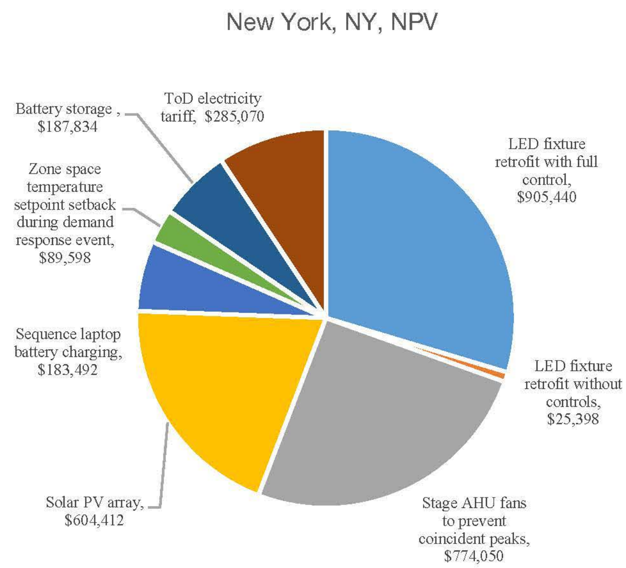
- New York time-of-day electricity tariff (switching from the "EL9 General Large" rate structure to the "EL9 Large Time of Day" rate structure)
- LED upgrades:
  - Fixture retrofit with full control in office and core services (electric + natural gas only)
  - LED tube retrofit without controls—back-of-house zones
  - LED tube retrofit without controls—office and core services (all-electric only, due to interactive effects)

- Stage AHU fans to prevent coincident peaks
- Solar PV array[xii]
- Sequence laptop battery charging
- Zone space temperature setpoint setback during demand response event
- Battery storage[xiii]
- Electric resistance heaters staged to manage peak demand of heating system (all-electric only)
- Increased filtration to reduce ventilation requirements (all-electric only)

The following charts represent the monetary investment and NPV by GEB measure for the New York City dual-fuel scenario. Over half of the first cost is spent on lighting, and another quarter on solar PV, yet the highest NPV measure is the staging of the air handling unit fans to prevent coincident peaks due to its low first cost and high relative impact.

EXHIBIT 14: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE NEW YORK CITY DUAL-FUEL SCENARIO





This sample demand profile shows the impact of GEB measures on a peak day in August, demonstrating that the bundle of measures provides a 32% reduction in peak demand while shifting the daily peak to occur three hours later in the day.

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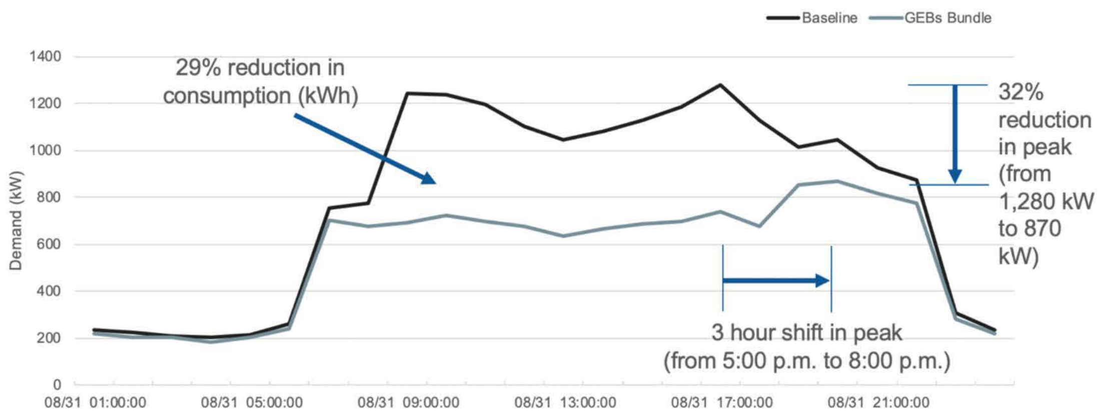
xii Solar PV and battery storage sizing assumptions can be found in Appendix E.

xiii Solar PV and battery storage sizing assumptions can be found in Appendix E.

EXHIBIT 15: NEW YORK—PEAK DAY DEMAND PROFILE



Note: This graph shows load reduction, not load shifting. Load shifting was modeled using battery storage in this location and the battery was charged/discharged in a targeted fashion during specific time periods to reduce monthly minute peak demand, which didn't occur on this day.

5. BENEFITS BEYOND THE GSA

Societal Value

In addition to being cost-effective, GEBs provide significant value in the form of grid services to the energy system at large. GEBs **provide benefits to utilities and grid operators, which provide savings to all energy users if valued and attributed properly.** Our analysis shows that GEBs could provide **up to $70 million per year in value to all grid users**. There are two primary sources for this value:

1. **Reduced generation capacity:** In many areas, generation (sources of electricity) is sized to meet grid peak demands. When buildings reduce or shift demand to balance the grid area's peak, they reduce the need for more generation sources (power plants), driving capital cost savings, and can reduce operations and maintenance costs for reserve power plants, driving operational cost savings.
2. **Transmission and distribution deferral or avoidance:** This occurs when the building reduces or shifts demand at a time that reduces local transmission and/or distribution delivery constraints. By preventing constraints on transmission and distribution infrastructure, GEBs can reduce the amount of new equipment and upgrades required on transmission and distribution systems, which reduces overall grid maintenance capital costs.

GEBs also contribute to reduced grid congestion, which provides other societal or grid benefits, including:

- **Providing operating reserves**, similar to traditional demand response programs where the utility sends the building operator a signal and the building reduces its power within to make up for a grid shortfall.
- **Frequency regulation**, which occurs when a building modulates its power demand in response to signals from the grid operator to balance sub-hourly electricity supply and demand to maintain grid power frequency.
- **Distribution voltage support**, which could avoid the installation of new capacitor banks, transformer tap changes, and other equipment.

The $70 million in societal value referenced above is a maximum value and should not be treated as absolute. Realistically, the societal value provided is between $0 and $70 million, with the upper bound being defined by a scenario in which GSA buildings deploy flexible loads in line with *grid* peak loads. RMI's analysis is focused on cost-optimization, so it seeks to limit a building's *billing* peak loads, rather than *grid* peak loads. Sometimes, a building's billing peak loads are coincident with grid peaks, but in many areas of the United States, these two peaks are not coincident—showing that there is a disparity between the way that buildings are charged for their energy usage and the actual capacity constraints that the grid is facing.

Electric utilities and regulatory bodies should design rate structures and other economic incentives for buildings to reduce grid peak, which will unlock the full potential of this societal value. The current utility rate structures in many of the locations that RMI studied incentivize buildings to limit their monthly peak demand, regardless of the time of day. This type of structure does nothing to help reduce grid peaks in many circumstances and could lead building owners to save costs by optimizing to current utility rate structures without providing any actual benefit to the grid. Even some time-of-use rate structures are not dynamic enough to support changes to the grid load profile due to factors like the rapid increase in renewable energy generation nationwide.

The grid value is very specific to regional and local constraints, so it is hard to estimate this for the entire GSA portfolio. Future research by the GSA and its partners could focus on assessing this specific value across the country OR by focusing in on one or two geographic areas with promising economic returns for GEB measures. Doing this would help the GSA and other players work on better understanding how this grid value could flow back to building owners.

The GSA should also work to identify a metric that can help to characterize a building's opportunity for investing in GEB measures. Several efforts are underway to create standardized load flexibility metrics, including the New Buildings Institute GridOptimal initiative and Lawrence Berkeley National Laboratory's Flexible Load metrics. Regardless of which metric is used, it should be accessible and easy for building operators to calculate and understand. It is recommended that the GSA follow these developments and adopt a GEB metric to track and set goals against. This metric should be used in parallel with energy use intensity (EUI) to assess future energy projects.

Elevating the National Conversation with Utilities, Regulators, and Grid Operators

The GSA is a substantial consumer of energy, spending approximately $332 million on energy each year. The GSA's size and its relationships with the largest utilities in the United States position the agency well to drive the conversation with utilities about the value that buildings can provide to the grid. The GSA should first focus on starting this conversation in constrained markets where the GSA has a notable presence. Working with utilities and regulators will allow the GSA to demonstrate the size of the opportunity, and to be a part of the long-term solution that utilities and regulators craft to better value load flexibility in buildings.

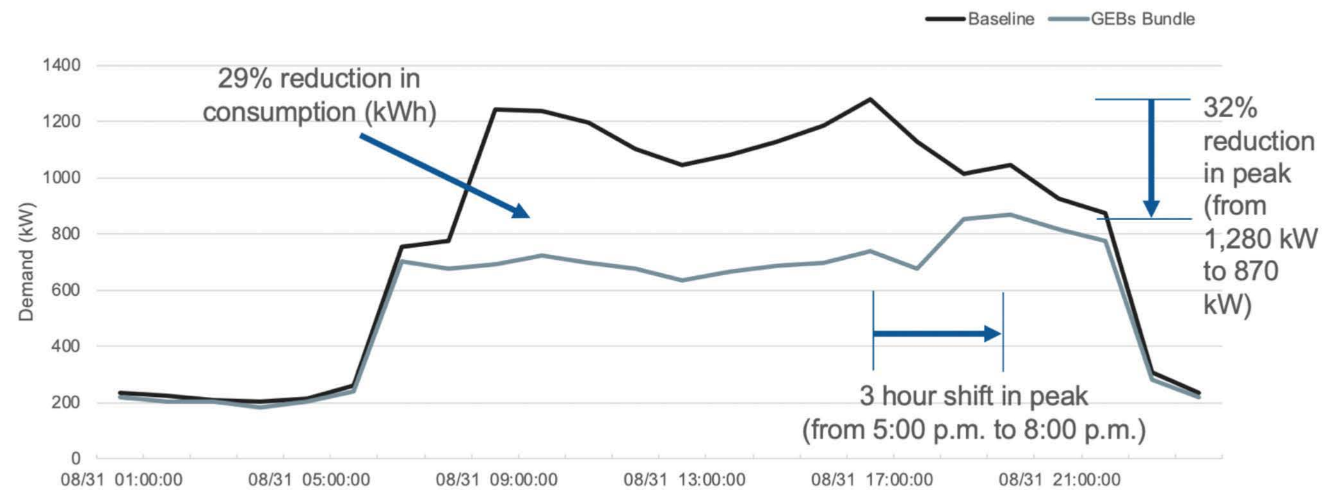
Elevating the Conversation: Consolidated Edison territory

The GSA owns 11 buildings in New York City, totaling over 8 million square feet. Consolidated Edison (ConEd), the transmission and distribution utility in New York City, has a summer peak of 13,300 MW that occurs between June and September from 2:00 p.m. to 6:00 p.m.[4, xiv] During that same timeframe, a large GSA office in New York City would be expected to average an hourly peak demand of 940 kW. Scaling that peak across the total square footage of the GSA's New York City portfolio would result in a peak of 15 MW.

During this timeframe, the recommended GEB measures for New York City provide a 32% reduction in peak demand, offering the potential to shave 4.8 MW during peak times. ConEd's average demand response from commercial customers is only 190 kW per customer; GSA buildings could shave 300 kW per customer with GEBs, making them nearly 60% more valuable (with associated higher revenue potential) than commercial buildings already enrolled in ConEd's DR programs. The GSA's portfolio also presents a useful consolidation point of peak demand reduction to ConEd and could provide currently untapped value to the larger New York City grid. Further explorations with the utility could build a case for some of this value to flow back to the GSA.

[xiv] Con Edison peak time inferred based on Super-peak Pricing rate structure, which is in effect from June through September on weekdays between 2 p.m. and 6 p.m.

EXHIBIT 16: NEW YORK—PEAK DAY DEMAND PROFILE

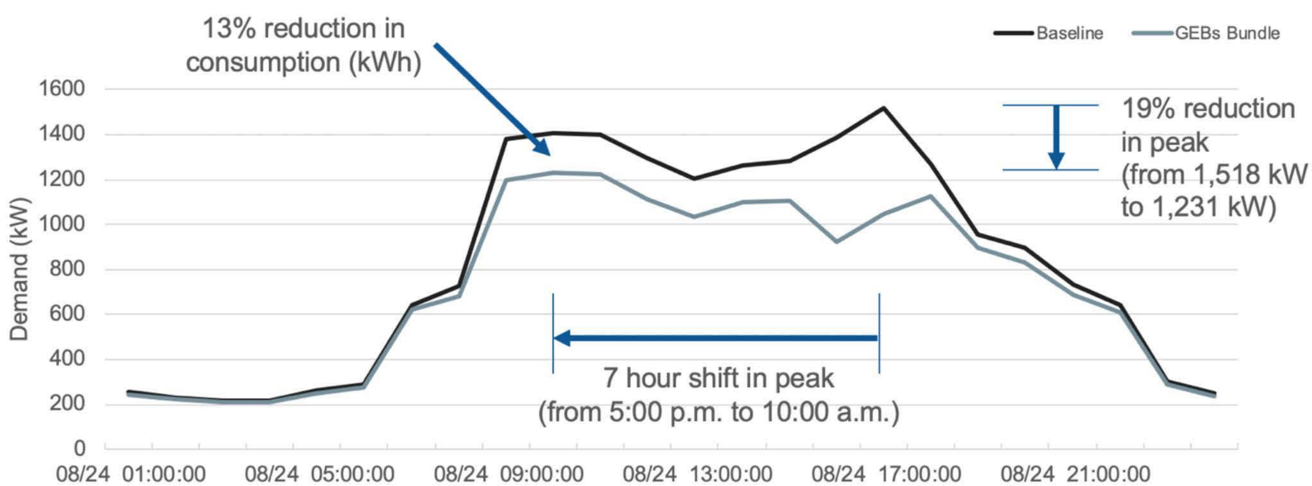


Note: This graph shows load reduction, not load shifting. Load shifting was modeled using battery storage in this location and the battery was charged/discharged during very specific time periods to reduce monthly minute peak demand, which didn't occur on this day.

Elevating the Conversation: Arizona Public Service territory

Some locations offer an opportunity to shift the timing of peak demand, including Phoenix, Arizona. The utility rates provided by Arizona Public Service include a peak summer period between May and October from 3 p.m. to 8 p.m.[5] During this timeframe in Phoenix, the GEB measures bundle provided a 19% reduction in coincident peak demand and shifted it to seven hours earlier in the day.

EXHIBIT 17: PHOENIX—PEAK DAY DEMAND PROFILE



Note: This graph shows load reduction, not load shifting. Load shifting was modeled using battery storage in this location and the battery was charged/discharged during very specific time periods to reduce monthly minute peak demand, which didn't occur on this day.

6. NEXT STEPS

The key next steps for the GSA lie in (1) taking immediate action to invest in GEBs, document performance, and reduce costs and (2) elevating the national conversation around GEBs to deliver societal value. This analysis has uncovered very specific recommendations around these core action areas.

Taking Immediate Action to Invest in GEBs and Reduce Costs

The GSA should invest in GEBs that can begin reducing costs immediately by:

- Investing in GEB measures immediately in buildings with all-electric heating, high demand charges, and high baseline energy consumption with a moderate or high demand charge.
- Pursuing all opportunities to **stage** and **control** loads and **manage demand daily** as a priority, and then implementing demand response programs. This will leverage existing equipment to drive greater savings before making capital upgrades.
- For ESPCs and UESCs:
    - Including a comprehensive list of GEB measures in the list of recommended measures for further review
    - Using the high value and low payback periods of GEB measures to decrease ESPC and UESC contract terms and pay deep retrofit measures
    - Providing formal guidance that allows for demand charge savings, even if only for a short period of time
- Implementing a GEBs pilot project, working with DOE, GSA Proving Ground, and the GSA National Deep Energy Retrofit Program
- Performing more field work to understand load shapes of GEBs, identify high opportunity buildings, and tackle key challenges around interoperability and cybersecurity
- Tracking peak demand and load factor (a measure of how extreme a building's peak loads are compared to average loads) to evaluate building performance, rather than just energy use intensity
- Evaluating additional locations and utility rate structures for GEB potential

Elevating the National Conversation Around GEBs

The GSA can elevate the national conversation around GEBs and unlock the immense societal value of GEBs by engaging regulators and utilities to understand their constraints and how the GSA can help alleviate them:

- Begin in the Northeast (e.g., New York), California, and Colorado, where the opportunity is greatest.
- Estimate the flexible load that the GSA could provide in these regions, including the size of the loads and the times of day when load flexibility is at its greatest.
- Aggregate these loads across all GSA locations in each region.
- Explore alternative utility rate structures that could better monetize GEB opportunities for the GSA and utilities.

Closing Thoughts

There is a large, untapped value for the GSA and other building owners to invest in GEBs today. The GSA can be both a first mover and a driver of investments in grid-interactive efficient buildings, saving money for the GSA today, and driving long-term value for all grid users into the future. This study identifies several actions that the GSA could take now to deliver extensive cost savings across its portfolio, as well as several long-term next steps that the GSA should take to engage utilities, leverage GSA buildings as grid resources, and save costs for the federal government and the taxpayer.

These easily adoptable measures can have substantial impacts, generating $50 million in annual utility cost savings to the GSA and up to $70 million per year in value to the grid. By leveraging its size and prominence, the GSA can pioneer opportunities to fully realize the societal value of GEBs, revolutionizing not only federal buildings, but also the broader commercial real estate space, helping all ratepayers save on their utility bills while improving grid resilience, balancing loads, and reducing carbon emissions.

7. APPENDICES

Appendix A: GEB Measures

This project requires a new framework for considering energy upgrade measures, going beyond the traditional energy efficiency measures that are considered in most energy retrofit projects. Rather than focusing on purely reducing building loads, this project includes measures that also shift loads to reduce peak demand, respond to grid events, and provide services to the grid.

The baseline conditions represent a modified DOE prototypical reference model, with some modification to more directly address a typical GSA building. These baseline conditions represent a fairly efficient building, and many GSA buildings exceed the baseline conditions included here in one or more categories. However, to define a "typical" GSA building, the RMI team, with input from the GSA, defined the following parameters, which represent a the most common scenario. The GSA's lighting systems illustrate this concept well; while many of the GSA's buildings have LED lighting installed, it is likely that more have T8 fluorescent lights at this moment in time.

EXHIBIT A1: GEB MEASURES

Measure	Baseline[xv]	GEB Measure
Lighting		
LED fixture retrofit with full control	• T8 fluorescent fixtures (defined by lighting power density) • No occupancy sensors • No fixture-level control or dimming available • Lighting scheduled 62 hours/week • Core office lighting not used on weekends or holidays • No lighting control beyond panel-level control for scheduling • Lighting power density of 0.82 W/sf	Fully dimmable LED fixture installed with advanced controls via Bluetooth wire-mesh node system.
LED fixture retrofit with occupancy controls		LED fixtures installed with occupancy sensors, and not connected to a fixture-level control system. Assumed to still be controllable at the panel level. This measure was pursued when the LED fixture with full control was not cost-effective, or in back-of-house areas that are seldom occupied and require less advanced control.
LED tube retrofit		LED tubes and appropriate wiring retrofit into existing fluorescent fixture. This measure was only pursued in small, back-of-house zones that don't require advanced LED fixtures.

[xv] The baseline measures described in Exhibit A1 were largely drawn from the DOE reference models for pre-1980 large office buildings created in EnergyPlus. There are 16 models that represent the range of ASHRAE climate zones throughout the United States. Most model inputs remain constant across the 16 models, but items such as building envelope attributes are modified based on climate. Any variation from the reference models is listed in Appendix D below. Additional information about the reference models can be found on the Department of Energy's website, at https://www.energy.gov/eere/buildings/existing-commercial-reference-buildings-constructed-1980.

Measure	Baseline[xv]	GEB Measure
Heating and Cooling		
Electric resistance heating staging	Electric resistance heating that turns on at full capacity to address high heating loads in winter months.	Electric resistance heating controlled to reduce demand during high heating loads. Heaters are cycled in "banks," one at a time, to reduce winter building peaks.
Zone space temp setback	Zone space temperatures set to maintain 72°F during all occupied cooling hours.	Zone space temperatures set back to 74°F when building approaches peak cooling. This is location-dependent due to different monthly billing demand structures. In select circumstances, this ECM was analyzed for demand response as opposed to peak reduction.
Window film	A variety of double-pane and single-pane window constructions, based on the location-specific DOE reference model for large commercial office buildings. No window film in place.	Several window films tested with low-E properties, low solar heat gain coefficient, and 50%–70% visible light transmission.
Thermal storage	No thermal storage.	Ice-based thermal storage system designed to reduce peak cooling loads during summer months. Controls enable this system to be used for peak reduction or demand response.
CHW and HW pumping pressure reset for demand response	Chilled water and hot water systems operating as scheduled to meet peak heating and cooling loads.	Chilled water and hot water systems reduce pumping pressure during demand response scenario to significantly reduce pumping energy consumption. This measure was determined to be duplicative of zone space temp setback.
Ventilation		
AHU fan staging	Air handler fan motors that may all turn on at the same time, at full capacity to address high heating or cooling loads.	Air handler fan motors that are controlled to reduce demand during peak heating or cooling events. Several banks of air handler fan motors are cycled back while one bank of motors operates at full capacity, and these banks of motors are cycled to ensure that space conditioning needs are being met.
Increased air filtration to reduce OA needs	Typical AHU air filtration system.	Reduce recirculated air contaminants using molecular air cleaners, which allows outside air intake to be reduced. This minimizes the energy required for tempering (heating and cooling) while maintaining indoor air quality.

Measure	Baseline[xv]	GEB Measure
Demand-control ventilation	Ventilation constant during occupied hours, and significantly reduced during unoccupied hours.	Ventilation controlled based on indoor carbon dioxide levels during occupied hours. This would reduce the amount of space conditioning needed to condition outside air. This measure was largely not cost-effective because we assumed that the baseline building was reducing ventilation during unoccupied hours.
Energy/heat recovery systems	No energy or heat recovery systems.	Heat pipe recovery system designed to pre-condition outside air as it enters the building for ventilation.
Static pressure reset for demand response	Ventilation systems operating as scheduled to meet peak heating and cooling loads.	Ventilation fan motors reduce static pressure in ducts during demand response scenario to significantly reduce fan energy consumption. This measure was determined to be duplicative of zone space temp setback.
Plug Loads		
Laptop battery charger staging	Laptop batteries that are typically plugged in, contributing to building demand, even when batteries are at high capacity.	Laptop battery chargers that are controlled to be “staged” as a building approaches its billing peak demand. One bank of laptop batteries will be charging at any given time, but for short (5–10 minute) intervals, some banks of laptops will rely on their batteries to remain powered until that bank of laptops is reconnected to power. This can include a user override to avoid staging when charging is critical.
Renewables and Storage		
Solar PV array	Building with no solar PV.	Building with a 258 kW rooftop solar PV array, which generates energy during daylight hours. Solar PV production often (but not always) aligns with building peak demand. Array was sized assuming 50% roof coverage.
Electric battery storage	Building with no electric storage.	Building with an electric battery (size varies by location), programmed to reduce peak building demand. Batteries could also be used for demand response in scenarios where demand-response revenues outweigh cost savings due to utility billing demand reduction.

Measure	Baseline	GEB Measure
Electric battery storage	Building with no electric storage.	Building with an electric battery (size varies by location), programmed to reduce peak building demand. Batteries could also be used for demand response in scenarios where demand-response revenues outweigh cost savings due to utility billing demand reduction.
Solar plus storage	Building with no solar PV or electric storage.	Including solar energy generation and storage ensures that a building can deploy the renewable energy produced when it is most advantageous to meet grid signals. In California, for instance, a large amount of solar production during the day is shifting grid peak demand later in the day than peak solar production, making batteries a more valuable component of the package.

Appendix B: Wiley Building Results

The GSA selected the Wiley Federal Building in College Park, Maryland, for a site-specific study.

RMI then:

- Performed a site visit in October 2018
- Generated an energy model of office space
- Engaged with laboratory efficiency experts

While the core focus of this study was on the six prototypical locations, the Wiley Building provided a useful calibration point for the DOE Reference Models. A significant portion of the Wiley Building's floor area is comprised of lab space, which has much higher energy consumption, lab-specific equipment, and HVAC requirements that are quite different from a typical office. Thus, the findings for the Wiley building should be used directionally and should be followed by a deeper evaluation of GEB opportunities before making investment decisions.

- For the office areas in the building, RMI found:
    - $76,000 in annual cost savings
    - $20,000 in rebates and incentives
    - $406,000 in NPV over 9 years (assuming a 3% discount rate)
- 2.4-year simple payback (with incentives)

For the Wiley Building, the top five GEB opportunities are:

1. Drive down laboratory ventilation:
    a. Laboratory ventilation is a critical load, driving at least (and often more than) 25% of total lab energy use.
    b. Strategies like demand-based ventilation and fume hood retrofits can reduce laboratory ventilation, heating, and cooling by more than 50%.
    c. Exhaust fans in the Wiley Building's labs already include variable frequency drives, enabling immediate, low-cost upgrades through controls.
2. Laboratory lighting upgrades to LED with full control:
    a. Laboratory spaces have T8 lighting fixtures that are controlled with wall light switches. Many of these lights are left on 24/7, even when unoccupied.
    b. Fixtures should be retrofit to fully controllable LED fixtures. They can allow full control by lab staff during the day and enable energy and demand-saving measures outside of occupied hours.
3. **Fully controllable LED lighting** in office zone (as described in core study)
4. **Central control** to stage laptop charging and AHU fan motors (as described in core study)
5. Zone temperature setpoint setback for monthly peak demand management

Appendix C: Site-Specific Findings (Electricity-Plus-Natural Gas Scenario)

This section provides deeper detail for the results from each location in the GEB study. These results signify a prototypical office building in each of the six locations explored below for both an all-electric and a dual fuel (electric and natural gas) scenario. These models are of "typical" buildings based off of the DOE reference model for a large office building (more detail in Appendix D) and modified to be comparable to average buildings in the GSA's building stock. The utility rate structures modeled are actual utility rate structures for GSA buildings in those utility territories.

Our assumptions for constructing baseline and proposed models and for performing the analysis are described in deeper detail in the *Analysis Methodology* subsection of Section 2 in the report and in Appendix D.

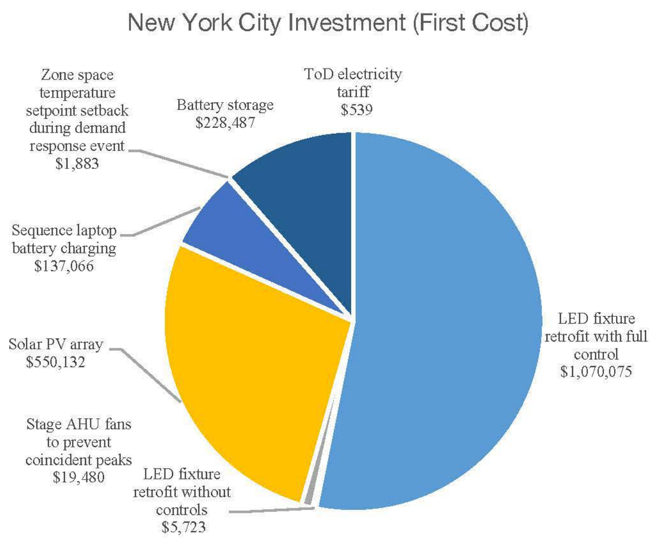
New York City Prototypical Model Results

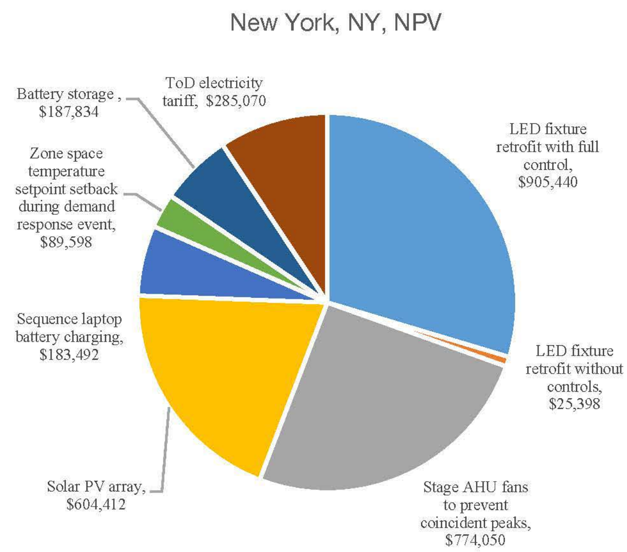
EXHIBIT C1: KEY METRICS: NEW YORK CITY

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	49.2	43.1
Baseline Electricity Consumption (kWh)	4,439,608	6,295,483
Baseline Electricity Consumption (kWh/sf)	8.9	12.6
Electricity Savings (kWh)	1,508,636	922,548
Electricity Savings (kWh/sf)	3.0	1.9
Baseline Peak Demand (kW)	1,539	5,033
Baseline Peak Demand (W/sf)	3.09	10.10
Maximum Economical Demand Reduction (kW)	1,122	1,644
Maximum Economical Demand Reduction (W/sf)	2.25	3.30

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$947,743	$1,507,057
Baseline Annual Energy Costs ($/sf)	$1.90	$3.02
Annual Energy Cost Savings ($)	$429,315	$741,186
Annual Energy Cost Savings ($/sf)	$0.86	$1.49
Proposed Energy Costs ($)	$518,429	$765,871
Proposed Energy Costs ($/sf)	$1.04	$1.54
% Reduction in Energy Costs	45%	49%
First Cost of GEB Investment ($)	$2,013,386	$2,151,382
Net Present Value of Bundle (excluding incentives) ($)	$2,059,660	$5,971,211
Payback (excluding incentives) (years)	4.69	2.90
Total Incentives ($)	$1,024,733	$1,920,865
Net Present Value of Bundle (including incentives) ($)	$3,084,392	$7,892,077
Payback (including incentives) (years)	2.30	0.31

EXHIBIT C2: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE NEW YORK CITY DUAL-FUEL SCENARIO





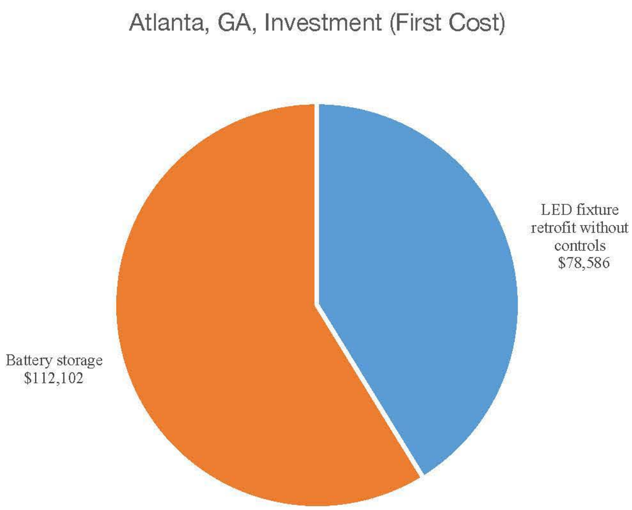
Atlanta, Georgia, Prototypical Model Results

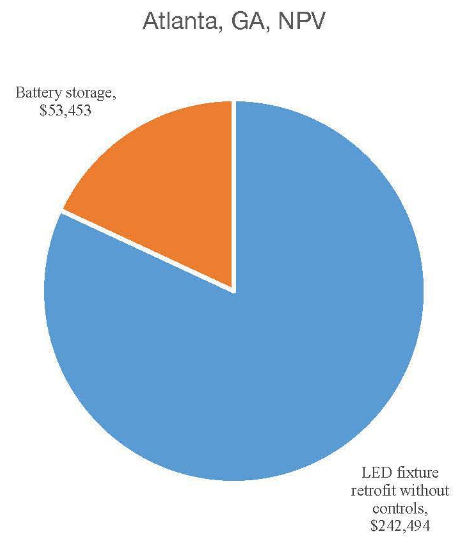
EXHIBIT C3: KEY METRICS: ATLANTA, GEORGIA

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	42.3	38.8
Baseline Electricity Consumption (kWh)	4,573,406	5,670,601
Baseline Electricity Consumption (kWh/sf)	9.2	11.4
Electricity Savings (kWh)	471,355	443,759
Electricity Savings (kWh/sf)	0.9	0.9
Baseline Peak Demand (kW)	1,523	4,287
Baseline Peak Demand (W/sf)	3.05	8.60
Maximum Economical Demand Reduction (kW)	235	52
Maximum Economical Demand Reduction (W/sf)	0.47	0.10

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$436,157	$522,972
Baseline Annual Energy Costs ($/sf)	$0.87	$1.05
Annual Energy Cost Savings ($)	$59,072	$35,973
Annual Energy Cost Savings ($/sf)	$0.12	$0.07
Proposed Energy Costs ($)	$377,085	$486,999
Proposed Energy Costs ($/sf)	$0.76	$0.98
% Reduction in Energy Costs	14%	7%
First Cost of GEB Investment ($)	$190,687	$78,586
Net Present Value of Bundle (excluding incentives) ($)	$218,969	$173,933
Payback (excluding incentives) (years)	3.23	2.90
Total Incentives ($)	$19,965	$19,965
Net Present Value of Bundle (including incentives) ($)	$238,934	$193,898
Payback (including incentives) (years)	2.89	1.63

EXHIBIT C4: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE ATLANTA DUAL-FUEL SCENARIO





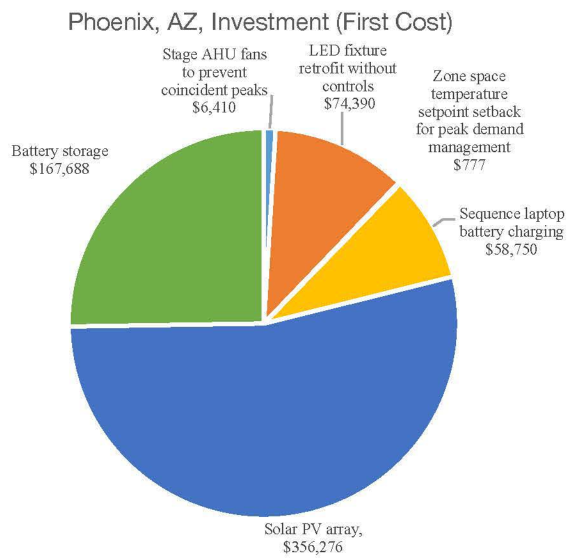
Phoenix, Arizona, Prototypical Model Results

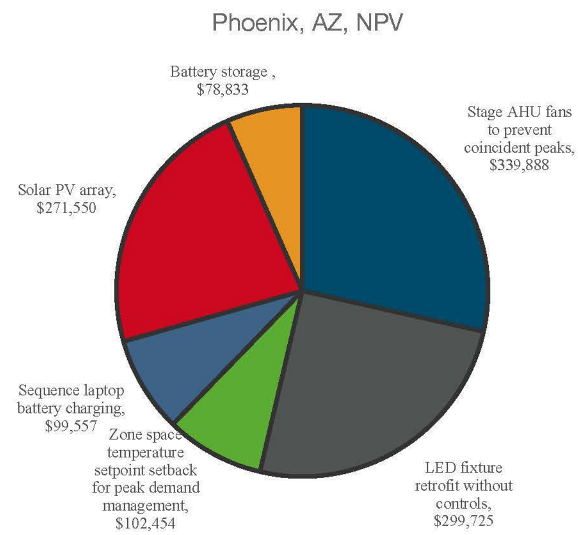
EXHIBIT C5: KEY METRICS, PHOENIX, ARIZONA

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	38.4	37.4
Baseline Electricity Consumption (kWh)	5,160,873	5,460,787
Baseline Electricity Consumption (kWh/sf)	10.4	11.0
Electricity Savings (kWh)	948,219	871,285
Electricity Savings (kWh/sf)	1.9	1.7
Baseline Peak Demand (kW)	1,549	2,777
Baseline Peak Demand (W/sf)	3.11	5.57
Maximum Economical Demand Reduction (kW)	902	1,774
Maximum Economical Demand Reduction (W/sf)	1.81	3.56

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$598,617	$722,623
Baseline Annual Energy Costs ($/sf)	$1.20	$1.45
Annual Energy Cost Savings ($)	$207,468	$248,244
Annual Energy Cost Savings ($/sf)	$0.42	$0.50
Proposed Energy Costs ($)	$391,70	$474,379
Proposed Energy Costs ($/sf)	$0.78	$0.95
% Reduction in Energy Costs	35%	34%
First Cost of GEBs Investment ($)	$664,291	$764,411
Net Present Value of Bundle (excluding incentives) ($)	$1,010,029	$1,925,090
Payback (excluding incentives) (years)	3.20	3.08
Total Incentives ($)	$11,202	$11,349
Net Present Value of Bundle (including incentives) ($)	$1,021,231	$1,936,439
Payback (including incentives) (years)	3.15	3.03

EXHIBIT C6: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE PHOENIX DUAL-FUEL SCENARIO





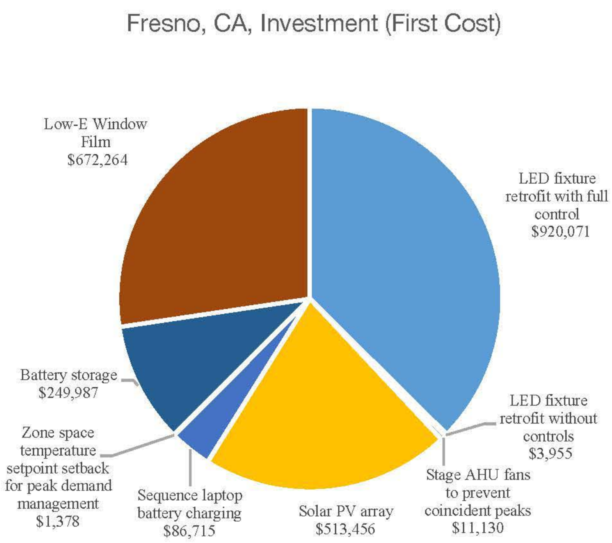
Fresno, California, Prototypical Model Results

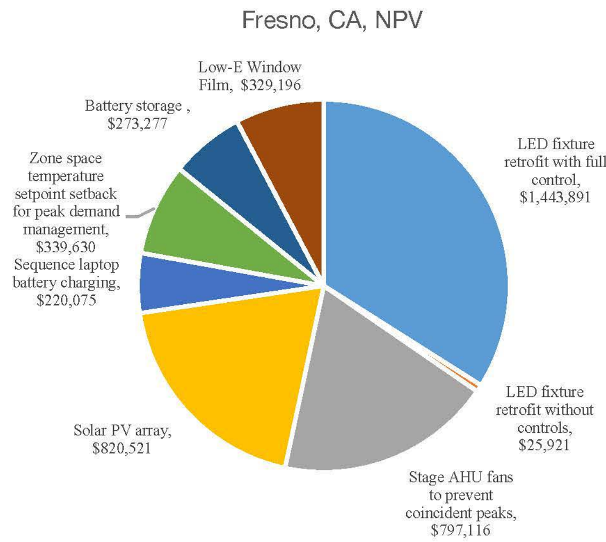
EXHIBIT C7: KEY METRICS: FRESNO, CALIFORNIA

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	38.8	36.2
Baseline Electricity Consumption (kWh)	4,517,341	5,288,227
Baseline Electricity Consumption (kWh/sf)	9.1	10.6
Electricity Savings (kWh)	1,803,877	1,216,463
Electricity Savings (kWh/sf)	3.6	2.4
Baseline Peak Demand (kW)	1,519	3,758
Baseline Peak Demand (W/sf)	3.05	7.54
Maximum Economical Demand Reduction (kW)	1,298	1,855
Maximum Economical Demand Reduction (W/sf)	2.60	3.72

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$1,043,122	$1,305,209
Baseline Annual Energy Costs ($/sf)	$2.09	$2.62
Annual Energy Cost Savings ($)	$612,178	$590,716
Annual Energy Cost Savings ($/sf)	$1.23	$1.18
Proposed Energy Costs ($)	$430,944	$714,492
Proposed Energy Costs ($/sf)	$0.86	$1.43
% Reduction in Energy Costs	59%	45%
First Cost of GEBs Investment ($)	$2,458,955	$1,828,227
Net Present Value of Bundle (excluding incentives) ($)	$3,789,892	$4,600,887
Payback (excluding incentives) (years)	4.02	3.09
Total Incentives ($)	$217,051	$146,771
Net Present Value of Bundle (including incentives) ($)	$4,006,943	$4,747,658
Payback (including incentives) (years)	3.66	2.85

EXHIBIT C8: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE FRESNO DUAL-FUEL SCENARIO





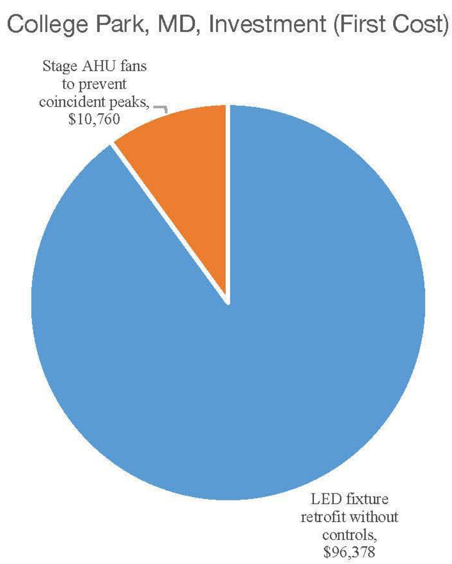
College Park, Maryland, Prototypical Model Results

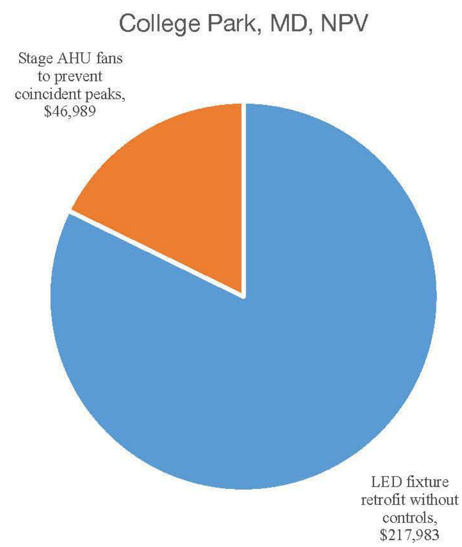
EXHIBIT C9: KEY METRICS: COLLEGE PARK, MARYLAND

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	48.3	42.5
Baseline Electricity Consumption (kWh)	5,160,873	6,199,827
Baseline Electricity Consumption (kWh/sf)	10.4	12.4
Electricity Savings (kWh)	472,937	237,616
Electricity Savings (kWh/sf)	0.9	0.5
Baseline Peak Demand (kW)	1,555	4,773
Baseline Peak Demand (W/sf)	3.12	9.57
Maximum Economical Demand Reduction (kW)	508	1,525
Maximum Economical Demand Reduction (W/sf)	1.02	3.06

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$515,503	$659,944
Baseline Annual Energy Costs ($/sf)	$1.03	$1.32
Annual Energy Cost Savings ($)	$48,251	$113,477
Annual Energy Cost Savings ($/sf)	$0.10	$0.23
Proposed Energy Costs ($)	$467,252	$546,468
Proposed Energy Costs ($/sf)	$0.94	$1.10
% Reduction in Energy Costs	9%	17%
First Cost of GEBs Investment ($)	$107,138	$107,138
Net Present Value of Bundle (excluding incentives) ($)	$227,549	$1,092,758
Payback (excluding incentives) (years)	2.22	0.94
Total Incentives ($)	$0	$0
Net Present Value of Bundle (including incentives) ($)	$227,549	$1,092,758
Payback (including incentives) (years)	2.22	0.94

EXHIBIT C10: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE COLLEGE PARK DUAL-FUEL SCENARIO





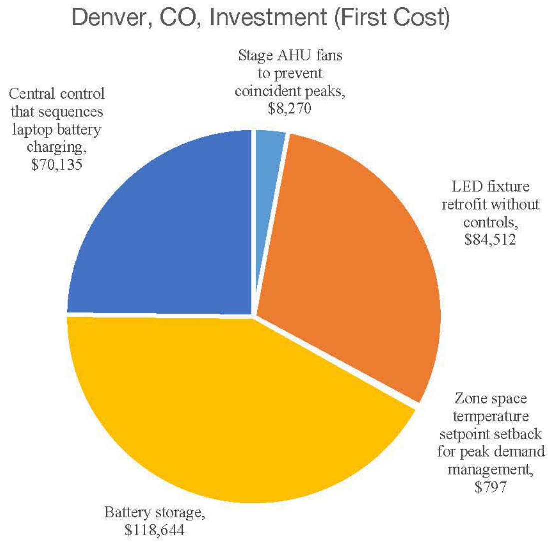
Denver, Colorado, Prototypical Model Results

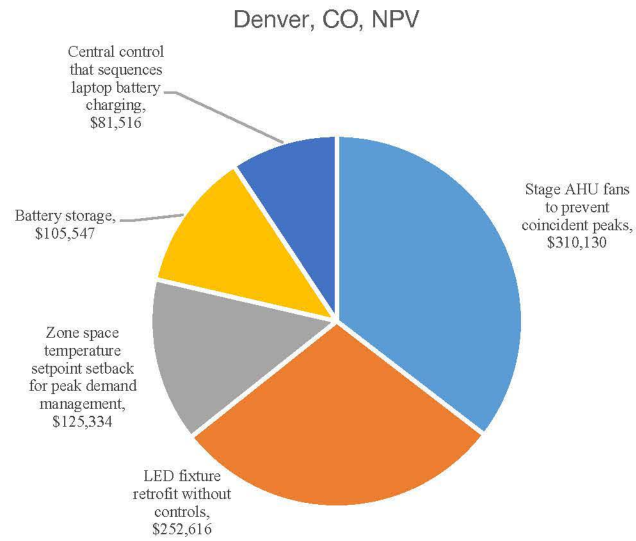
EXHIBIT C11: KEY METRICS: DENVER, COLORADO

	Electric + Natural Gas	All-Electric
Baseline Energy Use Intensity (kBtu/sf/y)	45.7	39.8
Baseline Electricity Consumption (kWh)	3,979,201	5,816,057
Baseline Electricity Consumption (kWh/sf)	8.0	11.7
Electricity Savings (kWh)	578,576	505,899
Electricity Savings (kWh/sf)	1.2	1.0
Baseline Peak Demand (kW)	1,348	4,377
Baseline Peak Demand (W/sf)	2.70	8.78
Maximum Economical Demand Reduction (kW)	528	1,971
Maximum Economical Demand Reduction (W/sf)	1.06	3.95

	Electric + Natural Gas	All-Electric
Baseline Annual Energy Costs ($)	$559,708	$950,636
Baseline Annual Energy Costs ($/sf)	$1.12	$1.91
Annual Energy Cost Savings ($)	$122,803	$341,170
Annual Energy Cost Savings ($/sf)	$0.25	$0.68
Proposed Energy Costs ($)	$436,905	$609,467
Proposed Energy Costs ($/sf)	$0.88	$1.22
% Reduction in Energy Costs	22%	36%
First Cost of GEBs Investment ($)	$282,357	$887,094
Net Present Value of Bundle (excluding incentives) ($)	$722,821	$3,112,653
Payback (excluding incentives) (years)	2.30	2.60
Total Incentives ($)	$171,491	$339,024
Net Present Value of Bundle (including incentives) ($)	$894,312	$3,451,677
Payback (including incentives) (years)	0.90	1.61

EXHIBIT C12: MONETARY INVESTMENT AND NPV BY GEB MEASURE FOR THE DENVER DUAL-FUEL SCENARIO





Appendix D: Baseline Model Assumptions

The DOE reference models are pre-1980 large office buildings created in EnergyPlus. There are 16 models that represent the range of ASHRAE climate zones throughout the United States. Most model inputs remain constant across the 16 models, but items such as building envelope attributes are modified based on climate.

Proposed modifications to reference models:

- Reduce lighting power density from 1.5 W/sf to 0.82 W/sf to reflect likely T8 fluorescents.
- Increase plug loads from 0.7 W/sf to 1 W/sf due to increased computing and other plug loads noted in the literature.
    - This will primarily affect HVAC loads.
    - For specific measures impacting plug loads (e.g., leveraging laptop computer batteries for demand reduction), we split the computer load from the general plug load per zone type and then apply a post-retrofit condition to only the computer power density.
- Create restroom zones and apply appropriate exhaust rates per ASHRAE 62.1 (reference models had zero exhaust).
- Increase infiltration rates based on professional judgment, as the rates in the reference models are lower than we have seen in the field.
- Modify the elevator schedule to reflect the occupancy schedule of the building. Elevators in the reference model are scheduled to operate the same each day of the week even though the occupancy schedule is different for weekdays compared to Saturday and there is zero occupancy on Sunday.
- The PEO tool is capable of quickly developing more detailed zoning in the model. The reference model is zoned perimeter/core and all zones are defined as office except the basement, which has a lower lighting power density and equipment power density. The simplified zoning can cause errors in a couple of ways (see sub-bullets). Because of this, we will use the functionality in the PEO tool to further divide the model into higher fidelity zones.
    - Ensure measures are applied to the appropriate portion of the building. This becomes particularly important when bundling to ensure the scope of each project is correctly impacting the bundle economics.
    - Schedules are correct. For instance, lighting schedules in open offices are likely significantly different than in closed offices due to local switches or occupancy sensors.
    - Add core services geometry to 35% of core zone in model.
    - Subdivide “office” into open office, closed office, lobby, conference room, hall, inactive storage, breakroom, and IT.
    - Modify several schedules and equipment power density to be appropriate to subzone.
- Space heating and domestic water heating:
    - Keep natural gas systems
    - Develop second set of models that have electric resistance heating instead of natural gas heating.
- Change cooling occupied setpoint from 75°F (reference model) to 72°F.
- Add air-side economizer to all climate zones and control based on differential enthalpy. This is likely better control than typically installed but provides a conservative estimate and ensures we don’t have too many unmet hours in the energy model. (Air-side economizer varies based on climate zone in reference models. When present it is controlled using differential dry bulb temperature with a high limit lockout of 82.4°F.)
- Reset discharge air temperature based on warmest zone to reduce simultaneous heating and cooling. Limits set between 55°F and 65°F. (VAV system discharge air temperature fixed at 55°F year-round in the original reference model.)

- Select centrifugal chiller with slightly higher COP and part load performance from Chillers.idf. Changed to WC Centrifugal Default 90.1-2004 with COP of 6.1 (Chiller in reference model is WC Screw Default 90.1-2004 with COP 5.11.)
- Change AirTerminal:SingleDuct:VAV:Reheat min flow frac from 0.3 (reference model) to 0.2.
- Use ventilation that meets ASHRAE 62.1 requirements splitting between oa_person and oa_area to accurately calculated DCV. (In original reference model, ventilation is defined as OA_person only and set to 26.486.)
- Change cooling tower from single speed (reference model) to variable speed.

Appendix E: Solar PV and Electric Battery Storage Sizing Assumptions

The proposed GEB models in each location included the below sizing for the solar PV and electric battery storage systems. The batteries are sized based on site-specific economic viability. The solar PV system is sized based on assumptions about the potential roof space available for a given site as well as site-specific economic viability.

Location	Battery sizing	Solar PV sizing
Phoenix, AZ	285 kWh / 150 kW	258 kW
Atlanta, GA	190 kWh / 100 kW	n/a
Fresno, CA	380 kWh / 200 kW	258 kW
College Park, MD	n/a	n/a
NYC, NY	285 kWh / 150 kW	258 kW
Denver, CO	190 kWh / 100 kW	n/a

We believe 258 kW to be a reasonable PV system size that could fit on the available roof area of many GSA buildings. This is validated by a 2016 analysis using the REOpt software that determined the solar potential across 120 GSA buildings. It examined available roof area on each building and recommended PV systems for 44 different buildings. The median size of the recommended PV system was 355 kW, well over our assumed 258 kW. Urban sites may be slightly more constrained and an analysis for the Capital Solar Challenge showed that within Washington, D.C., the average recommended size was closer to 150 kW.

ENDNOTES

[1] US Energy Information Administration (2018) *Annual Energy Outlook 2018*. Washington, DC. eia.gov/outlooks/aeo/ and BTO internal analysis

[2] https://www.gsa.gov/cdnstatic/GSA%20FY%202018-2022%20Strategic%20Plan%20-%20FINAL.pdf

[3] Lazard, 2018. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf

[4] https://www.coned.com/-/media/files/coned/documents/business-partners/transmission-planning/assumptions-for-2018-long-range-plan.pdf

[5] https://www.aps.com/en/business/accountservices/serviceplans/Pages/large-business-plans.aspx?src=RB

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