Memo: GridOptimal Utility Programs

December 2021

Introduction and value proposition

Buildings are the primary drivers of peak demand on the grid, driving ~80% of peak demand, and benefit from unlimited power availability. As a result, utilities and system operators are vulnerable to spiking energy generation costs during peaks and increasing capacity needs as demand grows from new construction, building electrification, and electric vehicles. While buildings drive summer and winter peaks, they also have the potential to act as a demand flexibility resource by reducing total energy demand. Even basic HVAC control strategies can deliver up to 20% demand reductions during peak times. Emerging demand flexibility (demand response 2.0) programs recognize this untapped resource and incentivize building systems and devices to shed load during peak periods. The success of grid decarbonization plans and the future of the utility business model depends on, in part, widespread programmatic deployment of behind-the-meter demand flexibility. Passive strategies, including some traditional "energy efficiency" strategies, can help shape building energy demand profiles to minimize peak demand. Active strategies, including today's "demand response" tools, can empower buildings to shed and shift demand. Utility programs should leverage both passive and active behind-the-meter measures in an integrated, optimized manner to save costs on both sides of the meter, reduce carbon emissions today, enable faster and deeper decarbonization tomorrow, and enhance resiliency.

This memo summarizes the results of NBI's research into the utility program implications of various energy efficiency (EE) and demand flexibility (DF) measures across multiple building types, grid regions, and climate zones. The goal of this research and memo is to inform utility program design and deployment, including both the adjustment of existing incentives and other strategies as well as to suggest potential alternate program frameworks. This memo highlights effective strategies that utilities can prioritize in order to limit peak system loads, grow the collective demand response potential of its served loads, or address other priorities (e.g., emissions). The information and analysis summarized here builds on years of work under the GridOptimal Buildings Initiative. The full analysis may be explored through this publicly accessible online dashboard.

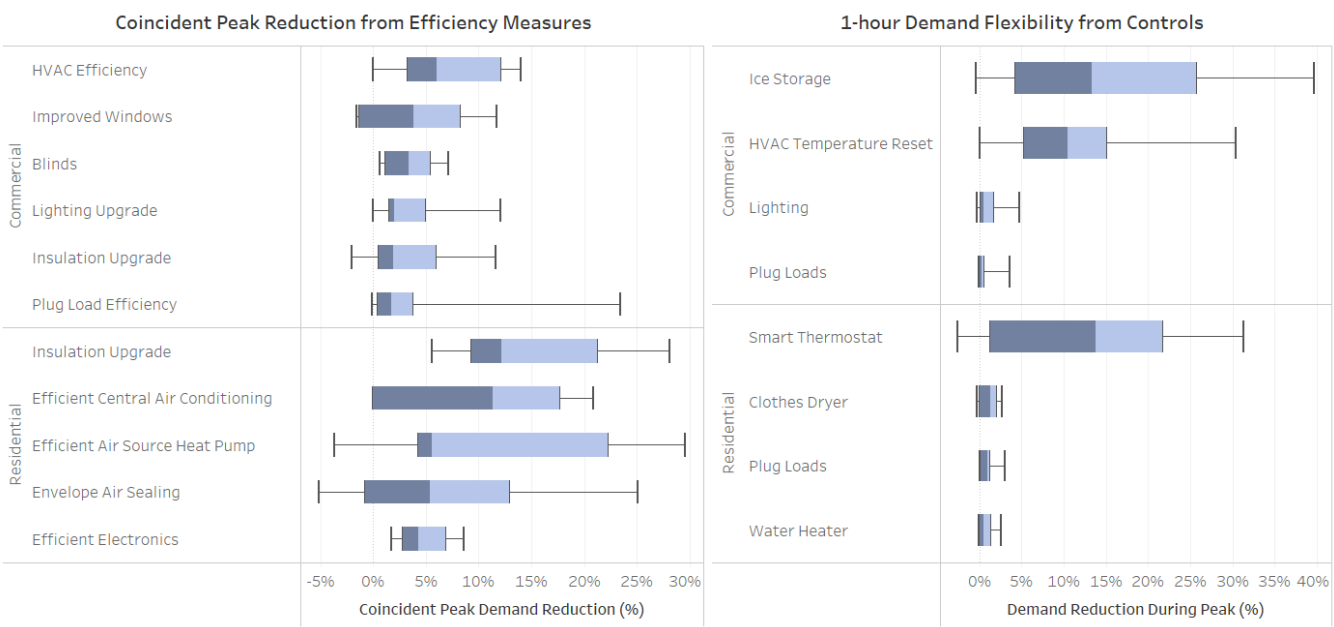
Key analysis results

To estimate the impact of various energy efficiency and demand flexibility measures, NBI both commissioned energy modeling analysis from Red Car Analytics and leveraged similar assessment studies from both Lawrence Berkeley National Laboratory (LBNL) and National Renewable Energy Laboratory (NREL). The analysis presented herein focused on evaluating the impacts of measures in terms of specific outcomes, such as coincident peak demand savings, upstream marginal hourly grid emissions, customer cost, etc., in order to identify strategies that "punch above their weight class" by delivering higher benefits in terms of one or more priority outcomes based on their time-of-use energy efficiency or demand flexibility characteristics. We compared over 20 EE, DF, and combination measures across seven building types and 16 climate zones. Across building types and climate zones, several measures consistently emerged above the rest, either by targeting typical system peak hours (e.g., summer evenings and/or winter mornings), or by providing significant demand flexibility during those same high-priority hours. The DF measures require a minimum level of connectivity and controllability that not all buildings may have, such as digital HVAC controls, smart thermostats, and/or networked appliances and power supplies.

The following table shows selected high-impact EE and DF measures that typically deliver benefits above and beyond their typical flat annual site energy savings.

Sector	System peak demand reduction	Demand flexibility
Commercial	HVAC efficiency	Battery storage
	Envelope upgrades	HVAC temperature reset (2-3°F)
	Window performance and treatments	Thermal energy storage
	Solar PV	Lighting controls
Residential	Insulation upgrades	Smart thermostats
	HVAC efficiency	Water heater controls
	Air sealing	Appliance controls
	Plug load efficiency	Pool pump controls

The impacts offered by these measures can vary substantially. The following charts show coincident peak reduction impacts from selected measures (only those with relatively high impacts – lower-impact measures are not shown). The box and whisker plots below show the minimum, 25th percentile, median, 75th percentile, and maximum values modeled across building types and climate zones for each measure. Impacts with a large range of results suggest a high degree of climate and/or building type dependence. The disaggregated results and a more comprehensive set of measures are available in the dashboard.



The energy efficiency measures listed above can passively reduce building demand during grid priority hours by up to 15% in commercial buildings and over 50% in single-family homes, depending on baseline system type, operations, and climate. The demand flexibility measures deployed during the same high-priority hours can provide 15% savings with modest HVAC controls or much greater savings with the addition of thermal or battery storage. In the residential sector, demand flexibility measures offer modest savings with large exceptions for electric water heaters and pool pumps, depending on system size, type, and climate. These active flexibility measures require operator intervention in most cases, though automated, dispatchable flexibility is available for batteries and increasingly common for building system controls (i.e., temperature setpoints).

Incentive program implications

In order to reduce system peaks and recruit additional flexible loads behind the meter, we recommend utility incentive and rebate programs include the following:

- **Building retrofit incentives** primarily focused on envelope upgrades and high-efficiency HVAC equipment replacements.
- **Equipment replacement and upgrades** including EnergyStar rated appliances, low-power office equipment, and plug load controls to cut equipment loads when not in use or after-hours.
- **HVAC control retro-commissioning and updates** to install digital controls *enabling demand response*, such as smart thermostats, as well as to update control sequences to the latest standards (i.e. ASHRAE Guideline 36) for low-to-no-cost energy savings.
- **Energy storage installation (battery and thermal)** to increase demand flexibility capacity. With proper controls and agreements in place, the utility may dispatch the energy storage to ensure firm demand response availability.
- **Grid-connected appliance installation** or replacement at end-of-life, including heat pump water heaters (NEEA tier 3 or greater) and residential appliances in order to automatically shift load on a daily basis in response to real-time signals from the grid or utility.
- **Process load measures and controls** for specific end-uses may also provide significant peak savings and demand response potential, including refrigeration, air compression, electric vehicle fleet charging, and other processes with inherent time-of-use flexibility.
- **Onsite solar PV installation** to reduce net building demand during grid peak hours, particularly during summer afternoons and evenings.

Existing programs typically cover the high-priority equipment and end-uses described above. However, they do not typically require the connectivity needed to build demand response potential. Examples include heat pump water heaters, electric vehicle chargers, and HVAC control updates. Small updates to existing programs requiring connected devices will enhance the benefits of the incentives by expanding behind-the-meter load flexibility potential. Paired with automated demand response incentive programs, customers can cost-effectively enroll additional load that the utility can then control to mitigate peak demand and costs.

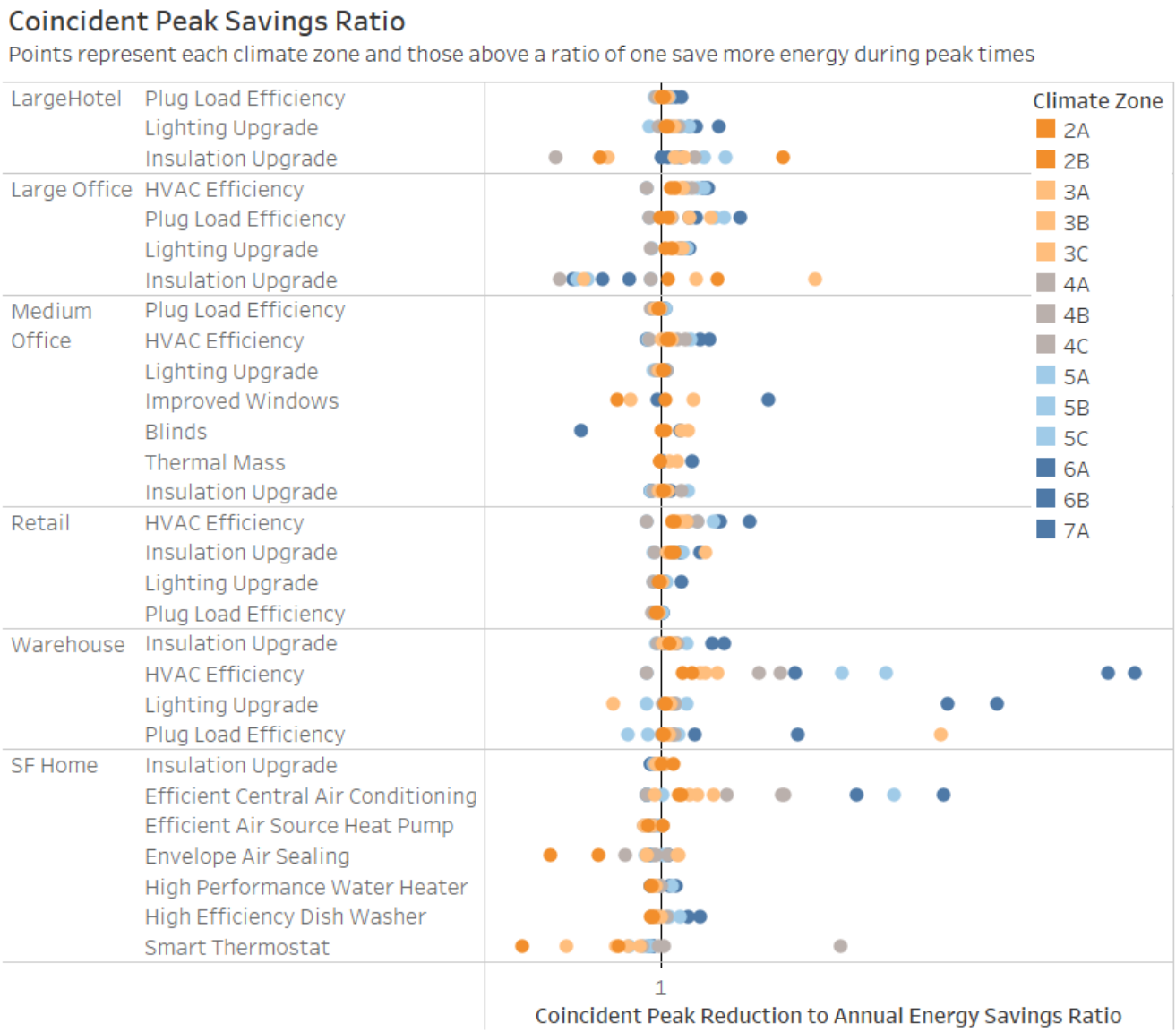
1	2	3
Run incentive programs to achieve key outcomes outlined in this memo	Ensure incentives include grid-connectivity to capture potential flexible loads	Offer automated demand response program to drive customer participation

Developed standards are available for smart grid communications and interconnectivity. The table below outlines specific standards (aligned with current and upcoming codes and policy) to specify by equipment type for utility incentives, including existing incentive programs that pair equipment incentives with connectivity requirements. Often, these requirements are part of the behind-the-scenes criteria for inclusion in incentive program qualified products lists: the customer need not be aware of the connectivity standards or even capabilities of their equipment.

Equipment	Common Standard(s)
Electric Vehicle Charger	OCPP 2.0 OpenADR 2.0
Smart Thermostat	OpenADR 2.0
Heat Pump Water Heater	ANSI/CTA-2045-B
Smart Inverter	IEEE 2030.5-2018 IEEE 1547-2018a

Program approaches and GridOptimal metrics

This information can be used to tune existing programs to achieve higher levels of coincident peak reduction, regionally-specific hourly upstream (electricity grid) carbon emissions savings, or other outcomes. NBI consider hourly impacts of measures across building types, climate zones, and grid regions and compared coincident peak demand reduction (i.e., Grid Peak Contribution impact) to "flat" annual energy efficiency savings. The chart below shows the results of this comparison. Evaluated cases (measure/climate/grid combinations) with relatively more coincident peak demand impact per flat annual kWh saved appear farther to the right on this chart, and cases with less appear to the left.



This chart can be used to identify building types and measures with relatively greater coincident peak reduction per kWh saved. For example, hotel, warehouse, and retail buildings offer relatively more coincident peak reduction per annual kWh saved than some other building types. In many cases this may be because the baseline load shapes for those buildings are more coincident in the first place – that is, their loads are higher during grid peak hours, so there are more options for coincident peak load reduction through a variety of measures. Programs seeking coincident peak demand reductions should consider focusing more aggressively on building types with highly coincident load shapes. Similarly, certain measures in certain building types are highly impactful. For example, in medium offices, improved HVAC

efficiency is, unsurprisingly, relatively impactful, whereas lighting upgrades have a roughly 1:1 ratio between coincident peak reductions and annual energy savings. Programs targeting medium office retrofits may thus want to focus on HVAC and envelope efficiency, especially in more extreme (hot and cold) climates with more weather-dependent peaks.

The existing program structure will to a large extent dictate what this analysis may be used to achieve. The use cases for this analysis vary between prescriptive and custom program types.

Prescriptive program adjustments

Prescriptive programs pay incentives per device ($/widget). This analysis may be used to adjust incentive levels to continue achieving targeted site energy savings while also enhancing the overall program's achievement of other outcomes. The chart above can be used to help identify high and low priority measures (but must be taken with a grain of salt – after all, these are modeled results and some of the assumptions such as equipment schedules can make a large difference in the results here). For example, a program offered by a utility seeking to achieve greater coincident peak load reductions might be interested in residential heat pump water heaters, which often offer substantial opportunity for coincident peak load reductions as shown in the chart above, whereas air conditioning appears to offer relatively lower reductions in coincident peak loads. The next action for this program could be to more deeply investigate customer and pre/post equipment load shapes. This must be balanced against other portfolio needs and goals, such as efficiency savings or customer cost impacts. In several cases, the chart shows high variability in coincident peak load impacts: careful attention should be paid to program design, customer targeting, and incentive/rate structure choices in order to be confident in measure prioritization. This analysis is mainly intended to provide a starting point for programmatic adjustments and to inform key areas to improve programs based on industry-wide observed best practices.

Custom program adjustments

Custom programs pay incentives based on the calculated project energy savings, usually $/kWh. In some cases, a peak $/kW savings is also included; this is typically system or whole-building peak but is not usually coincident peak. This analysis may be used to adjust incentive levels by project type, if a light touch is desired. Going deeper, programs could adjust the incentive basis ($/kWh and/or $/kW) metric itself or add additional metric(s) such as *coincident* peak demand savings and upstream carbon emissions to calculate part of the incentive payment.

GridOptimal Research and Market-Oriented Metrics

The full suite of GridOptimal metrics includes nine dimensions, including grid impacts, carbon emissions, resiliency, and demand flexibility. This comprehensive set of metrics addresses the needs of buildings owners and operators as well as utilities and grid operators. In this memo, we focus on grid-impact metrics for utility programs, namely grid peak contribution (coincident peak demand reduction) and short-term demand flexibility (1-hour load shed duration). These two metrics are energy-based to fit within typical utility program mandates. The underlying methodology prioritizes peak hours on the grid, which are often disproportionately high-carbon hours as well. These metrics are useful for research purposes and for programmatic (back-of-house) applications but may be too confusing and complex for many customers.

Programs may consider incorporating simple, straightforward metrics that provide a basis and framework for incentivizing customers to deploy high-priority strategies and technologies. Two recommended market-oriented metrics are:

- **Grid Peak Contribution Index:** a measure of a building's average normalized net power demand (W/ft²) during high-priority grid peak hours. The high-priority hours are limited to the 5% of the year (438 hours) when total system load is highest. The grid-delivered power to the building (i.e., net demand) during that subset of hours forms the entire basis for the metric. Measuring or calculating this index requires hourly net demand data available via building energy modeling or hourly building metering (smart meters).
- **Demand Flexibility Index:** a measure of how much load a building can shed (W/ft²) based on a utility signal over a one-hour period, much like a demand response call. DF is estimated based on the building's peak-day conditions. Buildings can provide DF several ways, including HVAC setpoint changes, onsite battery dispatch, using stored thermal energy to limit chiller or boiler power, cutting power to selected lighting/plug loads, or cutting power to tank-based water heaters. Measuring or calculating this index may in some cases require an

estimate of load shed potential based on parametric energy simulation modeling, customized technical assessments by facility managers, energy storage capacity evaluation, or other approaches.

These metrics are useful not only in a customer-facing application but also potentially useful as a way to compare program components to each other and to compare programs to other programs for evaluation and assessment.

Utility-scale programmatic cost/benefit calculations

This analysis may also be used to support utility demand side management (DSM) program-level cost/benefit calculations. These calculations may be conducted using customized spreadsheets and/or by using commercial software tools. The information used to produce this analysis, including the library of 8760 pre- and post- load shapes, can be used to expand the scope of the cost/benefit analysis so that more detailed hourly benefits are captured. For example, the commercially available Excel-based software tool DSMore calculates standard reference tests (e.g., PAC/UCT, TRC, RIM, and others) for utility incentive programs and can do so on a program-wide basis using either flat savings % estimates or hourly measure-level pre and post load shapes. The tool can accept 8760 savings as well as 8760 costs to define costs and benefits, and uses EPA AVERT (historical) emissions factors to provide emissions impacts as well. While the specific methodology used to define the hours for coincident peak demand varies somewhat from what is used in this GridOptimal analysis, the inputs for DSMore and GridOptimal can be aligned.

Conclusion

Utility programs are well positioned to both increase behind-the-meter demand flexibility and mitigate system peaks by incentivizing targeted retrofits to build controls capability, install storage, or upgrade building systems shown to reduce energy demand during common system peak periods. We recommend programs assess the monetary value of coincident (and noncoincident) peak load reduction as well as upstream electricity grid emissions in their service territory to establish appropriate incentive levels to reach these program goals.

Appendix

Data Sources

The analysis relies on multiple sources for both building-side data, primarily building energy simulation modeling, and grid-side data, primarily detailed government forecasts of electricity grid parameters. Data sources are both internal to GridOptimal and external, in large part from national labs working to explore grid-integrated efficient building (GEB) opportunities. For consistency, the same data sources and methodology were used to consider impacts of multiple measures across various climate zones and grid regions. However, in many cases changing the input data while using same approach would enable the development of utility-specific efficiency and demand flexibility measure comparisons.

Key building-side data sources include:

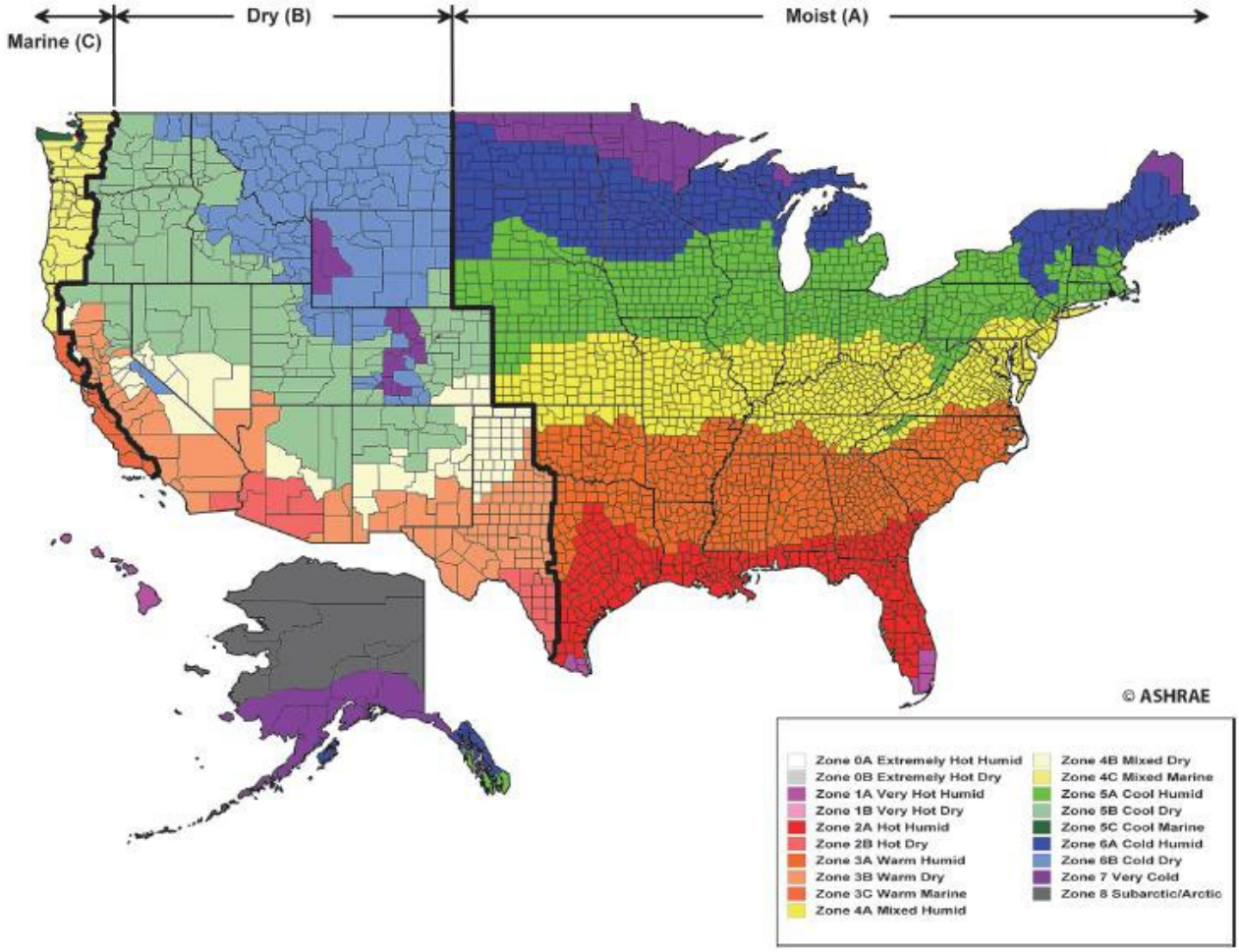
- Comprehensive GEB energy simulation model demand profiles (by LBNL, used as basis information for the 2021 DOE GEB Roadmap) by LBNL; referred to here as "DOE GEB Models"
    - Six building types: large office, large hotel, medium office, standalone retail, warehouse, single family home
    - 14 climate zones: ASHRAE zones 2A, 2B, 3A, 3B, 3C 4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 7 (see map on next page)
    - 14 electricity grid regions: comprehensive across lower 48 US states
    - One vintage: ASHRAE 90.1-2004 compliant building (commercial), ResStock single-family home model (residential)
    - Four scenarios: baseline, energy efficiency, demand flex, energy efficiency + demand flex
- GridOptimal energy simulation model demand profiles (by Red Car Analytics), referred to here as "Red Car Models"
    - Medium Office
    - Three climate zones: SF (CA), Austin (TX), Burlington (VT)
    - Two vintages: ASHRAE 90.1-2013 code-compliant baseline building and high-performance building (code-compliant building with additional efficiency measures built in)
    - 12 measures: mix of energy efficiency measures and demand flexibility measures
        - Eight packages combining multiple of the 12 measures
- Operational GEB energy simulation modeling by LBNL
    - Two building types: Medium Office, Small Office
    - Three climate zones: 3A, 3B, 3C
    - Three vintages: ASHRAE 90.1-2013 compliant building, ASHRAE 90.1-2004 compliant building, Pre-2000 building
    - 20 global temperature adjustment measures combining varying degrees of precooling and temperature resets, twelve global temperature adjustment measures combined with additional grid-efficient interactive building measures such as DR lighting, shading, and plug load control.
- GridOptimal Pilot Projects: actual building-specific data from design team scale engagement with buildings in Sonoma, CA; Seattle, WA; northern Vermont; Manhattan, NY; and Brooklyn, NY
- PVWatts modeling: online tool by National Renewable Energy Lab
    - Building-mounted PV generation profiles for every relevant combination of US state and climate zone

Key grid-side data sources include:

- Standard Scenarios, accessible in hourly format through the Cambium tool (by NREL): hourly forecasts of electric system load and long run marginal grid carbon emissions rates for each of the lower 48 states, primarily for the decadal average group surrounding 2040 (other years considered for comparison purposes), accessed in December 2021 and referred to here as "Cambium Data"
- WattTime: long run marginal carbon emissions rates, nearly comprehensive across lower 48 US states, mainly used for comparison purposes

ASHRAE Climate Zones

NBI's GridOptimal analysis covers all those shown here except zone 1A (southernmost Florida and Texas) and 8 (northern Alaska).



Metrics and Methodology

To evaluate the measures contained in the data sources described above, a multi-step process was required. First, the raw data was formatted into an hour-by-hour dataset containing electricity consumption information for all 8,760 hours of the year (8760 data), for both the baseline building and proposed building with measures applied. This data was placed into a calculator template based on the GridOptimal LEED ACP Pilot Credit calculator. The calculator was populated with state-level decadal averages of hourly grid demand and marginal carbon data from NREL's Cambium dataset (2021 version). The calculator used these inputs to evaluate each baseline/measure combination on the GridOptimal metrics described in the table below. The calculator output was then formatted for input to Tableau, which was used for data visualization to identify trends and most impactful measures.

The table below contains a summary of the GridOptimal metrics that were used for this analysis. A detailed summary of the methodology to develop these metrics can be found here: https://newbuildings.org/gridoptimal-metrics-offer-guidance-on-optimizing-building-grid-interaction/

Metric	Description
Grid Peak Contribution	Degree to which building demand contributes to load on the grid during system peak hours
Grid Carbon Alignment	Degree to which the building demand contributes to upstream (grid) carbon emissions over a year
Short-Term Demand Flexibility	The building's ability to reduce demand (shed) for 1 hour

Long-Term Demand Flexibility	The building's ability to reduce demand (shed) for 4 hours
Dispatchable Demand Flexibility	The building's ability to automatically reduce demand (shed) for 15 minutes, controlled by utility/ third party
Onsite Renewable Utilization Efficiency	The building's ability to consume energy generated onsite. A higher score indicates that the building can consume more of its own energy instantaneously, on the building side of the meter.
Building Carbon Emissions	Annual sum of net marginal carbon emissions of the baseline building vs. the building with efficiency and/or flexibility measure(s) applied.
Annual Building Energy Consumption	Annual total energy use of the baseline building vs. the building with efficiency and/or flexibility measure(s) applied
Building Peak Demand (AMRD)	Adjusted Maximum Reference Demand (AMRD) of the building, calculated using the top 10 highest building demand hours, at baseline vs. with efficiency and/or flexibility measure(s) applied.
Coincident Building Peak Demand (AMRD)	Coincident Adjusted Maximum Reference Demand (AMRD) of the building, calculated using the top 10 highest building demand hours, exclusively during the 438 hours of the year that constitute the top 5% of grid peak demand hours, at baseline vs. with efficiency and/or flexibility measure(s) applied.
Electricity Bill Cost	Dollars spent on utility bills, including both demand and energy charges, based on a typical general commercial rate structure (for selected utilities)

Prioritizing Building Measures and Strategies to Achieve Specific Program Priorities/Goals

Historically, the primary goal of utility energy efficiency programs has been to deliver energy savings: kWh and therms saved, on a flat (not TOU) basis. Some other program priorities are also often present, including peak demand savings, low/moderate income (LMI) customer benefits, or more recently greenhouse gas emissions savings. The table below shows several alternate or complementary program goals and shows a summary of the comparative benefits of various EE and DF measures in achieving these goals across various building types. The GridOptimal interactive web-based dashboard tool enables utility program planners and implementers to customize the comparisons of measures across many more dimensions (such as climate zone, grid region, building type, etc.) than are shown in the graphics below.

Program Goal	**Description and Metric(s)**
Reduce coincident peak demand	Change in Adjusted Maximum Reference Demand (AMRD) of the building, calculated using the top 10 highest building demand hours that also fall within the 95th percentile of peak bulk grid load.
Reduce building peak demand	Change in AMRD of the building alone, calculated using the top 10 highest building demand hours, regardless of grid peak load conditions.
Provide demand flexibility	Capability of the building to shed or shift load, using GridOptimal Short-Term (1 hour) and Long-Term (4 hour) Demand Flexibility metrics.
Reduce grid carbon emissions	Reduction in building carbon emissions, using GridOptimal Grid Carbon Alignment (GCA) and total gross (upstream, on grid) carbon change (kg CO_2).
Reduce Customer Electricity Bill Cost	Reduction in electricity bill cost for customers, including both demand and energy charges

Enhance resiliency[1]	Capability of the building to: safely island from the grid in the event of an outage and provide power for critical loads over 4 and 24 hours; and to aid grid resilience by restarting HVAC motors in soft-start mode after an outage.

In the following sections, this memo discusses the comparative evaluation of energy efficiency and demand flexibility measures across each of these program goals.

Example charts

For each program goal section below, a chart showing comparative impacts is provided. These charts can be further explored (for example, customized by climate zone, building type, hover-over text on each dot, etc.) in the online dashboard. Measures that resulted in a negative impact (e.g., an *increase* in coincident peak demand) or no impact (percent change of zero) are excluded from the charts. Similar measures that yielded similar percent reduction results % (e.g., precool by 2 or by 3 degrees) have been grouped together.

Coincident Peak Demand Savings

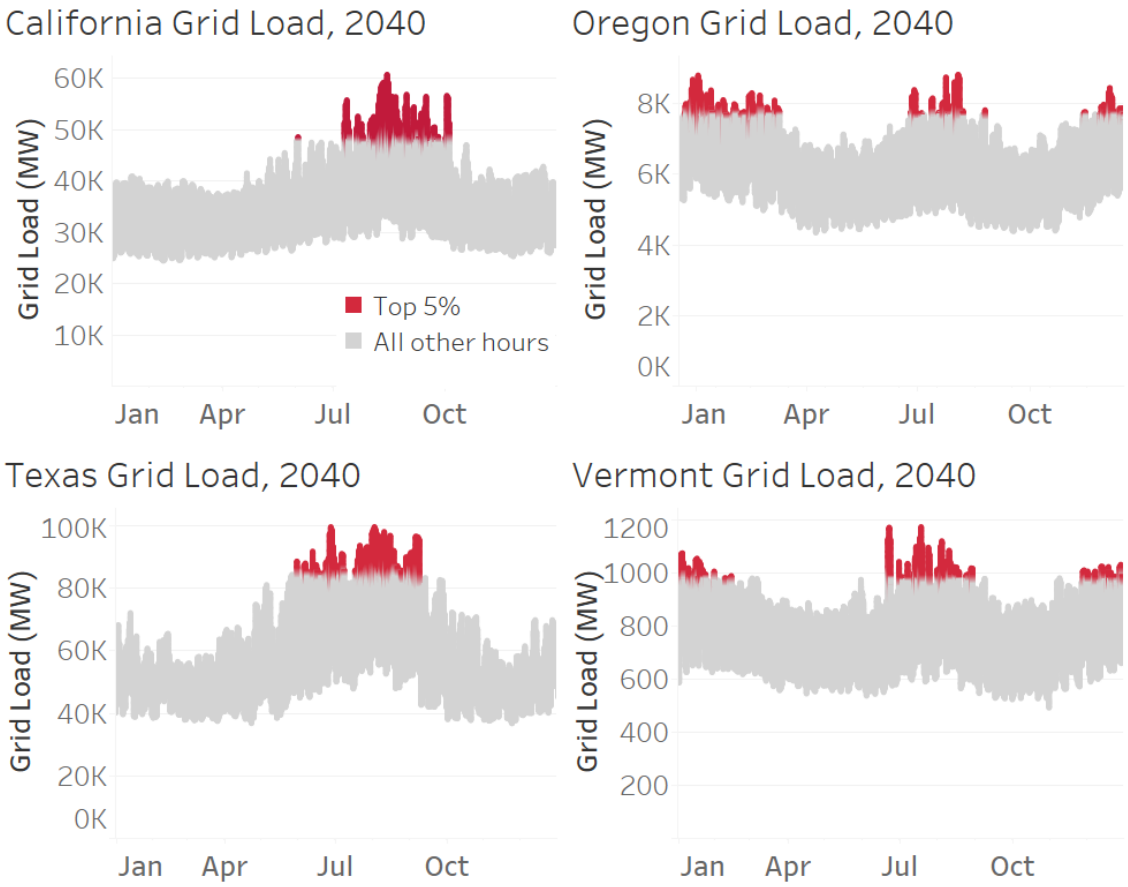
Energy efficiency measures usually save energy across all hours. While these measures yield savings during coincident peak demand hours, they are not necessarily more aligned with these hours than all others. Certain passive and active strategies can deliver time-of-use energy savings that maximize the benefit during coincident peak hours. For example, a passive energy efficiency measure like shading or blinds on west-facing windows can help reduce cooling demand during summer afternoon coincident peak hours, when load shifting is most needed for summer-peaking grids.

There are two important steps to determining the key strategies for enabling coincident peak demand reduction: defining the peak grid load hours and defining the measures to consider. Additional details on each of these steps are provided below.

Define peak load hours:

The hours during which grid load is predicted to be in the top 5% (i.e., the top 438 hours) are used to define the grid peak hours, or the "coincident" hours. This calculated definition is used because non-calculated definitions such as utility peak rate structure hours vary widely, often do not fully reflect peak conditions on the grid, and usually take some years to respond to changing grid conditions. The calculated approach allows for use of a consistent dataset, in this case Cambium state-level bulk system total busbar load for the decade surrounding 2040. The graph below highlights the top 5% of grid load in California, Oregon, Texas, and Vermont. As shown in the chart, Vermont and Oregon have peaks in both summer and winter, while California and Texas have higher peak periods in the summer. Examining the scale also shows the range in total grid load between states; Vermont's peak load is much lower than Texas and California.

[1] The GridOptimal resiliency metrics are intrinsically asset-based and do not lend themselves to quantitative evaluation in the same manner as the other program goals in this table. Therefore, in-depth quantitative evaluation of resiliency is not included in this memo.



As noted above, the analyses shown in this memo are done using consistent state-level data from Cambium, but it would be straightforward to use other data sources to define which hours are "peak hours," that is, the hours that are relevant for evaluating coincident peak demand impacts. Other potentially relevant options include:

- Utility peak hours, per rate structure
- Distribution grid (rather than bulk grid) top 5%, or other percentile, of hours
- High electricity procurement or avoided cost hours

Define measures to consider:

A variety of EE and DF measures were evaluated for coincident peak demand savings. Because multiple data sources were used, each with distinct methodology and measure definitions, each data source has its own measures shown in this table. This memo's charts show only a subset of these measures; more charts are available in the dashboard, although some data sources are organized/formatted in ways that preclude consistent graphical comparisons.

Source of Data	Building Types	Measures Evaluated
DOE GEB Roadmap - Commercial	Large Hotel Large Office Medium Office Retail Warehouse	• Efficient envelope • Efficient windows • Efficient HVAC • Efficient lighting • Reduced plug loads • All efficiency measures above with demand response added • Ice storage • Precooling
DOE GEB Roadmap – Residential	Single Family Detached	• Efficient HVAC • Efficient thermostat • Efficient envelope • Efficient appliances (clothes washer and dryer, dishwasher, refrigerator) • Reduced plug loads • Efficient lighting • Efficient pool pump • Efficient water heater • All efficiency measures above with demand response added where possible
LBNL	Medium Office, Small Office	Temperature reset of 2 to 6 degrees with up to 4 degrees precooling
Red Car Analytics	Medium Office	• Increased thermal mass • Interior automated blinds • Electrochromic window glazing • Expanded thermal comfort range • Pre-occupancy heating • Afternoon precooling • Lighting demand response • Grid-integrated appliances • Thermal energy storage • Electric battery storage

This list includes only a portion of the strategies that designers and operators can use to shed load. Other strategies are also relevant, including battery energy storage, solar PV, and managed electric vehicle (EV) charging. Because these strategies can layer on top of nearly any building regardless of its other energy efficiency measures, with no or minimal interactive effects, their impacts must be considered separately. A detailed analysis of these additional measures was not completed as a part of this phase of GridOptimal. If this analysis were to be undertaken, there would be a few key considerations:

a. PV sizing: because the size of the PV array is highly impactful and relatively easily fungible, a range of sizes should be evaluated. It would likely be helpful to align sizes with relevant codes and policies, such as California's Title 24 energy code, the IECC-2024 model code, and the IECC Decarbonization Overlay. Alternately, if using prototype buildings, the PV array could be assumed to occupy a certain portion of the total roof space (25%, 50%, etc.). NBI did evaluate the impact of solar PV on grid peak contribution and

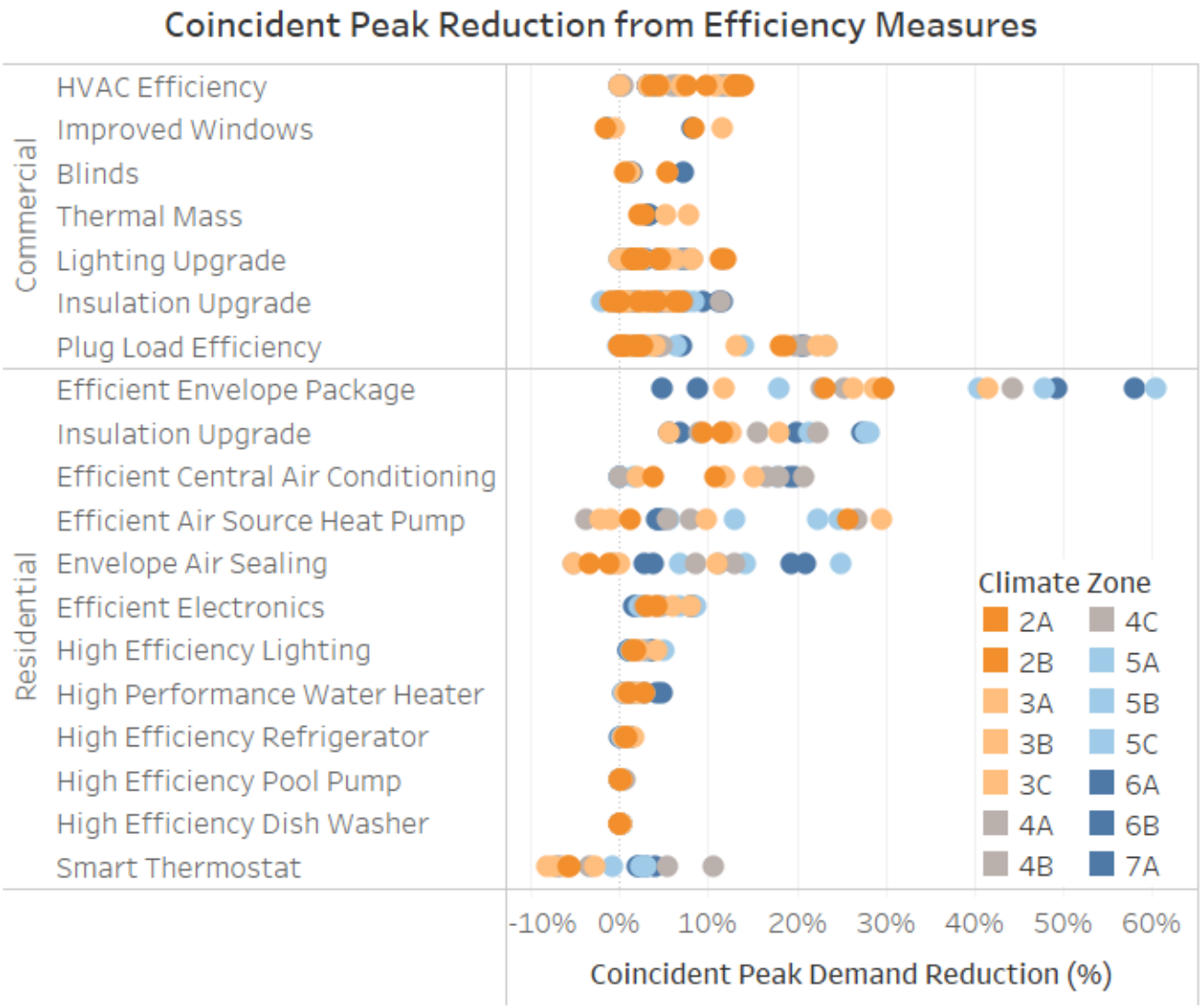
other GridOptimal metrics and wrote a memo about this which was provided to the GridOptimal TAC in 2020. This memo is available upon request.

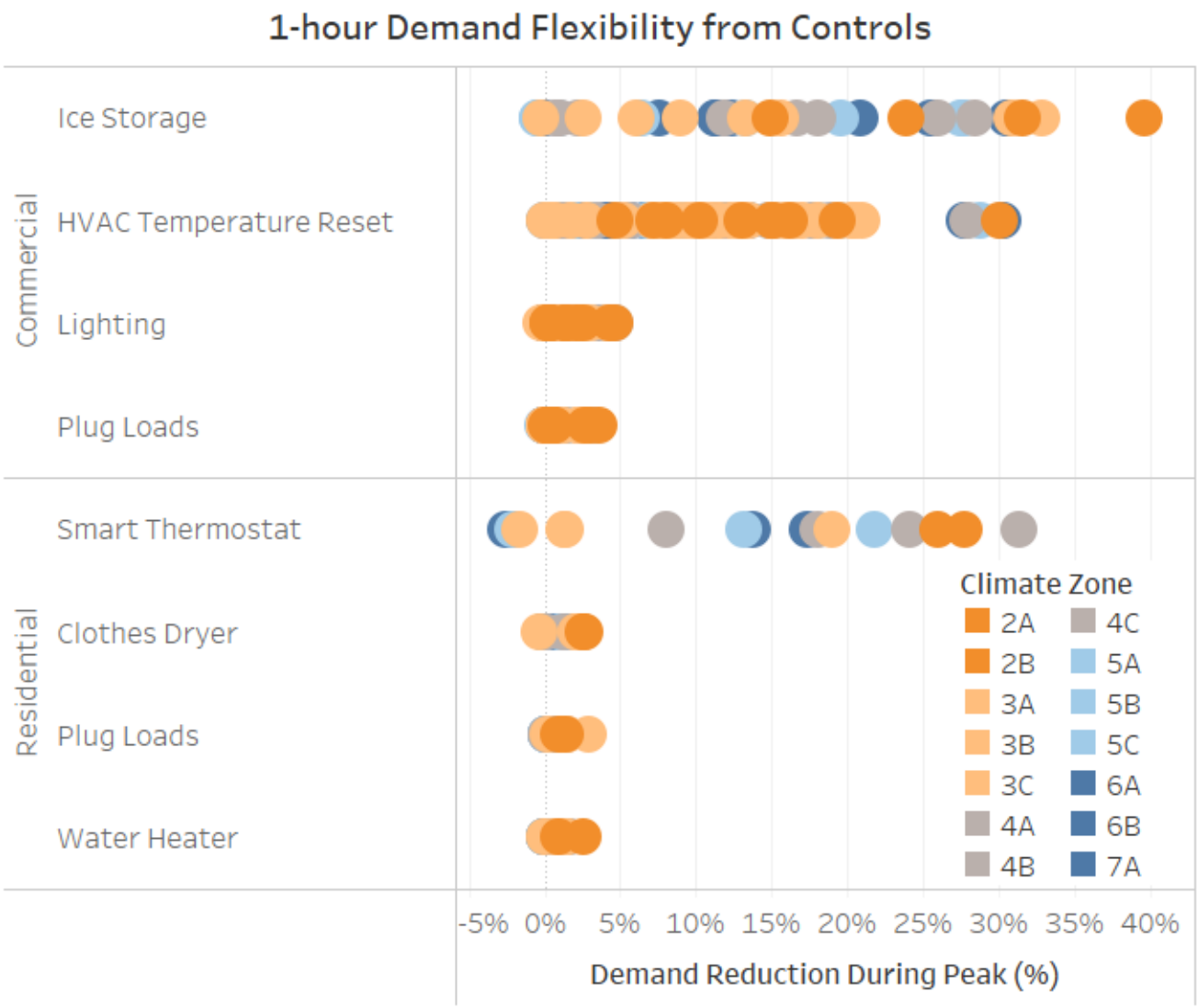
b. Battery dispatch strategy and sizing: batteries may help reduce coincident peak load if they are charged outside of grid peak hours and discharged during grid peak hours. However, they can add to grid peaks by charging during peak hours if the dispatch strategy is not carefully aligned with grid peaks. Also, like PV, battery sizing is fungible and highly impactful, so a range of sizes should be considered.

c. EV charging schedule, voltage (charging level), and other characteristics: EVs are expected to drive major grid load growth, and most EV chargers will probably be sited at buildings. While EV loads are considered “outside the bounds” of many building-oriented code and policy frameworks, EV loads must often be served by the same grid infrastructure that serves buildings. EV charging schedules vary substantially, between location contexts (dedicated single-family home charger, shared multifamily charger, office building charger, retail store charger) as well as from case to case. The degree of coincident peak load reduction achievable from EV charger control will vary based on location context, charger level (level 1 or 120V, level 2 or 240V, and higher levels), rate structures, and other variables. If evaluating impacts from EV chargers it would be best to consider multiple combinations of variables.

Coincident peak demand savings

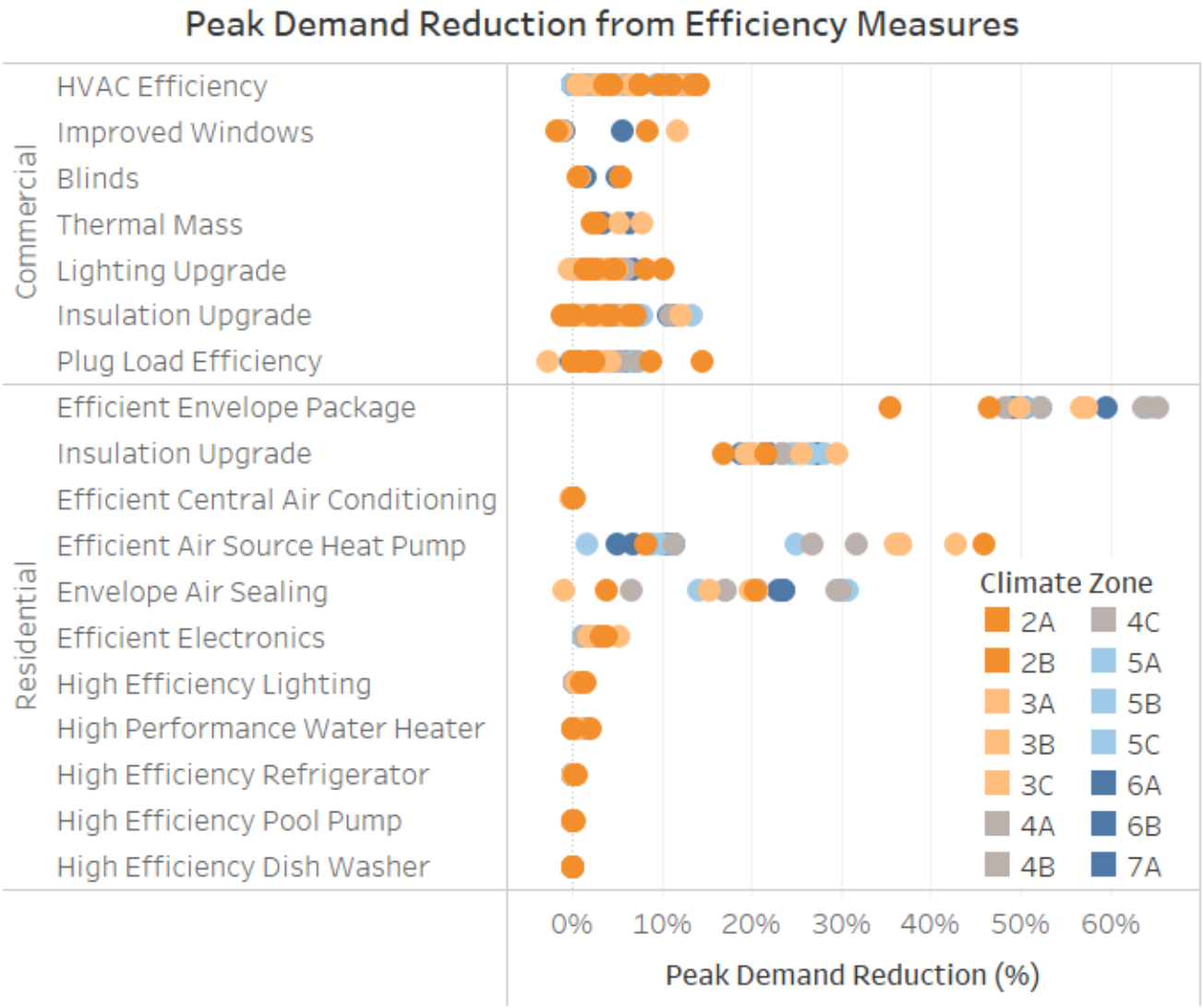
The charts below show the DOE GEB Roadmap efficiency and demand flexibility measures that yielded the greatest reduction in coincident peak demand.




1-hour Demand Flexibility from Controls
Commercial
Ice Storage
HVAC Temperature Reset
Lighting
Plug Loads
Residential
Smart Thermostat
Clothes Dryer
Plug Loads
Water Heater
Climate Zone
2A
2B
3A
3B
3C
4A
4B
4C
5A
5B
5C
6A
6B
7A
-5%
0%
5%
10%
15%
20%
25%
30%
35%
40%
Demand Reduction During Peak (%)

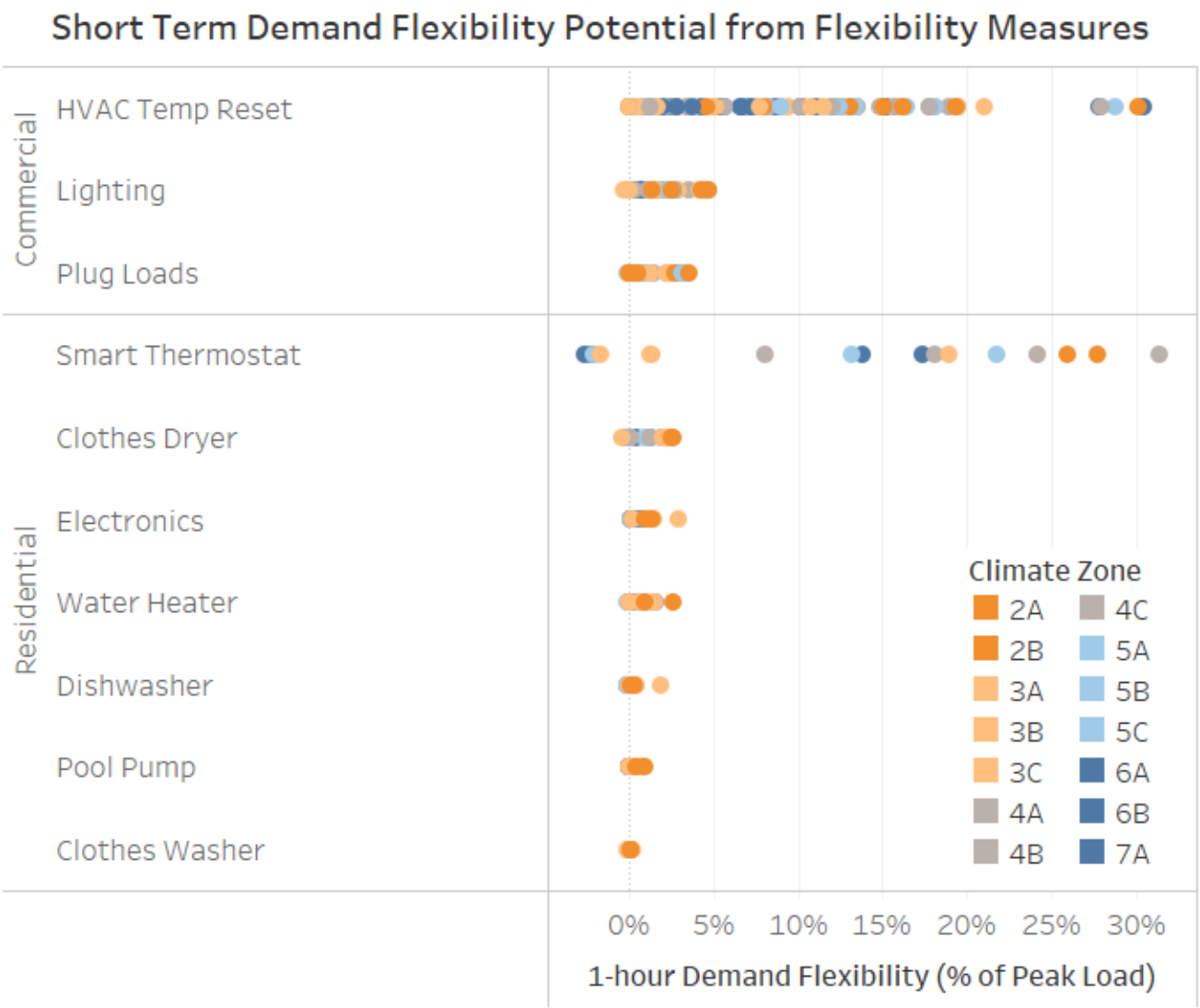
Building (non-coincident) peak demand savings

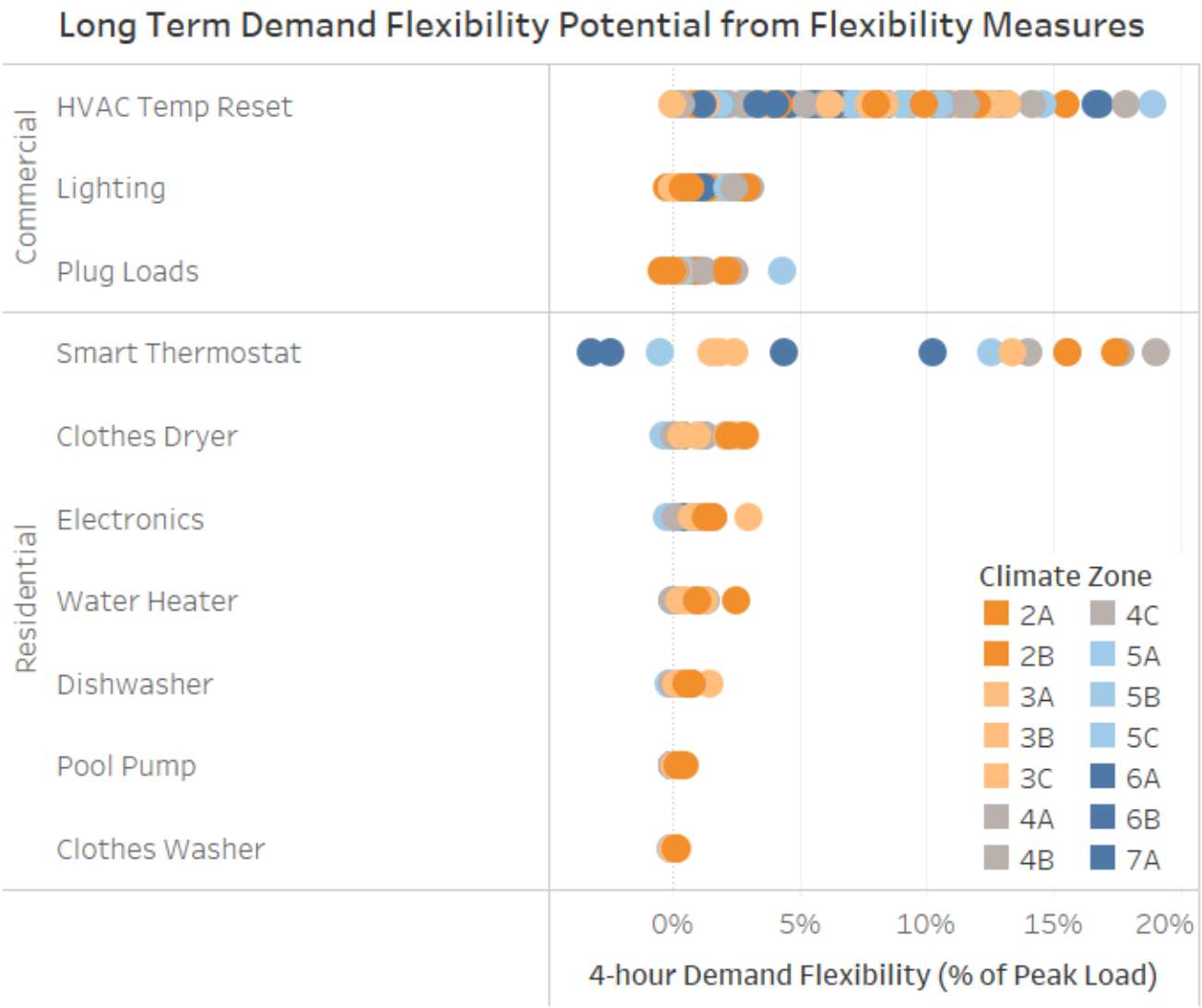
The chart below shows the DOE GEB Roadmap, LBNL, and Red Car measures that yielded the greatest reduction in building peak demand.



Demand flexibility

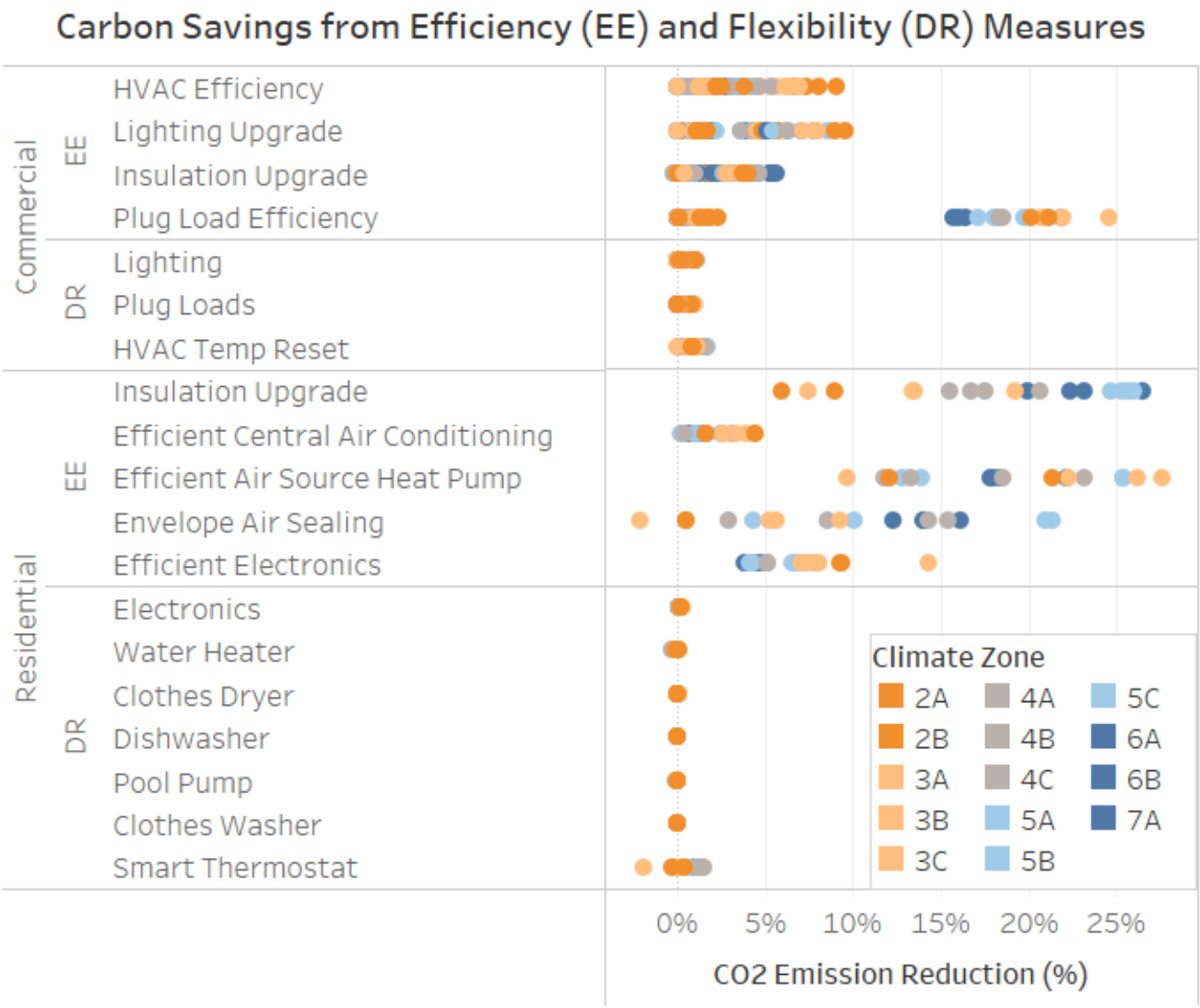
The charts below show the DOE GEB Roadmap demand flexibility measures with the largest short-term (1-hour) and long-term (4-hour) demand flexibility potential.




Long Term Demand Flexibility Potential from Flexibility Measures
Commercial
HVAC Temp Reset
Lighting
Plug Loads
Residential
Smart Thermostat
Clothes Dryer
Electronics
Water Heater
Dishwasher
Pool Pump
Clothes Washer
Climate Zone
2A
2B
3A
3B
3C
4A
4B
4C
5A
5B
5C
6A
6B
7A
0%
5%
10%
15%
20%
4-hour Demand Flexibility (% of Peak Load)

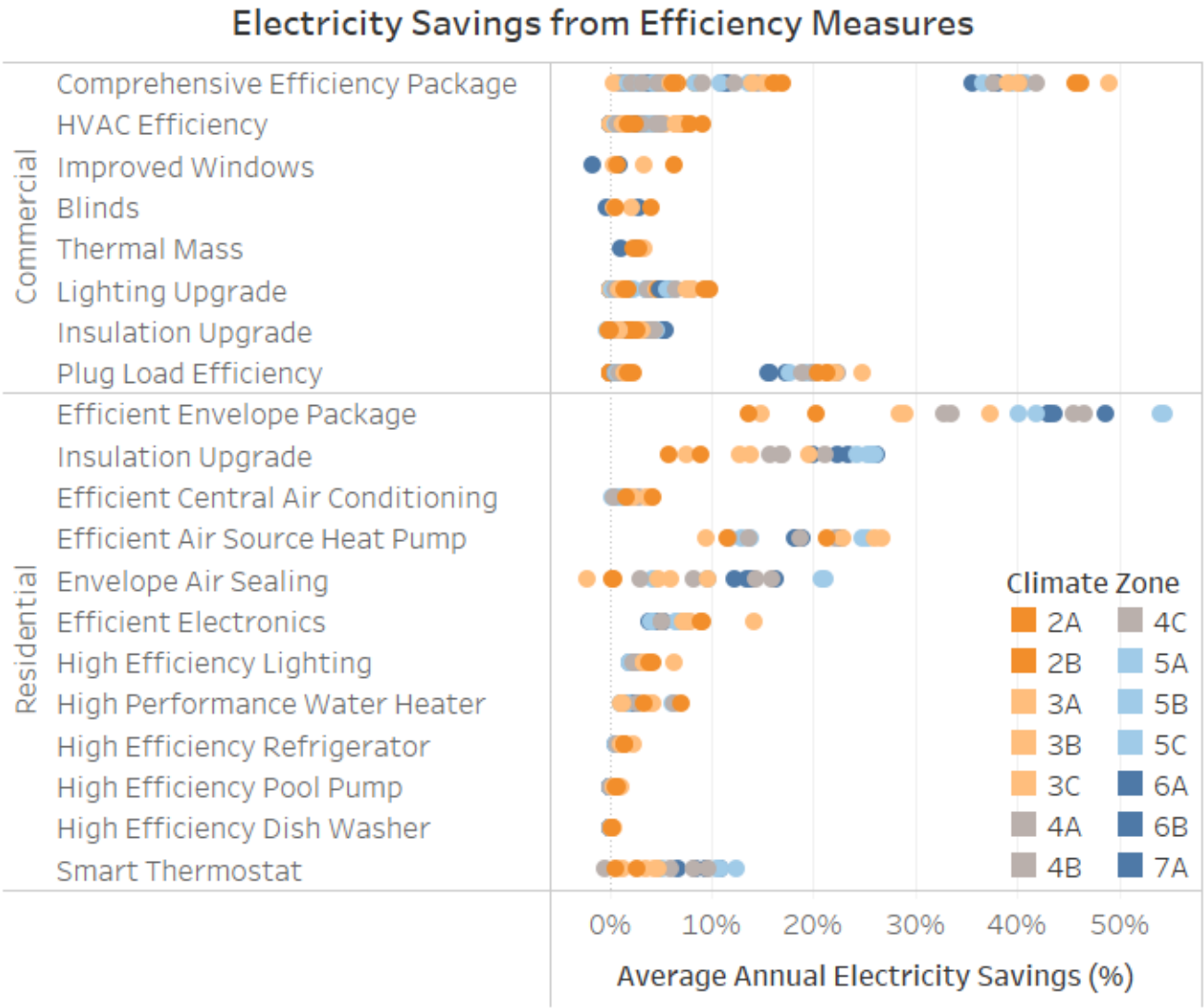
Grid carbon emissions reductions

The chart below shows the DOE GEB Roadmap measures that yielded the greatest reduction in building carbon emissions.



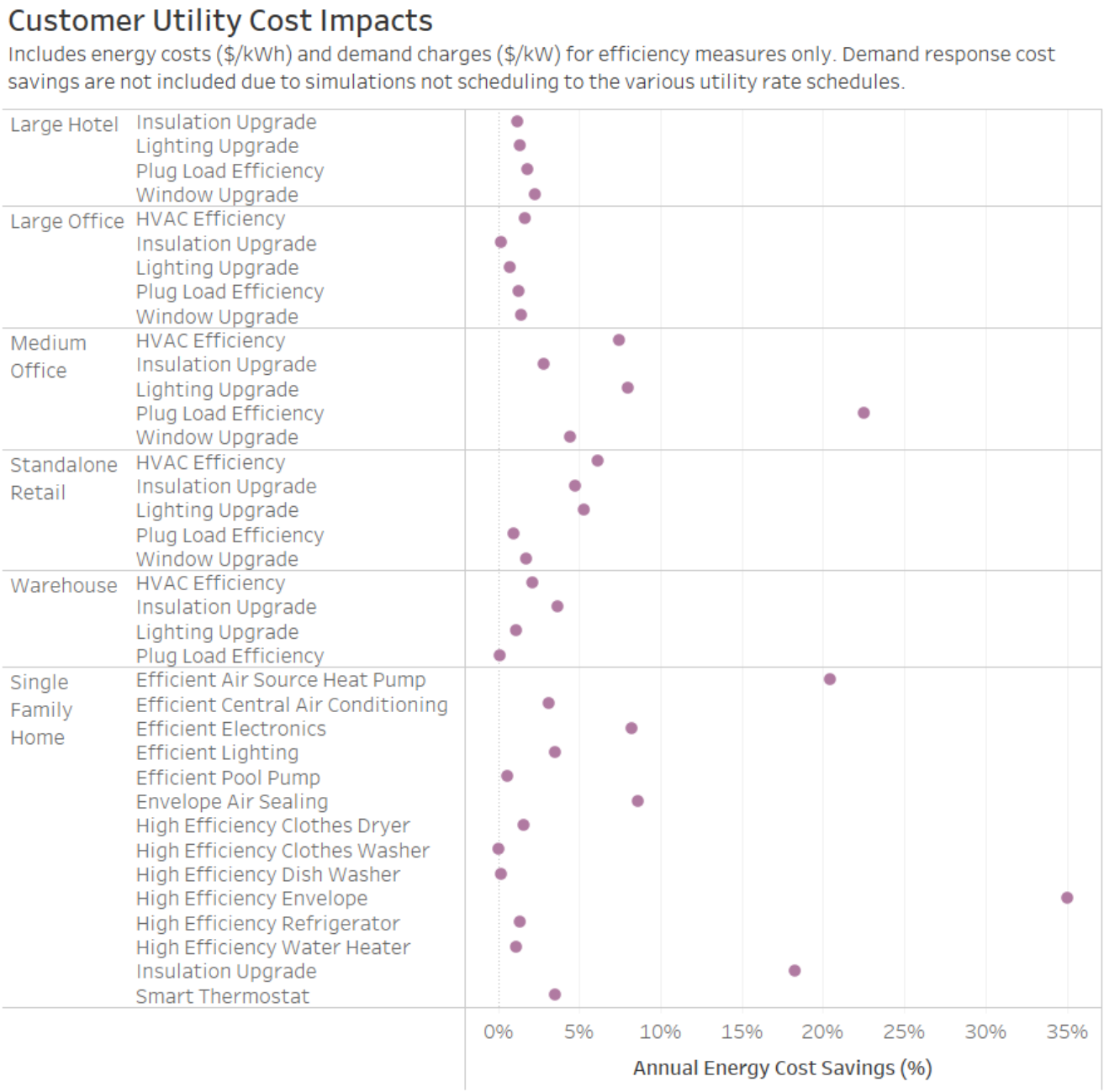
Electricity Savings

The chart below shows the DOE GEB Roadmap efficiency measures that yielded the greatest reduction in building energy use.



Customer Electricity Cost

The chart below compares various measures in terms of their total customer electric cost savings (considering both demand and energy charges), based on the SMUD rate structure. Similar analyses were conducted with rate structures from GridOptimal sponsors: Austin Energy, Green Mountain Power (sponsor: Efficiency Vermont), Portland General Electric (sponsor: Energy Trust of Oregon), Pacific Gas & Electric, and Southern California Edison. Customizable charts for all of these utilities are available on the dashboard.



GridOptimal Funders Utility Rate Summary

The table below summarizes the commercial and residential rates that were used for the cost analysis.

Commercial Rates

Energy charges ($/kWh)

		SMUD C&I Time-of-Day	SCE TOU-8	PG&E B-10	Austin Energy Commercial >=300 kW	PGE Schedule 85	Green Mountain Power Rate 63/65 C&I Time-of-Use
Summer	Off-Peak	$0.13560	$0.0423	$0.16806	$0.05453	$0.04691	$0.08795
	Mid-Peak	$0.13560	$0.0423	$0.19890	$0.05453	$0.04691	$0.08795
	Peak	$0.21530	$0.0423	$0.25720	$0.05453	$0.06191	$0.11573
Winter	Off-Peak	$0.09560	$0.0423	$0.11436	$0.05453	$0.04691	$0.08795
	Mid-Peak	$0.09640	$0.0423	$0.15071	$0.05453	$0.04691	$0.08795
	Peak	$0.11940	$0.0423	$0.18434	$0.05453	$0.06191	$0.11573

Demand charges ($/kW)

		SMUD C&I Time-of-Day	SCE TOU-8	PG&E B-10	Austin Energy Commercial >=300 kW	PGE Schedule 85	Green Mountain Power Rate 63/65 C&I Time-of-Use
Summer	Peak		$14.86				$16.40
	Overall Monthly	$9.44	$12.67	$14.15	$13.71	$3.39	$4.72
Winter	Peak		$5.00				$16.40
	Overall Monthly		$12.67	$14.15	$13.71	$3.39	$4.72

Residential Rates

Energy charges ($/kWh)

		SMUD Residential Time-of-Day	SCE TOU-D	PG&E E-6	Austin Energy Residential	PGE Residential TOU	Green Mountain Power Residential TOU
Summer	Off-Peak	$0.13000	$0.2239	$0.22924	$0.10814	$0.04128	$0.11946
	Mid-Peak	$0.18000	$0.2897	$0.30447	$0.10814	$0.07051	$0.11946
	Peak	$0.31000	$0.2897	$0.42290	$0.10814	$0.12380	$0.28027
Winter	Off-Peak	$0.11000	$0.2160	$0.23358	$0.10814	$0.04128	$0.11946
	Mid-Peak	$0.11000	$0.2239	$0.25041	$0.10814	$0.07051	$0.11946
	Peak	$0.15000	$0.2897	$0.25041	$0.10814	$0.12380	$0.28027