Hyperscaler Support for Community Energy Programs
Options and Impacts for Household Energy Investments

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JUNE 2026

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Notice

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Acknowledgments: We thank Sanem Sergici, Ryan Hledik, and Akhilesh Ramakrishnan for their review and feedback on this study. We thank Alison Savage Brooks for her contributions to the analysis.

Table of Contents

Table of Contents

Study Overview

Alongside other sources of growth, rapid data center (DC) expansion is increasing electricity demand and capacity needs across the United States. Community-based demand-side investments by large-scale developers ("hyperscalers") could help meet incremental energy and capacity needs, enable earlier DC connections, and deliver benefits to local communities.

- This report presents a preliminary assessment of avoided electric capacity, energy savings, emissions reductions, and costs for four representative distributed energy resources (DERs) that hyperscalers could fund in areas where data centers are being added.
- **The analysis focuses on four metropolitan statistical areas (MSAs): Atlanta, GA; Memphis, TN; Kansas City, MO; and Columbus, OH.**
- **We analyze hypothetical programs in which hyperscalers fund specific subsidies offered to all eligible households in each MSA**, with 3–8% participation rates, consistent with similar utility programs. We do not examine the administrative or regulatory aspects of this hypothetical structure.
- We assess four representative DERs: **energy efficiency retrofits in low-efficiency residential buildings, heat pump deployment in homes with electric resistance heating, community solar paired with storage, and residential demand response programs.** Other DER programs and technologies that could provide additional potential were not analyzed. The study also examines financing models for DER programs and urban infill as a complementary strategy.
- Results are based on publicly available data sources described in the Appendix. **Further implementation research would improve accuracy using more location-specific data.**

Summary of Findings – Community Benefits

Each of the four measures can provide significant capacity—and in some cases, energy—benefits across the four metropolitan areas studied, while also delivering net benefits to participating households.

Across the four MSAs, the combined investment program could:

- Unlock approximately 1.4 GW of summer and 1.2 GW of winter peak capacity.
- Save participating households approximately $50 to $1,175 per year in energy bills.
- Avoid approximately 1.15 million metric tons of CO_2 emissions annually.

Approximately 35–40% of eligible households are low-income, indicating that these measures can meaningfully reduce energy burdens where it is most needed.

These results depend on substantial financial contributions from hyperscalers, as outlined on the following page.

Summary of Findings – Hyperscaler Costs

Hyperscaler funding is critical to achieving high participation and rapid deployment, but comes at a cost that may exceed traditional supply-side benchmarks.

- To enable strong customer participation, we assume hyperscalers fund the majority of upfront costs:
  - ~50% for heat pumps
  - ~90% for solar + storage
  - 100% for other measures

  This high level of support is expected to minimize out-of-pocket costs for participating customers and accelerate adoption relative to traditional supply-side resources.

- Under these assumptions, annualized hyperscaler costs per unit of unlocked capacity range from approximately $80 to $450/kW-year across the four MSAs. With the exception of demand response, these costs exceed typical combustion turbine (CT) benchmarks (~$200–300/kW-year). However:
  - This comparison excludes additional costs of new generation (e.g., transmission upgrades).
  - It does not reflect longer development and interconnection timelines for supply-side resources.
  - These are gross hyperscaler funding costs per firm kW-year, not net social costs; customer bill savings, emissions reductions, and other value streams are shown separately and are not netted here.

- Under these conditions, hyperscaler-funded investments are likely additive to, rather than competitive with, existing utility programs.

Summary of Findings – Overview of All MSAs

Across all MSAs, the analyzed DERs vary in cost-effectiveness and impact, with trade-offs between cost, scalability, and capacity value.

Average Lifetime Measure Impacts for Four MSAs

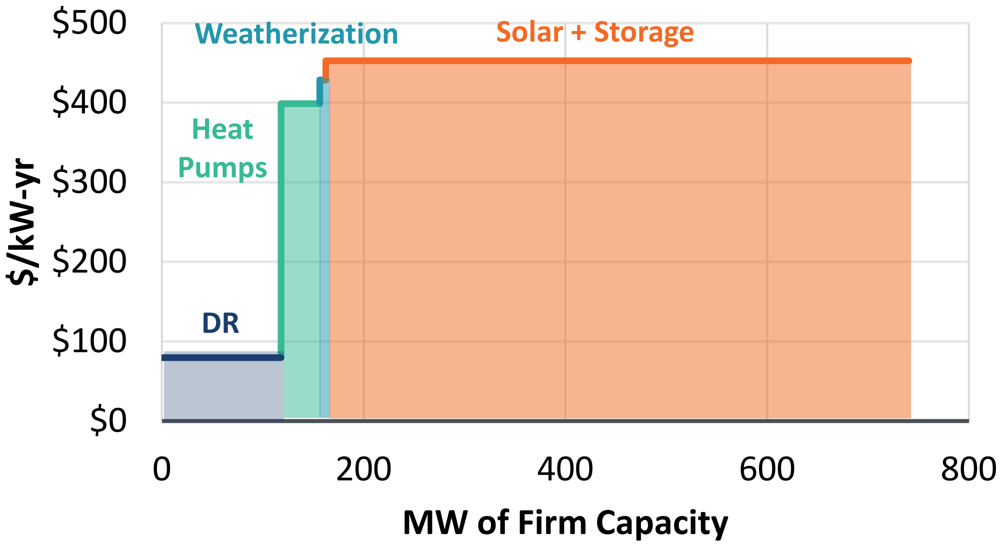
		Community Solar + Storage	Heat Pump	Weatherization	Demand Response (DR)
MSA results	Equivalent Total Capacity (MW)	294	21	5	57
	Adoption Rate (% of eligible population)	5%	8%	3%	8%
	Total Measure Cost ($)	$1,149,309,157	$109,004,750	$9,886,772	$34,394,891
Hyperscaler results	Total Cost for Hyperscaler ($)	$1,010,439,934	$58,042,386	$9,886,772	$34,394,891
	Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$453	$343	$291	$80
Customer results	Number of Participating Customers	58,703	14,511	5,273	75,543
	Customer Cost after Rebate ($)	$2,349	$3,512	$0	$0
	Present Value (PV) of Customer Bill Savings ($)	$5,954	$5,619	$3,702	$380
	Payback Period w/ Rebate (yrs)	3	5	0	0

- Community solar + storage provides the largest potential bill savings and firm capacity; while it has the highest gross hyperscaler cost, that metric does not net customer savings or other system benefits.
- Demand response represents the lowest-cost and most broadly scalable opportunity, driven by the large share of homes with central air conditioning that can participate via thermostat-based control.
- Differences in cost-effectiveness (total capacity and $/kW-yr) across MSAs are primarily driven by:
  - Variation in the available stock of eligible residential units.
  - Local climate conditions and solar irradiance, which affect per-home performance and total achievable capacity.

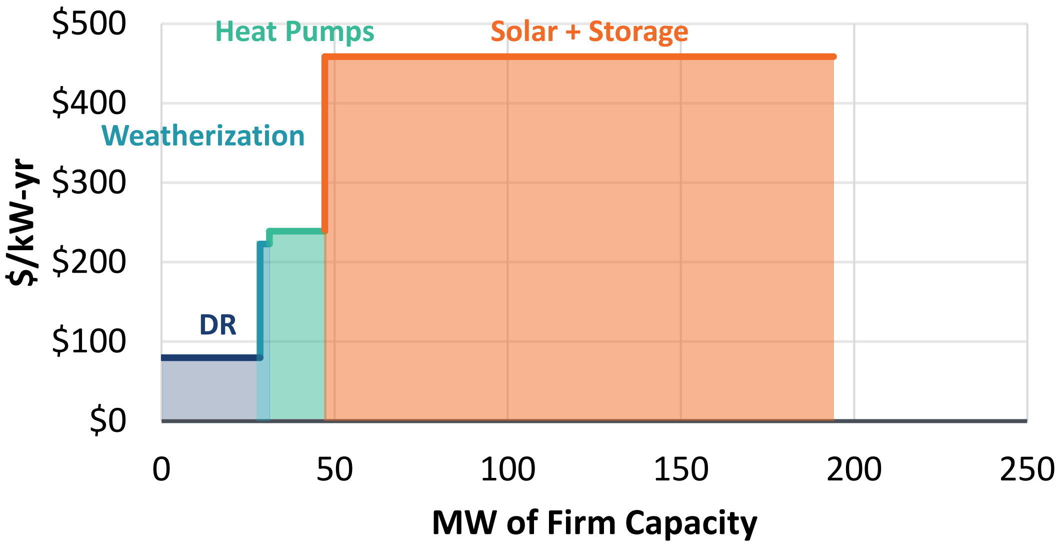
Note: Results are calculated separately for each metropolitan area and presented in detail in the Results section; values shown here are averages across the four areas. Measure costs are consistent across regions, except for solar + storage, which is calibrated to achieve an approximately three-year customer payback. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Adoption is modeled over a 3–5 year ramp period, applied to the eligible population (for solar + storage, this includes all residential customers). Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate. Equivalent Firm Capacity reflects the derated, dependable contribution to peak load reduction, accounting for technical and behavioral factors (see Appendix, p. 68).

Program Costs for Hyperscaler and Corresponding Firm Capacity

Atlanta Metro Area



Memphis Metro Area



Summary of Lifetime Economic Impact of Measures

Atlanta Metro Area

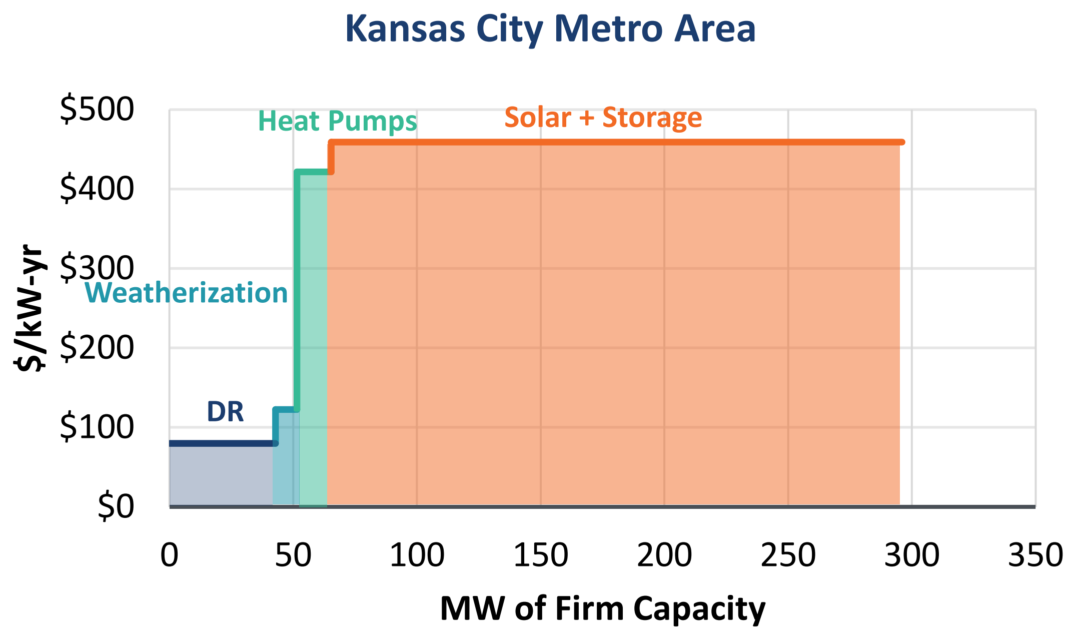
	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	578	38	6	118
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$2,263,323,786	$218,724,754	$19,452,197	$71,685,646
Total Cost for Hyperscaler ($)	$1,989,371,228	$116,465,627	$19,452,197	$71,685,646
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$452	$399	$428	$80
Number of Participating Customers	115,602	29,116	10,375	157,446
Customer Cost after Rebate ($)	$2,370	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$6,008	$3,133	$2,721	$380
Payback Period w/ Rebate (yrs)	3	9	0	0

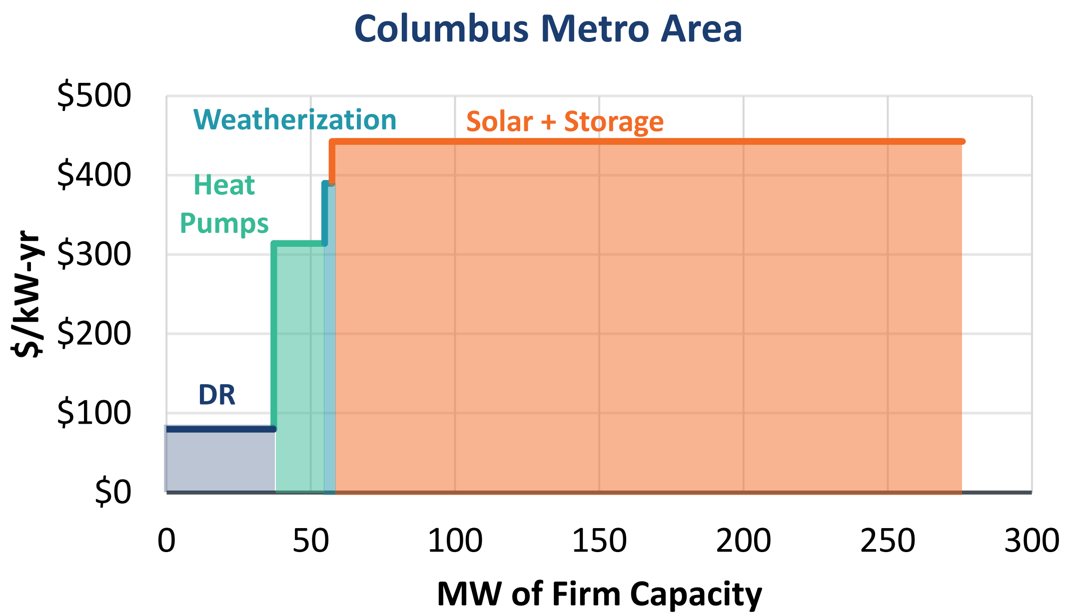
Memphis Metro Area

	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	147	16	3	28
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$575,151,685	$54,645,426	$4,541,702	$17,297,153
Total Cost for Hyperscaler ($)	$512,354,651	$29,097,364	$4,541,702	$17,297,153
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$459	$239	$223	$80
Number of Participating Customers	29,377	7,274	2,422	37,990
Customer Cost after Rebate ($)	$2,138	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$5,420	$4,685	$2,954	$380
Payback Period w/ Rebate (yrs)	3	6	0	0

Note: Load impacts—and the eligible housing stock—are based on NREL's End-Use Load Profiles (EULP), which capture region-specific building characteristics and weather conditions and allow us to define the share of the total housing stock eligible for each measure; impacts are then calculated based on adoption within this eligible segment (see Appendix, p. 69). Costs of technologies are assumed to be the same in every region except for solar + storage, which is calibrated to achieve an approximately three-year customer payback period in every region. See Appendix p. 71 for detailed assumptions and data sources. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Program Costs for Hyperscaler and Corresponding Firm Capacity





Summary of Lifetime Economic Impact of Measures

Kansas City Metro Area

	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	231	14	9	43
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$902,993,116	$83,684,749	$8,083,659	$26,002,087
Total Cost for Hyperscaler ($)	$804,780,835	$44,560,099	$8,083,659	$26,002,087
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$459	$422	$122	$80
Number of Participating Customers	46,122	11,140	4,311	57,109
Customer Cost after Rebate ($)	$2,129	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$5,399	$5,713	$5,734	$380
Payback Period w/ Rebate (yrs)	3	5	0	0

Columbus Metro Area

	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	219	18	3	37
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$855,768,042	$78,964,071	$7,469,529	$22,594,677
Total Cost for Hyperscaler ($)	$735,253,023	$42,046,453	$7,469,529	$22,594,677
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$442	$314	$390	$80
Number of Participating Customers	43,710	10,512	3,984	49,625
Customer Cost after Rebate ($)	$2,757	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$6,990	$8,946	$3,400	$380
Payback Period w/ Rebate (yrs)	3	3	0	0

Note: Load impacts—and the eligible housing stock—are based on NREL's End-Use Load Profiles (EULP), which capture region-specific building characteristics and weather conditions and allow us to define the share of the total housing stock eligible for each measure; impacts are then calculated based on adoption within this eligible segment (see Appendix, p. 69). Costs of technologies are assumed to be the same in every region except for solar + storage, which is calibrated to achieve an approximately three-year customer payback period in every region. See Appendix p. 71 for detailed assumptions and data sources. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Community Benefits of Urban Infill

In addition to the four housing upgrades analyzed, dense housing can deliver environmental benefits and bill savings while reducing the need for new infrastructure expansion. We review drivers of urban infill, highlighting promising projects in the cities included in this study. This research suggests an additional avenue for hyperscaler investments that reduce energy use and provide community benefits.

Urban Infill Considerations

- **Vehicle miles traveled:** Higher VMT signals greater potential for infill to reduce travel and emissions.
- **Population density:** Lower density indicates more capacity to add housing without major expansion.
- **Residential emissions intensity:** Higher emissions highlight opportunities for efficient, lower-carbon housing.
- **Zoning support:** Flexible zoning increases feasibility of higher-density infill development.
- **Land banks:** Active land banks reduce development risk and enable site assembly.
- **Vacant land availability:** Available parcels enable faster, lower-cost infill construction.

Benefits

- **Greenhouse gas emissions:** Higher-density areas are associated with lower household emissions due to reduced transportation needs and smaller homes.
- **Energy use:** Densification lowers residential energy demand through more compact housing and increased use of multi-family buildings.
- **Economic impact:** Infill development reduces costs by leveraging existing infrastructure instead of requiring new expansion.
- **Combined energy and transportation burden:** Urban households face lower total costs due to reduced energy use and shorter travel distances.

Table of Contents

DER Modeling Overview

We assess how hyperscaler investments in community energy measures can reduce peak demand, emissions, and household costs across four metropolitan areas.

The analysis has **two parts**—a quantitative set of measures and a qualitative set—reflecting data availability, geographic resolution, and the maturity of each measure category.

For the DER (distributed energy resource) packages, we apply a common evaluation framework across energy efficiency, heat pumps, community solar + storage, and demand flexibility, using consistent methods and city-level resolution. Results are produced for representative customers and aggregated cases to show broader community impacts.

Customer bill savings reflect electricity and fuel bill reductions and direct program participation credits.

We evaluate program results assuming participation levels approximately consistent with the level of incentives offered to customers and a deployment period of 3–5 years. Details of our modeling approach are shown in the Appendix.

DER Measures

- **Energy Efficiency:** Use NREL ResStock data to estimate the technical potential for air sealing and attic insulation taking note of health and safety barriers that limit eligible homes.
  - The cost of air sealing and attic insulation is assumed to be roughly **$2,000 per home** based on estimates of insulation costs of $1.50/sq. ft. (across various insulation materials in the National Residential Efficiency Measures Database, and an average insulation area of 1,250 sq. ft. (extrapolated from EIA Residential Energy Consumption Survey).
- **Heat pumps:** Identify homes using electric resistance heat and estimate the scale, peak-load reduction, and cost impacts of converting to efficient space- and water-heating heat pumps.
  - The installed cost of a residential air-source heat pump is estimated at **roughly $7,500** (EIA Updated Building Sector Appliance and Equipment Costs and Efficiencies).
- **Community Solar + Storage:** We assess the economics and peak-capacity value of community-scale solar plus storage, assuming that storage is primarily used to lower bills but also dispatched to avoid system peaks.
  - Solar and storage costs are estimated at roughly **$1,800/kW and $2,000/kW** respectively based on NREL cost estimates (Documenting 15 Years of Reductions in U.S. Solar Photovoltaic System Costs and Annual Technology Baseline).
- **Demand Flexibility:** Using Brattle's past FLEX work, we estimate peak-load reductions from smart thermostats; while other flexible loads are possible, we model only thermostat-based programs.
  - Typical cost of a smart thermostat is estimated at **$75** (see New York's Grid Flexibility Volume II: Technical Appendix).

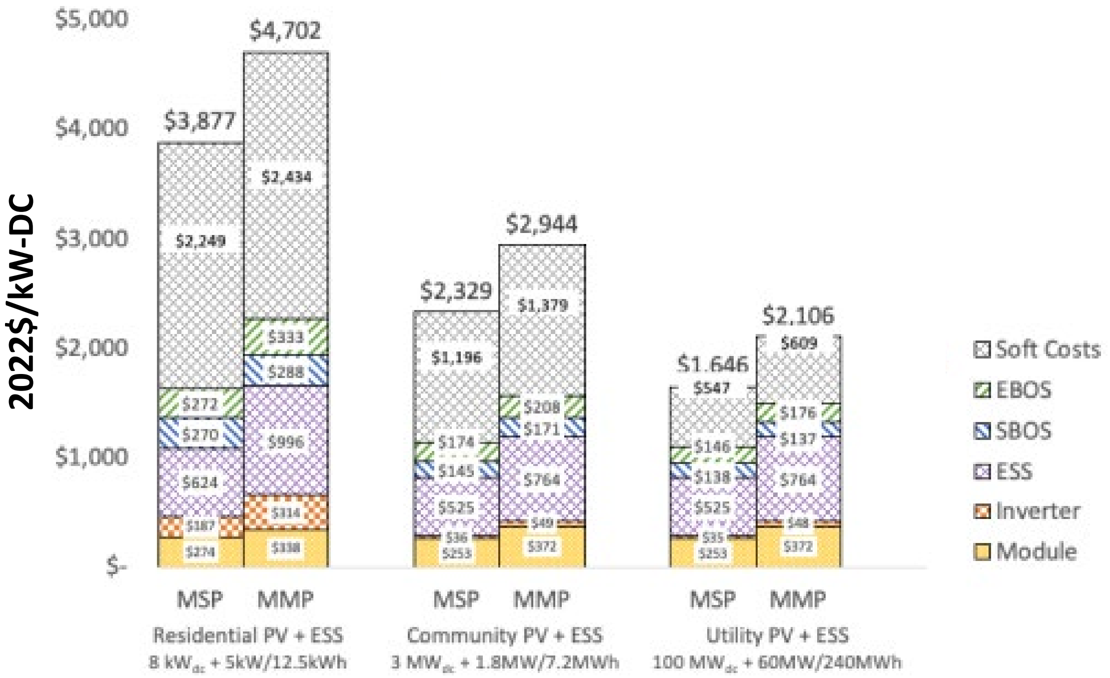
Note: These costs reflect technology installation costs. They do not account for program start-up and maintenance costs (salaries, marketing etc). We assume collaboration with local utility to set up and run these programs.

Modeling Choice: Community over Residential Solar + Storage

Community solar + storage is modeled instead of residential solar + storage because residential systems are approximately 60% more expensive on a per-kW basis and involve higher implementation complexity.

- **~60% higher costs for residential solar + storage:** Installed costs for residential solar are roughly 60% higher than community-scale and significantly higher than utility-scale systems, largely due to scale and soft cost differences.
- **Higher soft costs:** Customer acquisition, individualized system design, permitting, and interconnection significantly increase residential project costs.
- **Site-specific upgrade requirements:** Residential installations may require roof upgrades, electrical panel replacements, or other home modifications, adding cost and variability.
- **Economies of scale at community level:** Community solar benefits from bulk procurement, standardized design, and centralized storage integration, lowering per-unit costs.
- **More streamlined deployment:** Community-scale projects reduce customer-level complexity through centralized development, but depend on enabling policy and available distribution capacity at specific interconnection points.
- **System-level efficiency:** Siting community solar near load can reduce distribution upgrade needs without incurring the high per-customer costs of residential deployment.

2023 Solar + Storage Cost



Minimum Sustainable Price (MSP) vs Modeled Market Price (MMP).
Source: U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2023.

Note: Community solar + storage is modeled instead of behind-the-meter (BTM) systems due to its broader accessibility (including non-homeowners), lower per-customer costs, and higher expected customer acceptance.

Metrics Compared Across Measures

Capacity Value and Comparative Cost

- Firm capacity contribution in MW estimated from average peak load reductions during seasonal peak periods.
- Conservative realization rates and ELCC assumptions are applied.
- Recent capacity prices used to estimate capacity value.
- Cost of firm capacity for different measures (in $/kW-yr) compared to recent CT cost estimates.

Total Addressable Market

- Eligible customers identified using NREL ResStock by region and building characteristics.
- Market size adjusted for expected participation in the first 3–5 years of program deployment and customer uptake given level of subsidies modeled for each technology.
- We assume customer participation for full life of measure.

Annual Emissions Reduction

- Emissions impacts calculated from annual electricity and fuel savings by region.
- Electricity emissions based on 2026 regional marginal emissions rates.
- Fuel emissions based on EIA emissions factors for natural gas and propane.

Customer and Hyperscaler Economics

- For customers:
  - Bill savings from reduced electricity and fuel use and DR payments.
  - Electricity purchase valued at local utility rates; solar exports valued at avoided costs; fuels at state average residential prices.
  - Customers pay partial upfront costs depending on measure package.
- For hyperscalers:
  - Cost of firm capacity for each measure is the level of subsidy per home normalized by kW of peak capacity reduced by measure.

Note: For more details, see Appendix.

Financing Pathways for Hyperscaler-Supported Energy Investments

Hyperscalers can support community energy investments through actionable financial mechanisms that deploy capital through existing institutions, reduce upfront costs and risk, and enable scalable implementation.

We review practical, real-world pathways through which hyperscalers can fund or support the deployment and aggregation of the energy measures analyzed, focusing on where capital is deployed and who administers programs. Each of these mechanisms is already in use, including by some hyperscalers, but could be expanded.

The goal is to illustrate how system-level value—such as peak reduction, flexibility, and emissions benefits—can be translated into investable community projects, rather than to identify a single preferred financing model or optimize financial leverage.

Financial mechanisms included

Direct Utility Program Funding

Contributions to utilities to expand or enhance existing programs (e.g., energy efficiency, heat pump incentives, demand response technologies, or on-bill financing), lowering system peaks and supporting customer participation through established delivery channels.

Aggregator Partnerships

Funding or contracting with third-party aggregators or ESCOs to deploy measures, scale pilot programs, or aggregate customer-side resources. These partnerships can enable both community program expansion and participation in grid or market-based programs.

Contributions to Existing Public or Nonprofit Finance Entities

Capital provided to green banks, housing agencies, or Community Development Financial Institutions (CDFIs) that already administer loans and grants, enabling targeted support for affordable housing, electrification, and energy burden reduction using existing customer relationships and infrastructure.

Hyperscaler-Managed Community Investment Funds

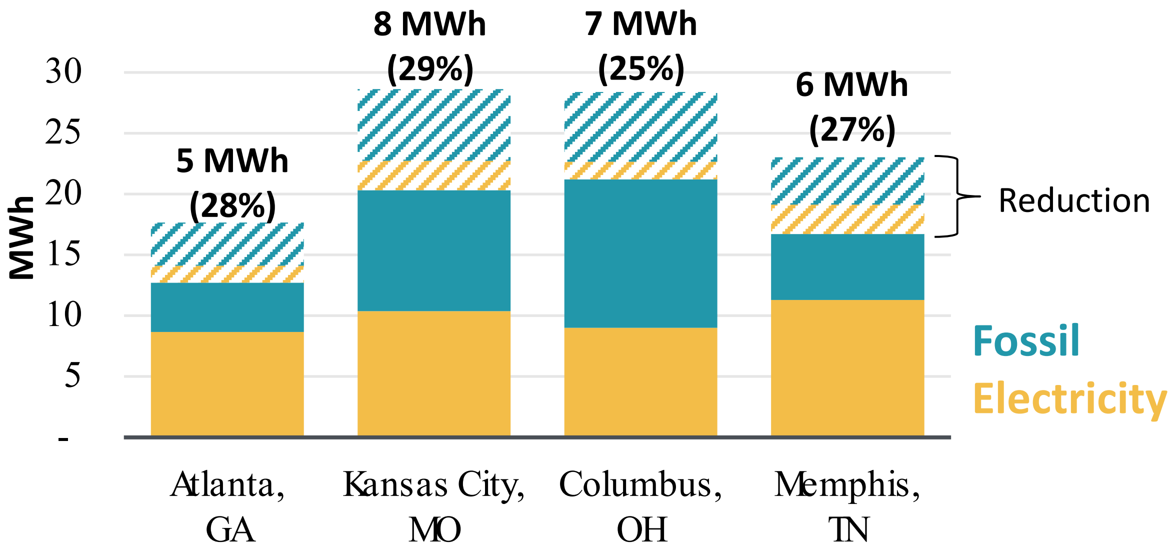
Hyperscalers can support housing and clean energy outcomes by creating and managing dedicated funds that finance affordable housing, energy efficiency, and electrification projects in partnership with public agencies and local organizations.

Table of Contents

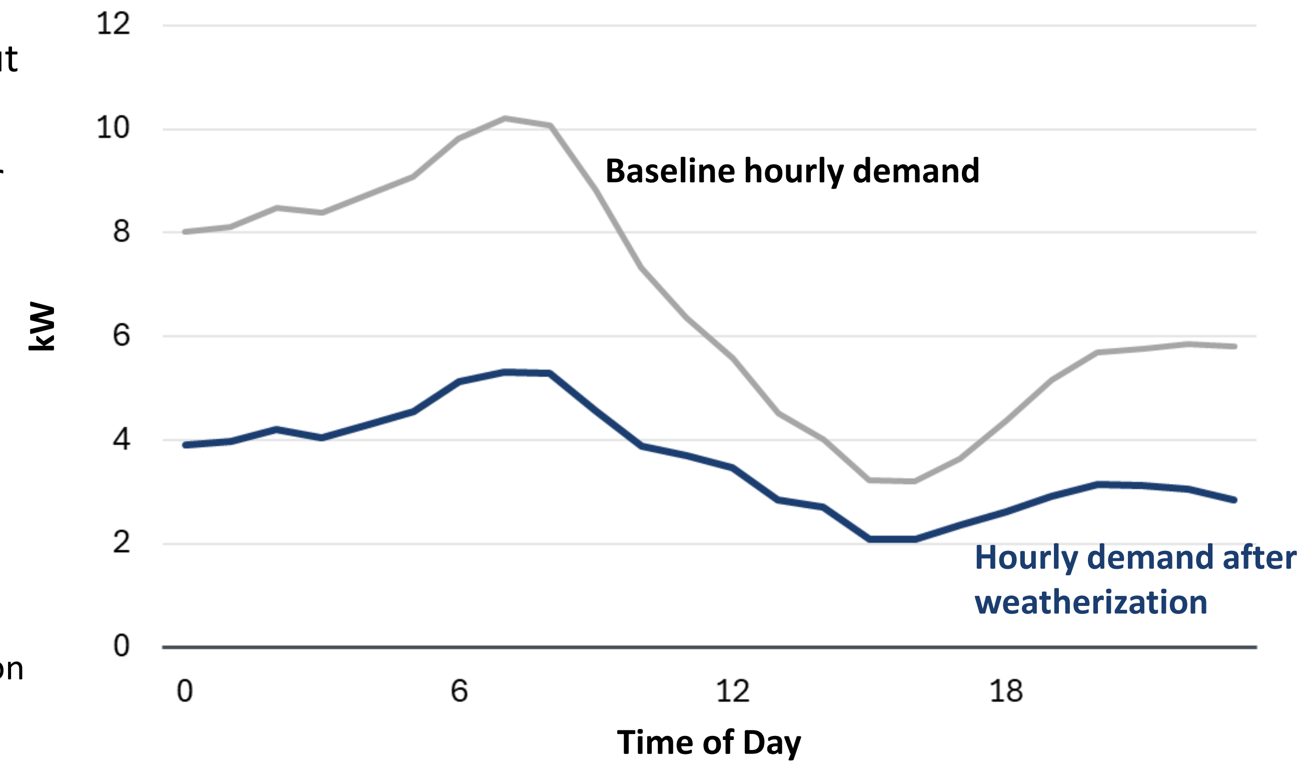
Energy Efficiency Measure Package

- The weatherization package models retrofitting homes with new attic insulation, window air sealing, and duct sealing (where applicable). The package is targeted at homes without adequate attic insulation.
- This package results in substantial primary energy savings for customers, including both electricity and fossil fuels.
- Peak winter load is also significantly reduced.

Annual Energy Savings for Participating Customer (incl. % reduction of usage)



Peak Winter Day Primary Energy Savings from Weatherization Package for Participating Customer



Note: Example weatherization savings are shown for Atlanta, Georgia. Note that primary energy savings include reductions in both electricity and fossil fuel consumption. While only electricity savings contribute to avoided generation capacity, reductions in fossil fuel consumption contribute to customer bill savings and emissions reductions. The weatherization package is applied to homes without ceiling/roof insulation or with insulation less than or equal to R-13 equivalent. Participating customer demand profiles are equal for the City and MSA (See Appendix p.69).

Barriers to Energy Efficiency Upgrades

Despite the existence of weatherization programs, many eligible customers cannot participate due to issues in their home.

- Weatherization efforts are primarily funded through the U.S. Department of Energy's Weatherization Assistance Program (WAP), which targets low-income households. According to an ACEEE survey, approximately 19% of homes assessed for WAP services were deemed ineligible for upgrades; of these, about 60% were eventually repaired.
- Preventable damage causes, such as, roof leaks (45% of deferred homes), floor damage (23%) and outdated or unsafe electrical service panels (23%) causes deferral. The cost of repairs is often out of reach for income-qualified customers. In addition, lack of awareness remains a significant barrier: the Association of Energy Service Professionals reports that roughly 60% of households are unaware that weatherization incentives exist.
- Pre-weatherization programs that target home repairs exist in various states, for example in Massachusetts, and can lower the number of homes deferred from WAP upgrades.

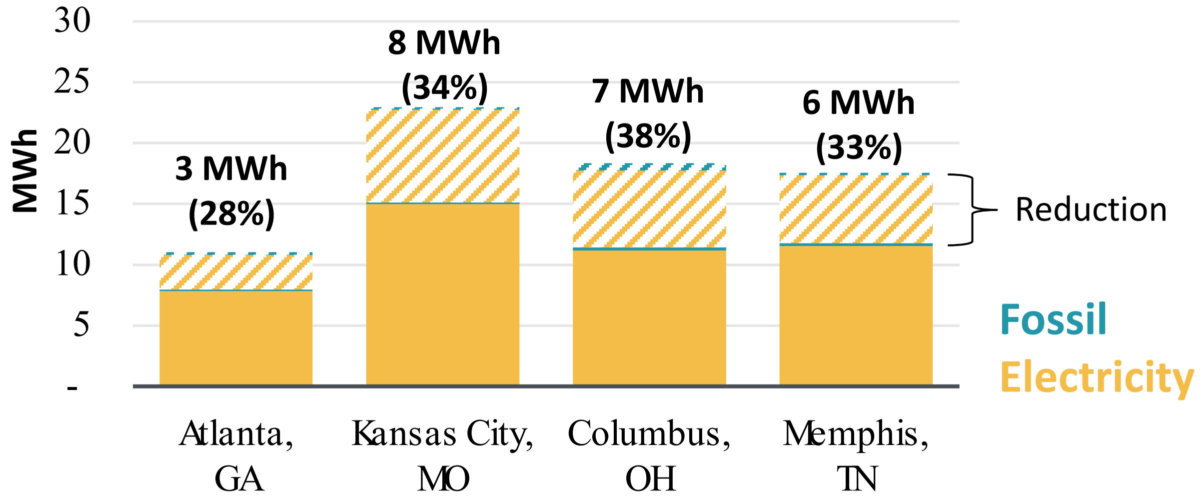
Memphis – "Share the Pennies" Program

- **Memphis Light, Gas, and Water Division (MLGW) operates an opt-out program that supports weatherization funding** called "Share the Pennies" which rounds up customer bills to the nearest dollar and directs the cents to a Weatherization Assistance Program (WAP).
- Over 1,000 homes have been upgraded through the "Share the Pennies" program, however, there are an estimated 100,000 homes that could benefit from weatherization.
- Share the Pennies WAP program is only available for homeowners, unlike some states such as New York and Massachusetts, **creating barriers for renters in Memphis.**
- "Share the Pennies" also requires homeowners to be up to date on property tax and MLGW bills.
- Beyond financial barriers and required home repairs, **a lack of contractors licensed to complete weatherization projects results in long wait times and eligible customers not participating.**

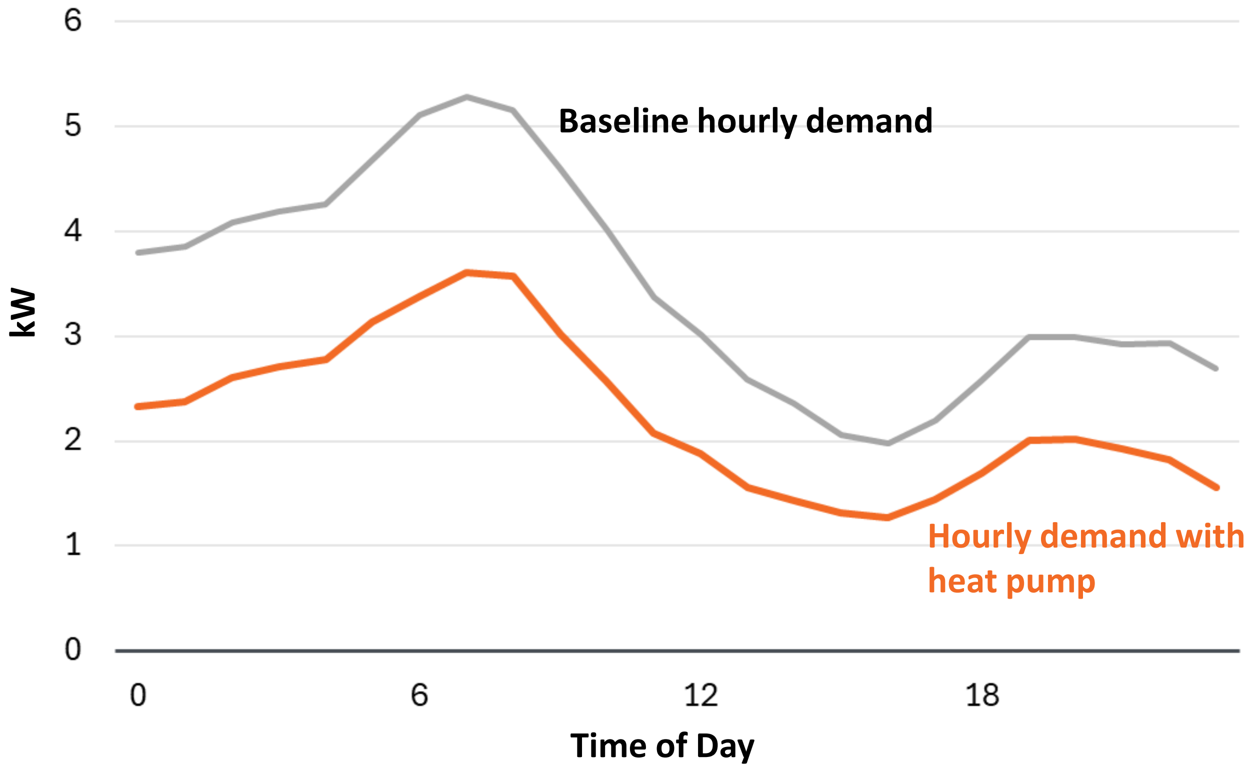
Heat Pump Measure Package

- The heat pump package models installing new heat pumps for space heating and heat pump water heaters (HPWHs) for domestic hot water.
  - This package targets homes that currently rely on electric resistance for space heating.
- This package results in a substantial reduction in electricity consumption and peak loads for applicable homes.

Annual Energy Savings for Participating Customer (incl. % reduction of usage)



Peak Winter Day Electricity Savings from Heat Pumps for Participating Customer

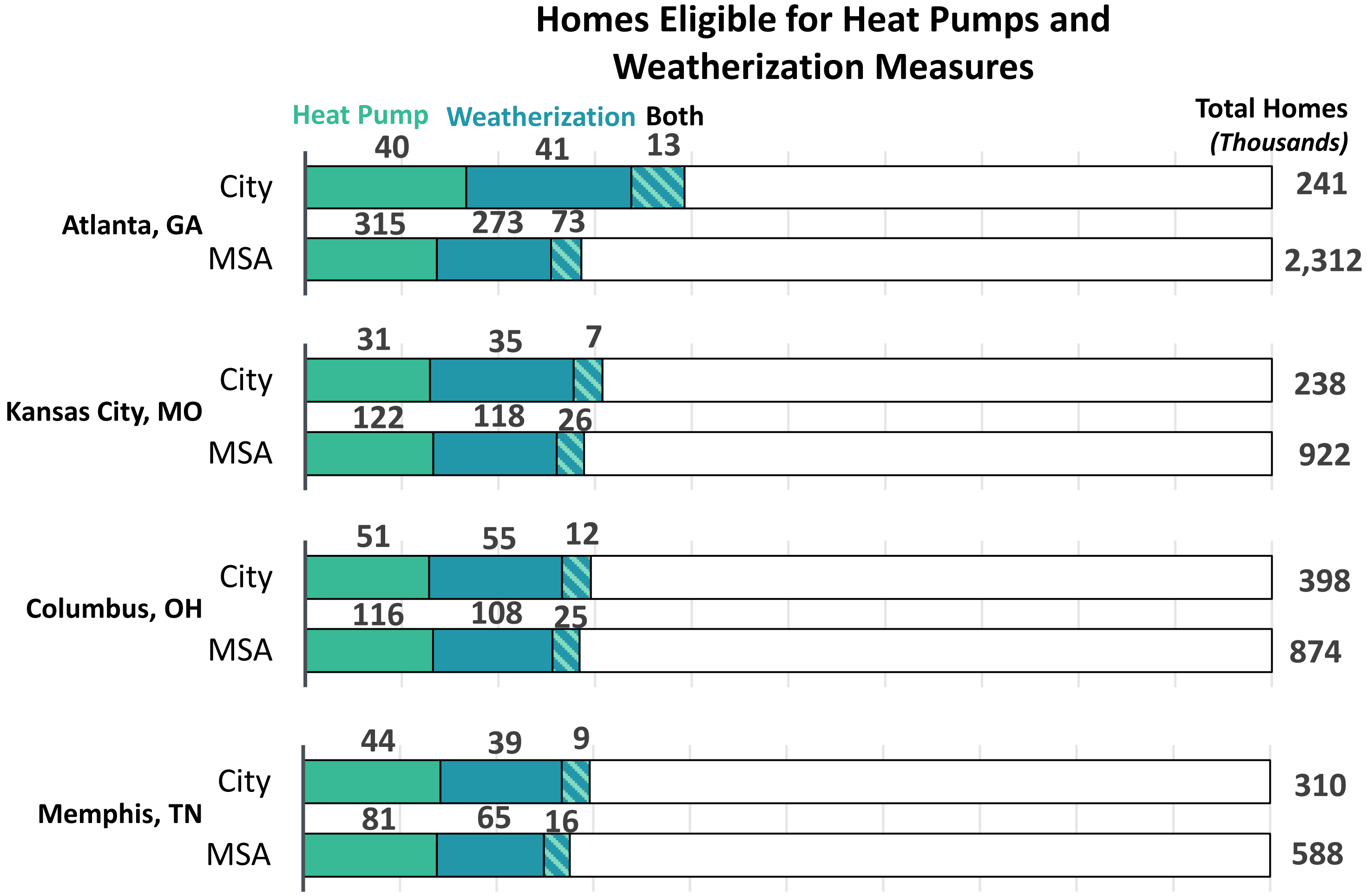


Note: Example heat pump savings are shown for Atlanta, Georgia. Note that primary energy savings include reductions in both electricity and fossil fuel consumption (from converted fossil fuel water heaters). While only electricity savings contribute to avoided generation capacity, reductions in fossil fuel consumption contribute to customer bill savings and emissions reductions. Participating customer demand profiles are equal for the City and MSA (See Appendix p.69).

Eligibility for Heat Pump & Weatherization Across Sample

There is limited overlap between households eligible for heat pump and weatherization measures, so most potential comes from distinct customer groups.

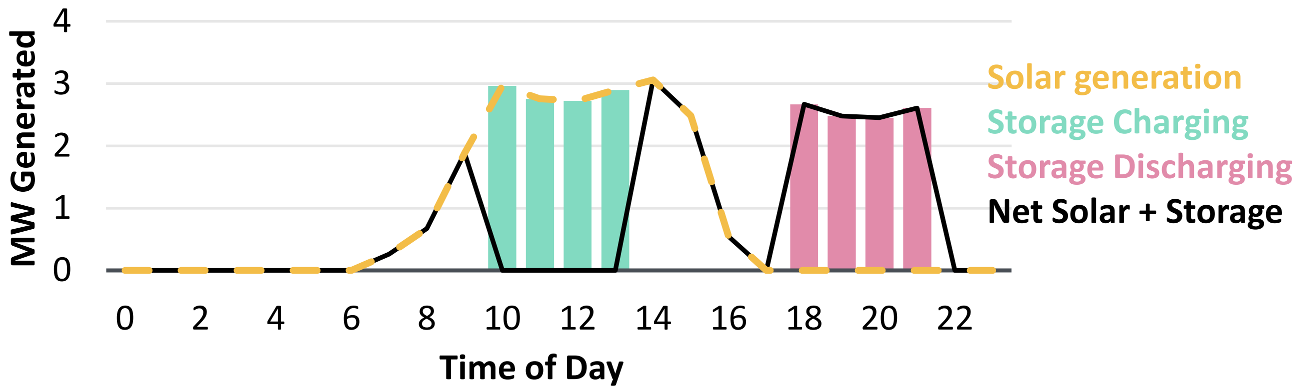
- Approximately 3–6% of customers in each city are eligible for both heat pump and weatherization measures.
- We treat each measure independently, estimating total potential as if different households participate in each program.
  - Given the relatively low assumed participation rates (3–8%), we assume each participating household enrolls in only one program, avoiding double counting of capacity across measures.
- While we do not explicitly model households adopting both measures, coordinated deployment may be beneficial where overlap exists:
  - Pairing energy efficiency with electrification can reduce required heat pump sizing and lower overall capital costs.



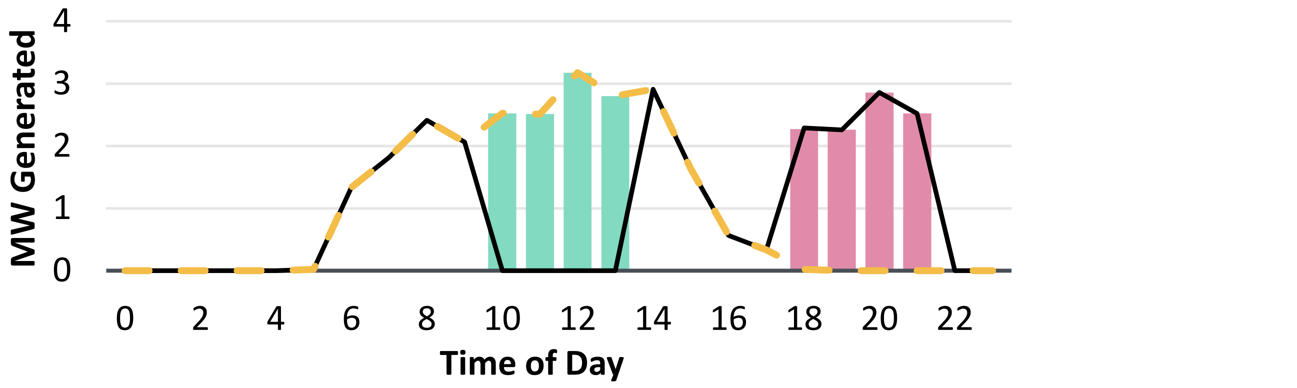
Community Solar + Storage Measure Package

- We model the installation of new community-scale solar and storage on large rooftops within each city's metropolitan area.
  - Solar and 4-hour battery storage are assumed to be sized at a 1:1 ratio (e.g. 1 kW of solar is paired with a 1-kW, 4-hour battery).
- The net solar + storage generation profile is computed by implementing a heuristic-based charging/discharging model on the city-specific solar generation profile produced using PVWatts.
  - The charging model prioritizes charging during the afternoon hours and discharging during evening hours, when electricity prices tend to be high.

Winter Day Solar + Storage Generation per Participating Customer



Summer Day Solar + Storage Generation per Participating Customer

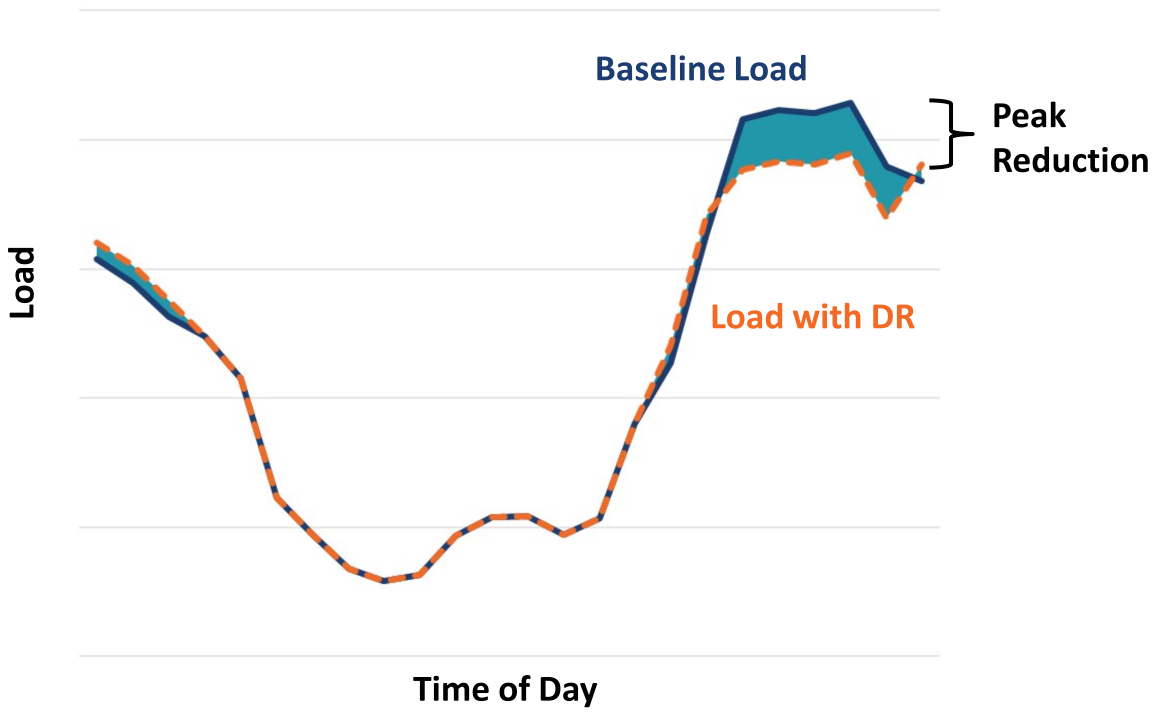


Note: Example solar + storage profiles are shown for Memphis, TN assuming 5 MW of solar and 5 MW of 4-hour storage. Participating customer solar + storage profiles are equal for the City and MSA (See Appendix p.69).

AC Demand Response Measure Package

- Demand response is modeled for homes with central air conditioning using smart thermostats.
- Each participating household is assumed to provide 1 kW of peak load reduction during a 4-hour event.
  - This assumption is consistent with a broad set of U.S. utility program evaluations and survey data[1].
- Effective per-customer capacity is reduced by a 25% realization rate to account for customer opt-out and non-performance.

Example of Net Load Reduction Due to Air Conditioning Demand Response for a Participating Customer



Note: Adapted from Real Reliability: The Value of Virtual Power. Participating customer demand profiles are equal for the City and MSA (See Appendix p.69).

1. See New York's Grid Flexibility Potential study for an example of a study citing this heuristic.

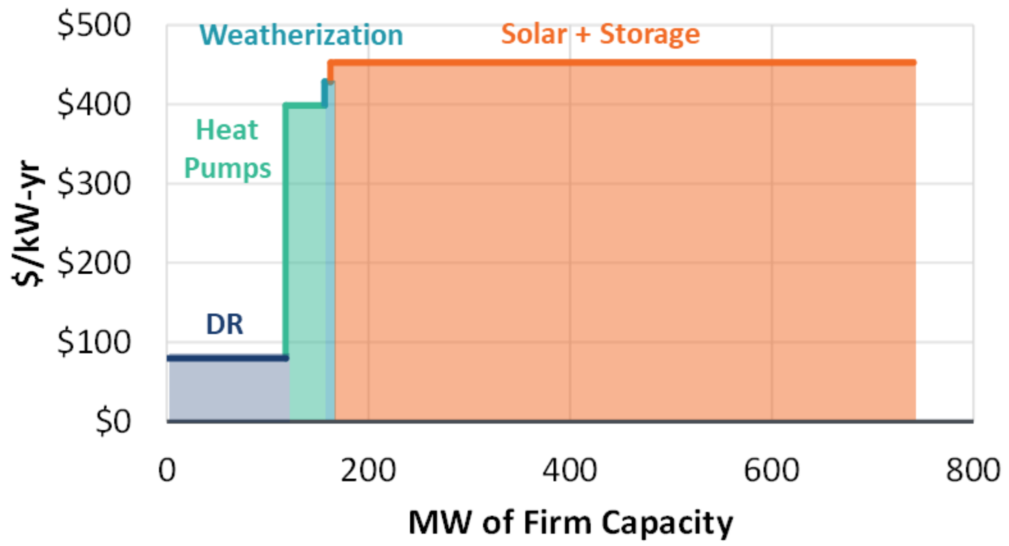
Table of Contents

Atlanta

At a Glance: Impact of Measures

- Under the modeled uptake assumptions, the Atlanta MSA includes approximately 157,000 demand response participants, 115,000 solar + storage subscriptions, 29,000 heat pump adoptions, and 10,000 weatherized homes.
- Annual customer bill savings range from roughly $50 for demand response to about $800 for solar + storage, with heat pumps and weatherization in the $350–$400 range.
- The strongest energy-burden reductions accrue to low-income participants in solar + storage, heat pump, and weatherization programs.
- At full modeled scale, the portfolio unlocks more than 700 MW of summer firm capacity in the Atlanta MSA, representing material capacity value and emissions reductions.

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area



Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Summary of Lifetime Economic Impact of Measures

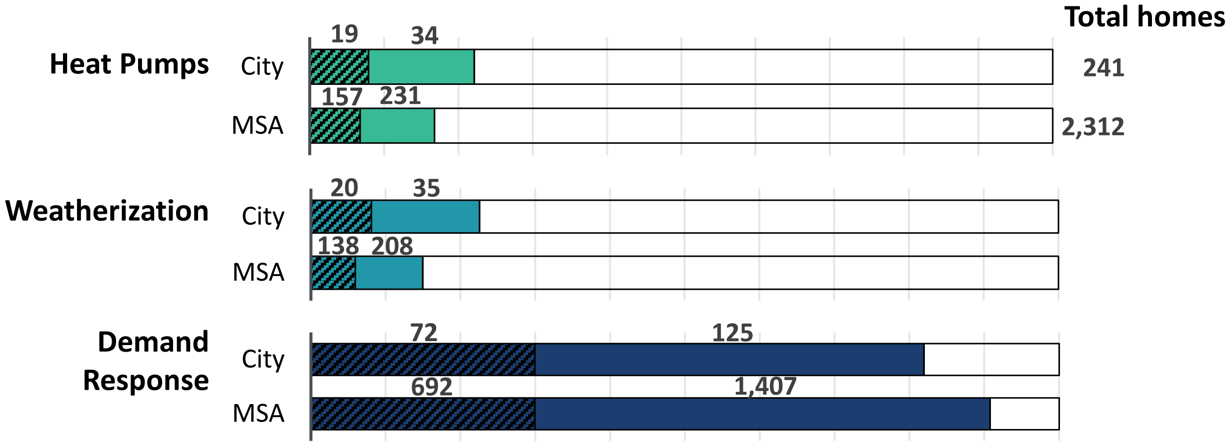
	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	578	38	6	118
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$2,263,323,786	$218,724,754	$19,452,197	$71,685,646
Total Cost for Hyperscaler ($)	$1,989,371,228	$116,465,627	$19,452,197	$71,685,646
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$452	$399	$428	$80
Number of Participating Customers	115,602	29,116	10,375	157,446
Customer Cost after Rebate ($)	$2,370	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$6,008	$3,133	$2,721	$380
Payback Period w/ Rebate (yrs)	3	9	0	0

Addressable Market

A large share of Atlanta households are eligible for at least one program, with demand response offering the broadest reach and weatherization and heat pumps serving more targeted customer segments.

- Demand response has the largest addressable market because most homes with air conditioning can participate through thermostat-based load control during peak periods.
- Eligibility for heat pumps and weatherization is more targeted, reflecting housing characteristics such as existing heating equipment, building shell conditions, and retrofit suitability.
- At our assumed levels of program participation, DR has the highest modeled adoption.

Homes Eligible for Each Retrofit Measure (Thousands)



Note: Dashed section indicates homes that are eligible for each measure and are also Low- to Moderate-Income, defined as homes earning up to 80% of the Area Median Income. Solar + storage modeled at 5% of total homes, well below city's potential.

Assumed Homes that Uptake Each Measure (Thousands)

Measure	City	MSA
Solar + Storage	12	116
Heat Pumps	4	29
Weatherization	2	10
Demand Response	15	157

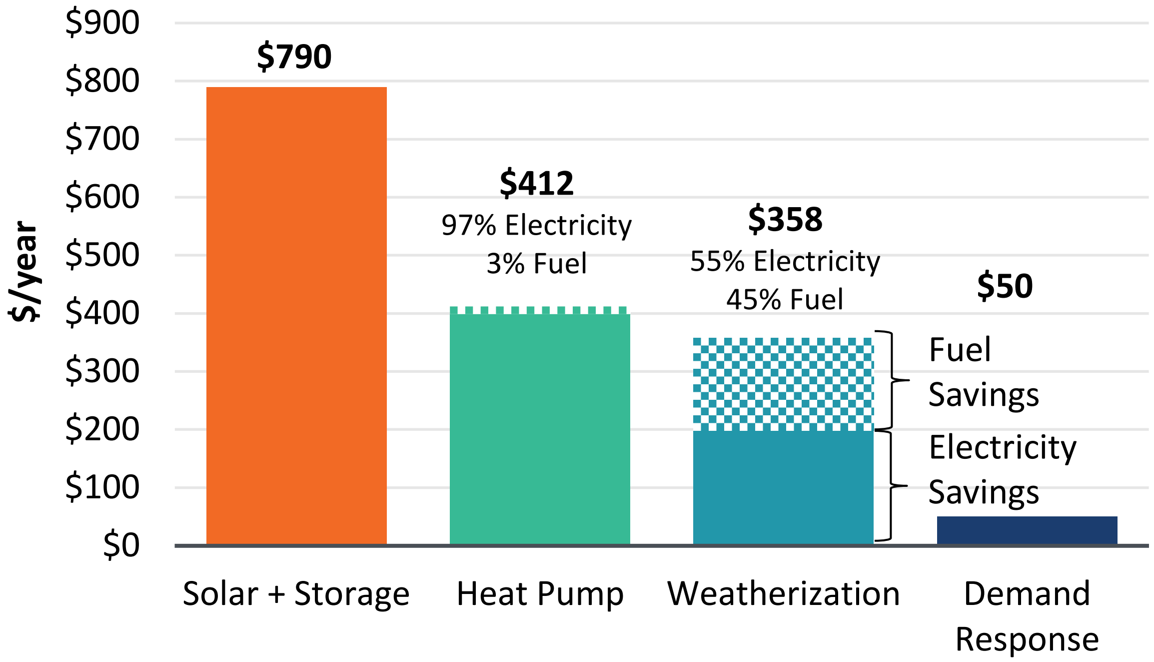
Note: We translate technical eligibility into an addressable market by applying assumptions about customer interest, practical deployability, and program uptake by technology. Solar + storage is modeled as a small share of total households, well below the city's broader technical potential. See Appendix p.71 for additional details on participation rates. See p.20 for overlap in eligibility for heat pump and weatherization customers.

Estimated Participating Customer Bill Reductions

The average customer participating in the solar + storage, heat pump, or weatherization program would be expected to save $350-800 on their annual energy costs.

- Electricity savings from load reduction are based on the applicable residential retail rate for Georgia Power, while fuel savings are based on winter 2024–2025 monthly average residential gas and propane costs in Georgia[1].
- Customers subscribed to the community solar + storage program are compensated on their excess generation at the avoided energy cost (based on a system lambda estimate of $0.04/kWh).

Annual Bill Savings for Average Participating Customer



Note: Demand response bill reductions are not modeled; we assume a $50/year economic incentive per home. 1. Applicable electric residential retail rate is based on EIA-861 average energy cost for Georgia Power, adjusted to remove fixed charges from customer bills which remain unchanged. Estimated fuel rates are based on EIA Residential Natural Gas Prices by month and EIA Residential Propane Prices by month.

Impact of Measures on Participant Energy Burden

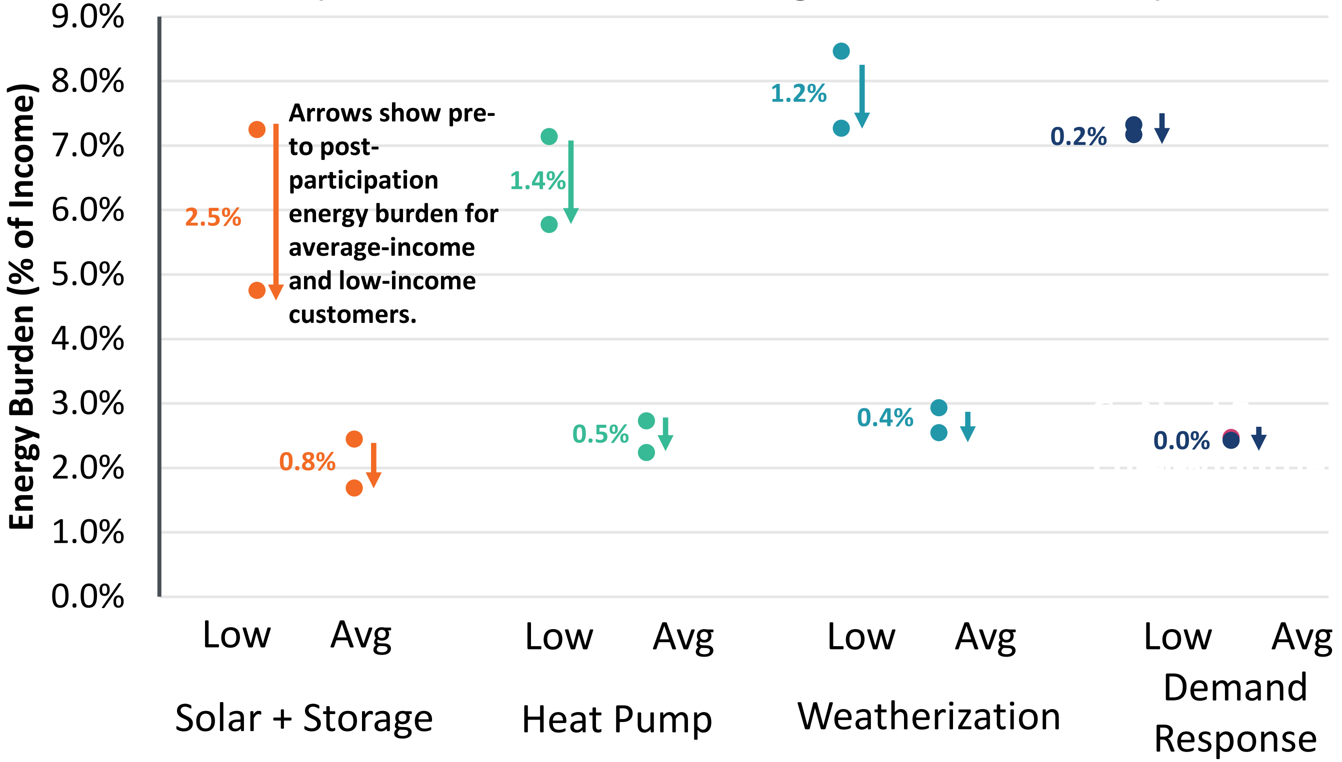
Customers see meaningful bill savings, with solar + storage providing the greatest impact, reducing energy burden for low-income households by ~2.5 percentage points.

- Solar + storage delivers the largest reductions in energy burden.
- Weatherization and heat pumps reduce energy burden by ~1–1.5 percentage points.
- Demand response provides smaller, but still positive, bill savings with broad participation potential.

Percent of Customers Eligible for Measures Studied that are Low Income

Eligibility	City	MSA
All	36%	34%
Heat Pumps	36%	40%
Weatherization	36%	40%
Demand Response	37%	33%

Annual Energy Burden for a Customer Participating in Each Program (for Low-Income and Average Income Customer)

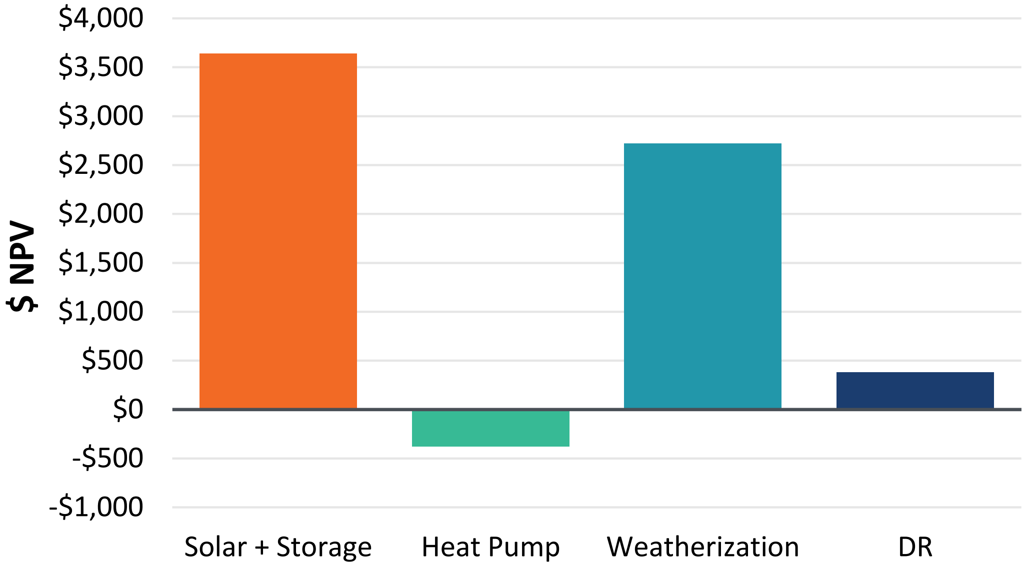


Note: Energy burden is calculated as annual household energy spending divided by household income. Low-income households begin with substantially higher energy burdens, so a given level of bill savings produces a larger relative benefit for those customers.

Participating Customer and Hyperscaler Economics

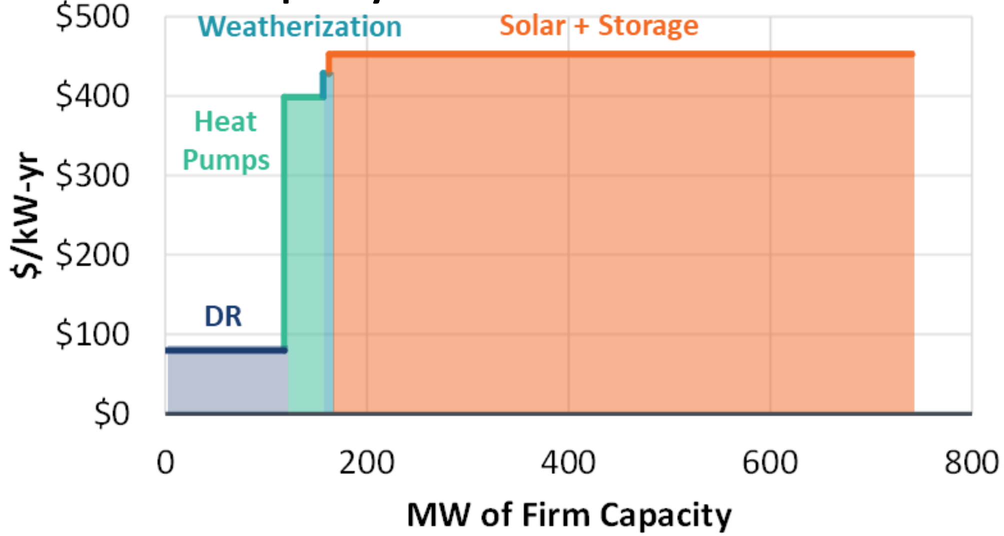
As designed, the programs analyzed create value for both customers and the hyperscaler: customers benefit from lower bills, while the hyperscaler funds targeted subsidies to provide firm capacity and other community benefits.

Participating Customer Net Present Value (NPV) of DER Measures



Note: Values represent the net present value (NPV) of each measure from the customer perspective, including both bill savings and upfront customer costs after rebates. NPV is calculated over a 15-year measure life (starting in 2026) using a 10% real discount rate. Positive values indicate net customer benefit (see Appendix, p. 66).

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area

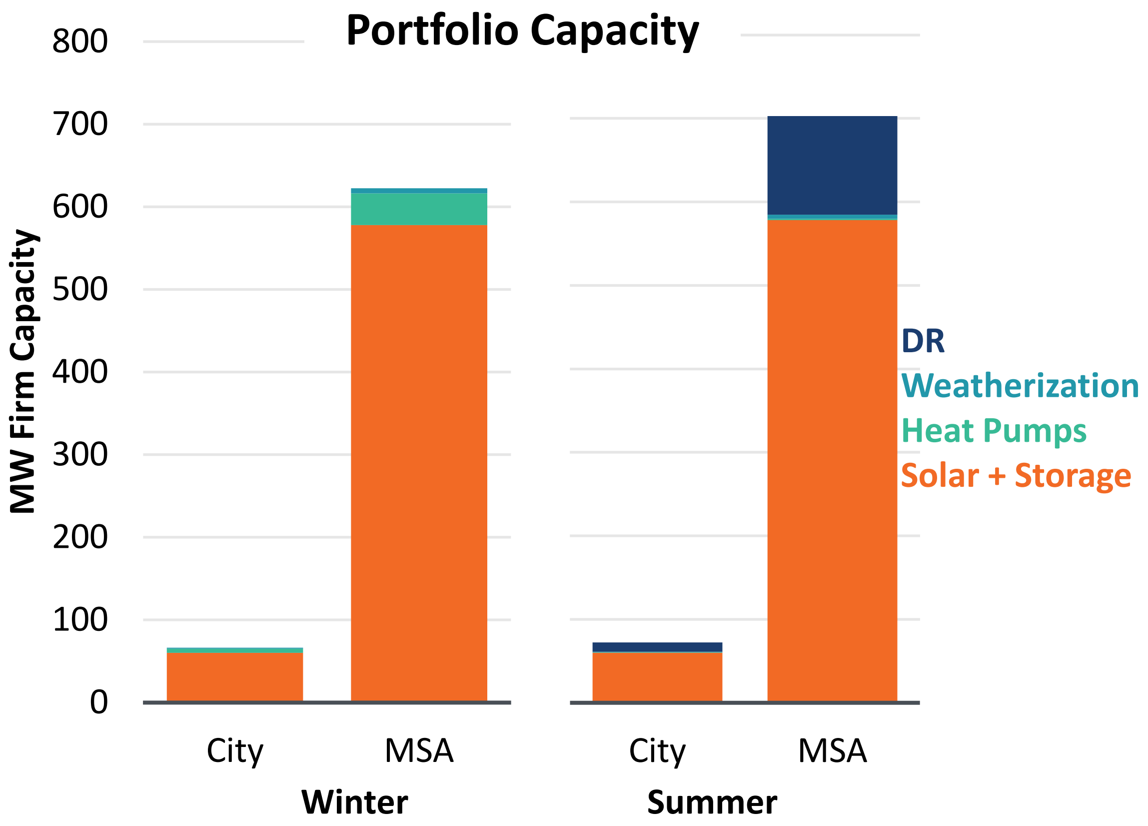


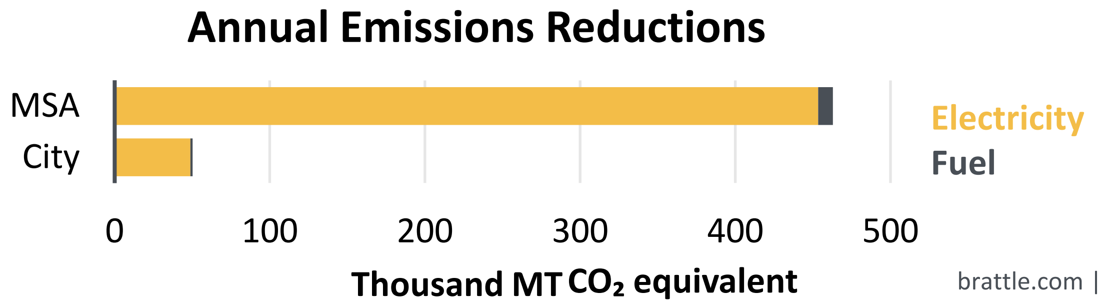
Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

System and Societal Benefits

We find that a portfolio of demand-side solutions in the city of Atlanta could provide over 70 MW of firm winter and summer capacity.

- Extending this portfolio approach to the larger Atlanta Metropolitan Statistical Area increases the capacity to over 600 MW in the winter and over 700 MW in the summer.
- This translates to approximately $7 million annually in capacity value in the city proper and $74 million for the wider metropolitan area[1].
- Emissions co-benefits: The portfolio delivers substantial emissions reductions at both the regional and local levels—approximately 450 thousand metric tons CO_2e annually across the MSA, with ~50 thousand of those metric tons CO_2e reduced within the city, providing societal and environmental benefits.





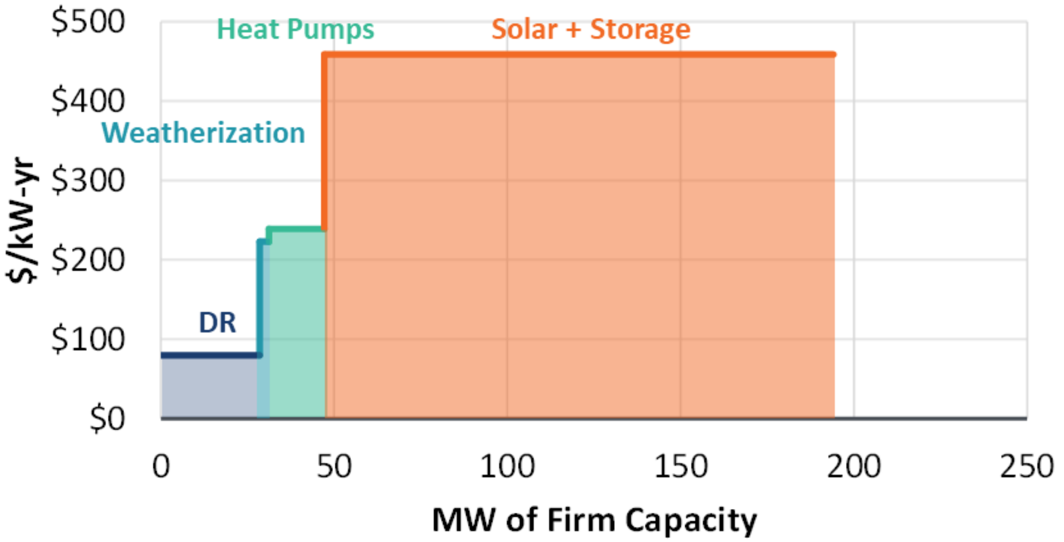
Sources:
1. This estimate assumes a capacity cost range of $80-120/kW-yr informed by recent PJM and MISO capacity auction results.

Memphis

At a Glance: Impact of Measures

- Under the modeled uptake assumptions, the Memphis MSA includes approximately 38,000 demand response participants, 29,000 solar + storage subscriptions, 7,000 heat pump adoptions, and 2,000 weatherized homes.
- Participating customers save about $50/year in demand response, ~$350–$400/year from weatherization, ~$600/year from heat pumps, and ~$700/year from solar + storage.
- For low-income households, solar + storage and heat pumps provide the largest reductions in energy burden, with weatherization also delivering meaningful savings.
- At full modeled scale, the portfolio provides ~160 MW of summer firm capacity and ~180 MW of winter capacity in the Memphis MSA.

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area



Summary of Lifetime Economic Impact of Measures

	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	147	16	3	28
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$575,151,685	$54,645,426	$4,541,702	$17,297,153
Total Cost for Hyperscaler ($)	$512,354,651	$29,097,364	$4,541,702	$17,297,153
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$459	$239	$223	$80
Number of Participating Customers	29,377	7,274	2,422	37,990
Customer Cost after Rebate ($)	$2,138	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$5,420	$4,685	$2,954	$380
Payback Period w/ Rebate (yrs)	3	6	0	0

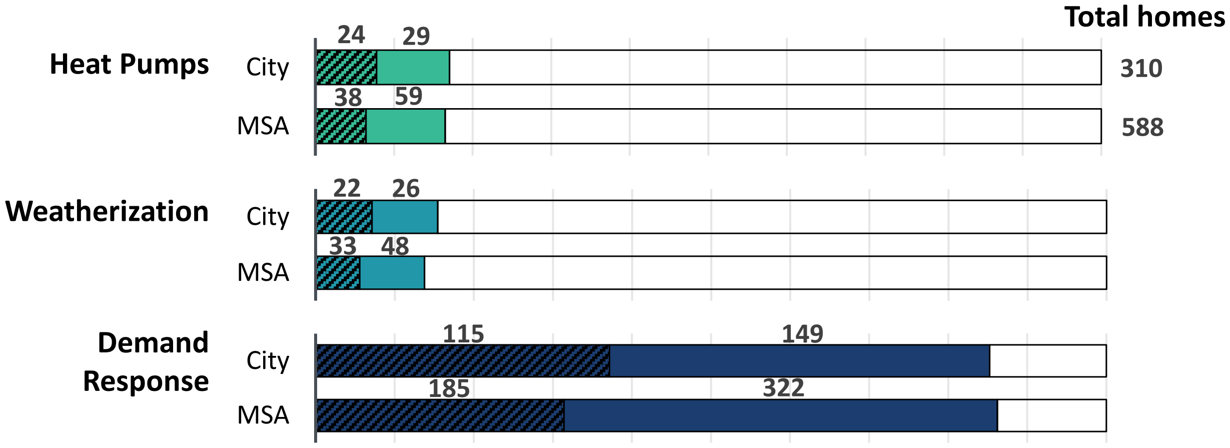
Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Addressable Market

A large share of Memphis households are eligible for at least one program, with demand response offering the broadest reach and weatherization and heat pumps serving more targeted customer segments.

- Demand response has the largest addressable market because most homes with air conditioning can participate through thermostat-based load control during peak periods.
- Eligibility for heat pumps and weatherization is more targeted, reflecting housing characteristics such as existing heating equipment, building shell conditions, and retrofit suitability.
- At our assumed levels of program participation, DR has the highest modeled adoption.

Homes Eligible for Each Retrofit Measure (Thousands)



Dashed section indicates homes that are eligible for each measure and are also Low- to Moderate-Income, defined as homes earning up to 80% of the Area Median Income. Solar + storage modeled at 5% of total homes, well below city's potential.

Assumed Homes that Uptake Each Measure (Thousands)

Measure	City	MSA
Solar + Storage	15	29
Heat Pumps	4	7
Weatherization	1	2
Demand Response	20	38

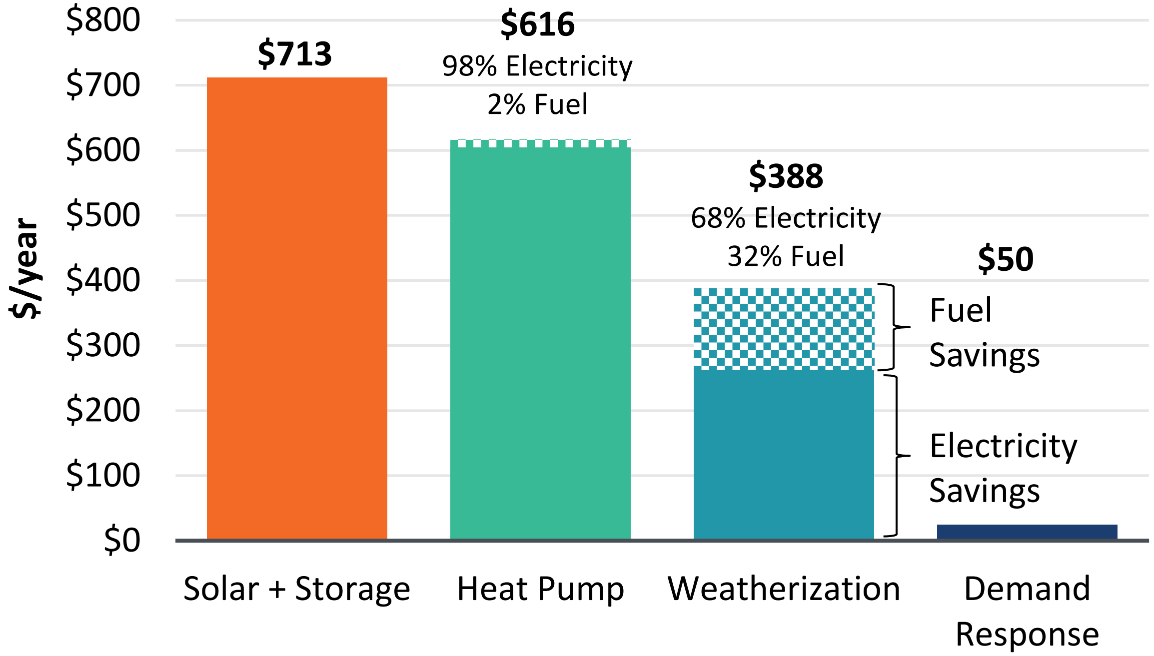
Note: We translate technical eligibility into an addressable market by applying assumptions about customer interest, practical deployability, and program uptake by technology. Solar + storage is modeled as a small share of total households, well below the city's broader technical potential. See Appendix p.71 for additional details on participation rates. See p.20 for overlap in eligibility for heat pump and weatherization customers.

Estimated Participating Customer Bill Reductions

Participating customers save about $50/year in demand response, ~$400/year from weatherization, ~$600/year from heat pumps, and ~$700/year from solar + storage.

- Electricity savings from load reduction are based on the applicable residential retail rate for Memphis Light, Gas, and Water, while fuel savings are based on winter 2024–2025 monthly average residential gas and propane costs in Tennessee[1].
- Customers subscribed to the community solar + storage program are compensated on their excess generation at the avoided energy cost (based on nearby MISO LMPs, $0.039/kWh on average).

Annual Bill Savings for Average Participating Customer



Note: Demand response bill reductions are not modeled; we assume a $50/year economic incentive per home. 1. Applicable electric residential retail rate is based on EIA-861 average energy cost for Memphis Light, Gas and Water, adjusted to remove fixed charges from customer bills which remain unchanged. Electric bill savings for customers in the Memphis MSA region serviced by Entergy Mississippi or Entergy Arkansas will experience 3% lower or 12% higher bills, respectively. Estimated fuel rates are based on EIA Residential Natural Gas Prices by month and EIA Residential Propane Prices by month.

Impact of Measures on Participant Energy Burden

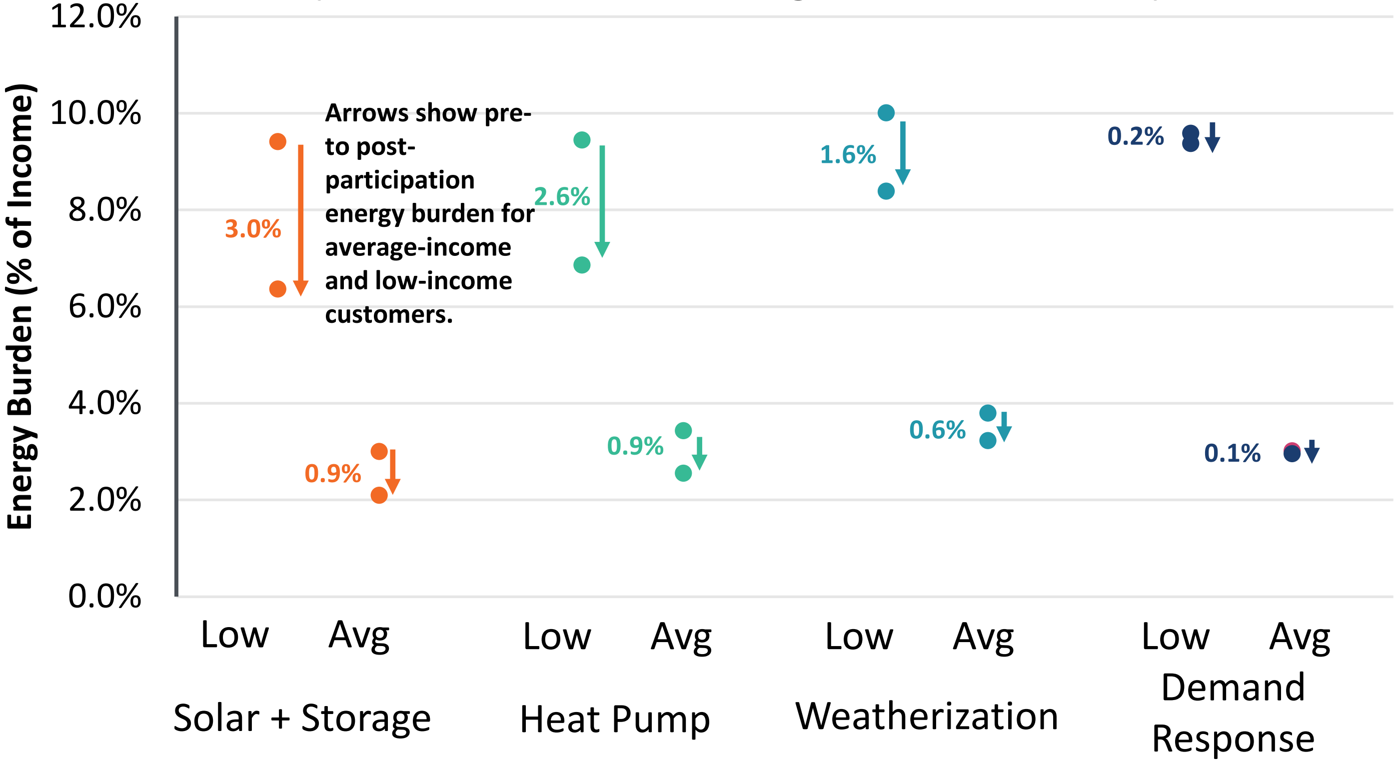
Customers see meaningful bill savings, with solar + storage providing the greatest impact, reducing energy burden for low-income households by ~3 percentage points.

- Solar + storage delivers the largest reductions in energy burden.
- Weatherization and heat pumps reduce energy burden by ~2–3 percentage points.
- Demand response provides smaller, but still positive, bill savings with broad participation potential.

Percent of Customers Eligible for Measures Studied that are Low Income

Eligibility	City	MSA
All	45%	38%
Heat Pumps	46%	39%
Weatherization	47%	41%
Demand Response	44%	37%

Annual Energy Burden for a Customer Participating in Each Program (for Low-Income and Average Income Customer)

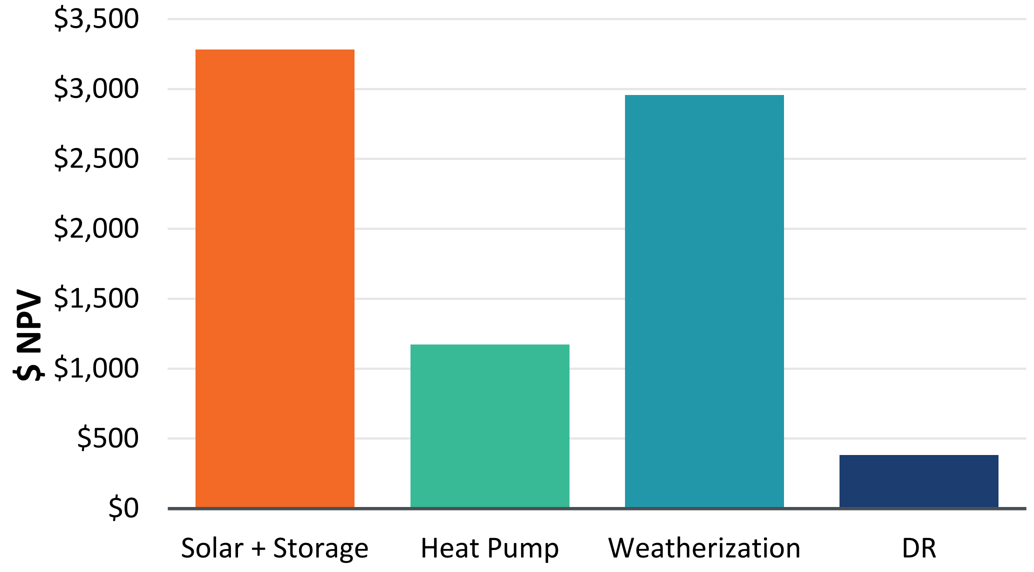


Note: Energy burden is calculated as annual household energy spending divided by household income. Low-income households begin with substantially higher energy burdens, so a given level of bill savings produces a larger relative benefit for those customers.

Participating Customer and Hyperscaler Economics

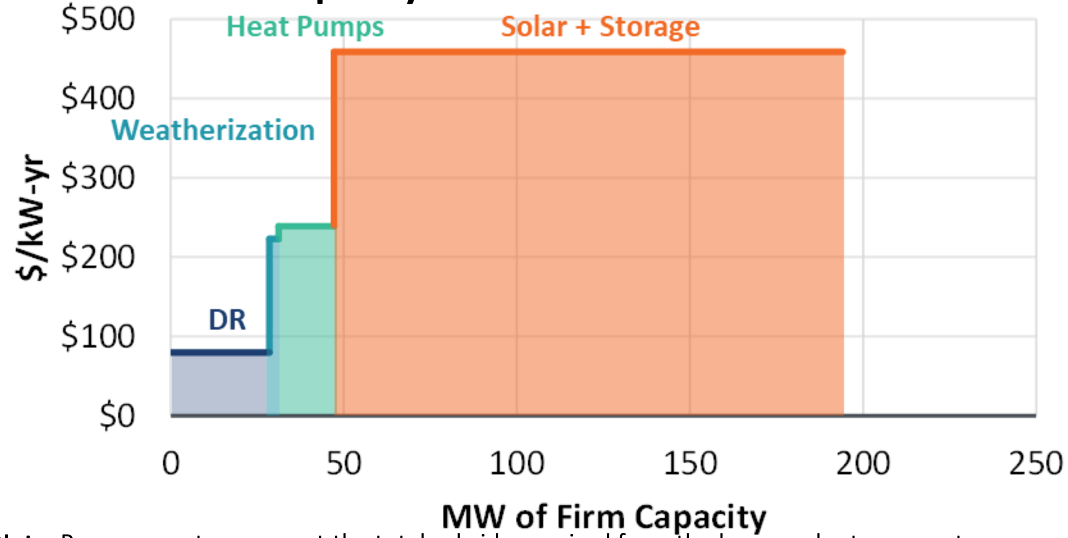
As designed, the programs analyzed create value for both customers and the hyperscaler: customers benefit from lower bills, while the hyperscaler funds targeted subsidies to provide firm capacity and other community benefits.

Participating Customer Net Present Value (NPV) of DER Measures



Note: Values represent the net present value (NPV) of each measure from the customer perspective, including both bill savings and upfront customer costs after rebates. NPV is calculated over a 15-year measure life (starting in 2026) using a 10% real discount rate. Positive values indicate net customer benefit (see Appendix, p. 66).

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area

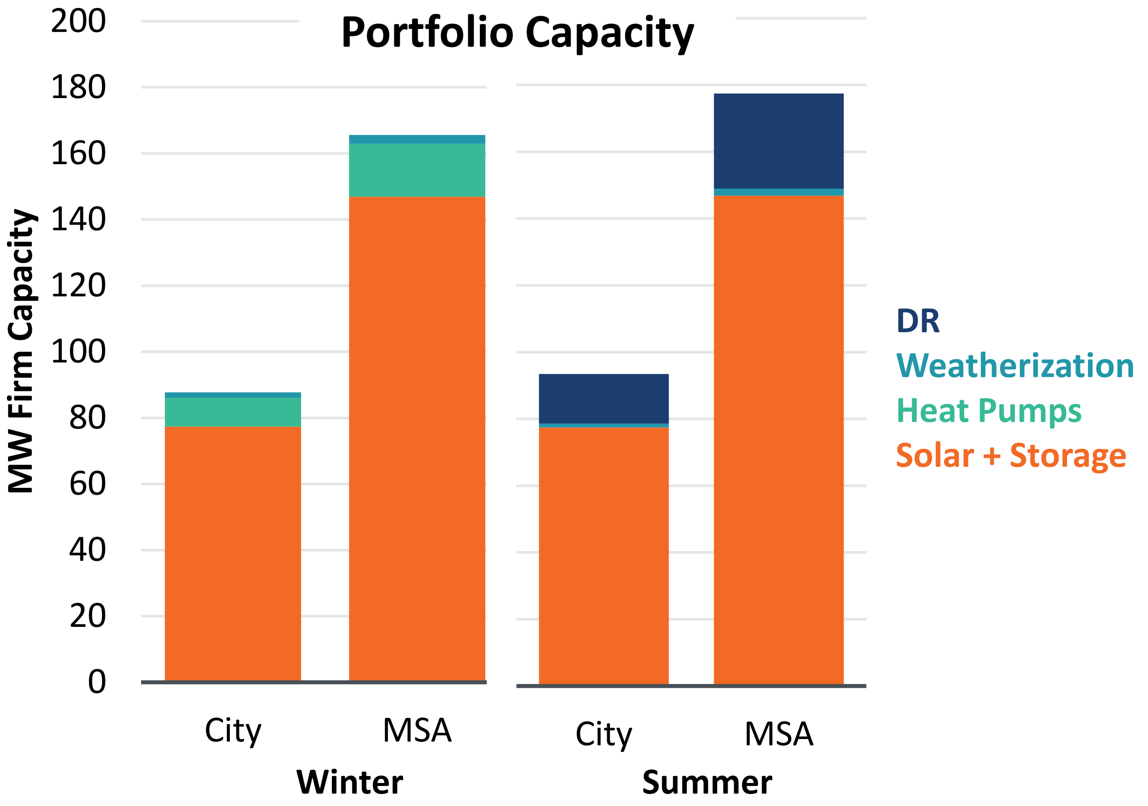


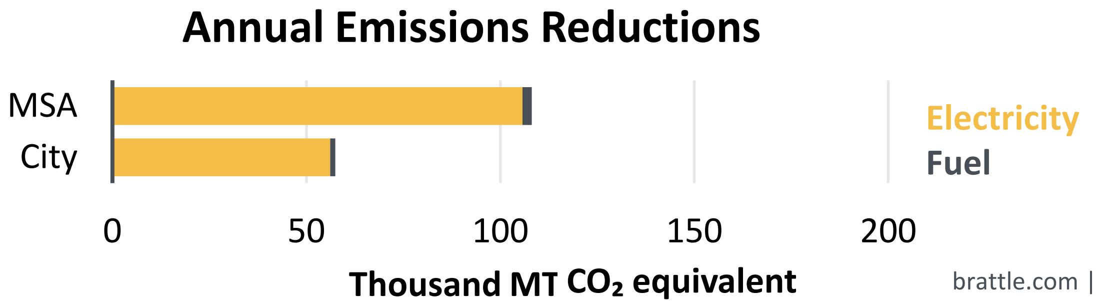
Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

System and Societal Benefits

We find that a portfolio of demand-side solutions in the city of Memphis could provide over 80 MW of firm winter and summer capacity.

- Extending this portfolio approach to the larger Memphis Metropolitan Statistical Area increases the capacity to over 160 MW in the winter and summer.
- This translates to approximately $10 million annually in capacity value in the city proper and $19 million for the wider metropolitan area[1].
- Emissions co-benefits: The portfolio delivers substantial emissions reductions at both the regional and local levels—approximately 100 thousand metric tons CO_2e annually across the MSA, with ~50 thousand of those metric tons CO_2e reduced within the city, providing societal and environmental benefits.





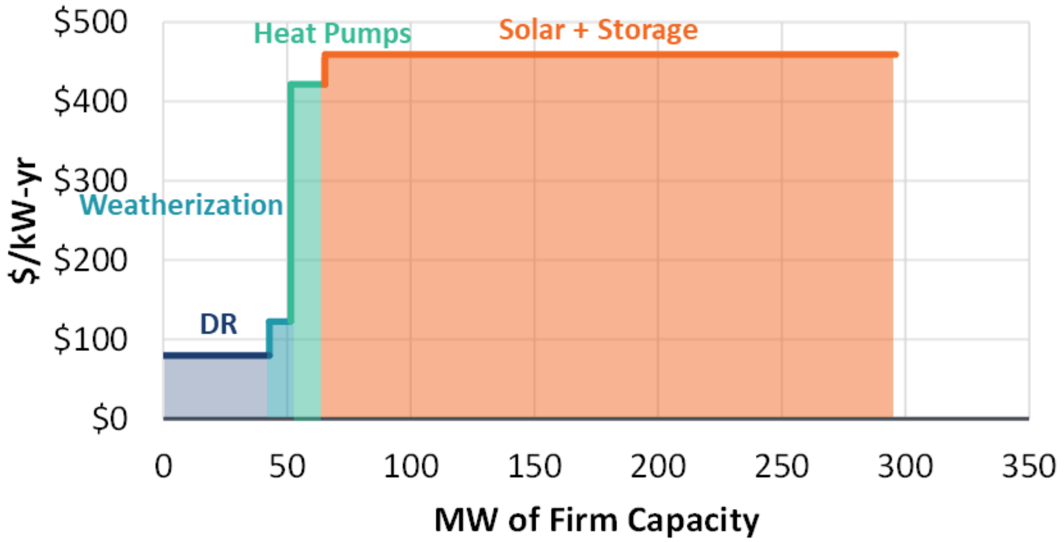
Sources: 1. This estimate assumes a capacity cost range of $80-120/kW-yr informed by recent PJM and MISO capacity auction results.

Kansas City

At a Glance: Impact of Measures

- Under the modeled uptake assumptions, the Kansas City MSA includes approximately 57,000 demand response participants, 46,000 solar + storage subscriptions, 11,000 heat pump adoptions, and 4,000 weatherized homes.
- Participating customers save about $50/year in demand response, ~$700–$750/year from weatherization, ~$700–$750/year from heat pumps, and ~$700/year from solar + storage.
- For low-income households, solar + storage, heat pumps, and weatherization all provide substantial reductions in energy burden, with particularly strong impacts from heat pumps & solar + storage.
- At full modeled scale, the portfolio provides over 250 MW of firm capacity in both winter and summer in the Kansas City MSA, representing ~$30 million in annual capacity value and significant emissions reductions.

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area



Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Summary of Lifetime Economic Impact of Measures

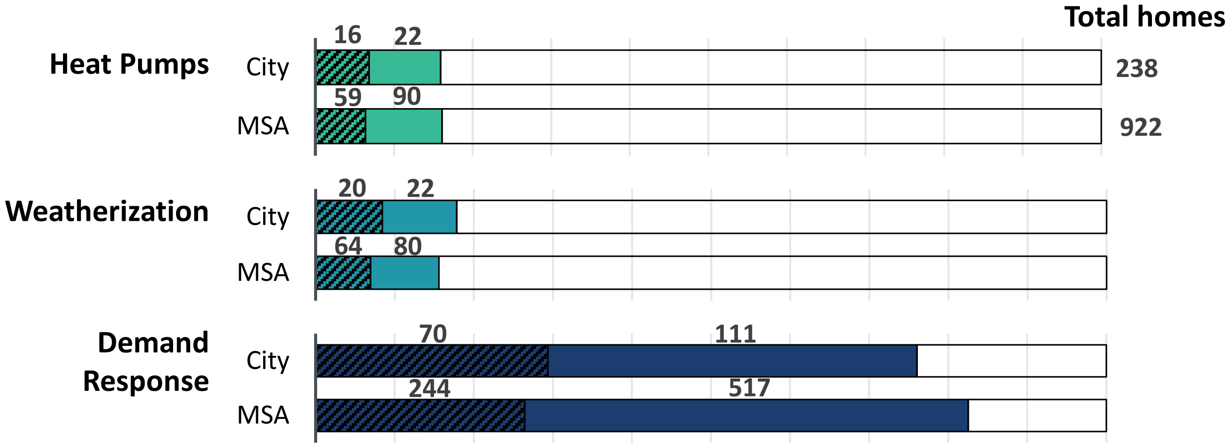
	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	231	14	9	43
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$902,993,116	$83,684,749	$8,083,659	$26,002,087
Total Cost for Hyperscaler ($)	$804,780,835	$44,560,099	$8,083,659	$26,002,087
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$459	$422	$122	$80
Number of Participating Customers	46,122	11,140	4,311	57,109
Customer Cost after Rebate ($)	$2,129	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$5,399	$5,713	$5,734	$380
Payback Period w/ Rebate (yrs)	3	5	0	0

Addressable Market

A large share of Kansas City households are eligible for at least one program, with demand response offering the broadest reach and weatherization and heat pumps serving more targeted customer segments.

- Demand response has the largest addressable market because most homes with air conditioning can participate through thermostat-based load control during peak periods.
- Eligibility for heat pumps and weatherization is more targeted, reflecting housing characteristics such as existing heating equipment, building shell conditions, and retrofit suitability.
- At our assumed levels of program participation, DR has the highest modeled adoption.

Homes Eligible for Each Retrofit Measure (Thousands)



Dashed section indicates homes that are eligible for each measure and are also Low- to Moderate-Income, defined as homes earning up to 80% of the Area Median Income. Solar + storage modeled at 5% of total homes, well below city's potential.

Assumed Homes that Uptake Each Measure (Thousands)

Measure	City	MSA
Solar + Storage	12	46
Heat Pumps	3	11
Weatherization	1	4
Demand Response	14	57

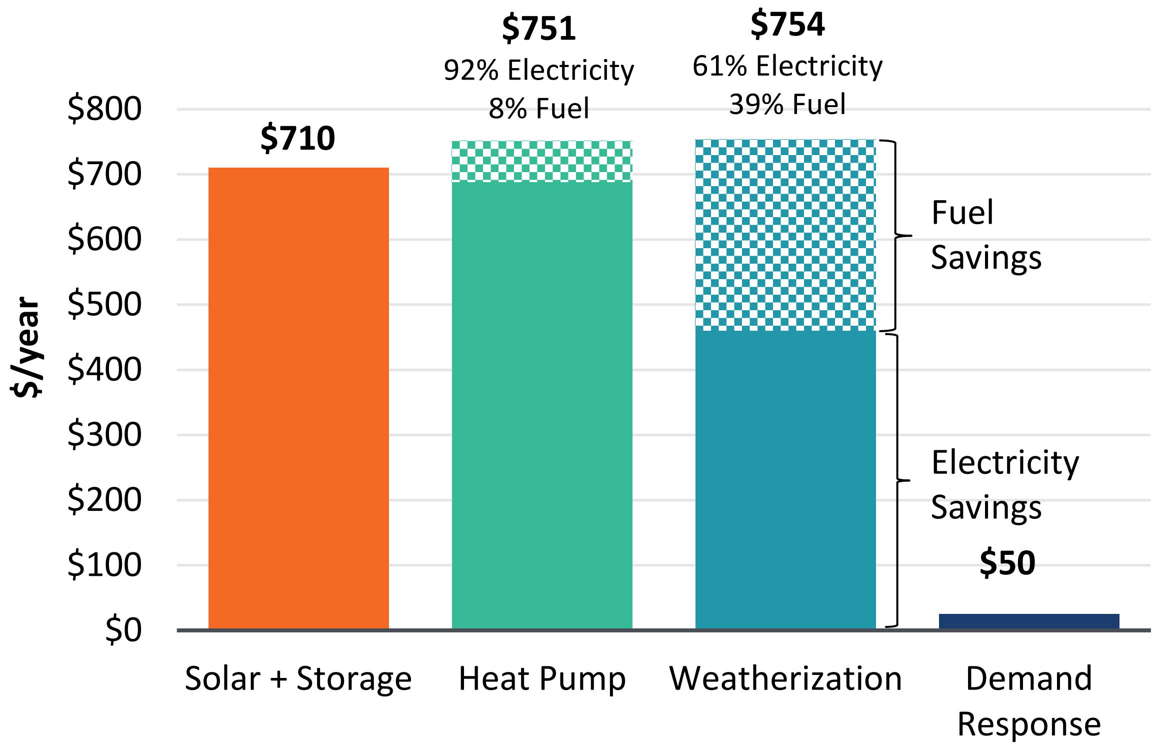
Note: We translate technical eligibility into an addressable market by applying assumptions about customer interest, practical deployability, and program uptake by technology. Solar + storage is modeled as a small share of total households, well below the city's broader technical potential. See Appendix p.71 for additional details on participation rates. See p.20 for overlap in eligibility for heat pump and weatherization customers.

Estimated Participating Customer Bill Reductions

Participating customers save about $50/year in demand response, ~$750/year from weatherization, ~$750/year from heat pumps, and ~$700/year from solar + storage.

- Electricity savings from load reductions are based on the applicable residential retail rate for Evergy Missouri West, while fuel savings are based on winter 2024–2025 monthly average residential gas and propane costs in Missouri[1].
- Customers subscribed to the community solar + storage program are compensated on their excess generation at the avoided energy cost (based on nearby SPP LMPs, $0.043/kWh on average).

Annual Bill Savings for Average Participating Customer



Note: Demand response bill reductions are not modeled; we assume a $50/year economic incentive per home.1. Applicable electric residential retail rate is based on EIA-861 average energy cost for Evergy Missouri West, adjusted to remove fixed charges from customer bills which remain unchanged. Estimated fuel rates are based on EIA Residential Natural Gas Prices by month and EIA Residential Propane Prices by month.

Impact of Measures on Participant Energy Burden

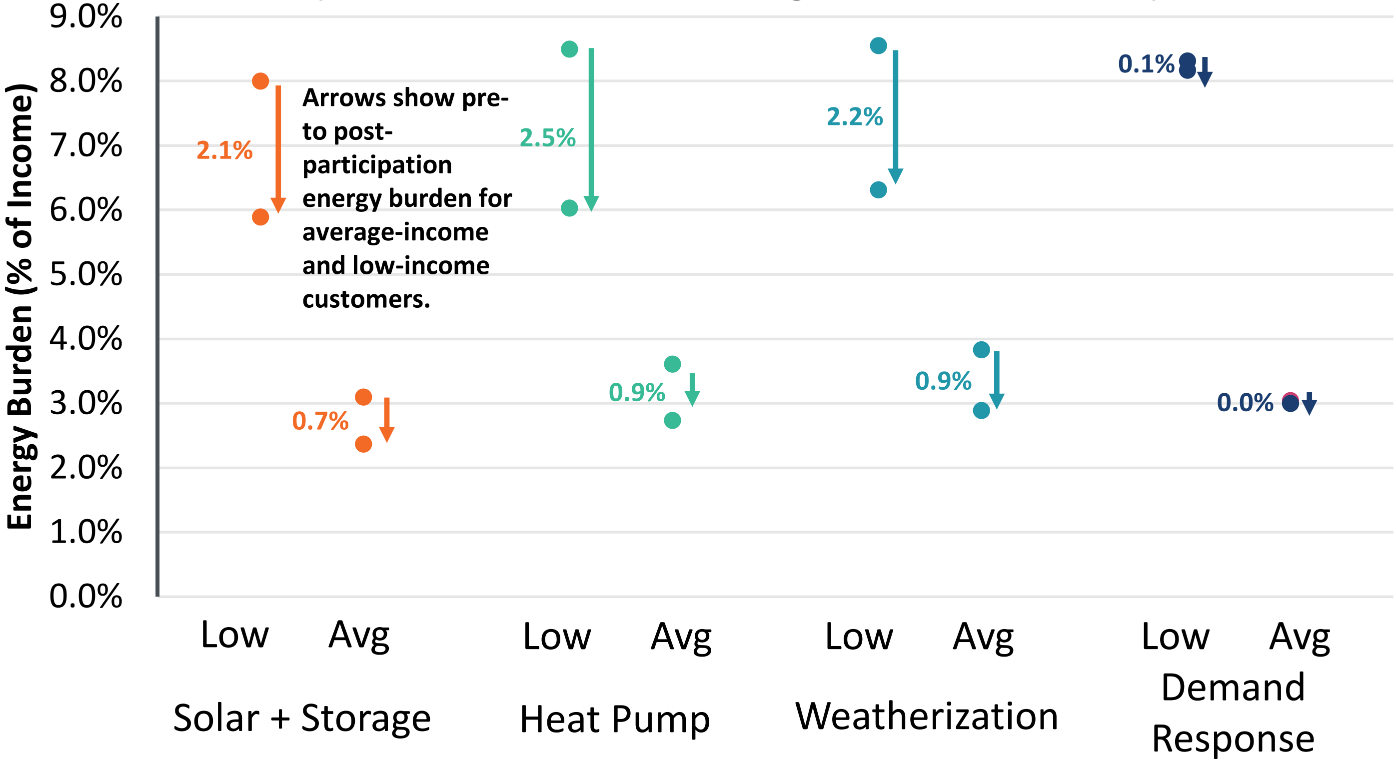
Customers see meaningful bill savings, with heat pumps providing the greatest impact, reducing energy burden for low-income households by ~2.5 percentage points.

- Heat pumps deliver the largest reductions in energy burden.
- Weatherization and solar + storage reduce energy burden by ~2 percentage points.
- Demand response provides smaller, but still positive, bill savings with broad participation potential.

Percent of Customers Eligible for Measures Studied that are Low Income

Eligibility	City	MSA
All	42%	36%
Heat Pumps	43%	40%
Weatherization	47%	45%
Demand Response	39%	32%

Annual Energy Burden for a Customer Participating in Each Program (for Low Income and Average Income Customer)

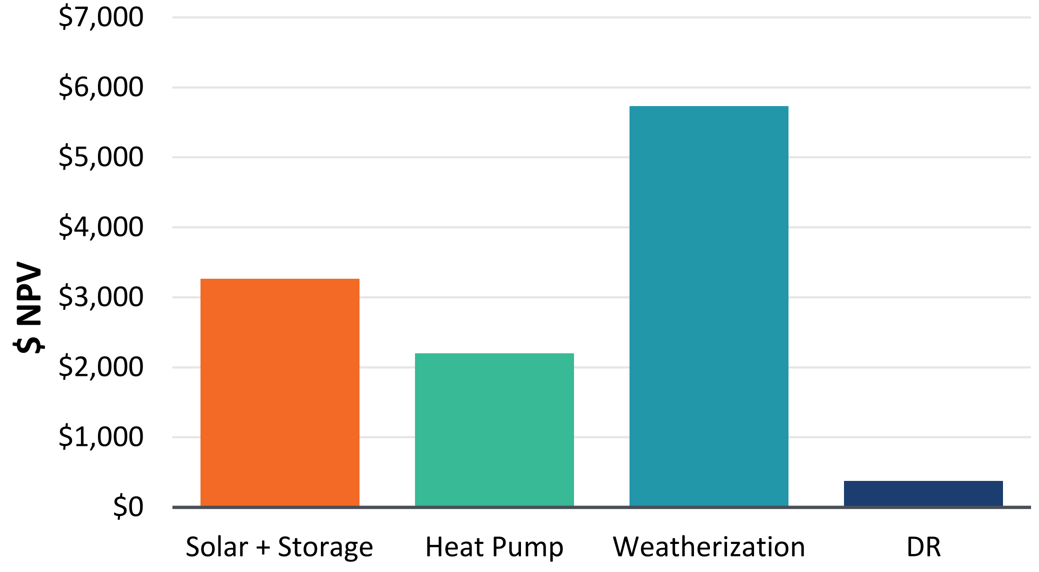


Note: Energy burden is calculated as annual household energy spending divided by household income. Low-income households begin with substantially higher energy burdens, so a given level of bill savings produces a larger relative benefit for those customers.

Participating Customer and Hyperscaler Economics

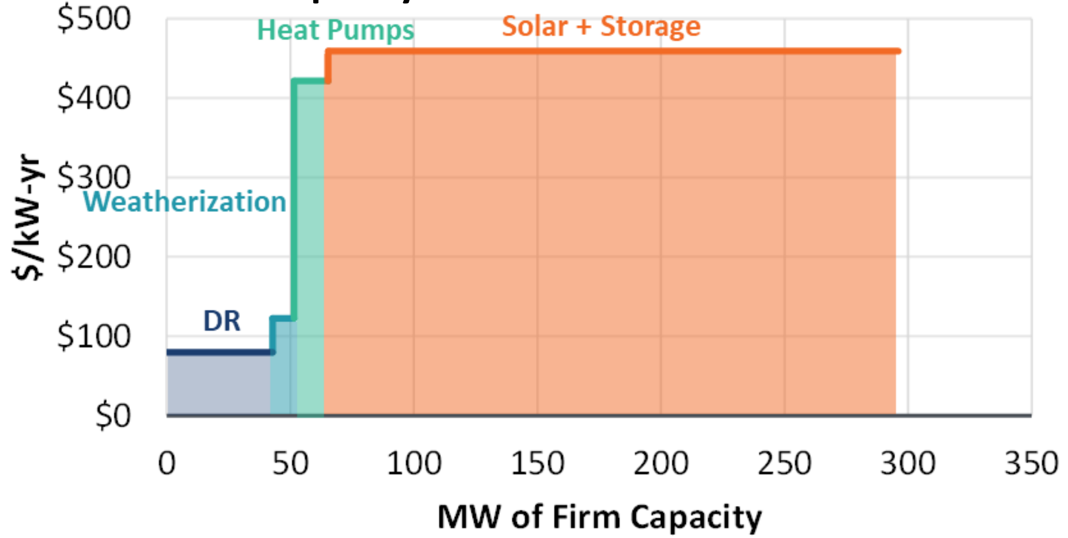
As designed, the programs analyzed create value for both customers and the hyperscaler: customers benefit from lower bills, while the hyperscaler funds targeted subsidies to provide firm capacity and other community benefits.

Participating Customer Net Present Value (NPV) of DER Measures



Note: Values represent the net present value (NPV) of each measure from the customer perspective, including both bill savings and upfront customer costs after rebates. NPV is calculated over a 15-year measure life (starting in 2026) using a 10% real discount rate. Positive values indicate net customer benefit (see Appendix, p. 66).

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area



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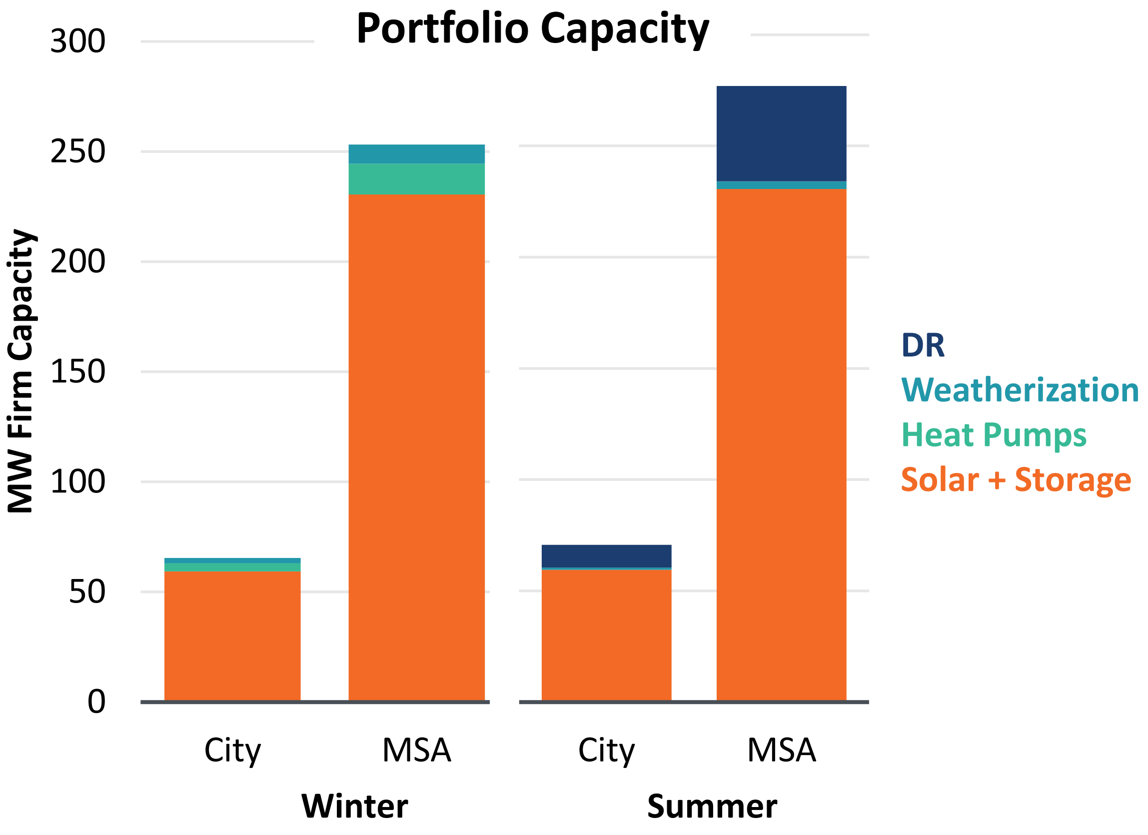
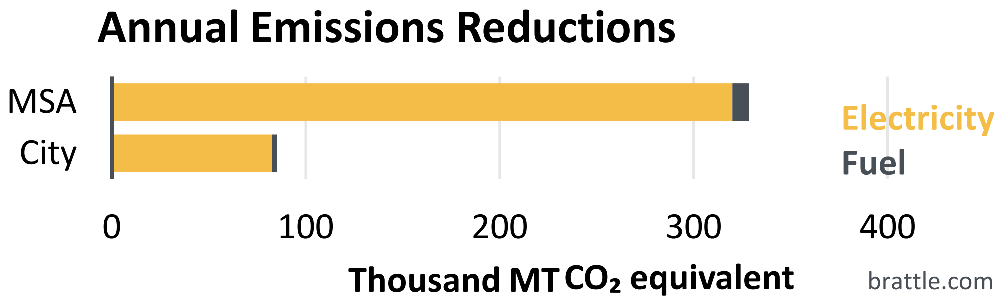
System and Societal Benefits

We find that a portfolio of demand-side solutions in the city of Kansas City could provide over 50 MW of firm winter and summer capacity.

- Extending this portfolio approach to the larger Kansas City Metropolitan Statistical Area increases the capacity to over 250 MW in the winter and summer.
- This translates to approximately $7 million annually in capacity value in the city proper and $30 million for the wider metropolitan area[1].
- Emissions co-benefits: The portfolio delivers substantial emissions reductions at both the regional and local levels—approximately 325 thousand metric tons CO_2e annually across the MSA, with ~85 thousand of those metric tons CO_2e reduced within the city, providing societal and environmental benefits.





Sources: 1. This estimate assumes a capacity cost range of $80-120/kW-yr informed by recent PJM and MISO capacity auction results.

Columbus

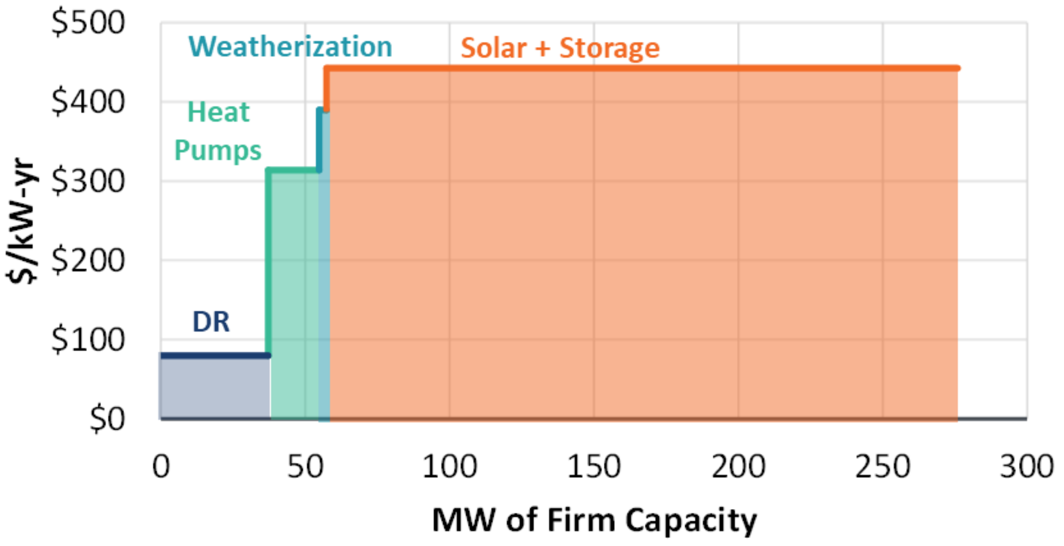
At a Glance: Impact of Measures

- Under the modeled uptake assumptions, the Columbus MSA includes approximately 50,000 demand response participants, 44,000 solar + storage subscriptions, 11,000 heat pump adoptions, and 4,000 weatherized homes.
- Participating customers save about $50/year in demand response, ~$400/year from weatherization, ~$1,100–$1,200/year from heat pumps, and ~$900/year from solar + storage.
- For low-income households, heat pumps and solar + storage provide the largest reductions in energy burden, with weatherization also delivering meaningful savings.
- At full modeled scale, the portfolio provides over 200 MW of winter firm capacity and over 250 MW of summer capacity in the Columbus MSA, representing ~$28 million in annual capacity value and significar emissions reductions.

Summary of Lifetime Economic Impact of Measures

	Solar + Storage	Heat Pump	Weatherization	DR
Equivalent Total Capacity (MW)	219	18	3	37
Adoption Rate (% of eligible population)	5%	8%	3%	8%
Total Measure Cost ($)	$855,768,042	$78,964,071	$7,469,529	$22,594,677
Total Cost for Hyperscaler ($)	$735,253,023	$42,046,453	$7,469,529	$22,594,677
Annualized Capacity Cost for Hyperscaler ($/kW-yr)	$442	$314	$390	$80
Number of Participating Customers	43,710	10,512	3,984	49,625
Customer Cost after Rebate ($)	$2,757	$3,512	$0	$0
Present Value (PV) of Customer Bill Savings ($)	$6,990	$8,946	$3,400	$380
Payback Period w/ Rebate (yrs)	3	3	0	0

Program Costs for Hyperscaler and Corresponding Firm Capacity Potential in Metro Area



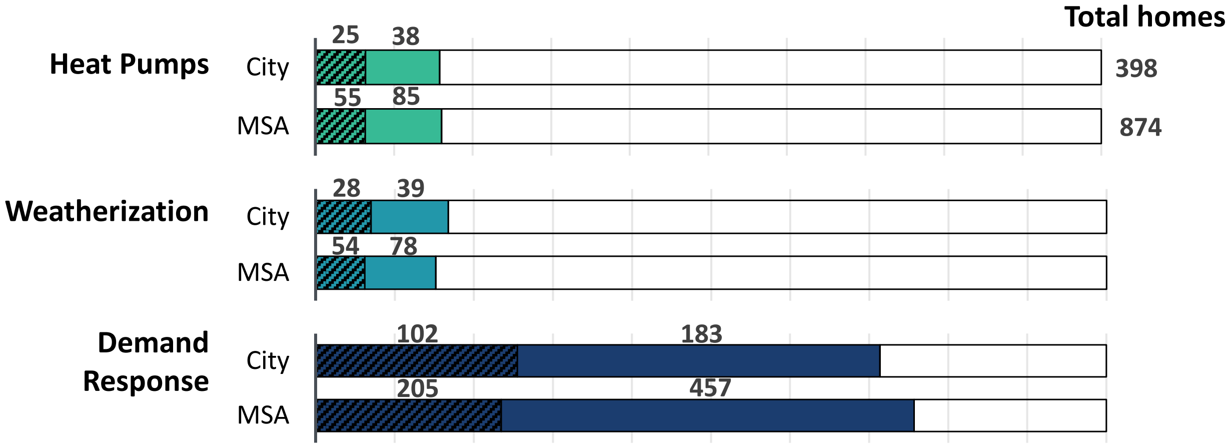
Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

Addressable Market

A large share of Columbus households are eligible for at least one program, with demand response offering the broadest reach and weatherization and heat pumps serving more targeted customer segments.

- Demand response has the largest addressable market because most homes with air conditioning can participate through thermostat-based load control during peak periods.
- Eligibility for heat pumps and weatherization is more targeted, reflecting housing characteristics such as existing heating equipment, building shell conditions, and retrofit suitability.
- At our assumed levels of program participation, DR has the highest modeled adoption.

Homes Eligible for Each Retrofit Measure (Thousands)



Dashed section indicates homes that are eligible for each measure and are also Low- to Moderate-Income, defined as homes earning up to 80% of the Area Median Income. Solar + storage modeled at 5% of total homes, well below city's potential.

Assumed Homes that Uptake Each Measure (Thousands)

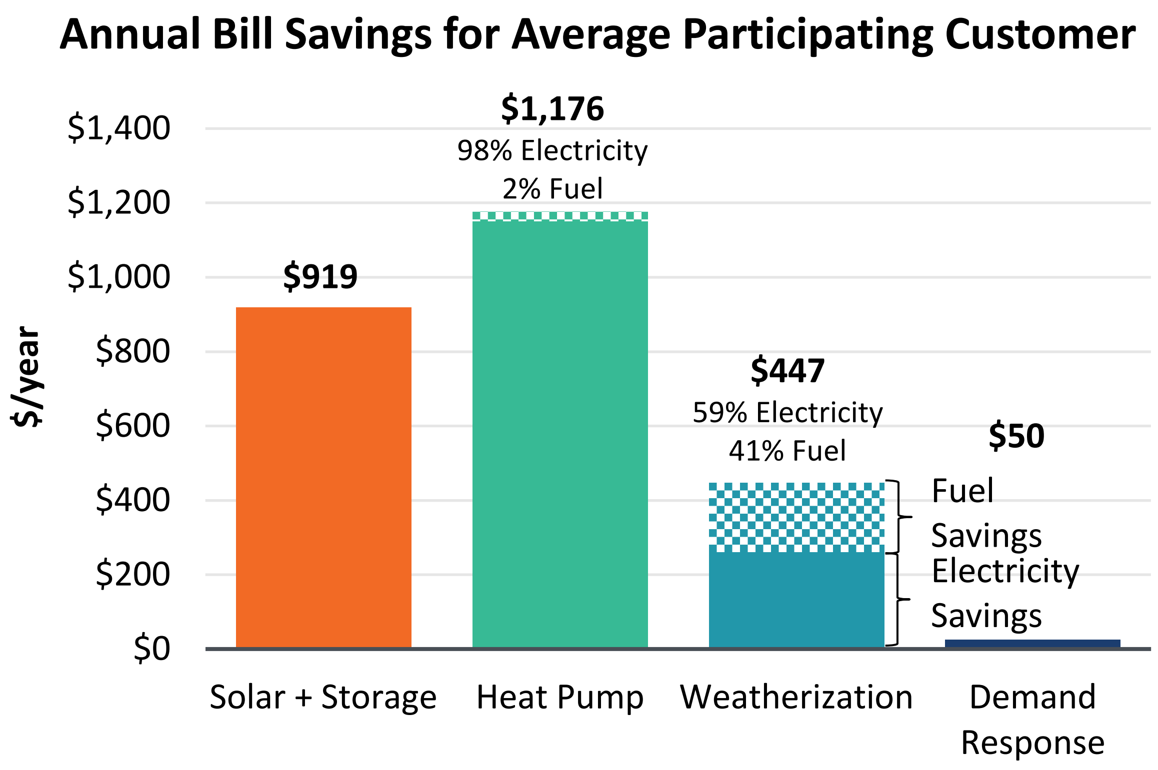
Measure	City	MSA
Solar + Storage	20	44
Heat Pumps	5	11
Weatherization	2	4
Demand Response	21	50

Note: We translate technical eligibility into an addressable market by applying assumptions about customer interest, practical deployability, and program uptake by technology. Solar + storage is modeled as a small share of total households, well below the city's broader technical potential. See Appendix p.71 for additional details on participation rates. See p.20 for overlap in eligibility for heat pump and weatherization customers.

Estimated Participating Customer Bill Reductions

Participating customers save about $50/year in demand response, ~$450/year from weatherization, ~$1,200/year from heat pumps, and ~$900/year from solar + storage.

- Electricity savings from load reductions are based on the applicable residential retail rate for Ohio Power, while fuel savings are based on winter 2024–2025 monthly average residential gas and propane costs in Ohio[1].
- Customers subscribed to the community solar + storage program are compensated on their excess generation at the avoided energy cost (based on a system lambda estimate of $0.054/kWh).



Note: Demand response bill reductions are not modeled; we assume a $50/year economic incentive per home.

1. Applicable electric residential retail rate is based on EIA-861 average energy cost for Ohio Power, adjusted to remove fixed charges from customer bills which remain unchanged. Estimated fuel rates are based on EIA Residential Natural Gas Prices by month and EIA Residential Propane Prices by month.

Impact of Measures on Participant Energy Burden

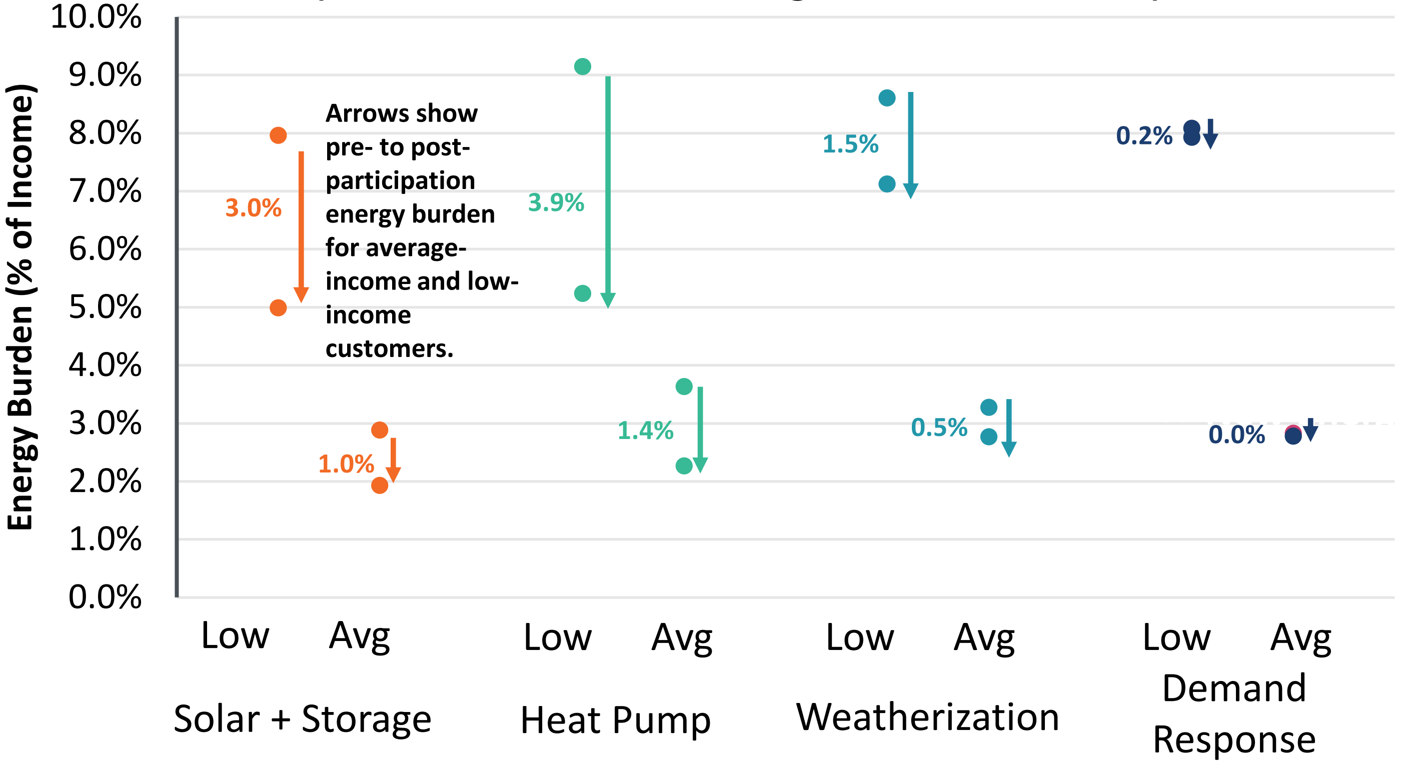
Customers see meaningful bill savings, with heat pumps providing the greatest impact, reducing energy burden for low-income households by ~4 percentage points.

- Heat pumps deliver the largest reductions in energy burden.
- Weatherization and solar + storage reduce energy burden by ~1.5–3 percentage points.
- Demand response provides smaller, but still positive, bill savings with broad participation potential.

Percent of Customers Eligible for Measures Studied that are Low Income

Eligibility	City	MSA
All	39%	35%
Heat Pumps	40%	40%
Weatherization	42%	41%
Demand Response	36%	31%

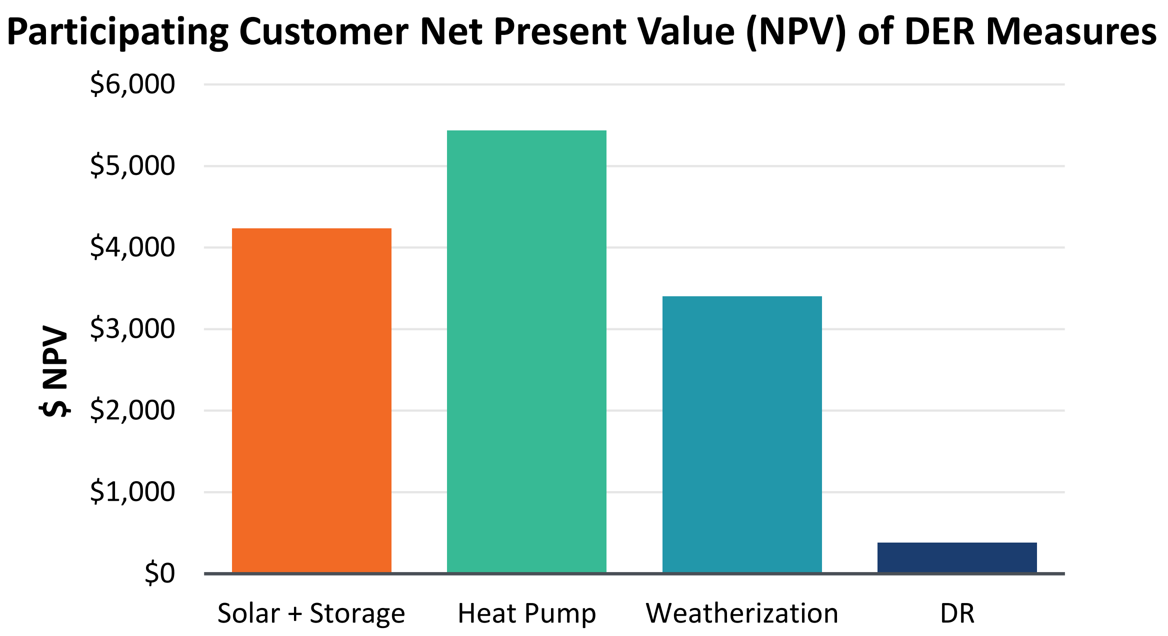
Annual Energy Burden for a Customer Participating in Each Program (for Low Income and Average Income Customer)



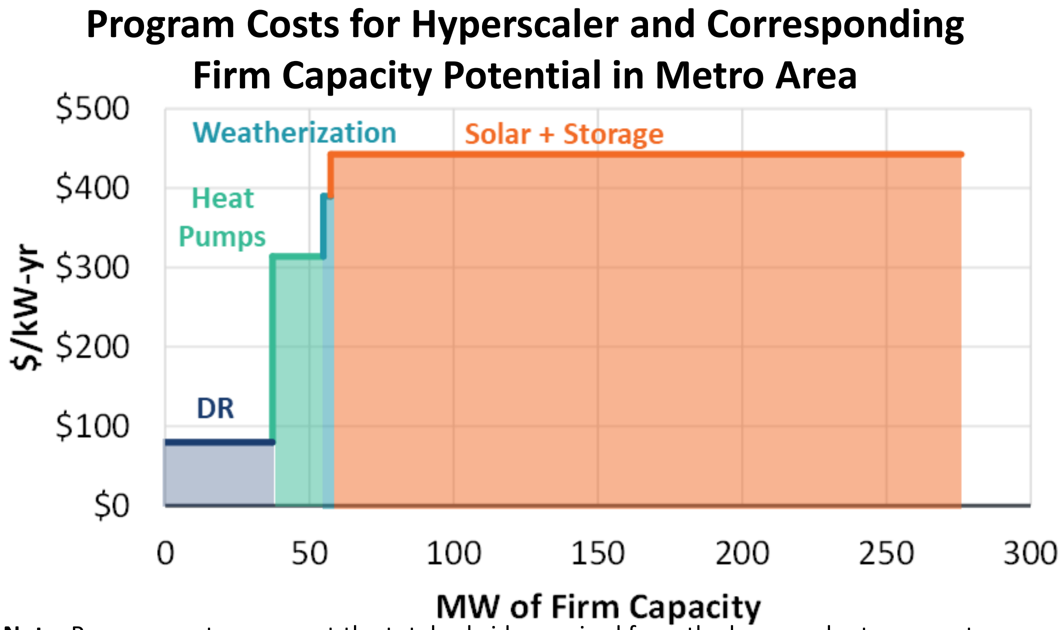
Note: Energy burden is calculated as annual household energy spending divided by household income. Low-income households begin with substantially higher energy burdens, so a given level of bill savings produces a larger relative benefit for those customers.

Participating Customer and Hyperscaler Economics

As designed, the programs analyzed create value for both customers and the hyperscaler: customers benefit from lower bills, while the hyperscaler funds targeted subsidies to provide firm capacity and other community benefits.



Note: Values represent the net present value (NPV) of each measure from the customer perspective, including both bill savings and upfront customer costs after rebates. NPV is calculated over a 15-year measure life (starting in 2026) using a 10% real discount rate. Positive values indicate net customer benefit (see Appendix, p. 66).

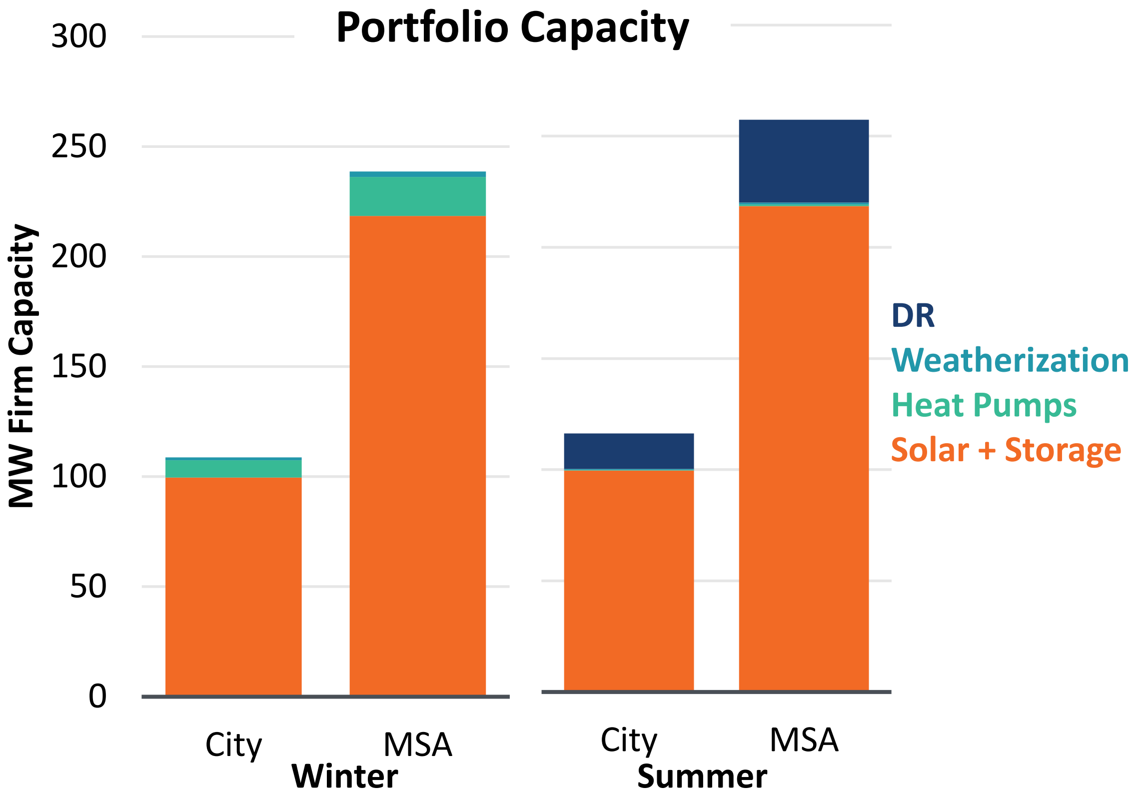


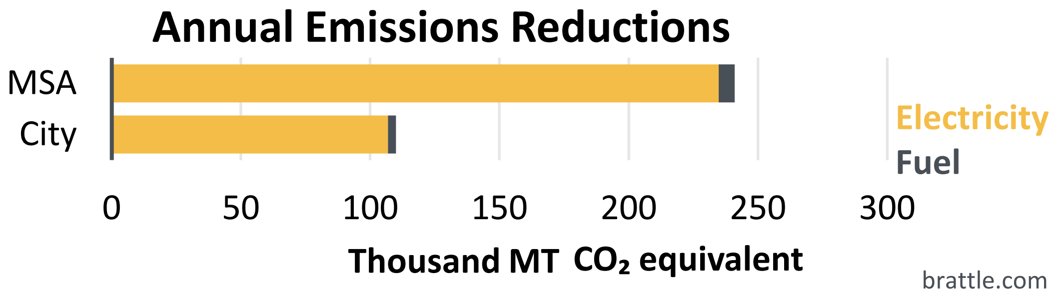
Note: Program costs represent the total subsidy required from the hyperscaler to support program buildout. DR costs also include the present value of annual economic incentives to customers. Capacity is reported as firm capacity, defined as the average load reduction on a representative peak day, which is summer for solar + storage and DR, and winter for weatherization and heat pumps. For solar + storage, firm capacity is estimated using the Effective Load Carrying Capability (ELCC) of each technology in the summer, applied to installed nameplate capacity to reflect its reliable contribution during system peak conditions. See Appendix p. 73 for firm capacity methodology. The annualized capacity cost does not take into energy benefits for any measure, which would be the highest for solar + storage. Measure lifetimes are assumed to be 15 years, with costs annualized using a 10% real discount rate (see Appendix, p. 68).

System and Societal Benefits

We find that a portfolio of demand-side solutions in the city of Columbus could provide over 100 MW of firm winter and summer capacity.

- Extending this portfolio approach to the larger Columbus Metropolitan Statistical Area increases the capacity to over 200 MW in the winter and over 250 MW in the summer.
- This translates to approximately $12 million annually in capacity value in the city proper and $28 million for the wider metropolitan area.[1]
- Emissions co-benefits: The portfolio delivers substantial emissions reductions at both the regional and local levels—approximately 240 thousand metric tons CO_2e annually across the MSA, with ~100 thousand of those metric tons CO_2e reduced within the city, providing societal and environmental benefits.





Sources: 1. This estimate assumes a capacity cost range of $80-120/kW-yr informed by recent PJM and MISO capacity auction results.

Table of Contents

Financial Mechanisms to Support Energy Efficiency and Housing

Different financial mechanisms can facilitate hyperscaler support for modeled measure packages, with distinct approaches to capital deployment, risk sharing, and monetizing system value.

Direct Utility Program Funding

Funding to support utility-administered demand response, energy efficiency, and electrification programs through cost reductions, increased incentives, and pilot funding.

Aggregator Partnerships

Contracting with or funding third-party aggregators to enhance customer programs and/or provide grid services.

Hyperscaler Managed and Operated Fund

Hyperscaler enables projects through creation of fund, direct advocacy, and partnerships.

Contributions to Existing Public or Nonprofit Financial Entities

Donations to green banks, CDFIs, housing agencies, or NGOs that administer loans and grants targeting energy efficiency, electrification or affordable housing.

Direct Utility Program Funding

Direct contributions to utilities can enhance or expand existing demand response, energy efficiency and electrification programs.

Funding Recipients

Funds for utility programs that in turn serve customers.

Benefits of Mechanism

Funds flow through institutions that already serve communities and understand local needs.

Implementation Complexity

Low — utilities already have programs and regulatory frameworks in place.

INVESTMENT CASE STUDY

The largest utility in Mississippi, Entergy, has launched its $300 million “Superpower Mississippi” initiative to modernize the grid and improve reliability. This investment has been enabled by new revenues from large customers, including Amazon data centers, whose load growth and associated funding allow Entergy to finance major transmission and distribution upgrades at no additional cost to customers. Rather than shifting costs to other customers, hyperscaler-driven investment supports system improvements that benefit the broader service territory.

Entergy projects that these upgrades will reduce outage frequency and duration by roughly 50% for the average residential customer, excluding major weather events. Utility leadership has noted that, absent the influx of large customers like Amazon, investments of this scale would typically require higher rates. Instead, the additional revenue associated with hyperscaler load allows Entergy to strengthen grid reliability while keeping customer bills below the national average.

While this arrangement does not involve a direct customer-facing program (such as efficiency rebates or demand response enrollment), it demonstrates how hyperscaler–utility collaborations can fund system-wide customer benefits through improved reliability and avoided cost shifting. Extending this model to fund utility-administered efficiency, electrification, or demand flexibility programs represents a logical next step, but remains an emerging opportunity rather than an established practice.

Aggregator Partnerships

Hyperscaler partners with or funds a third-party aggregator or ESCO to deploy and manage energy measures.

Funding Recipients
Third-party aggregator or ESCO.

Benefits of Mechanism
Access to home upgrades and distributed energy resource programs without managing enrollment or market participation.

Implementation Complexity
Medium — requires contracting and coordination with aggregators or ESCOs.

INVESTMENT CASE STUDY

Voltus, a leading distributed energy resource aggregator with 7.5 GW of DR capacity, and Cloverleaf Infrastructure, a data-center infrastructure developer, have introduced a "Bring Your Own Capacity" (BYOC) model that allows hyperscalers to finance virtual power plants (VPPs) in communities near new data centers. Hyperscalers fund the deployment of flexible resources—such as demand response, batteries, and controllable loads—which Voltus aggregates and operates as a VPP, delivering capacity directly to local utilities to support near-term reliability needs.

The innovation in the BYOC model is primarily commercial rather than technical. Instead of selling flexibility into wholesale markets, Voltus contracts capacity "out of market" directly with hyperscalers at a value that reflects their strong reliability needs and willingness to pay. Voltus then delivers that contracted capacity to the load-serving entity, sidestepping slower market-based capacity constructs and long market-reform timelines. The structure builds on familiar bilateral contracting used by large industrial customers, adapted for the AI-driven data-center era.

By aligning hyperscaler capital with community-based flexibility, the BYOC approach accelerates VPP deployment while delivering local benefits. Participating businesses (or households in utility/partner programs) receive devices, bill savings, and compensation, while utilities gain capacity without new fossil infrastructure.

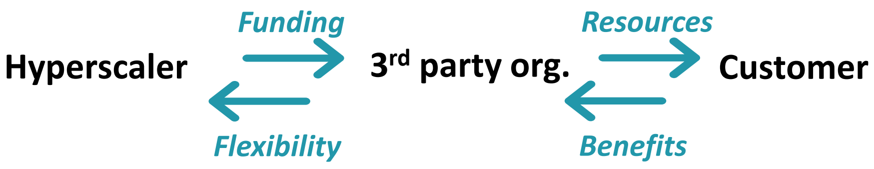
Contributions to Existing Public or Nonprofit Finance Entities

Hyperscaler provides capital to organizations focused on affordable housing or energy upgrades.

Funding Recipients
Green banks, CDFIs, housing agencies, nonprofits, or community lenders.

Benefits of Mechanism
Makes financing affordable and accessible while keeping program administration with experienced entities.

Implementation Complexity
Low to medium — relies on existing institutions and processes.



INVESTMENT CASE STUDY

Since 2021, Amazon has committed $3.6 billion to a Housing Equity Fund to support the creation and preservation of affordable housing for low and moderate-income residents in Washington, Virginia and Tennessee.

The fund supports efforts to develop and maintain affordable housing projects across three priority regions (Washington State's Puget Sound region; the Arlington, Virginia/National Capital region; and Nashville, Tennessee) through below-market rate loans or grants. For example, in Bellevue, Amazon provided an $11 million loan, combined with $13.3 million in recycled tax-exempt bond financing, to support Great Expectations' conversion of a former assisted-living facility into the 108-unit Crossroads Apartments. In Nashville, Amazon contributed $3.75 million to The Housing Fund, a non-profit Community Development Financial Institution (CDFI), to support eligible homeowners and landlords with property tax relief.

By partnering with local organizations and developers, the fund model allows for distributed geographic impact and relies on established local institutions rather than starting new programs from scratch. It illustrates how hyperscaler-driven investment can support housing stability and affordability through nonprofit intermediaries, generating community benefits without displacing public programs.

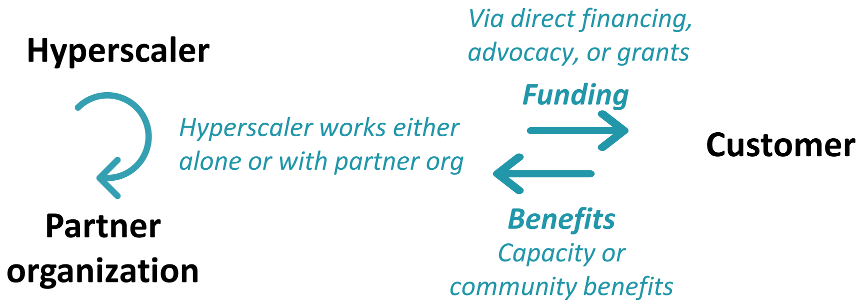
Hyperscaler Managed and Operated Fund

Hyperscaler enables housing or energy projects through innovative financing models, direct advocacy, and partnerships.

Funding Recipients
Housing authorities, state housing commissions, local organizations, advocacy groups or final customers.

Benefits of Mechanism
Financing and advocacy work directly enables development of affordable housing or energy efficiency programs.

Implementation Complexity
High — start-up costs to fund creation/management and contract with actual implementing organizations.



INVESTMENT CASE STUDY

Microsoft's Affordable Housing Initiative reflects a more direct funding model in which corporate capital is deployed to address specific financing gaps in affordable and middle-income housing projects. The $750 million fund conducts a mix of grant-making and innovative financing options.

Microsoft has also advanced bespoke financing structures—such as mezzanine capital paired with traditional bonds—to directly enable middle-income housing that falls outside traditional public subsidy programs. The funding model, dubbed Middle-Income Tax-Exempt Mezzanine (MIT-E Mezz) program, does not require capital investment from public or non-profit entities. Microsoft supported Renton Housing Authority's purchase of a 106-unit market-rate building using the MIT-E Mezz model.

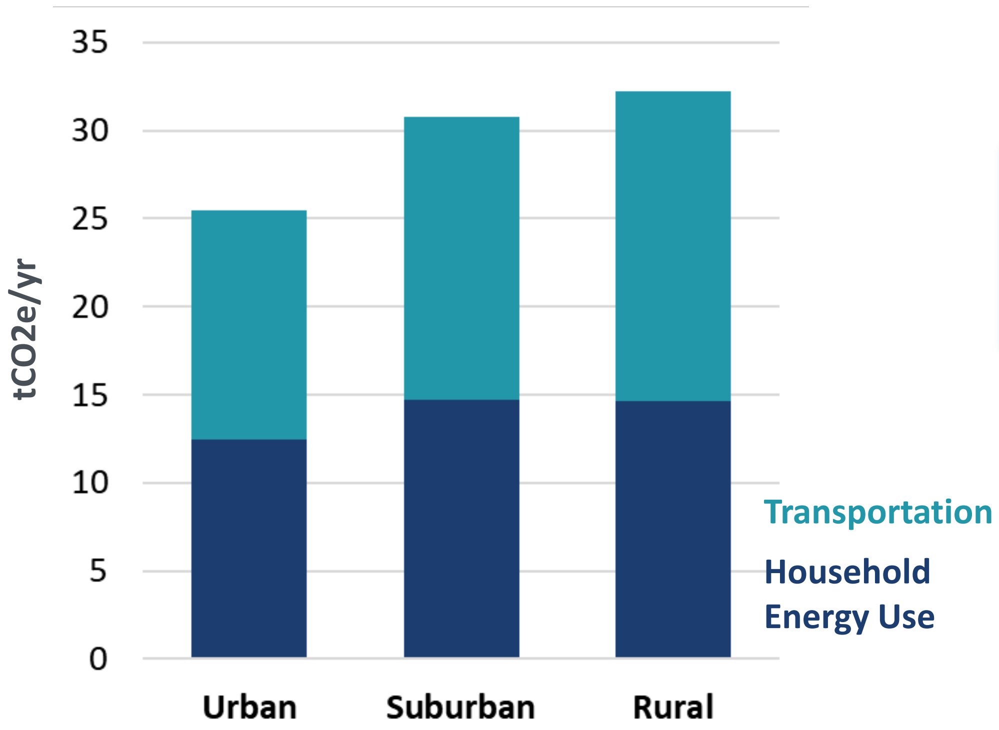
Unlike funds aimed only at grant and loan making, the Microsoft Housing Initiative also pairs capital deployment with state and local policy engagement. The goal of the fund is to intervene in housing markets where structural barriers—such as land constraints, financing gaps, and regulatory limitations—impede the development and preservation of affordable and middle-income housing, and to support policy and financing reforms that enable longer-term market participation beyond individual projects.

Table of Contents

Community Impacts of Urban Densification

Dense cities reduce emissions and household energy burdens primarily through transportation efficiency and housing form, delivering measurable environmental and economic benefits while efficiently using existing infrastructure.

Average Household Emissions by End Use[9]



GHG Emissions	In highly dense areas (>3,000 people per square mile), increased density is associated with lower household greenhouse gas emissions, driven primarily by reduced transportation emissions and smaller average home sizes. On average, **suburban households have carbon footprints about 25% higher than urban households**[1].
Energy use	Urban densification encourages multi-family housing and more compact floor plans, which reduce residential energy demand. Studies find that urban residential energy use is **5–8% lower per household**, with total household energy demand reductions of **27–47%** when accounting for housing type and size differences[2,3].
Economic impact	Infill development has been associated with up to a 2% reduction in construction costs in California[4]. By using existing roads, utilities, transit, and public amenities rather than extending new networks, infill also lowers long-term infrastructure expansion and maintenance costs compared with greenfield development[5].
Combined burden: energy & transportation	Urban households experience lower combined energy and transportation burdens than rural and suburban households. **Urban households average a 32% lower combined burden**, and metropolitan customers face **15–23% lower transportation fuel burdens**, largely due to improved transit access and shorter travel distances[6,7,8].

Sources: 1) Kammen and Jones, Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density 2) Berrill et al, Linking Housing Policy, Housing Typology, and Residential Energy Demand in the United States 3) EIA, Energy Use in Homes 4) Elkind et al, Right Type, Right Place: Assessing the Environmental and Economic Impacts of Infill Residential Development through 2030. Note: the 2% cited here is California specific and depends on regional construction costs 5) C40 Cities Suburbia is subsidised: Here's the math 6) Vaidyanathan et al Understanding Transportation Energy Burdens. Washington, DC: American Council for an Energy-Efficient Economy. 7) Makarewicz et al, Another Look at Location Affordability: Understanding the Detailed Effects of Income and Urban Form 8) ACEEE, Combined Energy Burdens: Estimating Total Home and Transportation Energy Burdens 9) Classifications from Dept. of Defense based on population density: Urban >= 3k ppl/sqmile, Suburban between 1-3k ppl/sqmile, Rural <1k ppl/sqmile, nationwide results shown.

Metrics for Assessing Urban Infill Potential

We summarize urban infill potential by measuring the *drivers* of infill—such as high vehicle travel and emissions—and the *feasibility* of infill, including zoning flexibility and land availability. This combined lens allows a comparison of cities' capacity to absorb new housing while maximizing system and environmental benefits.

Vehicle Miles Traveled	Higher household VMT indicates greater car dependence and stronger potential for infill to reduce travel, congestion, and transportation emissions.
Population Density	Lower existing density suggests more physical capacity to add housing through infill without major displacement or infrastructure expansion.
Residential Emissions Intensity	Higher per-household emissions signal inefficient or energy-intensive buildings, where infill combined with electrification and weatherization can deliver outsized climate benefits.
Zoning Density Support	Zoning policies that allow moderate-to-high residential density reduce regulatory barriers and increase the feasibility of infill development.
Land Banks	The presence of active land banks lowers development risk by facilitating land assembly and supporting public goals such as affordability and densification.
Vacant Land Availability	Vacant or underutilized parcels—especially publicly owned lots—reduce siting constraints and enable faster, lower-cost infill construction.

Metrics for Assessing Urban Infill Potential

Indicator*	Implication for infill	●●●	●●	●
Vehicle Miles Traveled *[annual miles/household]*	High VMT suggests dependence on commuting by car. Adding infill development can reduce transportation emissions and commute times.	Average annual miles traveled per household >1k of average	Average annual miles traveled per household within 1k of average	Average annual miles traveled per household <1k of average
Density *[ppl/sq mile]*	Low-density cities are better candidates for infill given the physical room to add new housing.	Below 5,000 ppl/sq mile of average	Within 5,000 ppl/sq mile of average	Above 5,000 ppl/sq mile of average
Household Energy Emissions *[tCO2e/yr]*	High emissions suggest inefficient and/or large homes as well as high energy use. Infilling can provide extra benefit through electrification and weatherization.	Above 5 tCO2e/yr of average	Within 5 tCO2e/yr of average	Below 5 tCO2e/yr of average
Zoning Density Support *[NLLUS survey ranking]*	Using NLLUS data, zoning density support is measured as the share of municipalities permitting moderate-to-high residential density using dwelling units per acre as a proxy. The higher the threshold, the easier it is to infill.	Strong zoning support	Moderate zoning support	Low zoning support
Land Banks	Existence of land banks reduces development risk and supports public development goals, such as densification and affordability, through strategic land use.	Legislation passed and operational	Legislation passed	Does not exist
Vacant land *[varies]*	Information presented where available. Vacant lots, especially those that are publicly owned, lower barriers to infill construction.			

(*) Numerical indicators are compared to average of top 20 most populated U.S. cities.

Comparison of Infill Potential Across Selected Cities

	Atlanta, GA	Memphis, TN	Kansas City, MO	Columbus, OH	Top 20 Cities by Population
VMT[1] *[thousand miles/ household-year]*	● 17.4	●●● 20.1	●●● 21.2	● 14.8	19.1
Density[2] *[ppl/sq mile]*	●●● 3,309	●●● 2,591	●●● 2,049	●● 5,229	9,753
Emissions[3] *[tCO2e/yr]*	●● 14.1	●●● 16.3	●●● 19.2	●● 15.9	11.7
Zoning[4] *[NLLUS survey ranking]*	●● Moderate	●●● High	●●● High	●● Moderate	High
Land Banks	●●● Metro Atlanta Land Bank, 1994	●●● Memphis Metropolitan Land Bank Authority, 2015	●●● KC Land Bank, 2012	●●● Columbus Land Bank, 1994	19 states have passed land-bank laws[5]
Vacant Land *[varies]*	2.3 sq miles of vacant land[6]	56 sq miles of vacant land[7]	17,000 vacant properties, 20% owned by land bank[8]	11 sq miles of vacant land[9]	40 sq miles

Sources: [1-3] Data from Jones, C., & Kammen, D. M. (2013). *Spatial distribution of U.S. household carbon footprints reveals suburbanization undermines greenhouse gas benefits of urban population density*. City limits are mapped based on Jones and Kammen city categorization. [4] Urban Institute National Longitudinal Land Use Survey 2019. Using maximum dwelling units per acre as metric. [5] National Land Bank Map | Center for Community Progress [6] Atlanta Department of City Planning Public Land for Affordable Housing, 2022 [7] Memphis 3.0 Comprehensive Plan [8] Kansas City Star, Kansas City plans to study, address 17,000 vacant properties [9] Commercial Cafe: Vacant Land Across the Largest U.S. Cities.

Urban Infill in Action

Many study cities already have successful urban infill projects.

Columbus, Ohio – AspireCOLUMBUS

AspireCOLUMBUS is a housing development on the former United Way of Central Ohio headquarters site in downtown Columbus, serving middle- and low-wage households and people with disabilities. The approximately $29 million project is led by the Columbus Metropolitan Housing Authority and is financed through sources including taxable general revenue bonds, federal 9% Low-Income Housing Tax Credits, CMHA public housing funds, and City of Columbus funding. The project will include 82 apartments, 31 of which, or 38%, will be rent-subsidized through CMHA's Housing Choice Voucher program.

Atlanta, Georgia – BeltLine

The Atlanta BeltLine is a large-scale urban infill and redevelopment initiative along a historic 22-mile rail corridor. In partnership with the City of Atlanta, Invest Atlanta, public agencies, nonprofits, and private developers. The project has attracted more than $9 billion in private development and is working toward a goal of creating or preserving 5,600 affordable housing units by 2030. *Separately, Microsoft has agreed to transfer about 22.5 acres of its paused Quarry Yards campus site to the City of Atlanta and AUDC for affordable housing and community development, illustrating how hyperscalers can support urban infill.*

Kansas City, Missouri – Linwood Apartments

Linwood & Main is a transit-adjacent infill housing project at Linwood Boulevard and Main Street, with direct access to the KC Streetcar route. Port KC and Driven Development are collaborating on a roughly $20 million redevelopment of a long-vacant site into 60 two-bedroom apartments, spread across 10 multi-unit buildings. The project is described as workforce housing intended to serve medical industry workers from nearby health facilities.

Memphis, Tennessee -- Bellevue Montgomery Project

Bellevue Montgomery is a 23-unit cottage-court infill development in Midtown Memphis aimed at expanding attainable housing for middle-income residents. The project is part of Memphis' Middle-Income Housing Pilot Program, which supports small-scale "missing middle" infill housing between single-family homes and large apartment buildings. The project financing includes a mix of public incentives, private investment, Community Development Financial Institution lending, and crowdfunding.

Table of Contents

Summary of Findings

Across the cities analyzed, targeted hyperscaler-supported energy investments can reduce peak demand, emissions, and household energy costs while advancing scalable community benefits.

Household energy and peak impacts

Energy efficiency and heat pump upgrades **reduce household energy use by ~25-38%. Across the range of measures, customer peak demands can be lowered by up to ~5 kW per home.** Annual household **bill savings range from ~$50 to $1,175 per participant**, with the largest benefits from heat pumps and solar + storage. These measures also deliver meaningful emissions reductions, particularly where they displace fossil heating.

Grid value and system benefits

Community solar + storage, demand response, weatherization, and electrification measures reduce peak demand by **~160–700 MW per metro area** at full scale. Benefits extend beyond participants, potentially improving system reliability and lowering costs for all customers.

Infill development and built-environment impacts

Supporting dense, efficient housing reduces residential energy use and transportation demand relative to greenfield development. Urban households can exhibit **~25% lower carbon footprints**, while infill development leverages existing infrastructure to limit long-term system costs and emissions growth.

Scalability and implementation

Hyperscalers can support deployment through utility programs, aggregator partnerships, and targeted financing mechanisms. Across cities, portfolios can reach **tens to hundreds of thousands of households**, unlocking **hundreds of MW of capacity**. With significant rebates, these measures reduce upfront customer costs, enable rapid scaling, and translate system-level value—capacity, flexibility, and emissions reductions—into investable community projects.

Leveraging Distributed Resources to Accommodate System Expansion and Provide Community Benefits

A LARGE, PROVEN RESOURCE POTENTIAL

Demand response represents a clear "low-hanging fruit," offering a low-cost, quickly deployable source of capacity given the broad availability of air conditioning and proven thermostat-based control. Weatherization and heat pumps provide additional, reliable reductions in energy use and peak demand, with outcomes dependent on targeting and appropriate subsidy design. Community solar + storage delivers the greatest overall impact, offering substantial firm capacity and customer savings across multiple markets, but its deployment is more dependent on enabling legislation.

VALUE FOR BOTH CUSTOMERS AND THE SYSTEM

When funded as modeled, these measures create value for both customers and the electric system. Households benefit from lower energy bills and improved comfort, while the grid benefits from reduced peak demand, potential deferral of infrastructure investments, and society benefits from lower emissions. Although firm-capacity costs can be significant, they are shown on a gross hyperscaler-funding basis and are not net of customer savings, emissions reductions, or broader system benefits.

GROWTH POTENTIAL

There is substantial room to expand these programs. Demand response programs can often scale rapidly and have a large untapped resource base in all areas studied. Weatherization, heat pumps and community solar and storage programs also have very significant potentials, though scaling will depend on enabling policy frameworks and market structures.

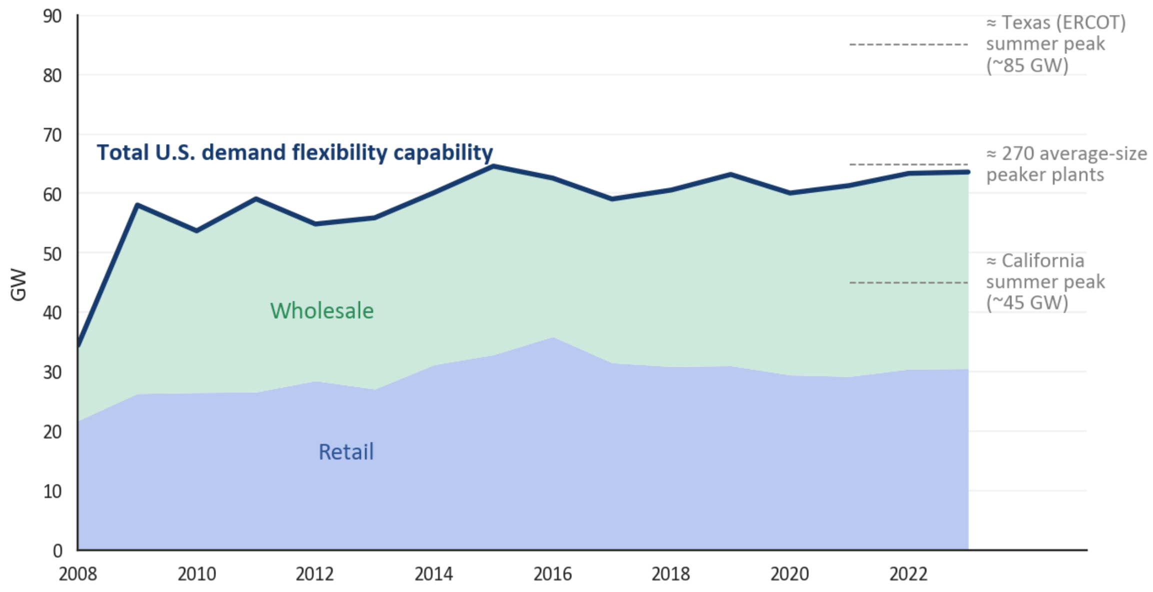
Additional Benefits of Flexible Clean Resources

Beyond modeled energy and capacity value, distributed clean resources can provide operational flexibility, distribution system peak reduction, and faster deployment relative to conventional simple-cycle combustion turbines used as peakers.

- Operational Grid Value
  - Battery storage provides fast-ramping, bi-directional flexibility and energy shifting. Demand response provides peak load reduction and contingency support. Conventional peaker plants provide dispatchable energy but cannot absorb excess generation or shift energy across time.
  - Solar + storage supports renewable integration by shifting energy from midday to evening peak periods.
  - DERs can help manage distribution substation upgrades by optimizing dispatch to operate under substation limits, reducing or postponing the need for upgrades.
- Resilience, Health & Equity Benefits
  - Peaker plants are disproportionately located in disadvantaged communities and emit high levels of local pollutants.
  - Community solar + storage and DR improve local reliability while avoiding emissions and health impacts.
- Low Cost and Speed to Deploy
  - Demand response, efficiency, and distributed resources can be deployed in months to 1–2 years, compared to 5–10+ years for new gas peaker plants.
  - Load flexibility and energy efficiency programs are currently the lowest-cost resources for reducing peak demand.

U.S. Demand Response Capability

Points of reference:



Sources and Notes: Total U.S. demand response capability aggregated from utility-reported data in Form 861 (EIA, 2025) and FERC annual DR reports. Note that wholesale and retail DR may not be entirely additive. Comparisons made to CAISO system peak (CAISO, 2024) and ERCOT system peak (ERCOT, 2025). The equivalent number of combustion turbine peaker plants is estimated by scaling the national total capacity of peakers (261 GW across 1,087 plants in 2022; Clean Energy Group, 2025) to the average unit size. Illustrative comparisons provided for context.

Securing Capacity for Utility Systems: Two Possible Paths

- Traditional supply side solutions can be **slow to deploy, costly** and **emissions intensive.**
  - *Emerging model*: hyperscalers may directly procure or own firm capacity (e.g., combustion turbines), shifting investment risk away from ratepayers but requiring upfront capital and fuel supply arrangements.
- Strategic community-based investments in demand-side options may be able to **help deliver incremental energy and capacity needs and deliver benefits to local communities.**
  - These investments can lower peak demand and reduce energy consumption, allowing the deferral of new generation investments.
  - Well designed programs can also deliver meaningful community benefits, including **lower household energy bills** and **reduced CO_2 emissions.**
  - These measures could be deployed faster than new utility-scale generation or large thermal assets.

Centralized	Distributed
Utility or Hyperscaler-Owned Supply	*Customer- and Community-Based Resources*
Interconnection timelines for transmission-connected resources have doubled from <2 years (early 2000s) to 4+ years for recent projects.[1]	Distributed resources can be added quickly as customers adopt and enroll technologies, providing some near-term affordability relief
Hyperscaler-owned generation can accelerate deployment timelines but may face fuel supply constraints, permitting challenges, and equipment procurement bottlenecks	Can scale rapidly (e.g., California's Demand-Side Grid Support Program enrolled >700 MW in <3 years) [2]

1. Based on the median duration from interconnection request to commercial operations date. See Lawrence Berkeley National Laboratory Queued Up 2025 Edition.
2. See The Demand Side Grid Support Program: An Assessment of Scale and Value, 2025.

Table of Contents

Metrics compared across Measure Packages

Estimated Customer Bill Reductions

- Bill impacts reflect reduced electricity and fossil fuel consumption and demand response compensation (15-year PV of savings at 10% real discount rate assumed). Electricity savings are based on local retail rates; fuel savings reflect state-level residential gas and propane prices. Excess solar + storage production value is based on LMPs or system lambda to approximate avoided energy costs. Demand response compensation assumes typical program incentives based on recent utility offerings.
- Cost of reduction of electricity use is based on average energy charge for each city's relevant utility. Reduction in fossil fuel consumption (natural gas and propane) is based on the state average residential cost for each commodity in winter months.
- Region specific load shapes and savings estimates are derived from NREL ResStock and PVWatts.
- DR compensation assumed to be $50/year for participation in peak day events based on recent Brattle DR program analysis.

Total Addressable Market

- Customer eligibility is based on NREL ResStock data, mapped to housing characteristics. Candidate customers for heat pumps, weatherization, and AC DR were ResStock customers that have electric resistance heating, poor insulation, and central air AC, respectively.
- We estimate achievable levels of adoption in 3–5 years after program deployed, reflecting real-world constraints, including customer willingness, contractor availability, and program design. Participation levels are sensitive to subsidy design and financing structure—higher incentives or low/no upfront cost models can significantly expand uptake. Assumes program ramp-up over several years, with uptake rates informed by observed performance in comparable jurisdictions.
  - The estimates of total addressable market are adjusted based on known factors that could affect customer uptake. For example, research shows that 25-50% of income-eligible homes for the weatherization assistance program (WAP) are initially deferred due to health/safety issues that require repairs. Heat pump installation requires qualified contractors and can be a complex process that customers are only willing to undertake when their existing heating system reaches end-of-life. Customers' perception of a "lack of control" from DR programs can also be a hindrance to its widespread uptake.
  - Final portfolios shown assume 3% of weatherization candidates, 7.5% of heat pump candidates, 7.5% of candidate AC DR customers, and 5% of candidate solar + storage candidates.

Metrics compared across Measure Packages (cont'd)

Annual Emissions Reduction

- Emissions reductions from energy savings derived from heat pump, weatherization and solar + storage uptake are calculated for both electricity saving and fuel saving measures.
  - For electricity saving measures, the annual electricity reduction for each measure is used to calculate total emissions impact using the 2026 emissions rate by region from the 2024 NLR Standard Scenario results.
  - Given recent policies such as the repeal of the Inflation Reduction Act (IRA) clean energy tax credits, the emissions rate selected reflects a scenario without the IRA or Clean Air Act Section 111(d) regulations.
  - Fuel-related emissions were calculated for both natural gas and propane. Annual savings for fuel and propane due to heat pump and weatherization measures were used alongside EIA estimates for fuel-specific emissions rates.
- AC DR programs emissions impacts are not captured in this analysis since we assume a shift of energy usage not a net reduction in energy use.

Customer & Hyperscaler Economics

- Economics are evaluated from both the customer perspective (bill savings vs. out-of-pocket costs on a Net Present Value basis) and the hyperscaler perspective (subsidy required vs. capacity and system value potential).
  - Customer participation depends on achieving attractive payback periods, which may require targeted subsidies, especially for higher-cost measures like heat pumps and solar + storage. Hyperscaler contributions are modeled as upfront subsidies, though in practice these could be delivered through on-bill financing or third-party program structures.
  - For community solar + storage the program design is flexible and could be implemented by either the utility or a third party, potentially using on-bill financing. While costs are expressed here as upfront customer payments, in practice these could be financed and recovered over time, including "no money down" structures, which would likely support higher participation rates. We remain agnostic to the specific financing approach.
- Program design (e.g., incentive levels, financing, and delivery model) directly affects both participation rates and cost-effectiveness.

Metrics compared across Measure Packages (cont'd)

Capacity Value & Comparative Costs

- Firm capacity contribution for each measure is estimated as the average load reduction during peak hours, defined as a representative 4-hour peak window (e.g., 4–8 PM) on high-load days for each season, a proxy for system level tightness. For demand response, capacity is assumed to be summer-only, while other measures (e.g., heat pumps, weatherization, solar + storage) may contribute across both seasons.
  - A realization factor (~75%) is applied to reflect performance uncertainty and availability for heat pumps, weatherization and DR.
  - For solar + storage, seasonal ELCC values are applied to translate nameplate capacity into firm capacity, using 20% of installed capacity for solar and 80% for storage (PJM 2026/27 BRA IRM, FPR and ELCC Class Ratings and MISO PY 2025-2026 Indicative Direct Loss of Load (DLOL) Results)
  - Capacity value for AC DR programs is assumed to only apply in summer. Firm capacity value assumes 1 kW of peak reduction per home, consistent with recent Brattle work with utility flexible cooling programs (see New York's Grid Flexibility Potential, Table 7). DR program ELCC value is assumed to be 75%, consistent with PJM, SPP, and CAISO estimates.
- Firm capacity value is calculated by season (summer and winter) as the product of (i) the estimated firm capacity contribution (kW) and (ii) the corresponding seasonal capacity price ($/kW-year). Seasonal capacity prices are based on recent market benchmarks (e.g., PJM, SPP, CAISO), and total annual capacity value reflects the sum of seasonal contributions where applicable.
- Program cost to the hyperscaler is calculated as the total subsidy required to achieve modeled adoption for each measure. This is expressed on a $/kW basis by dividing total program subsidy by the corresponding firm capacity contribution for each measure, in the season where that measure contributes the most capacity. To translate this into an annualized $/kW-yr cost suitable for comparison with capacity market values, we apply a standard capital recovery framework, assuming a 10% real discount rate and a 15-year asset life.
- These costs can be benchmarked against the cost of new firm capacity from combustion turbines, assumed to be approximately $200-300/kW-year, see Appendix p.69 for summary of costs estimation.

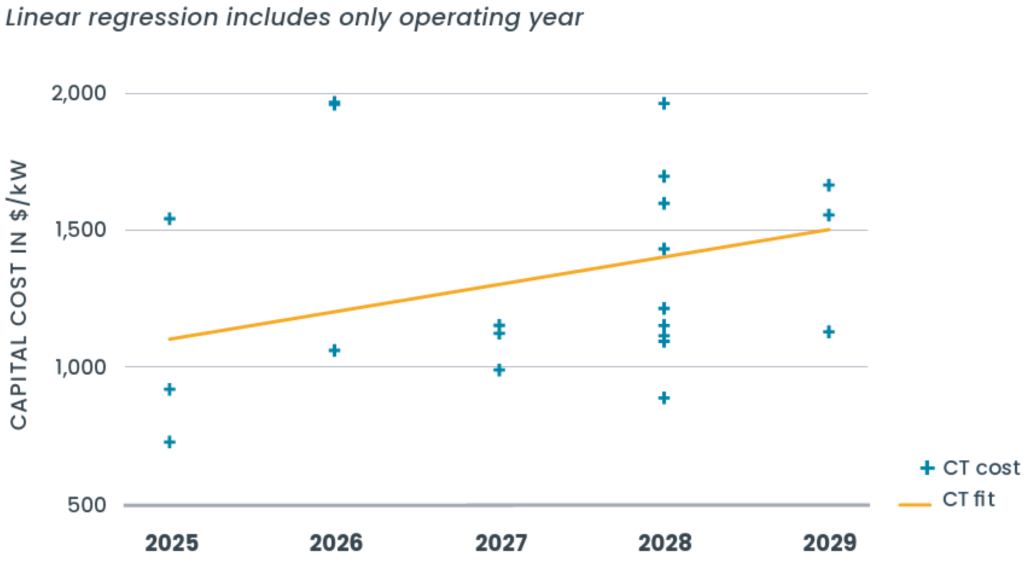
Description of measures modeled

- Customer load shapes are based on NREL End-Use Load Profiles (EULP) (ResStock), using geographically relevant profiles for each city. The customer profiles are calculated for each city, and the same usage profile is assumed for the broader metro area. To get from the customer level to the city and MSA level, we multiply the per-customer impacts by the number of participating customers in each measure and specified geographic area.
- Analysis uses the latest available version of the dataset, with hourly resolution and end-use disaggregation.
  - Upgrade packages analyzed include baseline package (upgrade 0), heat pump package (upgrade 4), heat pump water heater package (upgrade 9), air sealing + attic floor insulation (upgrade 15).
- Modeled measure packages include: energy efficiency retrofits, heat pump adoption, community solar paired with storage, and AC demand response.
- Eligibility criteria are defined for each measure (e.g., housing type, existing equipment, or baseline efficiency) to ensure realistic and non-overlapping participation assumptions.
  - For DR: Eligible homes are those with AC installed
  - For weatherization: Eligible homes are those with no roof insulation
  - For heat pumps: Eligible homes are those with electric resistance heating
  - For community solar + storage: Eligible homes are all homes in the city

Review of Upfront Cost Assumptions for Combustion Turbines

- Our estimates for the capital cost of a new gas CT are based on estimates from GridLab (2025), which report overnight costs for new gas combustion turbines of approximately $1,500/kW ($2025, for delivery in 2028-2029). To translate this into an annualized cost suitable for comparison with capacity market values, we apply a standard capital recovery framework, assuming a 10% real discount rate and a 15-year asset life (for comparison with the other measures).
  - These assumptions result in a capital recovery factor (CRF) of 0.13.
  - Applying this CRF yields an annualized capital cost of ~$195/kW-year in 2028 dollars.
  - To express this value in 2026 dollars, we apply a 2% annual inflation adjustment, resulting in: $198/kW-year in 2026 dollars.
  - Based on this derivation, we adopt a rounded benchmark assumption of ~$200/kW-year. This value represents a mid-range estimate of firm capacity costs for new gas CTs. It is intended to provide a reasonable comparator for evaluating capacity value in the context of DERs and other resource options.
- We further validate this estimate against a range of external sources, including: NREL Annual Technology Baseline (2024), EIA Annual Energy Outlook (2025), and Lazard Levelized Cost of Energy (2025).
- Importantly, recent data indicate that costs for gas turbines have increased in recent years, particularly for 2028–2030 delivery timeframes. Numerous press reports suggest overnight costs of $300/kW-yr for 2030+ delivery.

CT Costs vs. Operating Year



Source: Grid Lab (2025) "Gas Turbine Cost Reports." Reported capital costs reflect overnight costs for new combustion turbine units by projected online year. Values shown are in $2025.

Review of Upfront Cost Assumptions and Uptake Across Measures

We summarize installation costs and adoption assumptions for each DER measure, and benchmark these against alternative capacity investments (e.g., gas combustion turbines)

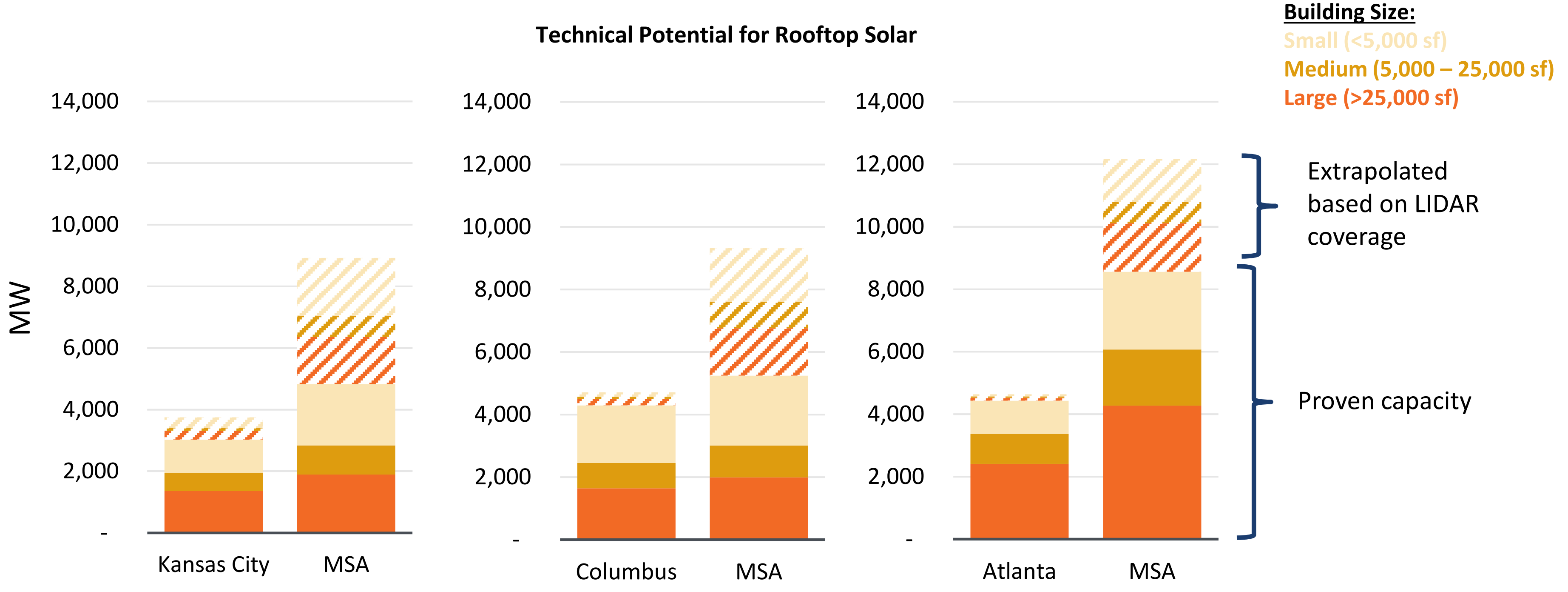
- **Scope and program assumptions**: These costs reflect costs of installation of technologies. They do not account for program start-up and maintenance costs (salaries, marketing etc). We assume collaboration with local utility to set up and run these programs.

	Solar + Storage	Heat Pump	Weatherization	Demand Response
Cost of Measure (Customer Cost without Subsidy)	Solar and storage costs are estimated at roughly **$1,800/kW and $2,000/kW** respectively based on NREL cost estimates (Reductions in U.S. Solar Photovoltaic System Costs and ATB), totaling **$20,000 per home** for a 5-kW share.	**Roughly $7,500** (EIA Updated Building Sector Appliance and Equipment Costs and Efficiencies)	**$2,000 per home** based on estimates of insulation costs of $1.50/sqft (across various insulation materials in National REMD) and average area of 1,250 sqft (EIA RECS)	Typical cost of a smart thermostat is estimated at **$75** (see New York's Grid Flexibility Volume II)
Participation rate of eligible customers	5%	7.5% (Northwest Energy Efficiency Alliance Heat Pumps Long-Term Monitoring and Tracking Report)	3% (Brookings)	7.5% (The State of Demand Flexibility Programs and Rates, LBNL)
Deployment Timeline	We evaluate program metrics assuming participation levels consistent with 3-5 years since program deployed.			
Subsidy Level	Calibrated for each city to achieve ≤3-year customer payback	$4,000 per heat pump	$2,000 per home (100% subsidy)	$75 (100% subsidy)
Customer Cost w/ Subsidy	Varies based on city subsidy level (*average of ~$2,300 across the four cities*)	~$3,500	$0	$0

Technical capacity of large rooftop solar deployment

We use this LIDAR-based estimate to check that our solar capacity estimations are well below total potential market in all cities.

- A 2016 study by NREL estimates the potential for rooftop solar using LIDAR data collected between 2004 and 2014.
- While these data are not comprehensive, and may not account for rooftop solar development that occurred since the LIDAR scan was performed, they provide the best available estimates of available rooftop space on large buildings (>25,000 sf) for solar installations.



Notes: The lower bound estimate (solid) is based on available LIDAR data for zip codes in the relevant metropolitan area. Because not all zip codes were comprehensively scanned, this represents a conservative estimate. The upper bound (solid + dashed) estimate multiplies the lower bound estimate for each zip code by the inverse of the percentage of the zip code scanned. This inherently assumes that the availability of rooftop space for solar is uniformly distributed throughout the zip code (e.g. if 1 MW is identified in a zip code with 50% LIDAR coverage, the upper bound estimate assumes that 2 MW is available in the complete zip code).

Memphis, TN does not have available LIDAR data; however, given its population falls between the other modeled cities, we assume a comparable technical potential—again, substantially larger than the uptake levels assumed in our analysis.

Methodology for Firm Capacity Accounting

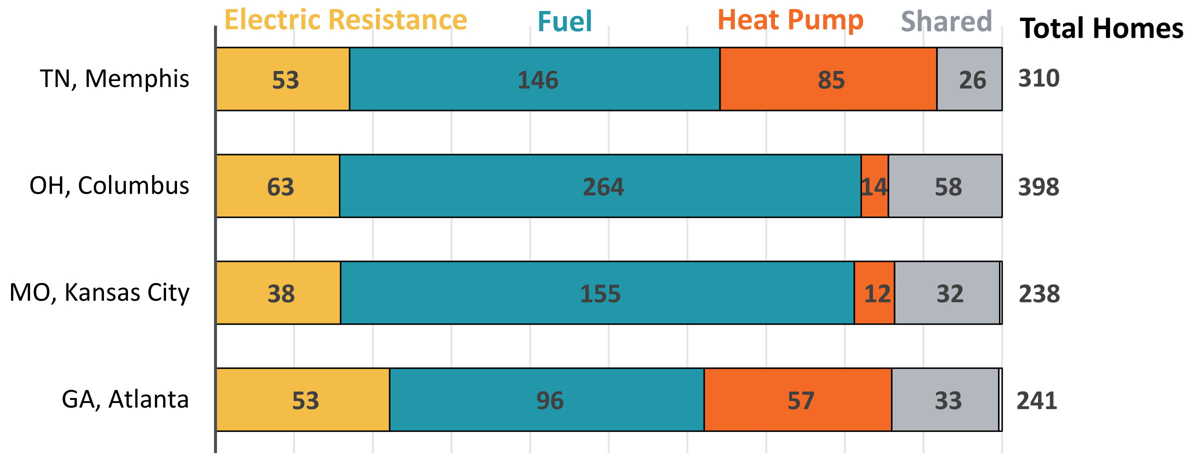
We estimate firm capacity contributions from each measure to quantify their impact on system peak demand and translate these into comparable cost and value metrics.

- The four cities modeled are primarily **summer-peaking systems**, with peak demand driven by cooling loads.
  - The key utilities in most cities are summer peaking (see Georgia Power, Memphis Light Gas and Water, and Evergy), though in Columbus, AEP Ohio is currently winter peaking. However, the peak load contribution of AEP in PJM is determined based on summer peaks.
- **Firm capacity (MW)** is defined as the load reduction during the peak for the season that the measure contributes the most to system needs.
  - For weatherization and heat pumps, the cost of firm capacity is estimated using the **average load reduction across the top four peak hours** on a representative *winter* peak day, using customer load profiles in the absence of system-level hourly peak data.
  - For **solar + storage**, the cost of firm capacity is estimated using **technology-specific *summer* ELCC assumptions applied to installed capacity**, reflecting the ability of these resources to reliably contribute during peak hours.
  - For **demand response,** the cost of firm capacity is estimated assuming 1 kW of peak reduction per participating customer, according to recent Brattle studies for flexible cooling programs in the *summer* only.
- All capacity contributions are **derated using realization factors** to reflect performance uncertainty, availability, and operational constraints:
  - Demand Response: 75%
  - Weatherization: 75%
  - Heat pumps: 75%
  - Community Solar + Storage: 80% storage and 20% solar (Summer ELCCs)
- For each city, we report:
  - Total firm capacity (MW) delivered by each program
  - Total unit cost ($/kW-yr) to the hyperscaler required to enable that capacity
- We also estimate the gross system value of capacity by applying recent market-based capacity prices (e.g., $/kW-yr) to the firm capacity estimates.
  - This cost of capacity metric does not capture energy benefits for any measures that accrue to customers or the emissions savings benefits that are socialized. We expect the highest benefits from a social welfare-maximizing resource investments to come from community solar + storage.

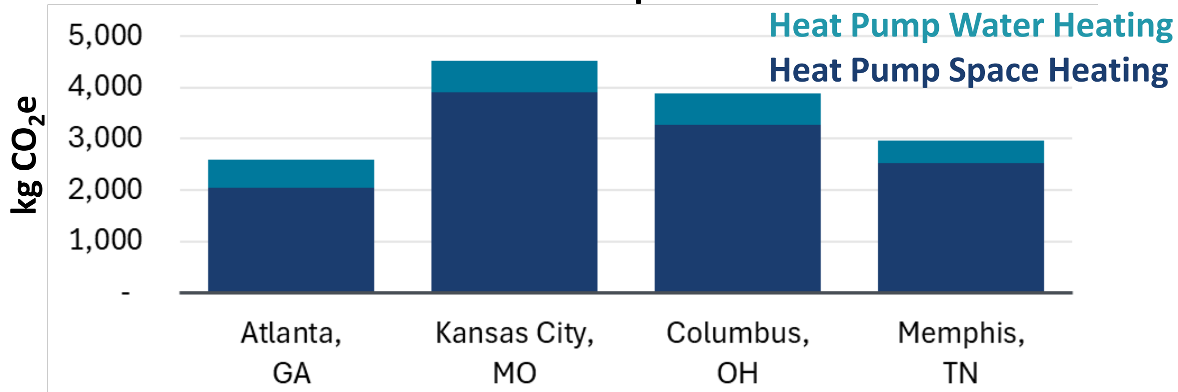
Heat Pump Adoption for Customers with Fuel Heating

- In all four cities, the plurality of customers use fossil fuel for space heating rather than electric resistance
- While installing heat pumps for these customers would increase both annual electricity consumption and winter peaks, this measure would still result in substantial emissions reductions
  - For the cities analyzed, average emissions reductions from converting from fossil fuel to electric heat pumps range from ~2,500 kg CO_2e per-home for Atlanta to ~4,500 kg CO_2e per-home in Kansas City, MO
  - These reductions are estimated using city-specific profiles. We expect similar reductions for participating customers in the broader MSA
- Installing heat pumps in these homes is also not guaranteed to reduce energy bills
  - Customers relying on fuel oil or propane would enjoy substantial bill savings
  - Customers presently heating with natural gas may see their aggregate energy bills increase[1]

Composition of Residential Heating Fuels by City (Thousands)[2]



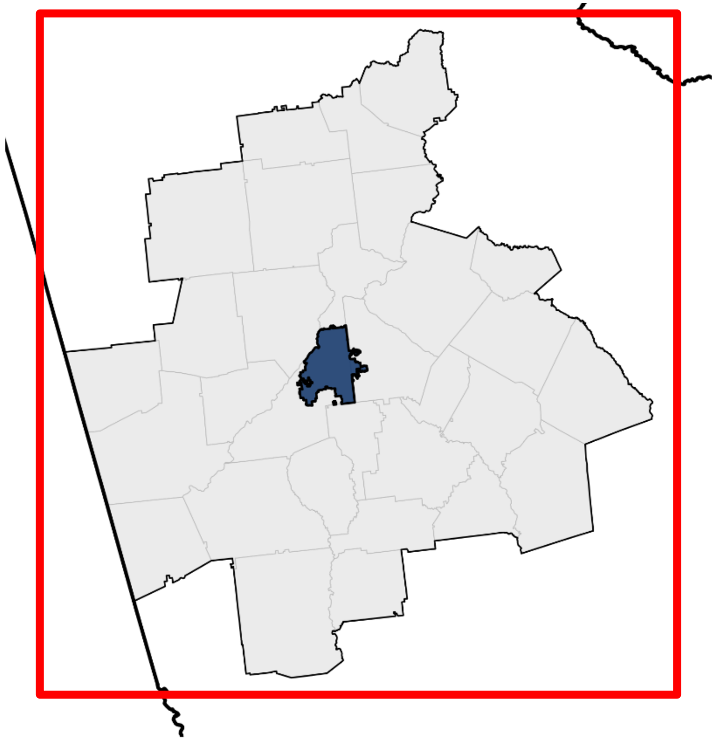
Emissions Reductions from HP Adoption in Fuel-Heated Homes



1. Rate design plays an important role in the relative cost of heating with electric heat pumps vs. natural gas furnaces/boilers. Volumetric electric rate design means that when a customer increases their consumption with a heat pump, they must bear a greater share of upstream fixed costs. A shift to more cost-reflective electric retail rates could improve the economics of electrifying for customers.

2. "Shared" heating refers to multifamily dwellings where multiple units are served by a single boiler or furnace. These homes are outside the scope of this analysis, as the cost and complexity of electrifying multifamily properties can vary significantly based on building typology and the layout of existing systems.

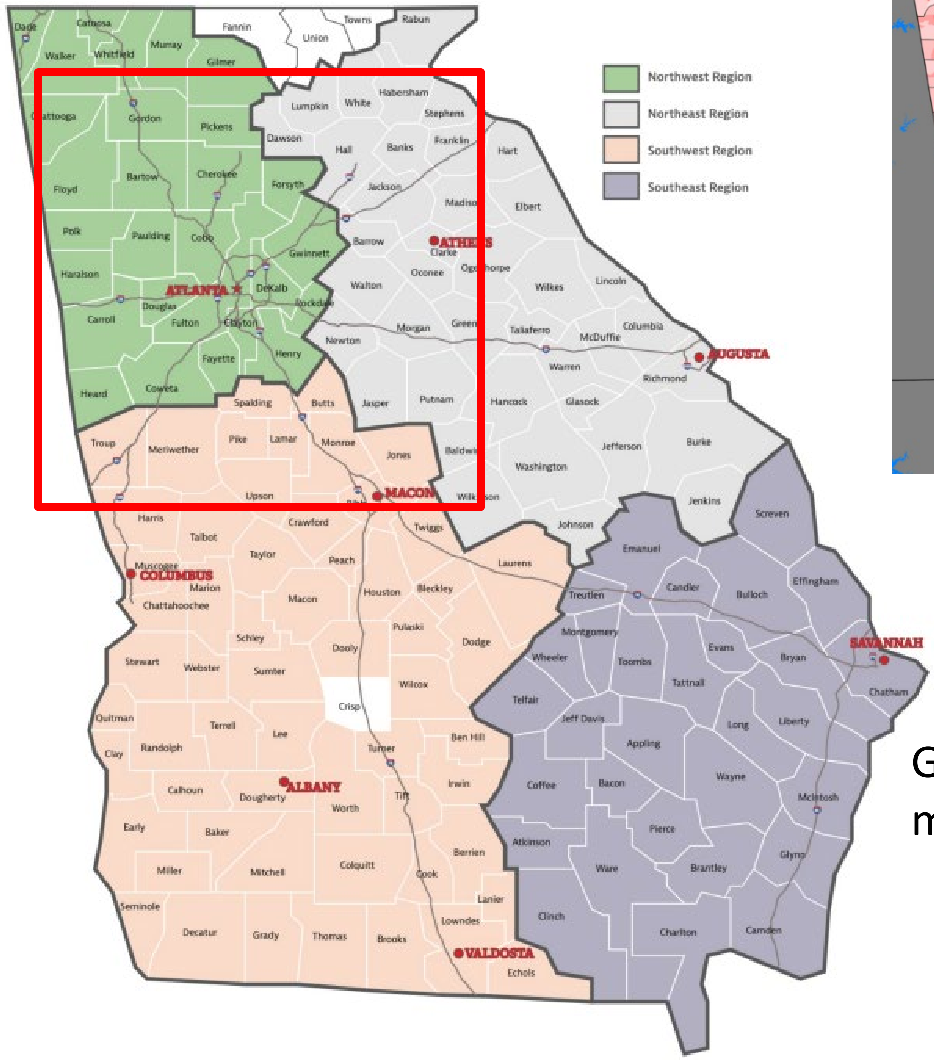
Atlanta, GA

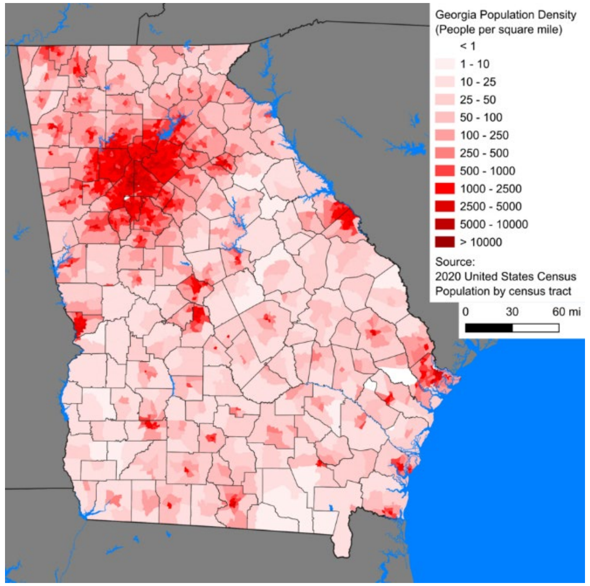


	Total Residential Customers
City Proper	241,000
Metropolitan Area	2,312,000

Atlanta City Proper

Metropolitan Area



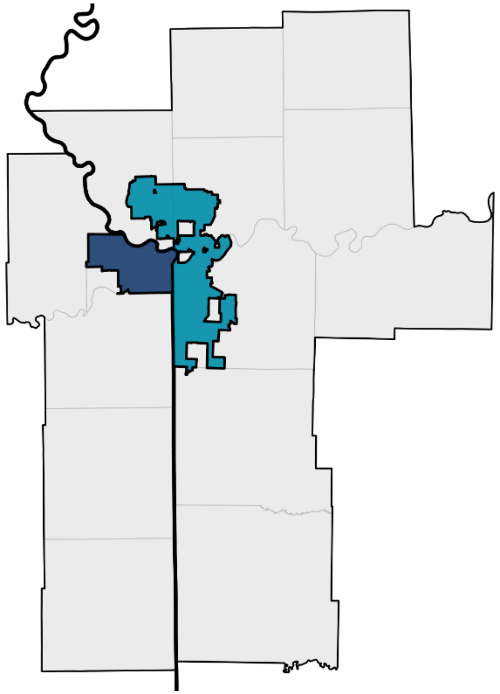


Population Density

Georgia Power serves ~2.5 million customers

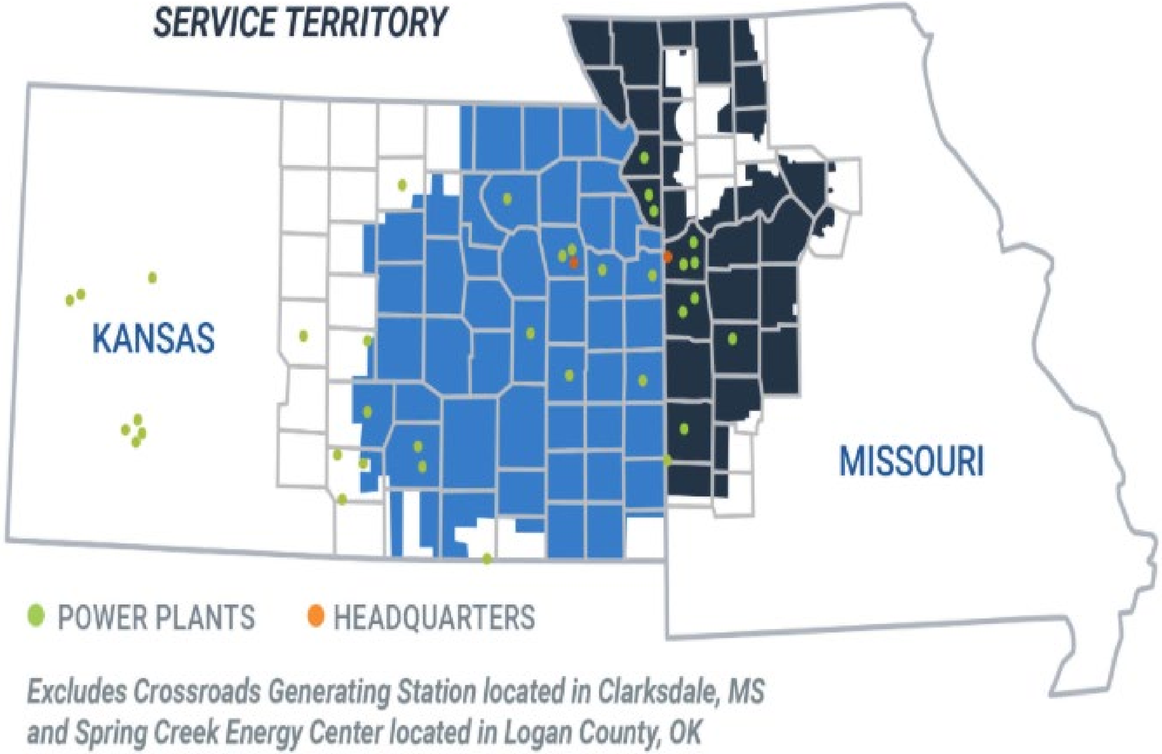
Sources:
https://www.eia.gov/electricity/data/eia861/.
https://www.georgiapower.com/content/dam/georgia-power/pdfs/residential-pdfs/GeorgiaPower_Regions_Map.pdf.
https://commons.wikimedia.org/wiki/File:Georgia_population_density_2020.png.

Kansas City, MO/KS



Kansas City, MO
Kansas City, KS
Metropolitan Area

	Total Residential Customers
City Proper (MO)	238,000
Metropolitan Area	922,000

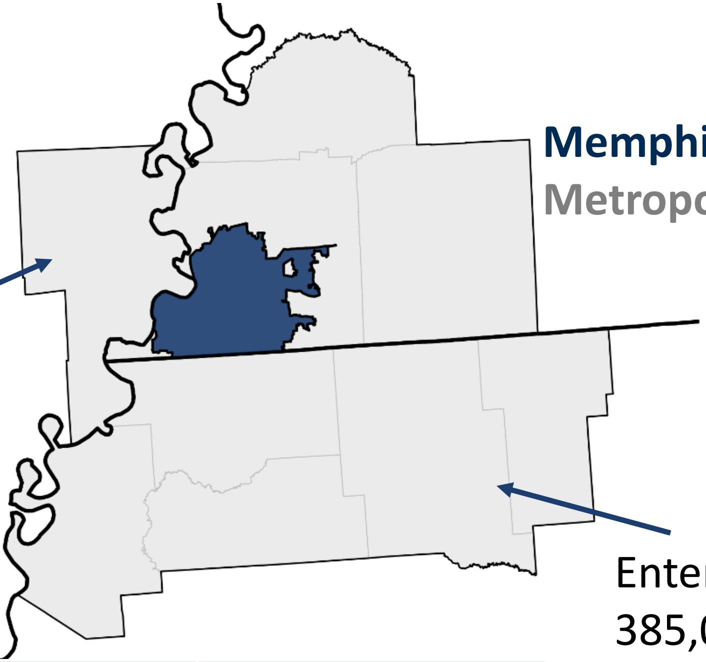


Evergy serves ~1.5 million residential customers across Kansas and Missouri

Sources:
https://www.eia.gov/electricity/data/eia861/.
https://investors.evergy.com/about-evergy/company-information.

Memphis, TN

Outside of the city proper boundary, customers are served by Entergy.



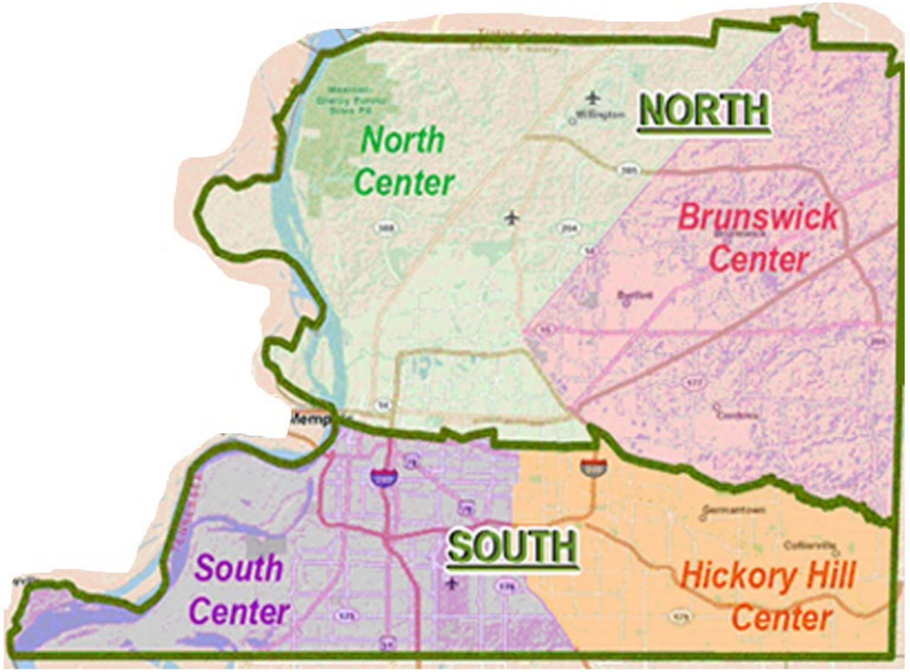
Memphis City Proper
Metropolitan Area

Entergy, AR
610,000 resi

Entergy, MS
385,000 resi

	Total Residential Customers
City Proper	310,000
Metropolitan Area	588,000

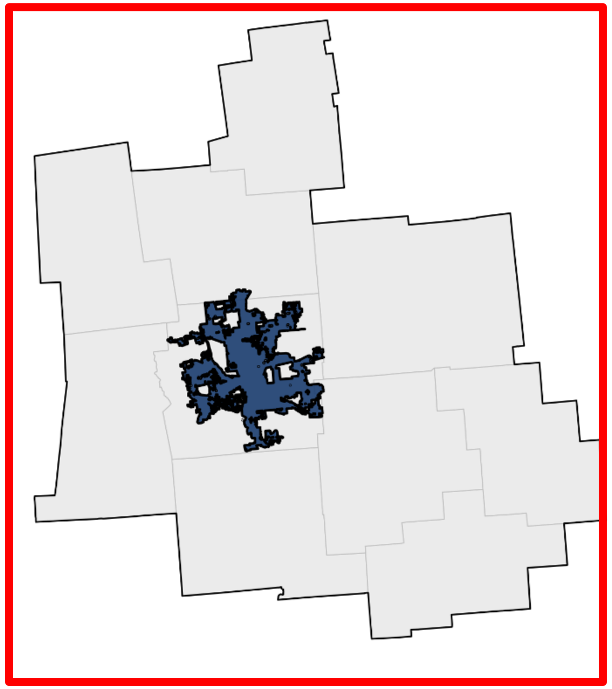
Memphis Light, Gas, and Water



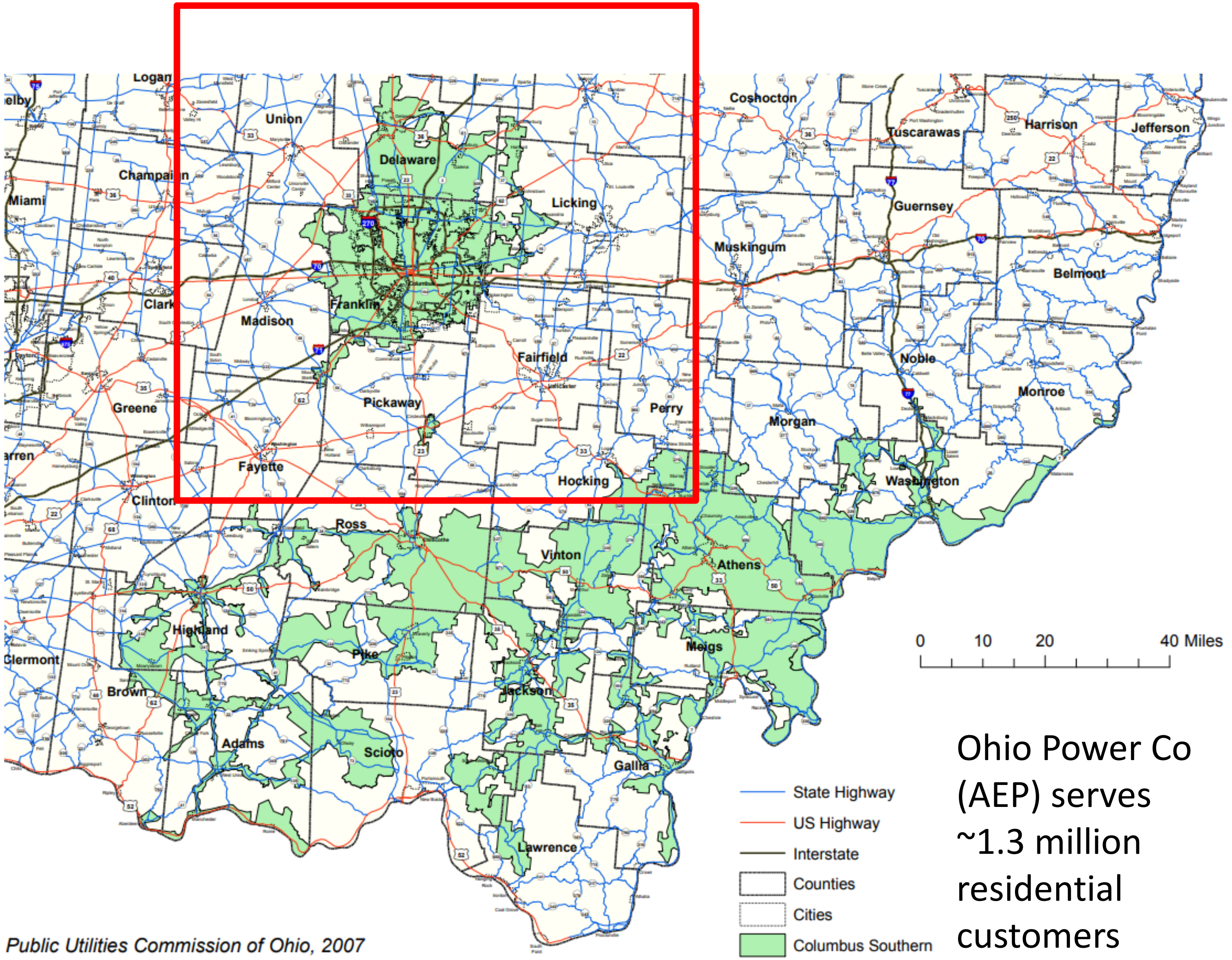
Memphis Light, Gas, and Water serves **380,000** residential customers

Sources:
https://www.eia.gov/electricity/data/eia861/.
https://www.mlgw.com/forms/commercial/temp_map_direct.php.

Columbus, OH



	Total Residential Customers
City Proper	398,000
Metropolitan Area	874,000



Public Utilities Commission of Ohio, 2007

Ohio Power Co (AEP) serves ~1.3 million residential customers

Sources:
https://www.eia.gov/electricity/data/eia861/
https://www.aepohio.com/lib/docs/company/about/choice/OH/ColumbusSouthernPowerMap.pdf.

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