Burying the Peak: Geothermal Heating and Cooling for Peak Reduction, Resiliency, and Cost Savings

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ABSTRACT

Geothermal (ground source) heat pumps (GHPs) are a proven technology for efficiently heating and cooling homes and buildings, but the peak electric demand reduction benefits of GHPs are often overlooked. The North American Electric Reliability Corporation identifies both summer and winter risks to electric grid reliability due to severe weather challenges and load growth from data centers and electrification of heating, and GHPs can provide critical grid benefits to address this growing concern. This paper analyzes ResStock and ComStock data sets from the National Laboratory of the Rockies to highlight the summer and winter peak impacts of GHPs compared to cold climate air source heat pumps and variable-speed rooftop units. The model incorporates local utility grid avoided cost data to quantify the economic value of avoided peak electric demand – demonstrating ratepayer benefits up to $45,000 per single-family home and over $300,000 per 10,000 square feet of commercial space.

Introduction

Geothermal (ground source) heat pumps are one of the most efficient forms of heating and cooling residential and commercial buildings (EPA). The high efficiency of geothermal heating and cooling can result in significant benefits to building owners – reduced energy usage, lower energy bills, reduced noise, and increased comfort. The North American Electric Reliability Corporation identifies both summer and winter risks to electric grid reliability across the country due to severe weather challenges and load growth from data centers and electrification of heating (NERC 2026), and GHPs can provide critical grid benefits to address this growing concern. The high efficiency of geothermal heating and cooling yields significant benefits to the electric grid in the form of peak demand reduction – and resultant lower infrastructure costs and rates – in both summer and winter. This benefit is often underappreciated in existing analysis and energy efficiency programs and is the focus of this paper.

System Design Options for Geothermal Heating and Cooling

Geothermal heat pump systems consist of three primary components: the ground loop, the heat pump, and the building distribution system (Akindipe et al. 2025, 40).

- *Ground loop*: The ground loop generally consists of a loop(s) of high-density polyethene (HDPE) pipe, buried in the ground or under a body of water, circulating potable water and (depending on the system design) a mixture of anti-freezing solution, often propylene glycol, a food-grade additive (DOE). In comparison to a typical air-source heat pump system, the ground loop takes the place of the outdoor condenser unit. Typical system designs are either open- or closed-loop, and either vertically-drilled, horizontally-trenched, or installed beneath a body of water (Akindipe et al. 2025, 41). Length of the ground loop, and the associated number and depth of boreholes, is determined by the overall seasonal heating and cooling needs of the building and the available space for the installation.

  - *Closed-loop systems* (the most common design in current practice) recirculate the same water solution through the heat pump and the ground loop for heat transfer in a continuous loop.
  - *Open-loop systems* withdraw ground or surface water, transfer heat to/from the water via the heat pump, then return the water into the ground or body of water.
  - *Vertical boreholes*, typically between 300-800 feet in depth,[1] provide greater capacity in a limited surface footprint.
  - *Horizontally trenched ground loops* offer lower-cost and easier installation where sufficient land area is available.
  - *Underwater loops* offer greater heat transfer than the ground due to higher thermal conductivity of water; other design features can include other sources of heat such as sewer/waste treatment or surplus process heat where available.
- *Geothermal heat pump*:[2] The GHP (often termed a "water-source heat pump" in commercial contexts) transfers heat from the ground loop to a refrigerant through a heat exchanger within the heat pump unit. Geothermal heat pumps have a form-factor similar to many heat pump/HVAC indoor air handler units, and generally fit within existing spaces in residential utility areas. In commercial buildings, the existing water-source heat pumps attached to a cooling tower or boiler heat transfer system are often similar (if not the same) units as for a geothermal system installation (WaterFurnace).
- *Building distribution system*: In residential buildings, heating and cooling is most typically distributed through central ductwork, though geothermal systems for hydronic heating systems are also available. Commercial buildings use a variety of distribution systems, including ducts and hydronics.

While geothermal heat pumps offer one of the most efficient and lowest-operating-cost heating and cooling systems, upfront costs of geothermal installation have remained a barrier to widespread adoption. The National Laboratory of the Rockies (NLR) estimates that just over 1% of buildings in the United States currently utilize a geothermal system for heating and/or cooling (Akindipe et al. 2025, 42).

State Heat Pump Goals Do Not Specify Share of Geothermal Heating and Cooling

States considering policies and goals for energy efficiency, peak reduction, or decarbonization must evaluate a range of potential technologies and incentive structures. Various states have established numeric heat pump deployment goals, but none have explicitly identified GHP deployment as a share of their overall heat pump targets. These overlapping goals, as depicted in Figure 1, include a target of deploying 20 million heat pumps in the 24 states of the U.S. Climate Alliance (USCA 2023), goals for heat pumps to represent 65% of residential space and water heating sales by 2030 (NESCAUM 2024), and individual state goals of installing 6 million heat pumps in California (Newsom 2022), 500,000 in Oregon (OR 2023), 420,000 in New Jersey (Murphy 2023), and 175,000 in Maine (Mills 2023). Widespread heat pump

[1] Vertical boreholes can be significantly deeper when necessary; the vertical boreholes installed to support St. Patrick's Cathedral in Manhattan are up to 2,200 feet deep (Otterman 2018).
[2] Direct use systems may not include a heat pump.

deployment can have significant impacts on electric grid peak demand in both summer and winter (Edwards 2020, Sergici 2023), and significant deployment of GHP systems in all states – even those without heat pump goals – can significantly improve outcomes for the electric grid.

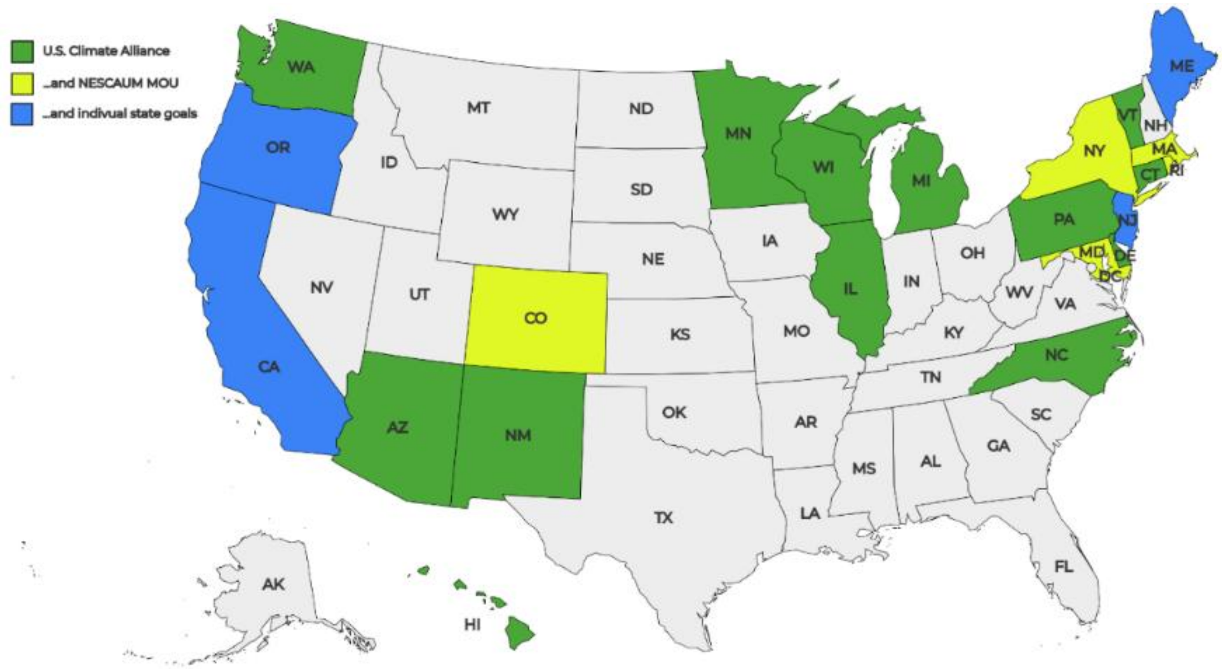

Figure 1. Twenty-four states have targets to promote heat pump deployment through Executive actions. *Source:* USCA 2023, NESCAUM 2024, Newsom 2022, OR 2023, Murphy 2023, Mills 2023.

Energy Efficiency Incentives May Not Reflect Full Benefits

Building owners evaluating options for HVAC systems rarely think about the impact their system will have on the electric grid; their primary considerations are upfront cost, operating costs, and comfort. Some jurisdictions offer energy efficiency incentives to encourage building owners to adopt technologies which provide cost savings to ratepayers or societal benefits, but in many states current incentives may not reflect the full benefits of geothermal heating and cooling to the electric grid. [3] Information published by the geothermal industry identifies only a handful of states with energy efficiency incentives for geothermal heat pumps greater than $5,000 (GeoExchange 2026).[4] This paper further explores the appropriate valuation of geothermal heating and cooling for peak reduction, and is intended to inform utilities, advocates, and policymakers as they develop programs for energy efficiency, demand reduction, or decarbonization.

[3] There are various reasons why an energy efficiency program may not fully reflect appropriate values for geothermal heating and cooling systems, including a lack of understanding of the technology, different assumptions of baseline alternatives, and, increasingly, due to values developed for utilities under flat load growth scenarios which are facing sudden load growth due to data centers. The value of peak reductions under a load growth scenario can be significantly higher than under flat load scenarios, and warrant reevaluation of existing incentives.
[4] States with incentives above $5,000 per residential system were identified to include Colorado, Connecticut, Illinois, Massachusetts, Maryland, New Jersey, New York, and Vermont.

Methodology

This paper seeks to quantify the peak electric demand reduction of GHP systems, as compared to existing building baselines and compared to a ccASHP (residential) or high-efficiency variable-speed heat pump rooftop unit (RTU)(commercial) alternative. We draw on data from the NLR ResStock and ComStock datasets to quantify the peak summer and winter demand impacts in various building types, then utilize other regulatory and public information sources to further quantify the benefits to the grid and ratepayers. ResStock and ComStock are datasets and modeling tools maintained by the NLR that offer "highly granular, bottom-up model[s] that [use] multiple data sources, statistical sampling methods, and advanced building energy simulations to estimate the annual subhourly energy consumption of the [residential and commercial] building stock across the United States." (Parker 2025, vii). Since 2024, ResStock and ComStock have included GHP systems, which enables new insights into peak electric impacts of GHPs in a variety of building types across the United States. While both datasets are models of simulated building stock and energy usage and do not include actual energy use data directly, they have conducted extensive calibration and validation to refine the accuracy of the models, including through comparison to utility meter data (Reyna 2025, 18).

GHPs in Residential Buildings – ResStock Analysis

We analyze ResStock 2025 Release 1 with actual meteorological year (AMY) 2018 weather data.[5] ResStock models baseline and upgrade outcomes for nearly 550,000 residential housing units, including single-family, townhouse, multifamily, and mobile housing units, distributed across the United States. We assessed the baseline conditions, a ccASHP, and a two-stage geothermal heat pump; the details of the upgrades are further described in Table 1.

Table 1. ResStock upgrade descriptions

Upgrade	Details
Cold Climate Air Source Heat Pump ("upgrade4")	Models a variable speed ducted air source heat pump (ASHP) (HSPF2 8.5, SEER2 17.5) with electric resistance backup. Applicable dwellings must have a ducted HVAC system heated by electricity, natural gas, propane or fuel oil (no wood or other fuel). The heat pump is sized for heating or cooling according to ACCA Manual J and Manual S.
Residential Two-Stage Geothermal Heat Pump ("upgrade7")	Models a two-stage GHP (4.0 COP, 20.5 EER) with vertical ground heat exchanger. Applicable dwellings must have a ducted HVAC system heated by electricity, natural gas, propane or fuel oil (no wood or other fuel). They must be within a low-rise building with less than 8 stories. The heat pump is sized for heating or cooling according to ACCA Manual J and Manual S.

Source: NLR 2025; Reyna 2025, 114, 126.

We then apply the following filters to the dataset:

- *GHP and ccASHP applicability*: We filter for buildings where both the GHP and ccASHP upgrade were identified as applicable in ResStock (based on the criteria in

[5] The 2025 release for ResStock and ComStock currently only includes AMY 2018; AMY 2012 is "coming soon," and it is unclear whether NLR will release a typical meteorological year (TMY) dataset.

Table 1) to ensure we only compare results for buildings where both systems are an option (384,118 buildings).

- *Occupied Buildings*: We filter for occupied buildings to reflect the impact only for occupied residences (338,425 remaining buildings).
- *100% Conditioned Buildings*: We filter for buildings where the baseline is 100% conditioned; while buildings which currently have less than 100% conditioned space will also benefit from GHP or ccASHP upgrades, they will also experience greater increases in peak summer demand due to the addition of capacity cooling for the building. For comparison purposes, we drop these from the analysis to ensure we are only assessing the impact of the GHP system itself, not the additional cooling benefit. This has a comparatively greater impact on buildings in the further northern latitudes of the United States. (268,135 remaining buildings).
- *Missing heating and cooling data*: A number of records in the ccASHP and GHP datasets show a zero value for electric heating usage or electric cooling usage; this occurs even in climates where heating and cooling are essential for comfort. We believe these records to be a data error, and they are therefore excluded from the results (262,655 remaining buildings).

We then sort the remaining buildings by state and by building type, and compare the summer and winter peak values for the baseline and the GHP and ccASHP upgrades.

GHPs in Commercial Buildings – ComStock Analysis

We analyzed ComStock 2025 Release 3 with AMY 2018 weather data. ComStock models baseline and upgrade conditions for nearly 150,000 commercial buildings of varying types distributed across the United States. We assessed the baseline conditions, a variable-speed heat pump RTU, and a comprehensive geothermal heat pump package; the details of the upgrades are further described in Table 2.

Table 2. ComStock upgrade descriptions

Upgrade	Details
Variable-speed Heat Pump RTU ("upgrade1")	High-efficiency heat pump RTUs are modeled as top of-the-line with variable-speed compressors/fans allowing for high-performance part load operation. The heat pump is sized to the design cooling load. Supplemental electric resistance heat is used for any additional heating. This upgrade package applies to 45% of all floor area included in the dataset.
Comprehensive Geothermal Heat Pump Package[6] - ("upgrade59")	Includes a variety of GHP system designs, based on the best fit for retrofit of the existing building heating and cooling system (only one upgrade is modeled for any individual building). This upgrade package applies to 80% of all floor area included in the dataset.

Source: CaraDonna 2024.

We then apply the following filters to the dataset:

[6] Includes Hydronic GHP (water-to-water), Packaged GHP (water-to-air through existing ductwork), or Console GHP (water-to-air without ducts).

- *GHP and RTU applicability*: We filtered for only buildings where both the GHP and RTU upgrade were identified as applicable within the ComStock dataset based on the existing building configuration (54,498 buildings).[7]
- *Missing heating and cooling data*: A number of records show a zero value for electric heating usage or electric cooling usage; this occurs even in climates where heating and cooling are essential for comfort. We believe these records to be a data error, and therefore exclude them from the results. (54,034 remaining buildings).

ComStock presents building peak electric demand as the maximum daily peak for a given month; this is in contrast to the ResStock value which presents the single highest hourly demand for the building across the entire summer and winter season. We therefore average the summer peak daily maximum for the months of June July and August, and the winter peak daily maximum for the months of December, January, and February. We sort the remaining buildings by state and by building type, and compare the summer and winter peak values for the baseline and the GHP and RTU upgrades using the weighted square-footage of the buildings within ComStock. As there is greater variety in building types and heating and cooling requirements in the commercial space, we present the results in terms of kW of peak savings per 10,000 square feet of building space; this provides an easily understandable reference to put the saving in context, and is often more understandable than a per-building or per-system-tonnage metric. A retail example of a building of this size might be a local hardware store.

Valuation of Grid Impacts

We then quantify the value to the electric grid from the geothermal heating and cooling peak reductions in four states, selected to represent a variety of current and future winter-peaking grid scenarios: Colorado, Maine, Maryland, and Washington.[8] To inform the analysis, we relied upon regulatory filings from major utilities or energy efficiency programs in each state to identify the value of avoided capacity and average system-wide costs of transmission and distribution (T&D) [9] in dollars per kW-year. We also identified whether the current electric grid is summer- or winter-peaking, and any projections for a transition to a winter peak. We then calculate the real dollar present value of capacity and T&D due to geothermal heat pumps based upon their peak savings compared to a ccASHP/RTU alternative. We evaluate capacity and T&D based on their projected summer or winter peak for each year in the 25-year time horizon of the analysis.[10] We use the utility weighted average cost of capital rate as the nominal discount rate, with an assumed inflation rate of two percent to convert to a real discount rate.[11]

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[7] The significant reduction in buildings is primarily driven by the applicability of the RTU scenario (55,556 buildings) rather than the GHP scenario (134,868 buildings).
[8] States were also chosen based on availability of utility data regarding avoided costs, which is not readily available in all states; for example, winter-peaking states in the Southeast often have predominant vertically integrated utilities without published avoided capacity or transmission and distribution values.
[9] While T&D costs are often location-dependent, few utilities publish avoided distribution values on a circuit-level basis. This research relies on the system-wide average values presented in utility filings.
[10] We selected 25-years based on the typical design life of the geothermal heat pump (ICC 2023, 544); this understates the full grid benefits, as the ground loop has an expected design life of 50+ years and will continue providing benefits well beyond the time horizon in this analysis (DOE).
[11] For greater discussion of appropriate discount rates in benefit cost analysis practices, see: Michals 2024, 45-49. We use a 2% value for inflation based upon the long-term target by the Federal Reserve.

Results

In comparison to ccASHP and high-efficiency RTUs, GHP upgrades yielded peak demand savings for both summer and winter across all states and all building types.

Residential

As compared to baseline HVAC of air conditioning or air source heat pumps, GHP are assessed to provide meaningful summer peak demand reductions. Winter peak impacts of GHP deployment depend on original fuel source: GHPs provide substantial winter peak savings compared to electric resistance and air source heat pumps, while increasing winter peak demand modestly as compared to fossil fuel sources (electrification of heating). In contrast to GHPs, ccASHPs are modeled in ResStock to increase summer peak demand as compared to existing baseline air conditioners and air source heat pumps. This result seems counterintuitive at first – higher efficiency heat pump equipment would generally be expected to reduce summer peak demand compared to legacy air conditioning. Based on discussions with the NLR ResStock staff, this is attributed to the ccASHPs being sized to address 100% of the building heating load, which in most states requires them to be significantly larger (in terms of capacity/tons) than the prior air conditioning or heat pump units. These larger systems drive higher system peak demand due to their larger size – despite the higher efficiency of the new units. These larger systems also provide a comfort benefit in reducing unmet hours for cooling as compared to the legacy air conditioning (NLR pers. comm., February 3, 2026).[12] The comparison of GHPs and ccASHP to the existing national baseline for single-family homes is presented in Table 3, and for medium multifamily buildings (defined as 5-9 units) in Table 4. At the individual state level, GHPs achieved peak savings compared to ccASHP for all states in both summer and winter, with higher winter savings consistent with larger performance degradation of ccASHP (and backup electric heat) for colder weather hours. Table 5 presents the state-by-state results for residential single-family detached homes and housing units in medium multifamily buildings.

Table 3. GHP and ccASHP peak savings vs. baseline– single-family detached homes[13]

Existing Heating and Cooling Source	GHP Peak Savings per Home (kW)		ccASHP Peak Savings per Home (kW)	
	Summer	Winter	Summer	Winter
Existing ASHP	1.3	7.4	0.0	1.6
Electric Resistance + AC	1.5	8.0	0.1	2.3
Natural Gas + AC	0.9	-4.3	-0.6	-13.2
Propane + AC	0.8	-4.5	-0.4	-14.3
Fuel Oil + AC	0.7	-5.4	-0.4	-15.7

[12] This building-level increase in summer peak demand due to ccASHP likely overstates the true impact on the summer grid; since these systems are oversized for cooling, they are unlikely to operate continuously at their peak summer demand for an extended period. When aggregated across many units, the overall coincident peak demand is expected to be lower than the individual building peak demand. This dynamic would also be true to GHP systems, but the effects are more pronounced for ccASHP. An initial review of the timeseries ResStock results confirms that the summer peak demand is often not sustained for an extended time period for any individual unit. These dynamics are less likely to affect winter peak demand, where ccASHP and GHP systems are expected to run continuously at their maximum output.

[13] Note that negative savings values reflect an increase in peak demand.

Table 4. GHP and ccASHP peak demand savings vs. baseline– medium multifamily units

Existing Heating and Cooling Source*	GHP Peak Savings per Unit (kW)		ccASHP Peak Savings per Unit (kW)	
	Summer	Winter	Summer	Winter
Existing ASHP	0.2	1.8	0.0	0.2
Electric Resistance + AC	0.2	1.6	0.0	0.1
Natural Gas +AC	0.1	-1.0	-0.2	-3.7

* Propane/fuel oil not reported due to low volumes

Table 5. Peak demand savings of residential GHP compared to ccASHP, by state

State	Single-Family Detached – Peak Savings per Home (kW)		Medium Multifamily – Peak Savings per Unit (kW)		State	Single-Family Detached – Peak Savings per Home (kW)		Medium Multifamily – Peak Savings per Unit (kW)	
	Summer	Winter	Summer	Winter		Summer	Winter	Summer	Winter
AK	*	*	*	*	MT	1.0	12.0	0.3	5.3
AL	1.3	6.6	0.2	1.4	NC	1.3	6.7	0.3	2.0
AR	1.7	7.6	0.3	1.9	ND	0.9	18.0	0.2	5.2
AZ	2.0	1.7	0.3	0.1	NE	1.5	16.4	0.6	4.1
CA	1.0	2.6	0.1	0.2	NH	1.1	11.7	0.4	2.2
CO	1.0	9.8	0.3	2.0	NJ	1.8	10.2	0.5	2.5
CT	1.1	10.6	0.4	4.2	NM	1.4	6.9	0.1	1.5
DC	2.0	11.0	0.3	2.7	NV	1.9	3.0	0.4	0.3
DE	1.4	8.1	0.4	2.3	NY	1.3	11.4	0.4	3.1
FL	1.1	2.0	0.2	0.2	OH	1.2	10.8	0.3	2.9
GA	1.2	5.9	0.2	1.8	OK	2.5	8.8	0.4	2.3
HI*	0.9	0.5	*	*	OR	1.3	6.3	0.2	1.2
IA	1.2	17.8	0.3	3.5	PA	1.1	9.9	0.3	2.6
ID	1.3	7.5	0.2	3.2	RI	0.9	9.4	0.6	2.9
IL	1.6	14.5	0.5	4.0	SC	1.2	5.7	0.2	1.6
IN	1.2	12.9	0.4	3.3	SD	1.0	15.3	0.4	3.4
KS	2.1	11.8	0.6	3.1	TN	1.3	7.8	0.3	2.2
KY	1.2	9.2	0.4	3.1	TX	2.1	5.9	0.3	1.1
LA	1.7	6.1	0.3	1.0	UT	1.4	7.1	0.4	1.8
MA	1.2	12.1	0.3	2.8	VA	1.2	8.2	0.3	2.3
MD	1.5	8.4	0.4	2.3	VT	0.9	16.6	0.7	3.8
ME	0.6	12.4	0.2	2.6	WA	1.0	7.2	0.2	1.8
MI	1.2	10.9	0.4	3.1	WI	0.9	12.4	0.4	3.7
MN	1.0	15.3	0.3	4.0	WV	0.9	9.1	0.2	2.0
MO	1.8	11.8	0.5	2.6	WY	0.7	11.4	0.6	4.4
MS	1.5	6.9	0.2	1.3	**Overall**	**1.4**	**7.8**	**0.3**	**1.8**

*Indicates no units met all filter criteria

Commercial

Similar to the results in the residential sector, GHPs achieved summer and winter peak savings for all building types and for all states as compared to high-efficiency RTU upgrades. As compared to baseline commercial cooling and heating equipment, GHP are assessed to provide meaningful summer peak demand reductions. Winter peak impacts of GHP deployment depend on original fuel source: GHPs provide substantial winter peak savings compared to electric resistance and air source heat pumps, while increasing winter peak demand modestly as compared to fossil fuel sources (electrification of heating).

Table 6 presents the GHP and RTU national average results for commercial buildings by type, and Table 7 presents the results for GHP vs. RTU for commercial buildings by state. These results highlight a key distinction that is often overlooked between GHP and high-efficiency air source heat pump units – while ASHP and RTU may provide robust annual energy savings (kWh), their impacts on peak power demand (kW) are more nuanced, with modest improvements in winter compared to other electric heating sources, and uncertain summer peak demand with systems sized for full electrification. GHPs, in contrast, provide reliable summer peak reductions across all states and building types, and offer significant reductions in winter peak demand compared to ccASHPs and RTUs.

Table 6. GHP peak demand savings vs. baseline building stock for commercial buildings

Building Type	GHP Savings vs. Baseline per 10,000 sqft (kW)		RTU Savings vs. Baseline per 10,000 sqft (kW)	
	Summer	Winter	Summer	Winter
Primary School	31.3	-3.9	15.5	-77.1
Secondary School	42.7	11.6	21.7	-89.4
Grocery	24.1	11.1	11.4	-24.1
Hospital	27.5	26.0	13.4	18.0
Outpatient	43.2	26.1	28.1	-18.6
Retail Stand-alone	38.4	14.7	20.0	-26.4
Retail Stripmall	49.2	10.5	27.7	-42.6
Restaurant – Full Service	67.1	-25.1	22.0	-61.3
Restaurant – Quick Serve	62.7	14.2	22.6	-23.5
Small office	24.5	11.7	13.7	-19.8
Medium office	14.4	19.4	8.5	-6.1
Large Office	20.8	-26.8	10.2	-104.3
Warehouse	11.4	2.4	7.9	-14.7
Overall	**33.3**	**6.7**	**17.2**	**-29.2**

Table 7. Peak demand savings of commercial GHP compared to high-efficiency RTU, by state

State	Per 10,000 sqft of commercial buildings – all types (kW)		State	Per 10,000 sqft of commercial buildings – all types (kW	
	Summer	Winter		Summer	Winter
AK	2.4	57.4	MT	14.2	78.1
AL	18.2	19.5	NC	12.7	23.0
AR	22.0	34.2	ND	12.6	94.3
AZ	27.3	6.6	NE	15.0	87.1
CA	22.1	6.8	NH	13.5	70.2
CO	14.7	42.8	NJ	13.5	38.9
CT	16.1	64.6	NM	17.6	19.2
DC	13.8	26.0	NV	22.6	9.6
DE	14.6	31.4	NY	13.8	54.2
FL	13.7	5.4	OH	15.5	62.1
GA	13.8	13.7	OK	23.7	40.5
HI	26.1	18.9	OR	10.3	17.1
IA	16.0	88.5	PA	14.1	40.3
ID	13.9	38.0	RI	12.5	71.4
IL	14.5	80.7	SC	14.6	12.2
IN	15.9	62.8	SD	16.4	100.7
KS	18.0	56.8	TN	16.0	27.8
KY	14.5	42.1	TX	18.5	10.0
LA	18.9	11.1	UT	16.0	23.5
MA	16.0	60.6	VA	11.6	25.1
MD	13.0	29.4	VT	12.2	80.1
ME	13.4	75.5	WA	11.3	19.6
MI	15.3	64.3	WI	13.1	80.9
MN	14.7	97.1	WV	14.6	58.4
MO	18.8	58.2	WY	14.2	69.1
MS	19.2	19.4	**Overall**	**16.2**	**35.9**

Grid Benefits Valuation

To further quantify the dollar value impact of these peak reduction savings, we relied upon a variety of regulatory filings to identify avoided cost values in each state; these values are described below and summarized in Table 8. We use a consistent inflation rate of 2% across all states to convert nominal to real dollars.

- *Colorado*: We use an avoided capacity value of $15.29/kW-month, avoided transmission value of $10.01/kW-year, and avoided distribution value of $2.72/kW-year (Xcel 2024). We project a potential transition to a dual summer and winter peak by 2032 based on analysis conducted for Xcel Energy by the Brattle Group (Hledik 2022). We use the Xcel weighted average cost of capital of 6.95% approved in the latest electric rate case as the nominal discount rate.

- *Maine:* Efficiency Maine Trust (EMT) uses the Avoided Energy Supply Components in New England: 2024 Report ("AESC 2024") results as the basis for the calculations of the avoided capacity costs (Synapse 2024). AESC 2024 publishes a range of scenarios (counterfactuals); we assess results for counterfactual #5, which models "a future in which program administrators continue to install new energy efficiency, active demand management, and building electrification resources," (Synapse 2024, 1) and which we view as the most consistent with existing policy.[14] We use the AESC future capacity values for summer and winter, ranging from $17-$114/kW-year (Synapse 2024, 158) and a nominal discount rate of 6.13% (the current yield of a 10-year Treasury bond plus 200 basis points)(EMT 2023, 11).[15] EMT further establishes an avoided transmission value of $43.31/kW-year (pooled transmission), $20.81 (non-pooled transmission), and an avoided distribution value of $278.18/kW-year based upon a study conducted by Synapse (Synapse 2024, 299); we apply these to summer or winter peak values consistent with the projected scenarios for overall ISO New England grid peak.
- *Maryland*: We use an avoided capacity value of $121.7/kW-year, based on the latest PJM capacity market auction results (PJM 2025).[16] We use avoided T&D value of $222.77/MW-day (BGE 2024). We project a potential transition to a winter peak on the distribution system by 2032 based on analysis conducted for the Maryland Public Service Commission by the Brattle Group (Sergici 2023); we therefore use summer peak values for capacity valuation and transition from summer to winter peak values for T&D beginning after 2032. We use the BGE weighted average cost of capital of 6.75% as the nominal discount rate (BGE 2023).
- Washington: We use an avoided capacity value of $135.69/kW-year and avoided T&D value of $82.45/kW-year (PSE 2025). PSE current experiences a winter-peaking system, so we use winter peak reduction values for capacity and T&D.[17] We use the PSE weighted average cost of capital of 7.16% (PSE 2025) as the nominal discount rate.

[14] The results for counterfactual (CF) #1 and CF#2 are generally similar, and the results for CF#3-CF#6 are generally similar in magnitude, with some variation. CF#1 and CF#2 assume a cessation or significant reduction in the installation of energy efficiency, demand management, and building electrification measures, and we assess these to be inconsistent with current policies and therefore less likely; these scenarios result in a continued summer peaking system through 2050. In contrast, CF#3 through CF#6 assume sustained deployment of energy efficiency, demand management, and building electrification, and generally result in a winter peaking ISO NE grid by 2035.
[15] As of March 7, 2026.
[16] This auction was subject to, and met, a price cap of $333.44/MW-day; true capacity costs are likely even higher.
[17] The increasing adoption of air conditioning within Washington state could also lead to a dual summer and winter peaking system under certain scenarios.

Table 8. Summary of avoided cost values and electric grid costs for different states

	Capacity ($/kW-year)	Transmission ($/kW-year)	Distribution ($/kW-year)	Projected Transition to Winter Peak	Nominal Discount Rate (%)
Colorado (Xcel Energy)	$183.48*	$10.01	$2.72	2032	6.95
Maine (Efficiency Maine)	Up to $114	$64.12	$278.18	2035	6.13
Maryland (BGE)	$121.70**	$81.31**		~2032 (Distribution only)	6.75
Washington (Puget Sound Energy)	$135.69	$82.45		Presently Winter Peaking	7.16

*converted from kW-month **converted from MW-day. *Sources*: See above.

Based on these values, each GHP systems installed provides the following incremental grid value over a ccASHP/high-efficiency RTU system, as detailed in Table 9:

Table 9. Present value of peak reduction from GHPs compared to ccASHP (residential) and RTU (commercial) in different states

	Per Single-Family Detached Home	Per Unit in Medium Multifamily Building	Per 10,000 sqft of Commercial Space
Colorado	$18,744	$3,821	$91,961
Maine	$45,854	$9,873	$307,100
Maryland	$9,660	$2,596	$51,137
Washington	$21,962	$5,635	$59,895

These values reflect only the incremental grid benefits of a GHP over a ccASHP/RTU unit; the overall benefits of GHPs (and ccASHP/RTU) are higher due to inclusion of emissions and energy bill savings. These results indicate strong benefit to the electric grid from geothermal heating and cooling as compared to even high-efficiency ASHP and RTU. The magnitude of the grid benefits vary widely across states, driven by differences in capacity prices, local costs for the transmission and distribution system, and anticipated timing of a winter-peaking grid. These grid benefits are generally higher – in some cases significantly higher – than the incremental incentives offered to GHPs under demand side management programs, indicating potentially undervaluation and missed opportunity for ratepayer savings, as the lower peak demand of GHPs can translate to lower overall costs to ratepayers through reduced infrastructure costs.

Recommendations for Further Work

Certain areas of this analysis would benefit from further refinement of assumptions or additional data, which should be the focus of future research in quantifying these benefits:

- *Comparison to real-world data:* The analysis could be further strengthened by anchoring the ResStock and ComStock data with real-world performance data. Geothermal industry practitioners have provided informal feedback that ResStock may underestimate the efficiency of GHP systems and predicts a lower annual average COP than expected based on their experience.

- *Coincident peak:* ResStock and ComStock provide values for the individual building peak, which may not align fully with the peak periods on the local grid. While there is assumed to be significant alignment based upon the high correlation of weather and heating and cooling load to peak grid conditions, additional work to compare the peak savings at the grid peak periods is warranted (EIA 2020). ResStock provides aggregated state-level timeseries for measure upgrades and ComStock provide peak reductions at grid peak, but these values are very narrow and do consider changing grid conditions for the current peak to a new peak time as the grids shift to a winter peak.
- *Expansion of grid value analysis to further states and utilities:* Converting peak reduction values from kW into dollars is critical to providing easily understandable context for policymakers, yet the data to do so is often lacking or difficult to find. The value of avoided capacity, transmission, and distribution are sometimes addressed in utility regulatory proceeding or energy efficiency programs, but the treatment is often inconsistent and difficult to locate. Further research to identify and improve the transparency of the avoided cost values used in utility energy efficiency and other proceedings would support the energy efficiency industry in conveying value to policymakers.

Conclusions

Geothermal heating and cooling represents a significant increase in efficiency and performance compared to ccASHP and high-efficiency RTU units on the coldest and hottest days. The benefits to the electric grid from this higher efficiency is substantial—in grids that are currently winter-peaking, or are predicted to be winter peaking within the next 10-15 years, the value of the GHP system to the grid may represent a significant majority of the overall benefits of the technology. As an example, Maine has adopted policies to successfully deploy 100,000 ccASHP in the state; installing GHPs instead could have provided an additional 1.2 GW of winter peak reduction, at an estimated grid value of $4.6 billion.[18] These savings in turn could put downward pressure on rates, helping to lower electric costs for everyone on the grid.

In many cases, the value of existing utility program incentives do not fully reflect the value of geothermal heating and cooling systems to the electric grid. Policymakers and stakeholders should incorporate these findings into policy decisions—from incentive programs to financing mechanisms to workforce development. Geothermal heat pump systems therefore present a significant opportunity for the building sector to transform the way we heat and cool buildings, with significant benefits to building owners, grid operators, ratepayers, and society at large.

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[18] Estimated as 100,000 homes at 12.4 kW of peak reduction (Table 5) and $45,854 (Table 9) of grid value per home.

datasets. This analysis leveraged artificial intelligence tools for assisted search and identification of original source materials.

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