Electricity Rates That Keep Bills Down after Electrification of Home Heating

Matt Malinowski, Reuven Sussman, Paul Mooney, and Grace Lewallen

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Research Report

ACEEE

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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Data and licensing information

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Executive Summary

Note: this is a corrected version of a paper published in March 2025 that incorporates significant changes in electricity and gas rates across the analyzed regions. The results in all four states have changed, and the conclusions of the paper have been revised to reflect the updated results.

Key findings

- In terms of rate design, the best way to encourage heat pump adoption for home heating and keep energy bills down is to offer a heat pump–specific electricity rate. Pairing heat pump installation with energy efficiency envelope upgrades further decreases ongoing electricity bills. These types of rates simplify decision making for customers.
- A winter electricity discount is a key rate structure change for ensuring energy bills do not increase in cold climates, which is where (in the United States) the economics of heat pumps are most challenged. Time-of-use and demand-based rate plans can also help reduce ongoing costs for heat pump users. Conversely, flat-rate plans increase costs for heat pump users.
- Nonfinancial barriers also prevent home electrification. Utilities work with contractors to improve knowledge and awareness. They can also provide tools and services that simplify the process of home electrification (e.g., bill calculators and visualizations alongside a recommended new rate when beneficial) and engender trust with consumers (e.g., through transparent communication). These and other behavioral strategies can increase residential electrification and satisfaction of consumers who have electrified.
- As a long-term investment strategy, electricity should be made as affordable as possible for consumers, as doing so enables electrification and the switch away from fossil fuels. State and federal investments in transmission and distribution will make electricity, and thus electrification, more affordable relative to natural gas across the United States. This affordability will compound with an anticipated long-term change to natural gas prices (bringing them more in line with electricity prices), a trend that can be accelerated with the implementation of clean heat standards or putting a price on carbon.

Electricity rates that keep bills down after home heating electrification with heat pumps

Electrification is the process of replacing fossil fuel–based technologies or systems with electric equivalents. With the U.S. electricity grid currently supplied by 40% zero-carbon sources[1] and this percentage increasing, electrification is a key part of greenhouse gas emissions reductions and climate change mitigation.[2] However, households are unlikely to electrify their homes if their energy bills will increase (or if they believe their energy bills will increase). In this report, we focus on post-electrification energy bills, but upfront costs are also an important barrier to electrification that should be addressed.[3]

In cold climates, once a home is electrified, its biggest electricity use in the home is space heating. We simulate energy bills in four regions of cold-climate U.S. states (using actual utility rates in those regions) under different home heating electrification scenarios and provide recommendations for policies and programs in those states to mitigate potential cost increases. The four states are among the most expensive in the United States for electrification and differ from most of the United States, where electrification is generally cost effective. We examine energy efficiency, electricity rates, fossil fuel rates, and novel financial strategies as potential solutions to mitigate energy bill increases. To encourage adoption, we suggest how to roll out solutions with the help of behavioral science principles.

Heat pumps always reduce energy bills for oil and propane users; can do so for natural gas with better rates

In our simulations of annual energy bills in four cold-climate states, customers who were previously using fuel oil or propane for space heating saw, on average, noticeably lower bills when installing an efficient cold-climate heat pump.[4] Although this finding is based on our simulations of four states, given similarities in rates and contexts, it likely applies to fuel oil and propane users across all or most cold-climate U.S. states (17% of fossil fuel–heated homes in these states). However, in all four states we examined with very high electricity prices relative to natural gas prices, the average gas household saw energy bills increase after home heating electrification. We examined how rate structure changes, efficiency improvements, and broader policy changes and investments could help keep energy bills down in these states.

In particular, we simulated energy bills of single detached residential buildings in regions of Minnesota, Colorado, Maine, and Connecticut, before and after electrification of home heating with efficient cold-climate heat pumps (using actual utility rates in those regions as a base).[5] We examined how bills might

[1] EIA. 2024. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files." Energy Information Administration. www.eia.gov/electricity/data/eia861/.
[2] Cleary, Kathryne. 2022. "Electrification 101." Resources for the Future, March 24. www.rff.org/publications/explainers/electrification-101/.
[3] See Appendix A for a brief discussion of upfront costs, rebates, tax credits, and loans.
[4] Fuel oil and propane are typically much more expensive as home heating fuels than natural gas. In Connecticut, for instance, our simulations found the two fuels to both be roughly twice as expensive as gas. Although we focus on conversion from fossil fuels to electricity in this report, customers switching from electric resistance heating to efficient cold-climate electric heat pumps would also see reduced energy bills.
[5] In each state, we used the rates of utilities serving the majority of customers in that state.

change in these states if energy efficiency envelope and appliance upgrades were included with electrification and if the home were on various electricity rate plans.[6]

Ensuring electrification does not increase energy bills

In any cold-climate U.S. state, the ongoing bills are lowest with cold-climate heat pumps when heat pump adoption is accompanied by energy efficiency improvements and a favorable electricity rate plan. Heat pump-specific rate plans are best for incentivizing heat pump adoption, with winter discounts being a potentially important facet of those plans. These rates are generally based on the cost of service for heat pump customers, without subsidizing other customer classes. Given homes with heat pumps use more electricity, particularly during off-peak periods, the cost of servicing these homes is different, as more of their use is during periods of lower grid strain. In absence of these types of rates (e.g., in places where technology-focused rates are not an option), time-of-use rates, demand-based rates, and simpler winter discount rates also favor heat pump adoption. In nearly all cases, these rates are revenue neutral for the utility's current customer base; however, they also have the added benefit of attracting new load and increasing electricity use (thus increasing overall revenues and helping to offset any potential revenue losses when rates are not revenue neutral).[7]

The various potential solutions can be seen in our state-specific analyses. In Minnesota, the utility we examined (serving approximately half of residential customers) offers a 31% winter discount for electricity that can be combined with a time of use rate (available to all electrically heated homes served by that utility).[8] After whole-home electrification and building envelope improvements,[9] average energy bills decrease from $2,680 with natural gas heat to $2,591 under the winter discount TOU rate. If the utility offered a winter discount demand-based rate, annual energy bills could drop further; an average of $2,576. With only heat pump and insulation (no additional electrification), energy bills of homes under a winter discount demand-based rate are still similar to those of natural gas-heated homes ($2,719/year).

In Colorado, the winter discount of the utility we examined (serving just over half of residential customers) is much smaller (~10%), so switching from natural gas to an efficient cold-climate heat pump would, on average, increase annual energy bills for single family homes. However, if the utility offered the Minnesota-level winter discount and TOU rate, then homes installing a heat pump alongside envelope upgrades would see energy bills like those of natural gas-heated homes ($1,941/year for gas, versus $1,975/year for heat pump customers). Adding whole-home electrification measures or pairing the winter discount with a demand-based rate (rather than TOU rate) could potentially reduce energy bills below that of natural gas users' bills (as it does in Minnesota), but this would require verification through additional analyses.

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[6] We did not include residential solar power as a method for offsetting the operating cost of an electrification upgrade, but generally, solar energy acts as a price hedge for electrification. This is because when the cost of electricity rises, the value of the solar power generated rises as well. However, photovoltaic solar panels are expensive, particularly when also updating the heating system and improving insulation and thus are not available to everyone.

[7] In our analyses, we simulate rates with current customers. Although we are confident that competitive electricity prices would increase the frequency of electrification, we could not estimate precisely how many customers would electrify their home heating system as a result of lower electricity rates.

[8] Anecdotally, we have heard that homes wanting to participate in Xcel Energy's Limited Off-Peak rate program for electric heat in Minnesota may require an electrician to install a submetering device for electric equipment. However, these details are unclear as requirements are not publicly available outside the service territory in Minnesota.

[9] Including insulation, heat pump and heat pump water heater, ENEGY STAR electric dryer, and induction stove.

In Maine and Connecticut, fuel oil and propane customers (representing a combined 41% of homes in Connecticut and 66% of homes in Maine in 2023)[10] can save money through electrification. However, natural gas users switching to a heat pump for electrification would see bills increase. The ratio of electricity to gas price is too high to be overcome with rate structure or efficiency changes in these states. Here, as in other states where electricity is much more expensive than gas, the states should consider deep public investment (not ratepayer-funded) in making electric power more affordable to their residents. This could include taking on some costs of grid maintenance and upgrades, putting a price on carbon, or implementing clean heat standards[11] that place performance requirements on all heating market actors. Fortunately, this high an electricity-gas price ratio is rare [12] and gas prices are expected to naturally increase in the coming years relative to electricity.[13]

Behavioral strategies supporting residential electrification

Despite energy bills staying the same or going down after electrification, nonfinancial barriers may still pose a challenge to electrification. Behavioral strategies can be used to enhance the energy savings messaging. The biggest barrier to electrification of home heating is a lack of awareness: awareness of heat pumps as an option for fossil fuel–heated homes and awareness that electric home heating could occur without increasing bills. To increase awareness, a traditional marketing and outreach campaign could be helpful. Providing the information through traditional media, social media, mailers, bill inserts, or in-person events is effective for educating customers.[14]

HVAC contractors can also be a key barrier to heat pump adoption. Contractors have misperceptions about the efficiency and costs of heat pumps: They see them as complex, and they believe the installation would be complicated and difficult. They feel pressured to complete jobs quickly and thus avoid lengthy discussions or challenging installations. Embedding more in-depth heat pump information in HVAC training courses, providing incentives to contractors, encouraging effective discussions with homeowners, and supporting a shift from getting jobs done quickly to maximizing homeowners' long-term satisfaction can help with electrification initiatives.[15]

Changing default rate plans for customers who electrify can be an effective strategy, but it must be done carefully, with great transparency and with repeated communication and outreach so as not to erode trust. Engendering trust with utilities offering electrification packages is critical to encouraging uptake. Trust is facilitated with transparent communications and community engagement that may take the form of working with local community-based organizations (e.g., housing counselors, neighborhood groups, local community leaders, or religious and cultural groups).

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[10] Maine fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=ME; Connecticut fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=CT

[11] A guide for applying clean heat standards is available from the Regulatory Assistance Project. Santini, Marion, Samuel Thomas, Richard Lowes, Duncan Gibb, Richard Cowart, and Jan Rosenow. 2024. "Clean Heat Standards Handbook." Regulatory Assistance Project. https://www.raponline.org/knowledge-center/clean-heat-standards-handbook/.

[12] For an extended analysis of where the costs may increase after electrification, readers can refer to analyses conducted by the National Renewable Energy Lab. NREL. 2024. "Heat Pumps for All—Economic Data | Tableau Public." Heat Pumps for All—Economic Data. February 14, 2024. https://public.tableau.com/app/profile/nrel.buildingstock/viz/Heatpumpsforall-Economicdata/Coverpage.

[13] An analysis of Maryland's gas prices provides an example of how electrification will increase, leading to a declining gas customer base and increased prices. OPC Maryland. 2022. "Climate Policy for Maryland's Gas Utilities." Office of People's Counsel, State of Maryland. https://opc.maryland.gov/Gas-Rates-Climate-Report.

[14] Kassirer, Jay. 2024. "Tools of Change." Tools of Change (blog). 2024. https://www.toolsofchange.com/en/tools-of-change/.

[15] Steiner, Ellen, and Kristin Heinemeier. 2024. "Spark the Switch: Overcoming Barriers to Heat Pump Adoption and Electrification." Presented at the BECC Webinar, November 19. https://beccconference.org/webinar-3/.

Recommendations

Electric Utilities and State Regulators: Provide electricity rates that favor heat pumps while still adhering to cost of service principles. Heat pump–specific rates are best for encouraging heat pump adoption. Winter discounts are critical and time-of-use rates or demand-based rates can also benefit electrification of home heating.

Federal and State Policymakers: Consider providing some public (non-ratepayer) investment in electricity distribution and transmission, put a price on carbon, and/or implement clean heat standards.

Program Administrators and Implementers: Use behavioral strategies to encourage electrification and shift consumption patterns. Raise awareness of heat pump electrification as an option for home heating and show how costs compare to other options. Work with contractors to dispel myths, provide training, and empower discussions about electric heating with customers.

Introduction

In this report, we simulate energy bills in four cold-climate U.S. states under different home heating electrification scenarios and provide recommendations for policies and programs in those states to mitigate potential cost increases. The four states are among the most expensive in the United States for electrification and differ from most of the United States, where electrification is generally cost effective. Moreover, the analyses are conservative because they are based on climate data from 2018 and global warming increases temperatures and improves the economics of home heating electrification.[16] We examine energy efficiency, electricity rates, fossil fuel rates, and novel financial strategies as potential solutions to mitigate energy bill increases, but the primary tool we examine are electricity rate structure changes. To encourage heat pump adoption, we provide suggestions on how to roll out solutions with the help of behavioral science principles. This report is intended to provide guidance to state and federal policymakers, electric utilities, state regulators, program administrators, and program implementers.

Electrification is the process of replacing fossil fuel–based technologies or systems with electric equivalents. With the U.S. electricity grid currently fed by 40% zero-carbon sources (EIA 2024a) and this percentage increasing, electrification is a key part of greenhouse gas emissions reductions and climate change mitigation (Cleary 2022). It is also a driver of job creation in the energy economy (Jones, Zamora-Duran, and Lipman 2024)[17] and it improves health by eliminating combustibles and the associated air pollution they create inside homes and workplaces (Grobler 2023). For these reasons, electrification has become a high priority for governments at all levels and organizations working to improve health and fight climate change.

Space heating is the biggest driver of electricity use in homes after electrification. Aside from lack of awareness about heat pumps (CEE and BIT 2024), the expectation that energy bills will increase after electrification is the top barrier for electrifying space and water heating in the United States, especially in cold climates such as the Northeast and Midwest (Sussman and Eisen 2024). In some cases, this expectation may be justified—without changes in electricity rates, energy efficiency upgrades, or behavior changes, electrification could result in costs increasing.

In recent years, a major strategy for driving electrification has been government incentives. With the Infrastructure Investment and Jobs Act (IIJA) of 2021[18] and the Inflation Reduction Act (IRA) of 2022, the U.S. federal government made available billions of dollars for clean energy investments, many of which are specifically designed to encourage homeowners to electrify their homes. The cost of upgrading to an all-electric home is high, and these incentives are a critical step in helping homeowners afford to upgrade. However, the incentives help cover the upfront costs of electrification and not the ongoing increases in energy bills that occur in some regions. In states where energy bills might increase, governments and advocates should find financial solutions for making the math of electrification work (i.e., ensuring annual energy bills do not increase) before encouraging residents to switch. This is particularly true for residents with high energy burdens who already spend a high percentage of their incomes on energy (Ayala and Dewey 2024).

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[16] We initially ran our analyses using ResStock™ typical meteorological year (TMY3), which is based on an average climate from 1976–2005, but when we re-ran our analyses using 2018 actual meteorological year (AMY), we found that energy bills for heat pump users were lower. NREL experts, responsible for developing and maintaining ResStock™, note that global warming explains this change.

[17] From 2022 to 2023, energy efficiency jobs increased 3.4% with air-source heat pump–related employment, specifically, increasing by 2.6% (Jones, Zamora-Duran, and Lipman 2024).

[18] Sometimes called the Bipartisan Infrastructure Law.

In this report, we focus on energy bills. In particular, we examine how electricity rate structures and energy efficiency improvements can be used to keep energy bills down after electrification of heating systems with efficient cold-climate heat pumps. However, readers can refer to Appendix A for a brief discussion of the upfront costs of electrification and how they can be reduced through rebates and tax credits.

Monthly energy bills

While upfront costs can be reduced using financial incentives, energy bills are more difficult to manage because they are paid monthly and depend on variable factors such as the global fuel market and customer energy usage. Still, there are economic mechanisms to make electrification more favorable.

Alternative billing structures

The most basic type of monthly electricity bill includes a flat rate for servicing a residence and a rate per kilowatt-hour (kWh) of electricity used, which covers the generation, transmission, and distribution costs of the electricity. When utilities charge the same per-hour kWh rates at all hours of day, the cost of electricity at off-peak hours is higher than it should be (because the electricity used has a lower marginal cost) and the cost of electricity at on-peak hours is lower than it should be (when peaker plants and higher marginal-cost sources are being used). The distribution and transmission costs are based on peak demand, and therefore, increasing off-peak demand has little to no impact on these costs.

This flat-rate billing structure overcharges heat pump customers. Relative to those with other heating types, electric heating customers use more electricity during off-peak hours.[19] This is particularly true in the winter, when electric heating customers' greatest electricity demand is heating their homes at night. As shown in figure 1, the post-electrification home actually has a usage spike occurring just before dawn, during the coldest part of the night in the coldest time of year.[20]

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[19] In our analysis, all TOU rates defined peak periods as being somewhere between the times of noon and 9 p.m. on weekdays year-round.

[20] While this example focuses on Connecticut, this is true generally of the United States, with the coldest part of the night typically occurring in the early morning before sunrise. In these simulations, residential electricity usage tapers off after midnight, with the intersection of these two time periods (around 2 a.m.) having the highest average usage.

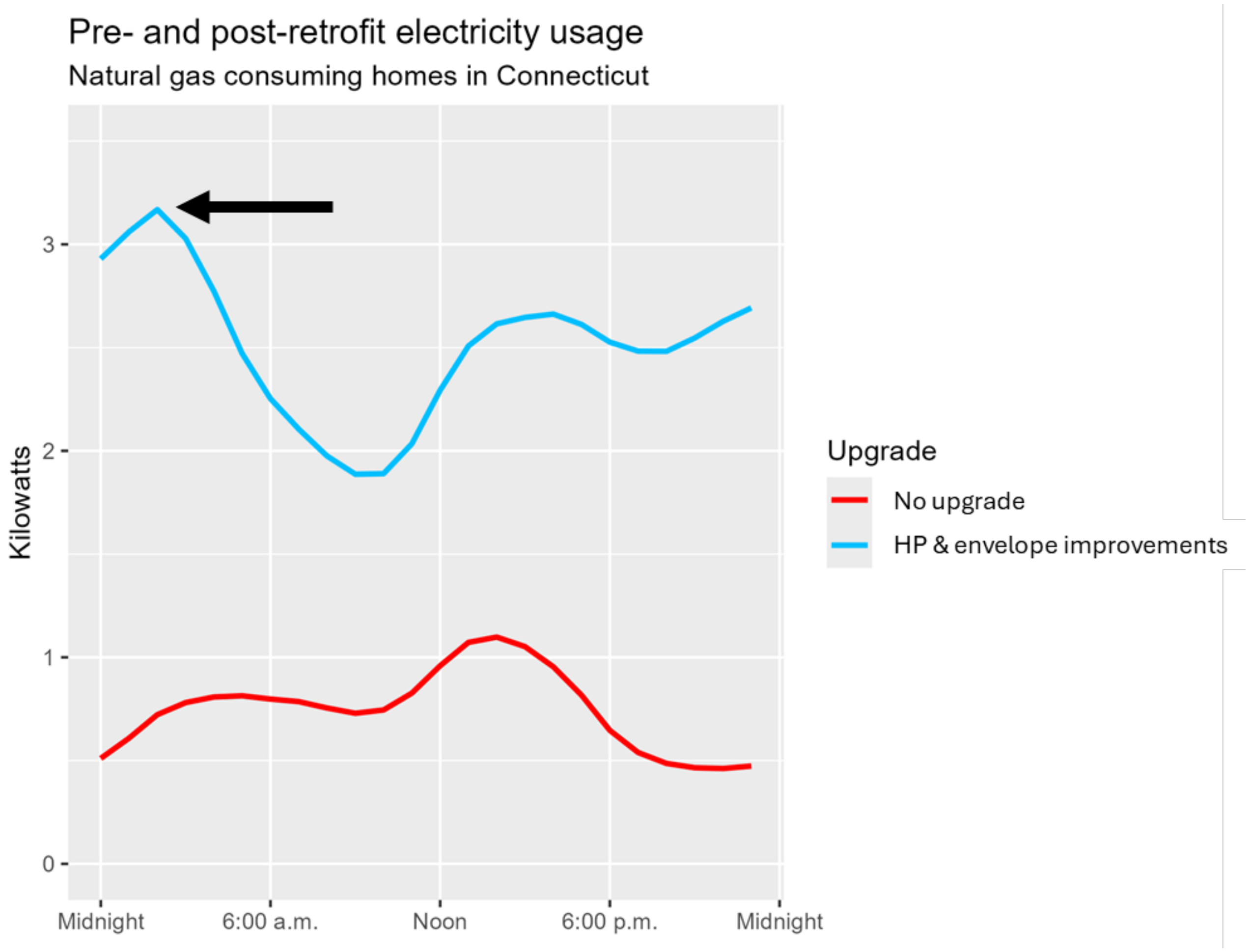

Figure 1. Average load pre- and post-electrification for homes in Connecticut in the month of January

Conversely, fossil fuel–heated homes use fossil fuels (usually gas) to provide heat during those off-peak hours. Most of the electricity use for those homes is during peak hours of the day, such as cooking (if cooking with electric appliances) after work, when everyone else is also cooking, watching TV, and so forth (Torriti 2012a). In summer, these afternoon/evening peaks for fossil fuel–heated homes are particularly large as they are layered with air-conditioning use. During this time, these customers are putting much more strain on the grid by using electricity when everyone else is too, though they are being charged the same rate as customers using electricity at off-peak hours (e.g., overnight).

Compared to their fossil fuel–burning counterparts, heat pump and other electric space heating customers have a peak load that is proportionally closer to their average use of electricity during the winter months of heavy use. Therefore, rate designs that favor heat pumps are rate designs that favor these steadier and higher load profiles (including lower off-peak prices).

Time-of-Use (TOU) Rates

Under a TOU rate, per-unit kWh prices are higher during a peak period and are discounted during off-peak times. For example, a customer might pay $6 monthly for the fixed charge, $0.15/kWh used between the hours of noon and 8 p.m., and $0.05/kWh at all other times. This favors the houses that are using electricity for heating (or any other end use) in the middle of the night, such as heat pump customers or electric vehicle drivers.

Seasonal Charges (Winter Discount)

Electricity usage in most states is highest in the summer, as that is when air-conditioning is used. As shown in figure 2, the highest usage across all regions occurs in the summer, with smaller peaks in the winter (EIA 2024a). While there are many fuel sources for heating, electricity is the exclusive source for air-conditioning, causing this spike in power usage. In contrast, cold-climate heat pump users typically use more electricity in the winter, as that is the fuel for heating their home. By charging more for electricity during the summer and less during other months, the costs of summer peaks are more evenly spread across all homes, while giving a discount for heat pump users during their period of highest electricity use in winter. Many utilities already offer lower electricity prices in winter (because of lower demand), but steeper winter discounts (and discounts that persist even after winter electricity loads increase) will help keep energy bills lower after electrification. For example, Xcel in Minnesota has a winter discount rate and is proposing to further lower the rate for electric space heating.[21]

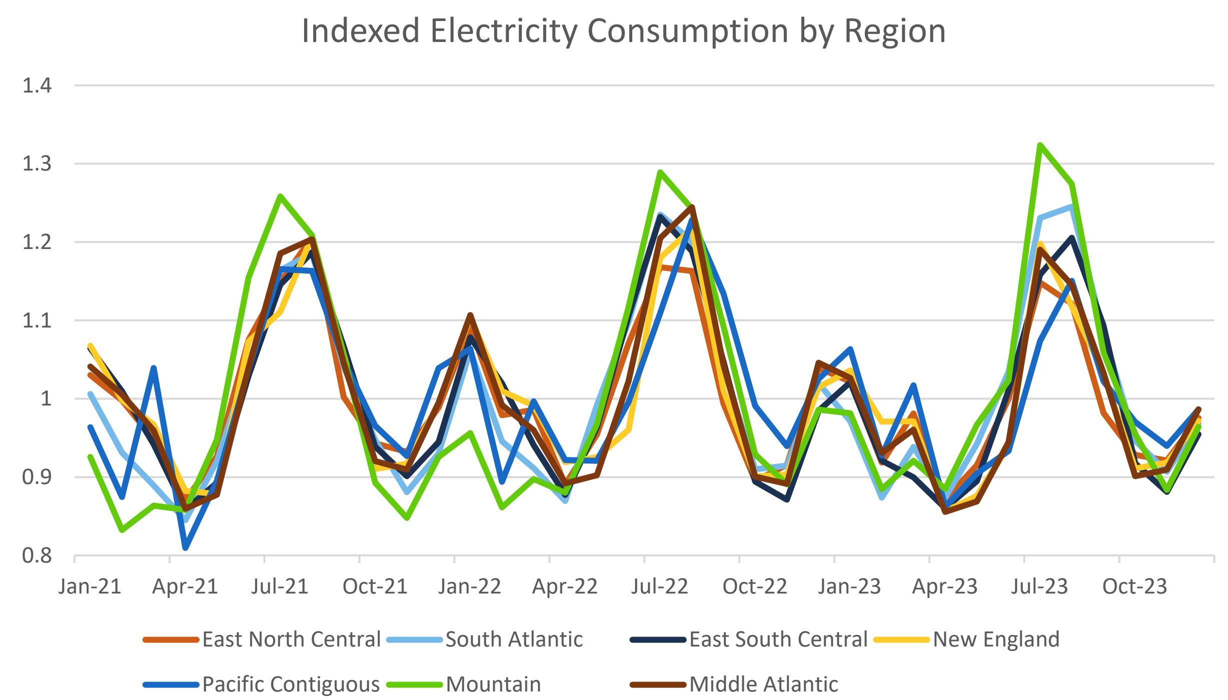

Figure 2. Peak and off-peak seasons for electricity use in regions across the United States (EIA 2024b)

Demand-based rates

A demand-based rate is where the customer is charged for the strain they put onto the grid.[22] That is, customers are charged for the highest rate of electricity that they use. To calculate this, the utility may take the four hours of the highest usage from a customer in a month, average them, and then charge

[21] This would cover both heat pumps and the less-efficient electric resistance heating.

[22] However, demand-based rates charge the customer for the peak load regardless of when it the day or week it occurs, and so a well-designed time-varying (dynamic) rate could be more effective at charging customers based on the strain they put on the grid, as high loads during afternoon are more problematic than those same loads at night, and may even be welcome during peak renewable generation in the middle of the day.

the customer based on this peak demand.[23] Proposed demand-based rates include a fixed rate and a volumetric rate, with the peak demand charge as an extra component. The demand charge is applied to the peak power usage (measured in kilowatts), and not the total volume of energy (kilowatt-hours). This rate structure is currently uncommon for residential customers, though it is frequently offered to commercial and industrial customers (Open Energy Information 2024).

In an earlier study of a Northeast utility, this rate design was found to give the highest discount to heat pump users (Sergici et al. 2023). This is because heat pump users have a more constant usage of electricity during their period of highest demand. As an example, figure 3 depicts the averaged use profile of pre- and post-retrofit homes in Connecticut in January. The average peak load for the pre-retrofit home is twice the average lowest daily load. For the post-retrofit home, the average peak load is 1.5 times the average lowest daily load. By charging for load factor, the post-retrofit home is favored, as shown in our analysis and in Sergici et al. (2023).

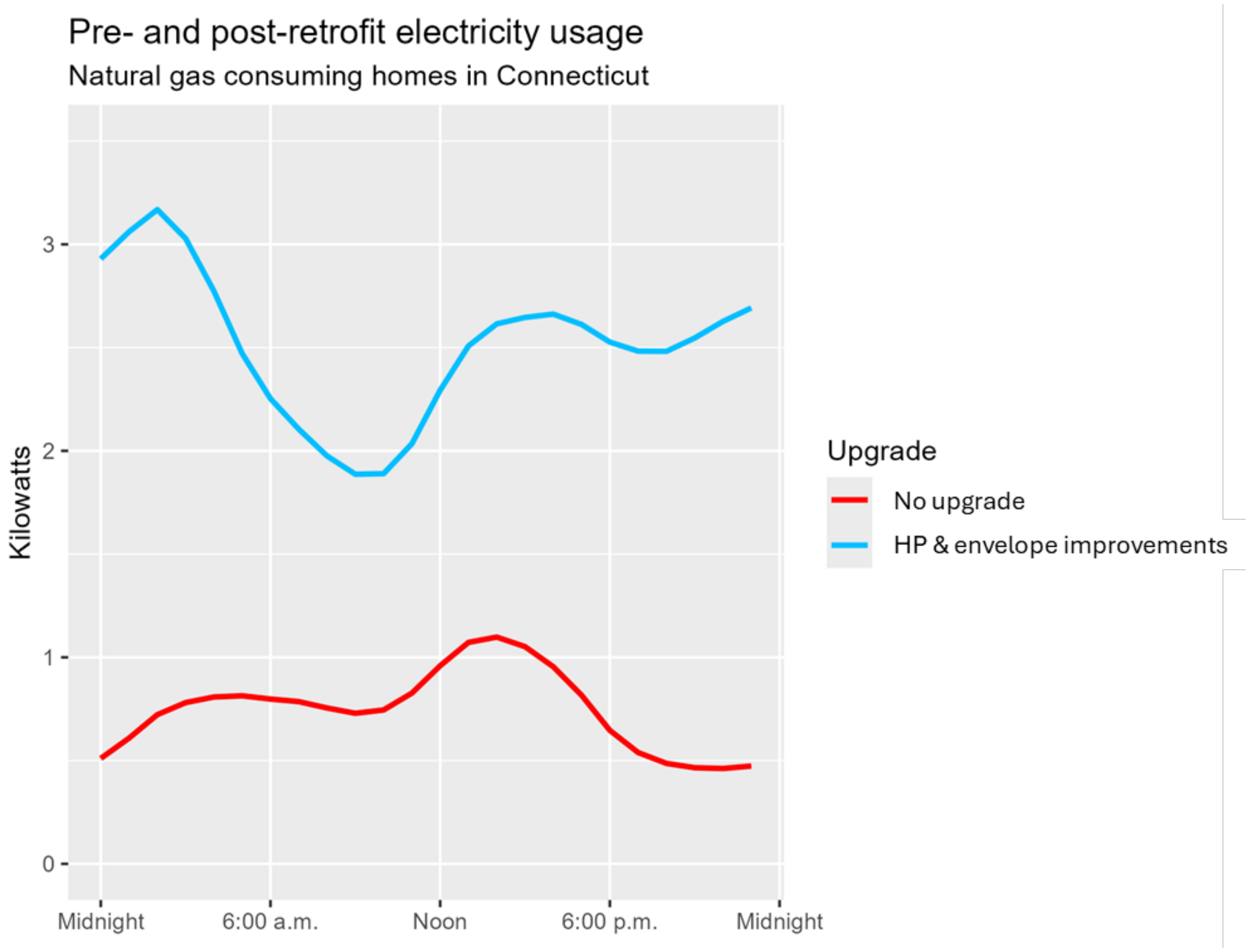

Figure 3. Average load pre- and post-electrification for homes in Connecticut in the month of January

[23] This is just an example; other definitions of peak usage are available, such as the 15-minute period of highest use in a month. Averaging the four highest hours is the method used here and in Sergici et al. (2023).

Heat pump discounts

A novel solution to prevent energy costs from rising from electrification in cold climates is to give households with high-efficiency heat pumps a different rate for electricity. This is similar to a winter discount rate but is available only to high-efficiency heat pump customers. If utilities have a mechanism for identifying homes that switch from fossil fuel space heating to electric heat pumps, this rate option could be most effective. In June 2024, regulators in Massachusetts approved a plan by the utility to allow for a significantly lower volumetric distribution rate for heat pump customers during winter months (Kresowik 2024).[24] On the policy end, Colorado has mandated a proposal that would require investor-owned utilities to submit a proposal for “rates for energy supplied to residential customers who utilize a heat pump as their primary heating source” by August 2027 to align with the state’s climate goals (McCormick et al. 2024). Rates are generally based on the cost of service. Given homes with heat pumps use more electricity, particularly during off-peak periods, the cost of servicing these homes is different, as more of their use is during periods of lower grid strain.[25] Both Colorado and Massachusetts are places where, due to high electricity costs, electrification may otherwise cause households’ bills to rise.

A cautionary note about behavior and rate design

When price signals are set to encourage one type of behavior, that price signal may have the opposite effect when market conditions change. For example, in California, electricity rates were restructured to encourage efficiency by eliminating the fixed cost and leaving only volumetric charges (i.e., only charging for energy used; Chhabra et al. 2024). This discourages electricity use because using more electricity means higher bills. However, it also inadvertently encourages the use of fossil fuels for heating and other end uses (when gas is much cheaper). Homes can decrease their bills by switching from electric heating to fossil fuel–based heating. Today, this type of rate design hampers electrification efforts.

Similarly, demand-based charges may provide some savings for heat pump users today. However, if in the future distributed energy is widely available in the market and renewables make up a significant share of the electricity produced nationwide, then residents might be encouraged to use energy during times of excessive solar and wind production. In this scenario, a demand-based charge would discourage households from using energy during the preferred times, potentially creating another California-type situation.

No rate-based solution is perfect in every scenario and will continue to be preferred in all future scenarios. The best guiding principle is to keep in mind that price signals should be based on cost of service and directly encourage the desired behavior.[26] For that reason, rate structures that are designed specifically to encourage heat pump adoption (e.g., revenue-neutral heat pump discount rates) are likely to be more effective at incentivizing heat pump uptake than more complex rates, such as TOU or demand-based charges. These also have the benefit, from a cognitive perspective, of being easier to understand for homeowners and, therefore, more likely to be adopted.

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[24] The volumetric distribution rate is a per-unit charge for the delivery of electricity. For example, a utility’s rate may be $0.11/kWh for the electricity, and $0.03/kWh for the distribution, for a total of $0.14/kWh.

[25] A Colorado analysis of cost of service has been conducted for heat pump water heaters (Boyle et al. 2022).

[26] In addition to questions about impacts to current ratepayers, electricity regulators should answer the following questions when making rate design decisions: Will this rate scheme result in greater demand for investment in fossil fuel generation capacity? Will the rate scheme penalize load shifting technologies? What is the current and long-term delta between gas and electric rates?

Although switching to electrical heating sources can raise electricity bills in some regions, there is limited research on how specific utility rates affect outcomes.[27] This is a problem generally throughout the energy efficiency research space: The costs and benefits of energy upgrades are difficult to estimate due to the lack of empirical data.[28]

The lack of data has real-world implications, because a large set of energy usage data and corresponding building characteristics would allow for more precise calibration of building energy models. Although public data collection efforts are underway for energy usage in buildings and residential energy consumption, research on the specific impacts of upgrades and rate structures on monthly energy bills is limited. In this report, we address this knowledge gap by looking, in particular, at cost changes in cold-climate single family detached homes resulting from switching from fossil fuel heat to high-efficiency cold-climate electric air-source heat pumps.

Another option: Percentage of income payment programs

Under a percentage of income payment program (PIPP), households below a given income threshold have their energy bill capped at a certain percentage. PIPPs are not programs created specifically for electrification, but instead are low-income utility programs to reduce the energy burden for less wealthy households.[29] Nonetheless, they provide an indirect benefit for electrification, as they lessen the financial risk for low-income homeowners by removing the possibility of rising utility bills. PIPPs are often funded through charges to other utility customers (industrial, commercial, and/or residential).

Where energy bills would increase

For residential electrification of single family detached homes, space heating will be (by far) the biggest factor increasing electricity consumption and electricity bills within the home (electric vehicles could be significant as well). Therefore, to identify the homes that are most likely to see an increase in energy costs after electrification, we examined the costs of heating those cold-climate homes with fossil fuels relative to the cost of heating with high-efficiency cold-climate electric heat pumps.[30] Given the high costs of heating with electricity in cold-climate regions, we decided to analyze four states in those regions—Minnesota, Colorado, Maine, and Connecticut. The reasons for selecting those states are explained in the following section of this report.

[27] Some existing studies include Wilson et al. (2024), Malinowski et al. (2022), and Nadel and Fadali (2022). These studies utilize average prices, whereas our study uses utility rates, and the latter two studies use relative efficiencies of equipment, whereas ours uses ResStock™ data, as does Wilson et al. (2024). A Minnesota-specific study was conducted by the Center for Energy and Environment (CEE 2022). Consumer-facing tools for estimating one's own costs and benefits include Rewiring America's Personal Electrification Planner (Rewiring America n.d.) and RMI's Green Upgrade Calculator (RMI n.d.).

[28] A team from the Lawrence Berkeley National Laboratory developed a database of simulated energy upgrades to commercial buildings. They described the need for simulated results as such: "Systematic retrofit information and impacts on building energy efficiency are difficult to obtain […]. In many cases, the industry stakeholders rely on simple assessments using rules-of-thumb [which] lack accuracy in estimating energy savings [as] custom energy modeling by professionals is expensive" (Lee et al. 2015). Since that research was published, a more comprehensive dataset has not emerged.

[29] For more on PIPPs, see ACEEE's recent white paper Equity and Electrification-Driven Rate Policy Options (Yim and Subramanian 2023).

[30] To decide which heat pumps to use in our simulations, we consulted experts at NREL and Nadel and Fadali (2022). We chose to simulate costs of high-efficiency cold-climate heat pumps rather than ultra-high-efficiency cold-climate heat pumps or non-cold-climate heat pumps because this was deemed the most appropriate in the four U.S. states we examined.

Simulation methodology

A 2023 study prepared by the Brattle Group for the Energy Systems Integration Group (ESIG) conducted an analysis similar to ours using data from one unnamed Northeast utility (Sergici et al. 2023). This was used as a reference for our research methodology. The study found that, without changes to electricity rates, bills for households would rise by about $200 per year, though changes to electricity pricing could improve the economics of heat pumps. The most helpful rate design (a demand-based peak load rate, explained earlier) was able to change this cost gap from $200 in increased bills to about a $1,000 reduction in bills without additional costs to the utilities in a pre-retrofit scenario (i.e., the rate is revenue neutral).[31] In the current study, we focused on the states with the most challenging economics for electrification, to examine how the rate solutions offered by the preceding study would fare under the most challenging of market conditions.

To simulate energy bills under different electrification scenarios, we used simulated data for residential buildings in the four target states from the ResStock™ dataset developed by the National Renewable Energy Laboratory (NREL 2024b). We used the energy load profiles for these homes included in the dataset. We combined these data with fuel oil and propane prices from the Energy Information Administration (EIA 2024b) and natural gas and electricity costs from utilities and providers in those regions.[32] We calculated average energy costs each month under scenarios with full electrification of space heating (using a cold-climate heat pump),[33] building envelope upgrades (e.g., improved sealing and insulation), and different rate structures either currently available to customers or constructed based on similar real-world rates. A complete description of the simulation methodology and the rates we employed is available in Appendix C.

We chose to analyze these four states for their high electricity prices compared to their natural gas prices, as well as to provide geographic diversity among cold-climate regions with high prices. These states have among the highest electricity prices relative to gas prices (i.e., the highest differences in rates). For each state in our analyses, we assumed utility rates for natural gas and electricity based on the largest providers in the state. We examined average utility bills of single family detached homes in each state before and after electrification. We then modeled how those bills might change if energy efficiency envelope and appliance upgrades were included with heating electrification, and if the home were on a different electricity rate plan.[34] In nearly all cases, these rates are revenue neutral for the utility's current customer base; however, they also have the added benefit of attracting new customers and increasing the customer base (thus increasing overall revenues and helping to offset any potential revenue losses when rates are not revenue neutral).[35]

[31] The rates were designed to be revenue neutral. This means that if the utility adopted the rates and the customers did not undergo upgrades, the revenue accrued by the utility would be the same. This ensures that homes which do not upgrade are not impacted by the rate design and the immediate impact on the utility's revenue is lessened.

[32] See Appendix B for details. Current utility rates were used for analysis.

[33] To decide which heat pumps to use in our simulations, we consulted experts at NREL and Nadel and Fadali (2022). We chose to simulate costs of high-efficiency cold-climate heat pumps rather than ultra-high-efficiency cold climate heat pumps or non-cold-climate heat pumps because this was deemed the most appropriate in the four U.S. states we examined.

[34] We did not include residential solar power as a method for offsetting the operating cost of an electrification upgrade, but generally, solar energy acts as a price hedge for electrification. This is because when the cost of electricity rises, the value of the solar power generated rises as well. However, photovoltaic solar panels are expensive, particularly when also updating the heating system and improving insulation, and thus are not available to everyone.

[35] In our analyses, we simulate rates with current customers. Although we are confident that competitive electricity prices would induce electrification, we could not estimate precisely how many customers would electrify their home heating system as a result of lower electricity rates.

Heat pumps reduce bills for average oil and propane users, but not always for natural gas users

In our simulations of annual energy bills, customers who were previously using fuel oil or propane for space heating saw, on average, noticeably lower bills when installing a heat pump, with even greater savings after home envelope improvements.[36] For natural gas users in these states, however, the relatively lower price of gas means that costs would likely go up without intervention.[37] We examine various rate structures, with and without energy efficiency envelope improvements. Importantly, our analysis focused on states where an increase in bills is most likely, which is not the case for most regions in the United States. As shown by other ResStock™ analysis (NREL 2024a), adding a high-efficiency cold-climate heat pump with insulation improvements is likely to decrease energy bills in the majority of the United States.

Minnesota and Colorado: Winter Discounts and Efficiency Upgrades Make the Math Work

Minnesota

Table 1. Average annual energy bills in Minnesota under different simulated conditions

Average annual bills, Minnesota			
Upgrade and bill type	*Original fuel source*		
	Natural gas	*Fuel oil*	*Propane*
Baseline, flat rate billing	$2,680	$5,987	$4,717
Baseline, TOU billing	$2,725	$6,035	$4,773
Baseline, demand charge	$2,715	$6,038	$4,769
After heat pump install, flat rate billing with winter discount for electrically heated homes	$2,934	$3,579	$3,312
After heat pump install, TOU billing with winter discount for electrically heated homes	$2,900	$3,530	$3,278
After heat pump install, demand charge with winter discount for electrically heated homes	$2,875	$3,492	$3,247
After heat pump and insulation install, flat rate billing with winter discount for electrically heated homes	$2,769	$3,299	$3,135
After heat pump and insulation install, TOU billing with winter discount for electrically heated homes	$2,741	$3,261	$3,106
After heat pump and insulation install, demand charge with winter discount for electrically heated homes	$2,719	$3,230	$3,080
After full electrification and insulation install, flat rate billing with winter discount for electrically heated homes	$2,615	Not analyzed	Not analyzed
After full electrification and insulation install, TOU billing with winter discount for electrically heated homes	$2,591	Not analyzed	Not analyzed

[37] For comparison, baseline annual bills were typically twice as high for fuel oil and propane customers compared to gas customers, as illustrated in the tables below.

Average annual bills, Minnesota			
Upgrade and bill type	*Original fuel source*		
	Natural gas	*Fuel oil*	*Propane*
After full electrification and insulation install, demand charge with winter discount for electrically heated homes	$2,576	Not analyzed	Not analyzed

Note: Rates (available in Appendix A) are from one utility serving the majority of the state. Color-coding indicates the difference in annual energy bills from pre- to post-electrification. Red = increase; yellow = little or no change; green = decrease. For technical specification on the upgrade packages and insulation details, see the ResStock™ documentation (Present et al. 2024, section 5).

We based our analysis of Minnesota on rates provided by an electric utility serving almost half of the state's residential customers. Notably, each of Minnesota's electric rates for this utility include a discount in winter for customers who use electricity for their space heating (available to customers with any type of heat pump or electric resistance technology).[38] The effective winter discount once various fuel charges and regulatory riders are factored in is 22% for the flat rate and 31% for the on-peak period of the TOU rate compared to customers without electric heating. This is quite useful, as this is the period of the year when the economics of electric space heating are the most tested.

Households in Minnesota transitioning from natural gas to heat pump heat can reduce their energy bills if they adopt the winter discount and TOU rate, alongside envelope improvements, and whole-home electrification (heat pump water heater, ENEGY STAR electric dryer, and induction stove). As shown in Appendix A, many of these upgrades are incentivized through state and federal rebates and tax credits, and they could reduce energy bills from $2,680/year with natural gas to $2,591/year with a heat pump.

Figure 4 depicts how energy bills would change for each of these upgrade options (heat pump only; heat pump and insulation; and heat pump, insulation, and whole-home electrification). As shown in the graph of monthly bills, the greatest savings from whole-home electrification were in the summer months, while the heating-intensive winter months were closer to parity with the other upgrade packages, with an increase in bills in January. We assume that this is because the heat pump water heater performs better in the summer when it can draw heat from an already warm house.

Rates that are lower in winter for any type of electric heating customer (not just heat pump users) are advantageous because they reduce the burden on utilities. They do not need to verify the type of electric technology that homes are using to ensure it qualifies (e.g., ensuring there are no backup fossil fuels or that the heat pump is sufficiently efficient). Con Edison's demand-based rate ("Select Pricing Plan") provides beneficial pricing to heat pump users but is open to all residential customers (Consolidated Edison Company of New York 2023). It is revenue-neutral and has seasonal variation with lower energy costs in the winter relative to the default volumetric rate.

[38] Although the rate is available, this does not necessarily mean that customers are aware of it. Anecdotally, we have heard that homes wanting to participate in Xcel Energy's Limited Off-Peak rate program for electric heat in Minnesota may require an electrician to install a submetering device for electric equipment. However, these details are unclear as requirements are not publicly available outside the service territory in Minnesota.

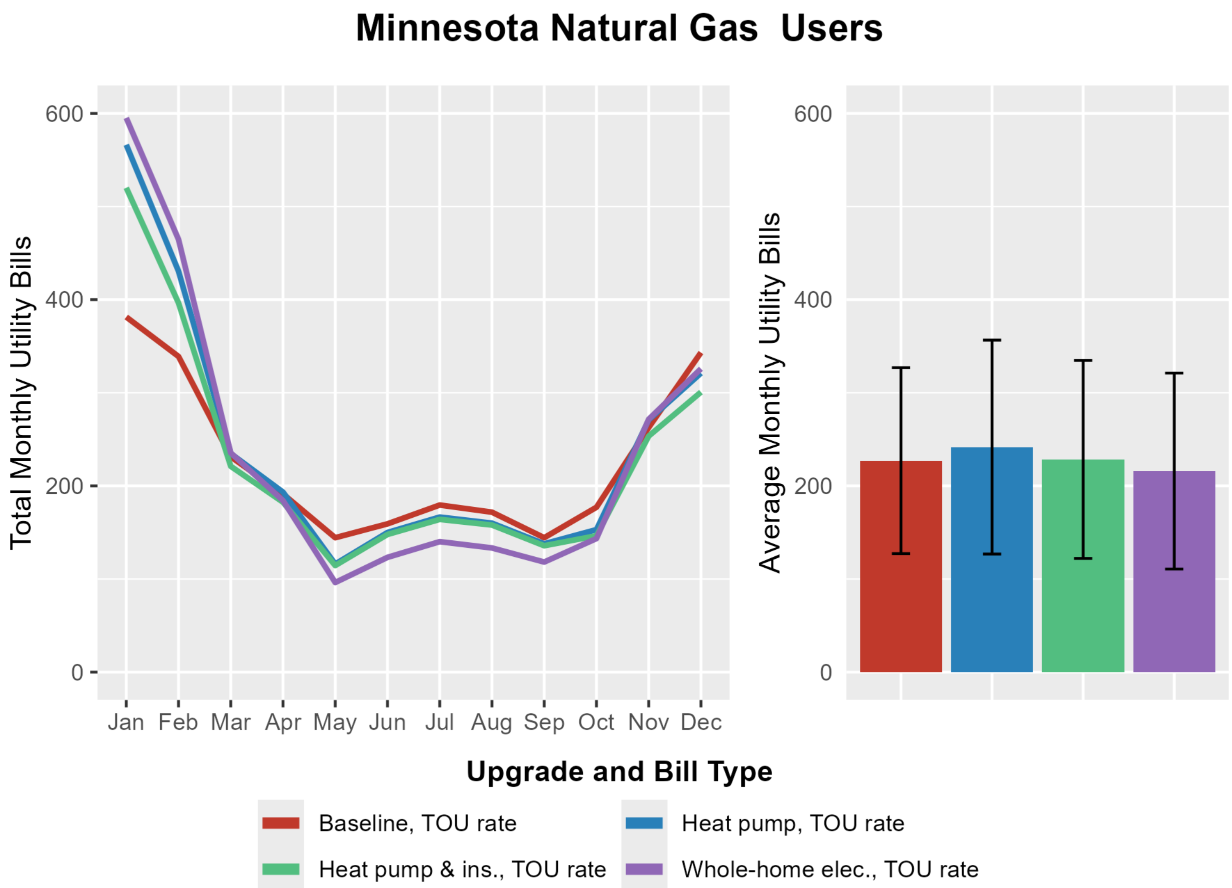

Figure 4. The estimated monthly utility bills of the average gas-heated single detached home in Minnesota before and after electric heat pump installation, envelope efficiency upgrades, and whole-home electrification with time-of-use rates. Baseline: no upgrade; Heat pump & ins.: heat pump and envelope improvements; TOU rate: time-of-use rate. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

Colorado

Table 2. Average annual energy bills in Colorado under different simulated conditions

Average annual bills, Colorado		
Upgrade and bill type	*Original fuel source*	
	Natural gas	*Propane*
Baseline, flat rate billing	$1,941	$3,339
Baseline, TOU billing	$1,994	$3,391
Baseline, demand charge	$2,022	$3,405
After heat pump install, flat rate billing	$2,118	$2,309
After heat pump install, TOU billing	$2,139	$2,324
After heat pump install, demand charge	$2,082	$2,240

Average annual bills, Colorado		
Upgrade and bill type	*Original fuel source*	
	Natural gas	*Propane*
After heat pump install, TOU with winter discount	$2,044	$2,225
After heat pump and insulation install, flat rate billing	$2,044	$2,234
After heat pump and insulation install, TOU billing	$2,066	$2,252
After heat pump and insulation install, demand charge	$2,018	$2,176
After heat pump and insulation install, TOU with winter discount	$1,975	$2,156

Note: Rates (available in Appendix A) are from one utility serving the majority of the state. Color-coding indicates the difference in annual energy bills from pre- to post-electrification. Red = increase; yellow = little or no change; green = decrease.

Colorado has more challenging economics for switching from natural gas heat to electric heat pumps, as shown in Figure 5. The lack of a deep winter discount on electricity makes ongoing costs of switching from gas to electric heat pump more expensive. Although adding energy efficiency envelope upgrades reduces costs, as does switching to demand-based charges, the heating costs are too high for the price structures to overcome.[39]

However, using the Minnesota type of winter discount pricing (adding a 31% discount for winter peak electricity prices) would solve the problem, as shown in Figure 5. The winter peaks discount rate keeps the bills almost the same for gas customers and could encourage more heat pump retrofits.

The “heat pump with discount” package shown in Figure 5 results in average annual energy costs of $2,044. Adding envelope upgrades brings down the annual cost to $1,975, almost the same as the “no electrification” flat rate baseline ($1,941).

[39] The demand-based charge here is a revenue-neutral rate that we constructed for the purpose of this comparison. In some materials, the utility references a residential demand rate that is not available to customers but is likely left over from a pilot program. Modeling bills with this rate causes a sharp increase in bills in all three scenarios and thus was not used here.

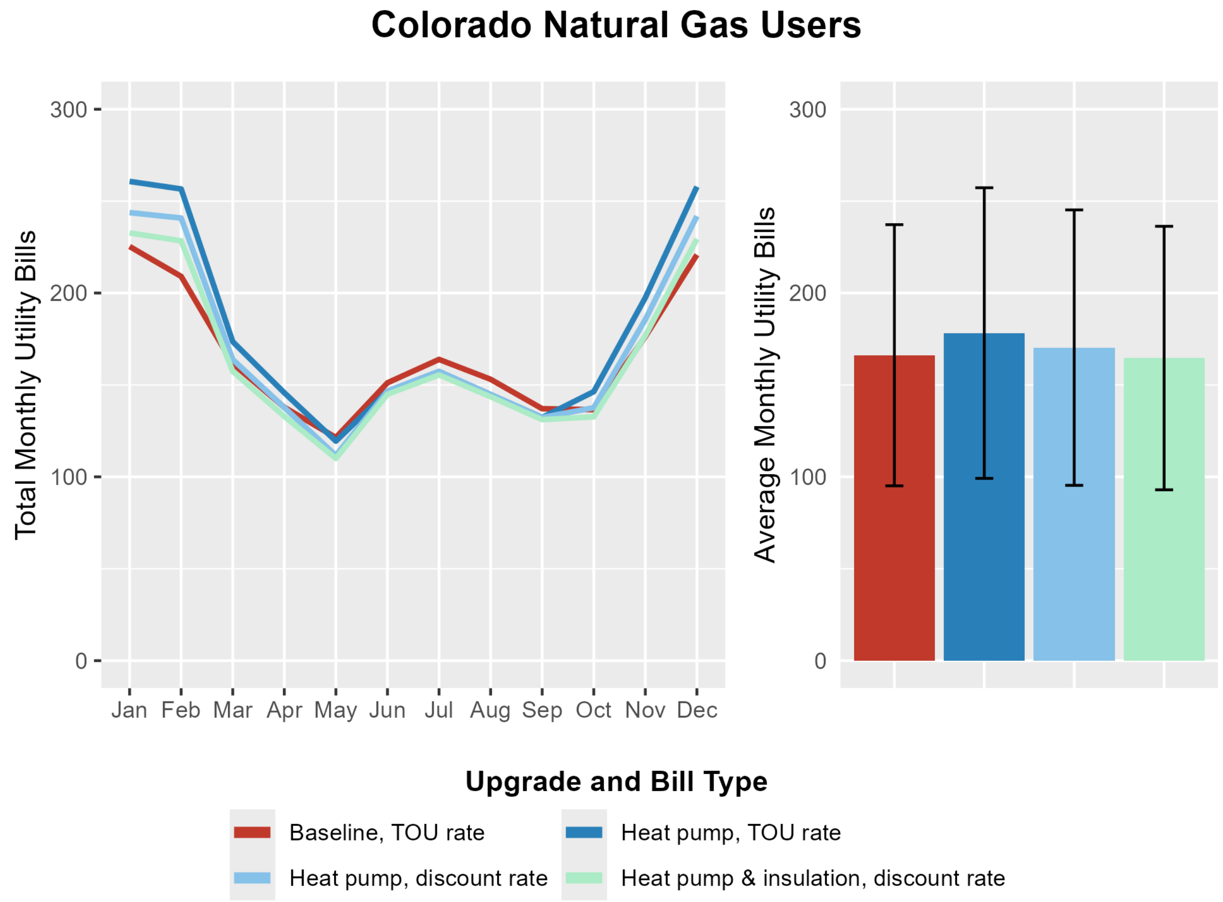

Figure 5. A 35% winter peaks discount (similar to Minnesota's) can make the math work in Colorado. The estimated monthly utility bills of the average gas-heated single detached home in Colorado before and after electric heat pump installation, with and without the winter discount rate. Baseline: no upgrade; discount: winter peak discount. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

Although it may not be revenue neutral given the Colorado customer base, the Minnesota-level winter peak discount would increase electricity sales (customers will be more likely to electrify if energy bills will not go up). We also include recommendations for investment in the midstream and upstream costs of electrification to further improve the economics of providing this rate to heat pump customers.

Maine and Connecticut: Deep Investment and Policy Needed

Maine and Connecticut have high proportions of fuel oil and propane heated homes. Fuel oil and propane customers represented a combined 41% of homes in Connecticut and 66% of homes in Maine in 2023.[40] These homes can greatly decrease their energy bills with an efficient cold-climate heat pump and envelope upgrades. Average fuel oil customers would save $1,060/year in Maine under the utility's heat pump-specific electricity rate, and $820/year in Connecticut under the utility's TOU rate (Connecticut does not currently offer a heat pump rate). Propane customers are a much smaller proportion of the population (14% in Maine and 6% in Connecticut in 2023),[41] but these customers would also save an average of $1,953 in Maine under the heat pump rate, and $1,704 in Connecticut under the TOU rate.

However, these two states have the most challenging economics in our analysis for switching from natural gas to electric heat pump. Here, rate interventions are ultimately not enough to match the high electricity prices. Layering a Minnesota-level winter discount on top of existing TOU rates and adding envelope improvements resulted in the lowest costs to consumers but still increased annual energy bills by $260–$276 as compared to heating with natural gas (with a flat rate electricity plan).

In these states, ensuring bills do not increase for gas-heated homes will require more substantial work, such as infrastructure updates and policy changes, as discussed in the conclusion. Implementing a clean heat standard is one type of policy that could be helpful. A PIPP can also help support low-income homeowners when they electrify. Fortunately, as demonstrated by other analyses (NREL 2024a), most states in the US are unlike these two.

Maine

Table 3. Average annual energy bills in Maine under different simulated conditions

Average annual bills, Maine			
Upgrade and bill type	*Original fuel source*		
	Natural gas	*Fuel oil*	*Propane*
Baseline, flat rate billing	$2,528	$4,163	$5,084
Baseline, TOU billing	$2,618	$4,249	$5,170
After heat pump install, flat rate billing	$3,269	$3,614	$3,573
After heat pump install, TOU billing	$3,298	$3,621	$3,585
After heat pump install, heat pump rate	$3,052	$3,232	$3,248
After heat pump, TOU billing and winter on-peak discount	$2,946	$3,181	$3,165
After heat pump and insulation install, flat rate billing	$3,098	$3,412	$3,392
After heat pump and insulation install, TOU billing	$3,134	$3,429	$3,413
After heat pump and insulation install, heat pump rate	$2,941	$3,103	$3,131

[40] Maine fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=ME; Connecticut fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=CT

[41] Maine fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=ME; Connecticut fuel oil and propane users (2023): https://www.eia.gov/state/print.php?sid=CT

After heat pump and insulation install, TOU billing and winter on-peak discount	$2,804	$3,014	$3,015

Note: Rates (available in Appendix A) are from one utility serving the majority of the state. Color-coding indicates the difference in annual energy bills from pre- to post-electrification.[42] Red = increase; yellow = little or no change; green = decrease.

In Maine, electrification of gas-heated homes will increase energy costs, especially in winter (as shown in Figure 6). Adding energy efficiency envelope upgrades will reduce those costs (see Table 3). However, even with these changes, energy bills after home heating electrification with heat pump are likely to increase in Maine.

The utility we examined in Maine (serving over three-quarters of residential customers) offers an innovative rate that provides a large decrease in energy bills for the winter months, partially offset by a summer increase. Using these rates in our simulation, the average annual bill for the electrified and insulated Maine household switching from gas was $2,941 with the special heat pump rate, and the flat and TOU rates were both around $3,100. Importantly, however, customers who switch to heat pumps in the summer will see an immediate increase in their bills (even if bills go down overall across the course of the year). In the last section of this report, we provide recommendations for communicating this increase and setting customer expectations.

The existing heat pump rate is an excellent initiative by the utility to encourage electrification. Although it does not close the gap between the cost of natural gas heating and heat pump heating, it is currently the best option for customers in Maine, especially when combined with envelope upgrades. The Minnesota-level (31%) winter discount, alongside the utility's existing TOU rate would save customers more money than the existing heat pump rate, but also does not close the financial gap between natural gas and electric heating ($2,528 with natural gas, versus $2,804 with the Minnesota-level winter discount and TOU rate).

[42] Energy bills of homes currently serviced by different fossil fuels will each have slightly different bills after converting to heating with electric heat pumps. There are a variety of reasons for this, including slight differences in average characteristics of the homes being electrified, expected energy use patterns of those homes, and others.

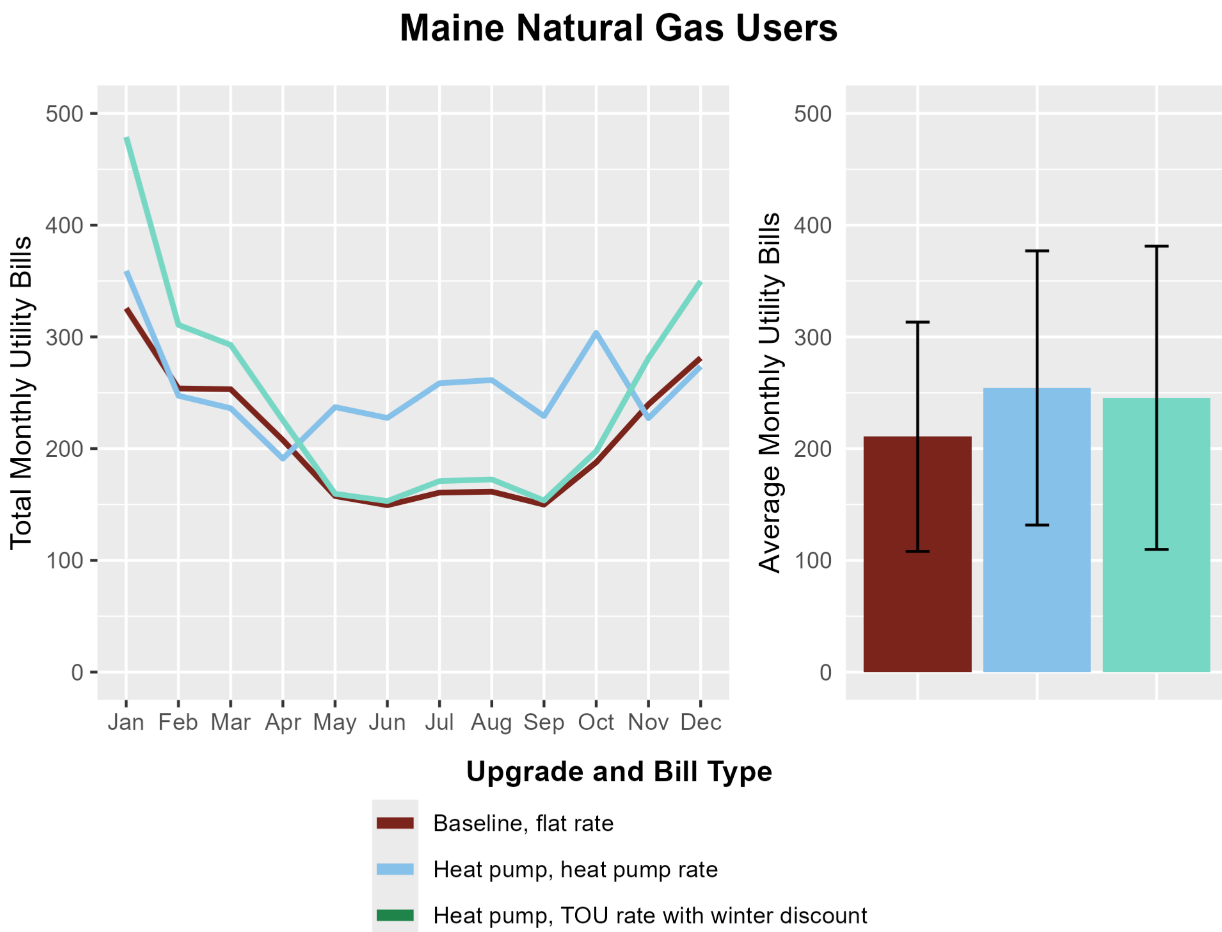

Figure 6. The estimated monthly utility bills of the average gas-heated single detached home in Maine before and after electric heat pump installation, envelope efficiency upgrades, and various rate designs. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

Connecticut

Table 4. Average annual energy bills in Connecticut under different simulated conditions

Average annual bills, Connecticut			
Upgrade and bill type	*Original fuel source*		
	Natural gas	*Fuel oil*	*Propane*
Baseline, flat rate billing	$3,289	$5,483	$6,252
Baseline, TOU billing	$3,279	$5,465	$6,238
Baseline, demand charge	$3,347	$5,577	$6,324
After heat pump install, flat rate billing	$4,091	$5,046	$4,859
After heat pump install, TOU billing	$4,014	$4,934	$4,762
After heat pump install, demand charge	$3,883	$4,750	$4,603
After heat pump install, winter discount TOU rate	$3,729	$4,544	$4,392
After heat pump and insulation install, flat rate billing	$3,883	$4,763	$4,636
After heat pump and insulation install, TOU billing	$3,815	$4,663	$4,548
After heat pump and insulation install, demand charge	$3,708	$4,512	$4,415
After heat pump and insulation install, winter discount TOU rate	$3,549	$4,298	$4,197

Note: Color-coding indicates the difference in annual energy bills from pre- to post-electrification. Red = increase; green = decrease.

For Connecticut, post-electrification bills with a demand-based charge (the lightest lines) would be noticeably lower than the other revenue-neutral rate structures currently available in the state. However, the gap is still too large to be filled by alternative revenue-neutral rate designs. When using the simpler 31% peak winter discount TOU rate from Minnesota (simulated for this analysis in Figure 7), this non-revenue-neutral rate (when applied in Connecticut) closes slightly more of the gap, though the annual cost is still approximately $260 higher.

One contributing factor is that gas utilities in Connecticut provide a discount to customers with gas heating—a mirror image of the electric heating discount. Therefore, once gas households switch to a heat pump, they will pay more to fuel their remaining appliances such as water heaters. This could be an added incentive for these households to fully electrify.

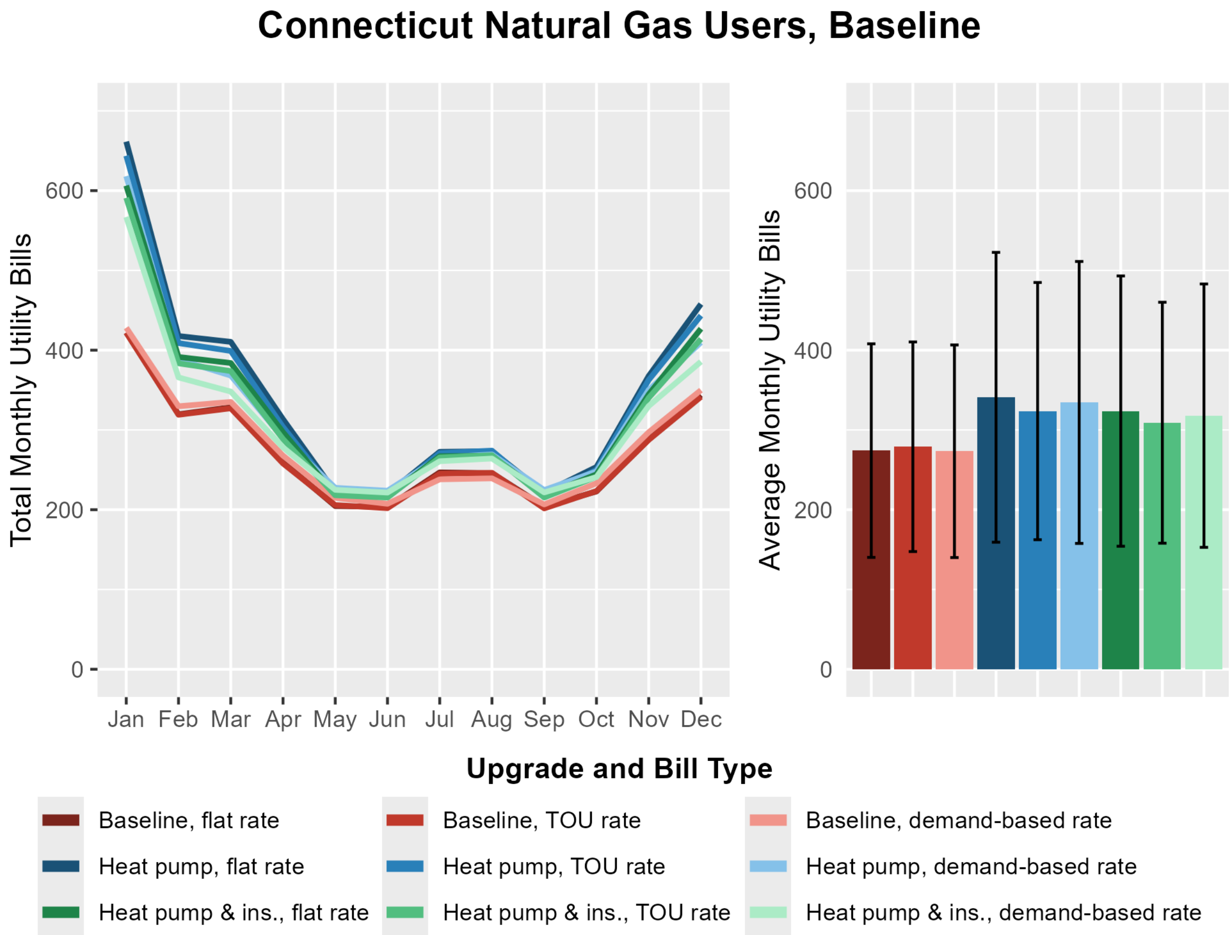

Figure 7. The estimated monthly utility bills of the average gas-heated single detached home in Connecticut before and after electric heat pump installation, with various rates structures currently available in the state (as well as a simulated demand-based rate). Baseline: no upgrade; Heat pump & ins.: heat pump and envelope improvements. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

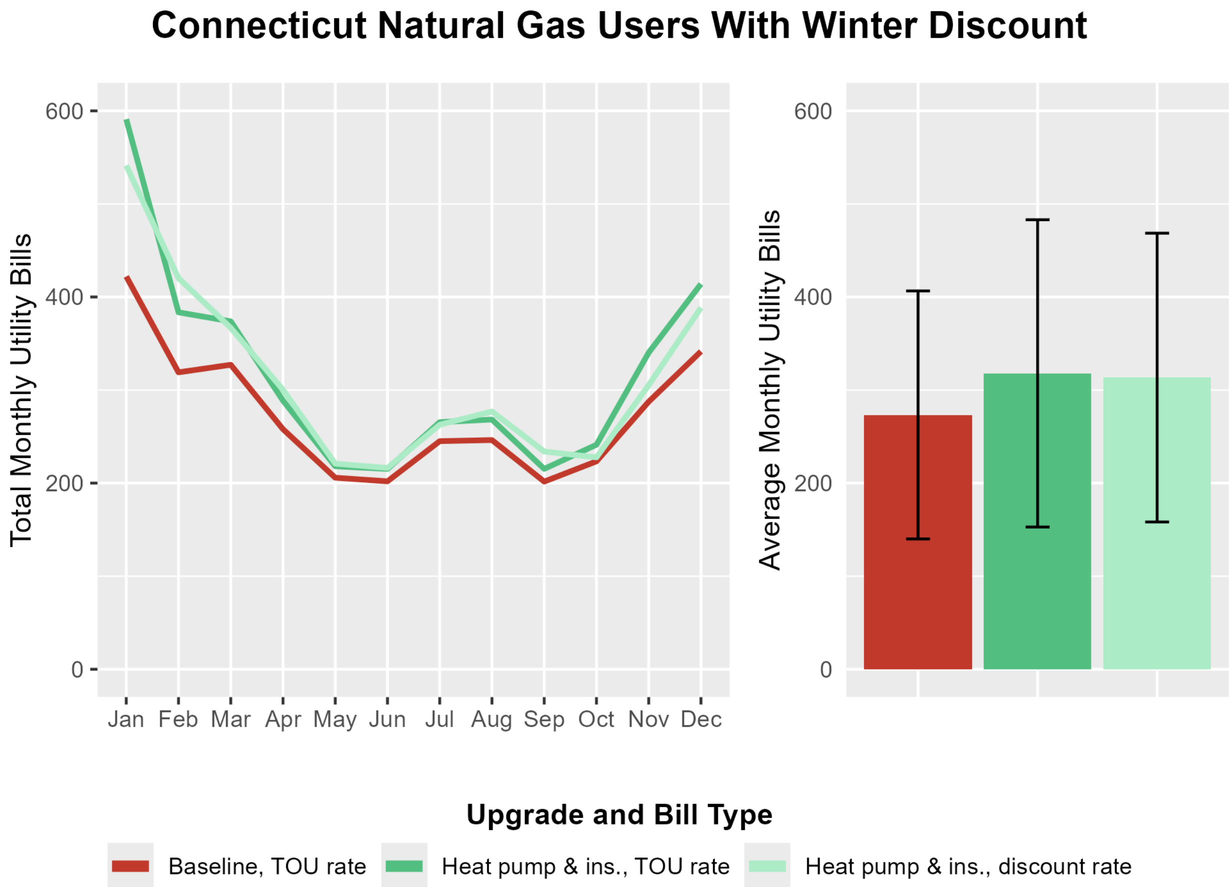

Figure 8. A 31% winter discount rate (similar to Minnesota's) in Connecticut is not enough to ensure energy bills do not increase. The estimated monthly utility bills of the average gas-heated single detached home in Connecticut before and after electric heat pump installation, with and without the winter discount rate. Baseline: no upgrade; Heat pump & ins.: heat pump and envelope improvements; TOU: TOU rate; discount: winter peak discount. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

The economics for natural gas customers may be difficult to overcome, but electrification is a clear winner for propane and fuel oil customers, as shown in figures 9 and 10. Notably, fuel oil is common in Connecticut, with approximately 40% of homes in the ResStock™ sample using it. Propane is used by approximately 3% of homes in the sample (or 34% and 6.4% of total homes, respectively, according to the US Energy Information Administration in 2023).[43]

[43] https://www.eia.gov/state/print.php?sid=CT

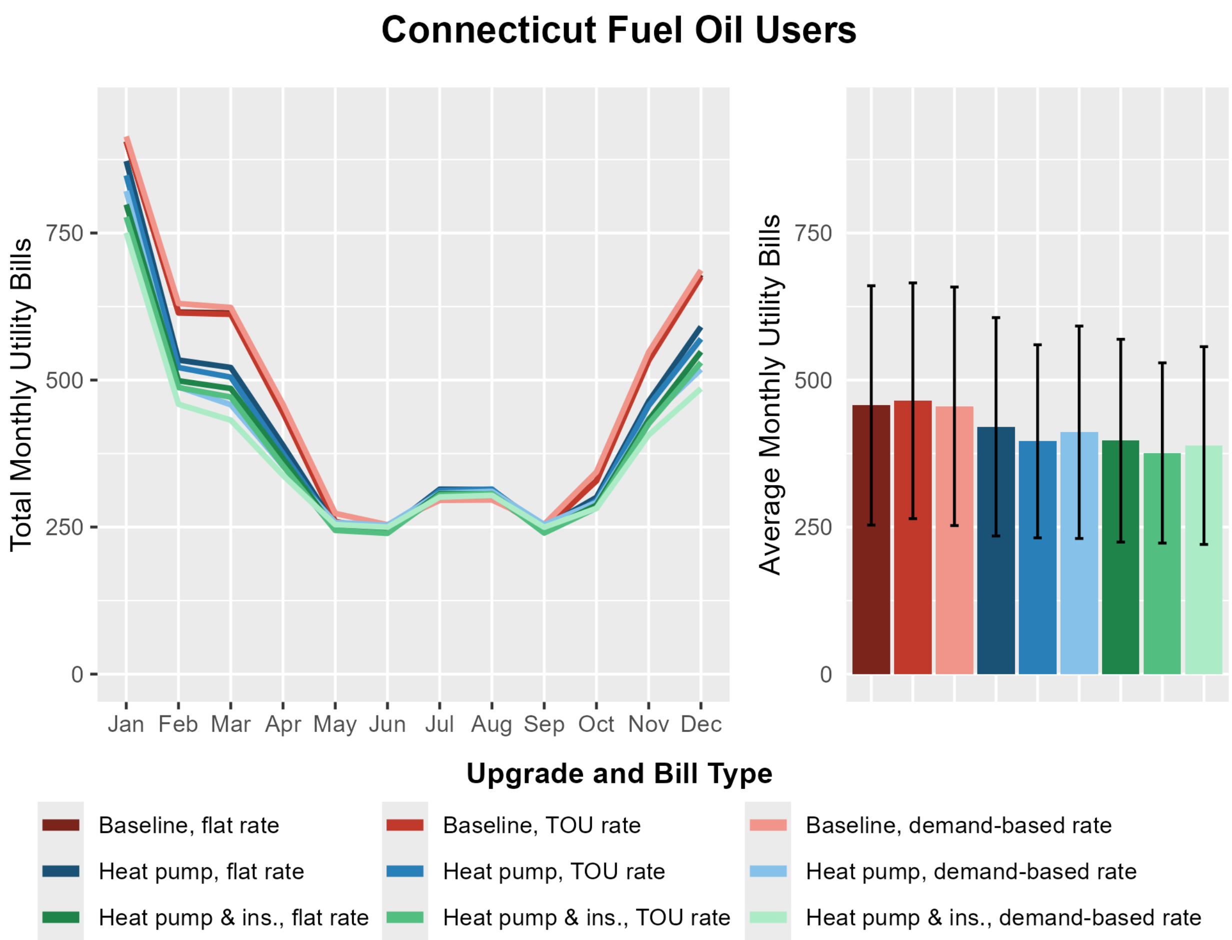

Figure 9. The estimated monthly utility bills of the average fuel oil–heated single detached home in Connecticut before and after electric heat pump installation, envelope efficiency upgrades, and various rate designs. Baseline: no upgrade; Heat pump installation & ins.: heat pump and envelope improvements. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

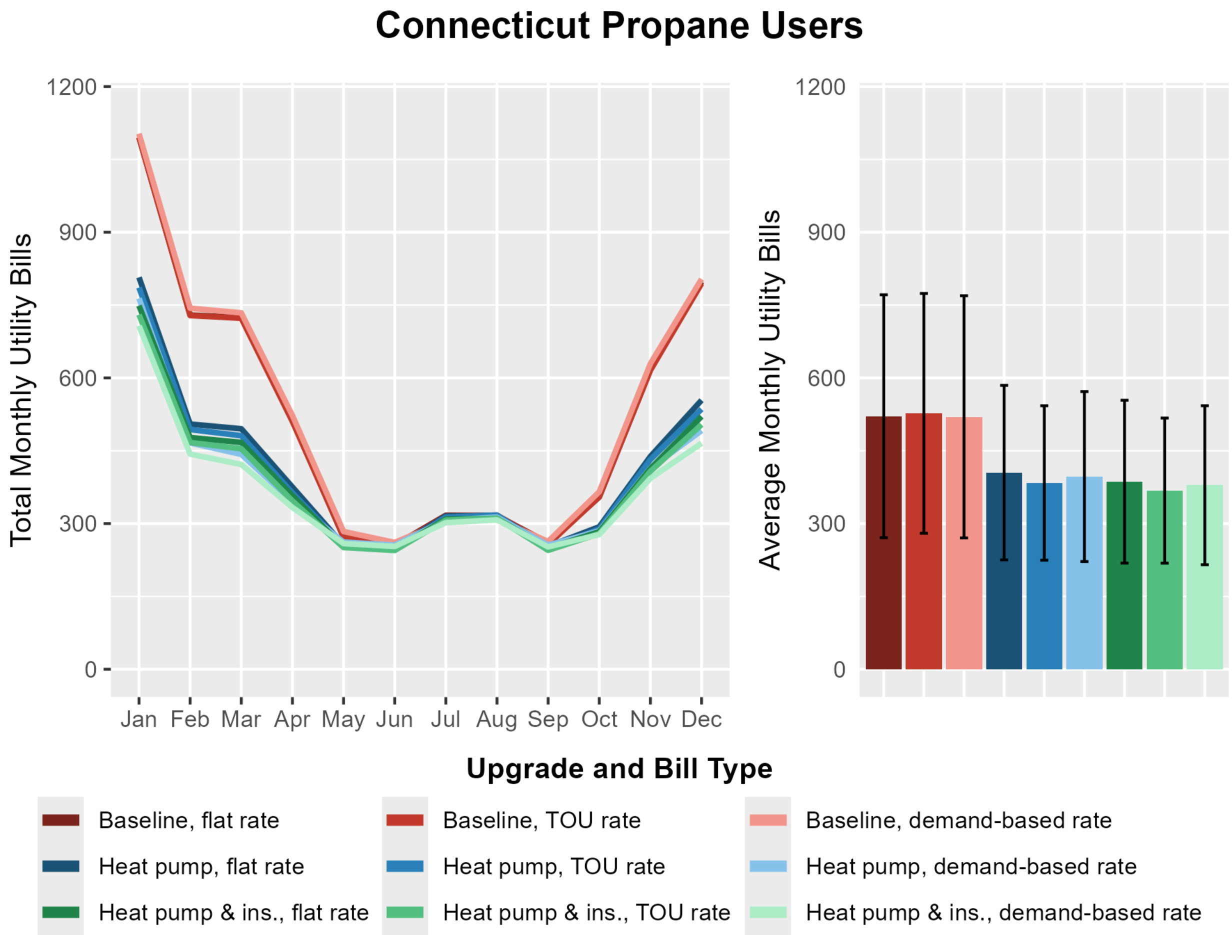

Figure 10. The estimated monthly utility bills of the average propane-heated single detached home in Connecticut before and after electric heat pump installation, envelope efficiency upgrades, and various rate designs. Baseline: no upgrade; Heat pump installation & ins.: heat pump and envelope improvements. Whiskers on the bar graph represent +/- 1 standard deviation from the mean.

Federal and state long-term solutions

Much of the energy infrastructure across the United States is decades old (U.S. DOE 2023) and, as such, requires more frequent maintenance, which increases costs. Moreover, with more demand for electricity in transportation and buildings, and new renewable capacity coming online, an aging grid would be more expensive to run than a modern, more resilient and smarter grid (IEA 2023; Elmallah, Brockway, and Callaway 2022). Additionally, ratepayers are currently footing the bill for some infrastructure maintenance that might be considered a public good. For example, California electricity customers' high rates are partly a result of wildfire protection measures (PAO 2024). Normally, grid upgrades are funded by ratepayers but given the scale of upgrades needed across the country, state and federal government investment should help defray these costs. This would allow customers the benefits of lower electricity costs without the offsetting costs of grid upgrades.

The problem is not that natural gas is too cheap. In fact, Connecticut has the seventh highest gas price in the country (EIA 2025). Rather, Connecticut's electricity prices are so high as to dwarf gas prices in comparison. Maine and Connecticut could benefit from deep investment in making electric power more affordable to its residents. This could include taking on some costs of grid maintenance and upgrades, putting a price on carbon, or implementing clean heat standards[44] that place performance requirements on all heating market actors. Fortunately, Maine and Connecticut's electricity-gas price ratios are rare and gas prices are expected to naturally increase in the coming years relative to electricity. [45]

A note on climate and temperature

Our analyses are conservative in a number of respects and the economics of heat pumps likely works somewhat better than our simulations show. Warmer climates support the economics of heat pumps for three reasons. First, heat pumps are less efficient in cold weather; with fewer extremely cold days, heat pumps will work more efficiently. Second, with fewer cold days, less heating is needed overall, and this would reduce costs in places where heating with heat pumps is more expensive than heating with natural gas (i.e., places with much higher costs of electricity relative to natural gas). Third, in warmer climates more cooling is needed, and efficient cold-climate heat pumps are generally more efficient at cooling than air conditioners (although this benefit may tail off at extremely high temperatures). In short, global warming in cold-climate states means more savings (or fewer costs) from heat pumps. For this analysis, we used building simulations that were based on 2018's meteorological data. Given 2024 was a warmer year than 2018, and the climate will continue to warm, heat pump costs are likely lower than our estimates and will continue to go down slightly with each degree of warming.[46] Therefore, although we cannot determine exactly how conservative our analyses are, heat pumps are more likely to save money both today and into the future.

Behavioral strategies to encourage electrification when the math works

In most U.S. states, the math for electrification works (or can be made to work) with rate structure changes and energy efficiency. Moreover, even when the economics favor electrification, the math always works best when energy efficiency and rate structure changes are included. Nevertheless, some homeowners resist electrification for nonfinancial reasons: for example, lack of trust in their utility or contractor, contractors lacking knowledge about heat pumps, preference for the status quo, or hesitance about ongoing or upfront costs. Behavioral strategies can be employed to overcome these barriers.

Behavioral science can also provide insights on how to encourage homeowners to invest in energy efficiency alongside electrification, and how to change residents' behaviors to maximize the benefits of a new rate structure (e.g., shifting their energy use patterns to avoid on-peak usage).

Importantly, many residents who electrify their home heating will see an increase in their electricity bills (alongside a decrease/elimination of natural gas or other fossil fuel heating bills), and overall bills might be higher in some months even if they are lower in aggregate over the course of the year. This can lead to a negative experience of electrification. Negative experiences can translate to negative word of mouth and a backlash against electrification. Behavioral science can offer recommendations to mitigate this issue as well. Using insights on human perception and decision making, we offer suggestions for

[44] A guide for applying clean heat standards is available from the Regulatory Assistance Project (Santini et al. 2024).
[45] An analysis of Maryland's gas prices provides an example of how electrification will increase, leading to a declining gas customer base and increased prices (OPC Maryland 2022).
[46] We initially ran our analyses using ResStock™ Typical Meteorological Year (TMY3) climate data (average temperatures between 1976 and 2005), but when we re-ran the analyses with Actual Meteorological Year (AMY) climate data, the economics of efficient cold-climate heat pumps improved.

communicating with consumers who have electrified, as well as those who may not yet think it is right for them.

Encouraging electrification when the math works

Knowledge gaps and lack of awareness

The biggest barrier to electrification of home heating is the perception that electric home heating would cost too much (Sussman and Eisen 2024). If this barrier is based on a misperception or if it can be removed through rate changes and energy efficiency upgrades, then the problem becomes one of awareness. In a study of the Midwest, 79% of customers knew little to nothing about heat pumps (CEE and BIT 2024). Consumers may not be aware that heat pumps do not raise energy bills, or even that switching is an option. Moreover, they may not be aware of ancillary benefits such as dehumidifying effects in the room with the heat pump. Heat pumps are different from traditional electric resistance heating systems in several ways. To encourage awareness, a traditional marketing and outreach campaign could be helpful. Providing the information through traditional media, social media, mailers, bill inserts, or in-person events is effective for educating customers (Kassirer 2024).

Status quo bias and lack of motivation

If general awareness is not the problem, then a lack of motivation and a status quo bias could be the issue. Status quo bias is the general principle that, all things being equal, people prefer not to change (Samuelson and Zeckhauser 1988). Changing messaging around electrification could be an effective way to tackle this challenge. A few behavioral science principles could be applied to improve messaging.

The principle of *loss aversion*—that people act to avoid a loss more than to achieve a gain (Kahneman and Tversky 1979)—suggests one option. Rather than telling customers that they can gain money or earn savings from electrification, messages can show customers how they are losing money by not electrifying. Utilities or other program managers can use a loss aversion message by framing inaction (not electrifying) as a missed opportunity. For example, utilities running heat pump programs can communicate that "by not switching, you are losing out on [dollar amount] in energy savings per year" to motivate customers who are naturally inclined to avoid losses to electrify. Reframing costs and benefits by making the payback period more concrete and providing clear, personalized feedback can help utilities shift customers' focus from short-term perceived losses to long-term financial gains, increases in comfort, and health benefits (Sussman and Chikumbo 2017).[47] As discussed later in this section, however, for utilities' messages to be accepted, they first need to cultivate trust with their customers.

Communicating that other people are electrifying could also be a successful message framing strategy. People may be more likely to trust the behavior of their peers than savings-focused messages from utilities. Using dynamic norms messaging (Sparkman and Walton 2017)—showing that others in the community are *increasingly* electrifying their homes even if electrification rates are still relatively low—can tap into social influence to encourage adoption of electrification. Simply emphasizing that more people are making the switch helps build credibility and reduce skepticism, as the behavior of others can reinforce the perception that electrification is a viable option. This has not yet been tested in a field study encouraging electrification, but it is effective in many other domains, including reducing laundry loads during drought and encouraging federal contractors to adhere to energy efficiency policies

[47] Personalization, in itself, can change attitudes and increase motivation to act as well (e.g., Ho and Bodoff 2014).

(Chalasani et al. 2020; Sparkman and Walton 2017). In other words, leveraging social proof instead of relying solely on the savings promises of the utility can motivate more people to electrify.

The hassle factor

The electrification process is rarely a single or one-time decision. The effort required to think through the decision and then actually install the upgrades (and change rate plans) is significant. Utilities can reduce decision paralysis and help people act by making each step in the process easier. One way to do this is to offer prepackaged solutions or step-by-step electrification plans. Breaking down complex decisions into smaller, more manageable steps can reduce decision fatigue, prevent customers from feeling overwhelmed, and increase the uptake of electrification. For example, a utility might create a phased electrification plan that starts with home energy upgrades like insulating the home before installing a heat pump or electrifying all other appliances (Amann, Srivastava, and Henner 2021). A third-party concierge service, general energy efficiency contractor, or one-stop shop could also be a solution for smoothing out the friction involved in electrification upgrades and changes. The City of Fort Collins offers this sort of one-stop shop for home energy upgrades and financing (City of Fort Collins n.d.).

Trust

With all the inherent complexities and uncertainties in the rate design, energy bills, and load shifting, trust of the electrification agent (usually the utility) becomes critical. Thus, another potential barrier to electrification is the low level of trust some customers have in their utilities (Parrish et al. 2020). Many customers view utility companies as primarily profit driven as opposed to customer driven (Escalent 2024). Indeed, the business model of investor-owned utilities is based on earning a profit from services. Among low-income households, minorities, and historically underserved communities, experience has led to a particularly sharp lack of trust in government, corporate entities, and other institutions (e.g., Candelo, de Oliveira, and Eckel 2023; Pierce, Connolly, and Blanco 2021). Maintaining or building trust is critical not only for supporting individual decisions but also for fostering broader behavior change and electrification policy support across the customer base. Focusing on transparent communication and working with community partners are two effective strategies for engendering trust with customers.

Focus on transparent communication

Trust between consumers and utilities takes time, consistency, and transparency to build. Historically, utilities have struggled with building and maintaining this trust due to issues like confusing billing practices and limited customer engagement (Field 2022; Escalent 2024). To truly improve customer trust and support the clean energy transition, utilities need a long-term cultural shift in their practices to prioritize customer transparency, responsiveness, and reliability. While this larger change is underway, utilities can foster trust through clear communication.

Customers are more likely to engage with electrification and TOU rates when they are provided with transparent, easy-to-understand information about the costs, benefits, and timelines, along with tools such as automation and bill comparisons to aid decision making (Hledik et al. 2017). If utilities do not communicate this information effectively, customers may feel blindsided by unexpected changes, such as an increase in their electricity bill, which can erode trust and lead to disengagement. For the most vulnerable households, additional measures like temporary bill protection may be implemented to enhance engagement and trust in new rate structures (Trotta 2021).

Partner with community organizations

Community partners, such as organizations working directly with households, can serve as effective intermediaries in promoting electrification. These could include housing counselors, neighborhood groups, local community leaders, or religious and cultural groups. In discussions with experts, community organizations were repeatedly identified as the "bridge" that connects utilities with customers, helping to build trust and credibility. This is documented in research on promotion of EVs in the low-income community, for example (e.g., Pierce, Connolly, and Blanco 2021). By leveraging social network effects through collaboration with trusted organizations, utilities can effectively spread awareness of cost-effective electrification solutions and motivate action within local communities. Social network effects occur when innovations, behaviors, and ideas spread through a community like a snowball—increasing the rate of adoption as more people engage.

Educate contractors

In many cases, HVAC contractors are the only in-person contact customers have with an expert in home energy. Engendering trust in contractors and leveraging that trust is crucial. Contacts with contractors occur at moments when homeowners are making decisions about home heating, often in emergencies. Contractors are perceived as trusted experts, and they have the ability to shift decisions at a crucial decision-making juncture, but they often recommend like-for-like replacement and shy away from suggesting home heating electrification with heat pumps (Steiner and Heinemeier 2024).

Contractors have misperceptions about the efficiency and costs of heat pumps: They see them as complex and they believe the installation would be difficult (Steiner and Heinemeier 2024). Moreover, even when contractors have the training and knowledge to conduct complete home energy assessments and to discuss the climate implications of homeowner decisions, they do not feel empowered to do so (Steiner and Heinemeier 2024). Embedding this information in HVAC maintenance training courses, providing incentives to contractors, supporting effective discussions with homeowners, and encouraging a shift from getting jobs done quickly to maximizing homeowners' long term satisfaction, can help both with electrification initiatives and contractor trust (Steiner and Heinemeier 2024).

Encouraging energy efficiency alongside electrification

When the barrier of increased cost is removed, homeowners are likely to electrify their home heating because they see electricity as safer, better for the environment, more efficient, more reliable, healthier, or better able to leverage renewable energy sources (Sussman and Eisen 2024). However, among the group of homeowners interested in electrification, the benefits of adding energy efficiency may not be readily apparent. Focusing homeowners on the added benefits of energy efficiency could improve outcomes.

When energy efficiency envelope improvements are paired with electrification to reduce ongoing costs, the financial argument for efficiency is effective. Financial drivers are cited as the top motivator of energy efficiency investment among homeowners in the United States and abroad (e.g., Fischback 2014; Mortensen, Heiselberg, and Knudstrup 2014). However, educating homeowners about the additional comfort and health benefits of energy efficiency envelope improvements can also be a significant motivator of upgrading, possibly even more effective than relying purely on a financial explanation (Sussman and Chikumbo 2017). Talking about comfort in concrete and specific ways (e.g., reducing cold drafts, glare from windows, and noise) is more effective than using the general term "comfort" (Shelton 2017). Contractors doing home energy assessments are ideal actors for delivering this message as they are one of the few direct, in-person, touch points with customers. Training contractors on behavioral science principles can help encourage upgrading (Gonzales, Aronson, and Costanzo 1988).

Homeowner misconceptions about the value or ease of doing upgrades, uncertainty about the contractor's skill level or the savings that will be earned, and long payback periods can also be barriers to investing in energy efficiency (e.g., Fuller 2009; Fischback 2014). These can be mitigated through streamlining the process (including how rebates are found and applied for), creating a trusted certification for contractors, and offering simple standardized packages with standardized prices. When city leaders in Fort Collins, Colorado, implemented this sort of streamlined program, they were able to reduce natural gas use by 70% (as opposed to 50% with previous efforts) while doubling the number of homes participating in their program (Kassirer 2018).

Encouraging adoption of new rate structures

Complexity and uncertainty of the outcomes of actions are major barriers to climate change mitigation behavior (e.g., Barrett and Dannenberg 2014; Bushell et al. 2017). Alternative rate structures are more complex than flat rates and customers are often uncertain about how much they might save by adopting electrification measures and/or new rate plans (Faruqui and Sergici 2010). Customers usually do not know which behaviors and technologies in their homes use the most energy (Lesic et al. 2018), and they are typically not aware of their household energy use patterns. Moreover, even if they know their current usage patterns, those patterns are liable to change if they electrify their home and switch to a heat pump for space heating. This lack of knowledge can lead to decision paralysis—a situation in which people delay or avoid making decisions because they feel overwhelmed (e.g., Huber et al. 2012). Residents then allow their decisions to be guided by inertia and the status quo, sticking with their current (flat rate) rate plan and paying more for electrification.

A related barrier to opting for an alternative rate is that customers are likely to resist changes that interfere with their daily routines, especially when it comes to practices like household chores or leisure activities that are hard to shift to off-peak times (Torriti 2012b). If they perceive that they need to change these behaviors to capitalize on the alternative rate structures, they will be unlikely to switch rate plans.

A few evidence-based behavioral science strategies can be applied to remove or lessen these barriers among customers considering a new rate structure as part of electrification. First, to lessen complexity of the rate plan, maximize certainty about saving money, and reduce the impression that behavior change is necessary for the plan to work, utilities could offer a simple heat pump discount rate to any customer heating with an electric heat pump. This type of rate is currently offered in Maine and can help customer decision making. It is the most effective rate design to make the math work and encourage heat pump adoption.

Second, when utilities learn that a customer has switched to an electric heat pump (e.g., because they used a rebate offered through the utility), an alternative rate structure can be made the default. Changing defaults can be a simple way to encourage switching to a new money-saving rate. Setting defaults is among the most effective no-cost ways to change behavior and can be used to encourage behaviors such as choosing to receive electricity generated by clean energy (Pichert and Katsikopoulos 2008). Switching the default changes the force of inertia toward making a decision that is likely to be optimal for the customer's energy bills (i.e., it changes the "status quo").

Importantly, however, defaults must be handled carefully and with full transparency to customers to avoid eroding trust and creating long-term challenges for electrification and other initiatives that are difficult to undo. If changing the default is not feasible then creating an active choice (i.e., eliminating the default) could be an effective alternative. Requiring customers to actively choose their rate plan without a default (possibly noting which plan is "recommended") could have a similar effect to changing the default. Although not many examples of this currently exist in the energy domain, this is a common strategy in healthcare and other settings, in which it is used to encourage patients to comply with health directives (Keller et al. 2011). Offering multiple alternative rate options further increases the likelihood that customers will not choose a flat-rate option (Lang, Qiu, and Dong 2023).

Third, decision-making tools, such as simple calculators and tailored energy use graphs can be used to show customers how their bills would likely change after electrification with various rate structures. PG&E offers one such tool to help customers decide which of its eight residential electricity rate structures would work best for them (Pacific Gas and Electric 2024b). If defaults or active choices are not feasible, then simplifying the rate structure choice with supplemental resources could help customers change their plans. Critically, these resources must be designed for clarity and simplicity. We highly recommend rigorous testing with customers prior to launching any resource. A poor tool can increase perceived complexity and lead to incorrect conclusions (i.e., the opposite of the desired effect). This type of misunderstanding was similarly observed when readers examined older climate change graphs published by the Intergovernmental Panel on Climate Change (McMahon, Stauffacher, and Knutti 2015).

Fourth, to further alleviate concerns about expenses, a hassle-free trial period or automatic reversal to previous plan could be offered alongside a new rate. Customers on the new rate can be provided with information on how their bills compare to what their bills would be on a traditional plan and then either offered the choice to switch at any time or automatically switched after a period of several months if their bills are higher. This type of solution is currently offered by PG&E, which allows its customers to change rates up to two times within a 12-month period (Pacific Gas and Electric 2024a).

Encouraging load shifting of customers on alternative billing rates

TOU and demand-based rates help reduce electricity bills for households that use heat pumps relative to fossil fuel–heated homes. However, these rate structures are best for residents who understand them and can shift their behavior to reduce costs. Research on TOU rates suggests that they are less effective in shifting behavior if customers are unaware of them or their appliances/technologies do not automatically change energy use to take advantage of them (Harding and Sexton 2017). By providing heat overnight, heat pumps necessarily take advantage of off-peak electricity pricing, but customers can save even more if they are able to shift additional energy use to off-peak times.

To address this, utilities should offer support through tools and technologies like usage tracking apps, smart thermostats, and other “set and forget” technologies. For example, many new Wi-Fi-enabled appliances include demand response capabilities, allowing customers to take advantage of monetary rewards during peak energy-use events (sometimes even going beyond saving money to earning a little). Equipping customers with such tools from the start of the electrification process can help alleviate some of the perceived responsibility for managing energy use as well as reduce the peak load demand for the benefit of the grid. This was the case for OGE Energy Corp’s variable peak pricing program, in which OGE customers could elect to have the utility install smart thermostats with a price trigger (Faruqui, Hledik, and Sergici 2019). By simplifying customers’ energy management and reducing the perceived risk or effort required, utilities can help customers adhere to alternative rates without feeling overwhelmed by the complexity of changing their daily energy use behaviors.

Additionally, customers may need ongoing positive feedback to maintain the necessary energy usage behaviors to achieve meaningful savings. For example, research on regularly delivered home energy reports that give energy use feedback shows that customers reduce their energy use immediately after they receive each report (Allcott and Rogers 2014). Utilities should provide feedback mechanisms on bills and other communications that remind customers of their progress and savings.

Communicating an increased electric bill to residents who electrified

Even when electrification is financially beneficial, a key challenge is that customers will often see higher electricity bills after switching heating fuel sources—but they will see lower bills for the fuels they are no longer using. Or they may see energy bills go up in some months, even though they go down on an annual basis. The salience of the increased electricity bill has the potential to dominate customer perceptions in a way that overshadows the actual savings they are experiencing and the long-term financial benefits of electrification. Worse, this salience could lead to a misperception that their expenses have gone up, even though their total energy costs have in fact decreased.

Behavioral biases like loss aversion and mental accounting play a significant role in this perception (Hahnel et al. 2020; Kahneman and Tversky 1979). Mental accounting may lead customers to treat different energy bills as separate financial accounts rather than considering their total energy expenses. As a result, when the electricity bill increases post-electrification, customers perceive it as a significant financial hit, even though their total energy costs have likely decreased. They focus on the loss and either devalue the gain or fail to include it in their mental calculations.

Additionally, savings that slowly accrue over time are by nature difficult to grasp. Struggling to connect their current decisions with future outcomes, people value gains in the present more than gains in the future (van den Bos and McClure 2013). If savings are small and incremental after electrification, or if they are inconsistent (savings in some months and losses in others), then they may not be perceived as savings at all.

Utilities can help customers shift their focus from their rising electricity bills to the total reduction in energy costs by merging their mental accounts: that is, showing customers the net financial impact of electrification through personalized descriptions of their total energy costs, including what they are currently and what they would have been without electrification. This may be challenging if the utility only has access to the electric bill and not the gas bill. Moreover, after electrification, the gas bill may no longer exist. Therefore, modeled or estimated total energy costs could be provided.

Critically, to encourage an appropriate mental accounting of overall spending on energy, cost must be shown as a comparison to a modeled business-as-usual scenario (as opposed to no comparison, a historic comparison, or a comparison to other homes). This is because electricity bills can increase for non-electrification reasons or in some months but not others (e.g., changing seasons, an additional household member, or adding an electric vehicle). Additionally, comparisons should be shown over a sufficient time span as to demonstrate that even if bills go up in some months, they will be lower overall: including graphs that show total annual energy costs, rather than just monthly, could be helpful. Such report-building tools could be impactful, but (to our knowledge) are yet to be developed and distributed at scale.

Summary and recommendations

To retain customer trust and ensure the highest savings possible, electrification measures should be paired with efficiency improvements and rate changes. The benefit to ongoing costs is significant. Although envelope upgrades add to the upfront cost, these expenses can be defrayed with a variety of programs and incentives, such as those created through the IRA and IIJA. Without envelope upgrades, customer’s bills are more likely to increase post-retrofit, discouraging wider adoption. Below we offer specific recommendations for electric utilities, state regulators, federal policymakers, and program administrators and implementers.

Electric utilities and state regulators

Provide electricity rates that favor heat pumps

Within the realm of rate design, we first recommend providing discounts directly to heat pump customers, particularly in the winter, as this directly incentivizes heat pump adoption with the lowest chance of unintended side effects. From a behavioral standpoint, a heat pump discount rate is more likely to encourage heat pump adoption, by clearly communicating to prospective customers what the rate is intended to do without demanding they grasp the finer details of electric load profiles and varying times of electricity use. If the rate cannot be made heat pump–specific, then a winter discount to customers with any type of electric heating will help. A winter discount rate is particularly important to prevent energy bills from increasing in cold-climate regions.[48]

These rates can then be made more economically attractive by combining them with pricing terms that indirectly benefit heat pump customers. Our modeling, as well as the Brattle Group's, show that a demand-based charge (combined with a TOU charge for a per-unit cost) also favors heat pump customers (Sergici et al. 2023). TOU and demand-based charges may be more feasible than winter discount rates in states where technology-focused rates are explicitly not permitted (a full list of states with these policies is available in the biannual *State Energy Efficiency Scorecard*) (Subramanian et al. 2022).[49] However, a flexible regulatory landscape (i.e., being able to change rate structures as needed) should also be prioritized by regulators in the event that market conditions change. For example, if renewable capacity increases and on-peak energy use becomes more desirable, a demand-based charge would discourage this helpful behavior.

Federal and state policymakers

Invest in energy distribution and transmission

As a wider policy recommendation, public (not ratepayer-funded) investment should focus on bringing down the residential price of electricity compared to fossil fuels. An updated grid can directly and strongly draw down the delivered cost of power. On a federal and state level, great investment is needed in updating the electricity grid to lower the cost of distribution and transmission. If these upgrades are solely funded through utility ratepayers, fixed charges may increase (although the per-unit cost of delivering electricity should still come down). Government investment will help reduce costs to consumers without directly increasing fixed charges. In California, utility ratepayers are paying the costs of fireproofing the grid to deal with the increased risk of wildfires. This type of investment could be at least partially shouldered by government to reduce costs to ratepayers.

An improved grid is essential to the energy transition. More renewable energy production necessarily involves more electricity on the grid, and the grid must be improved to serve this increased strain. This is widely acknowledged, and NGO research on the energy transition has found that robust grids are essential in expanding renewable energy (IEA 2023). Although an improved grid is needed to transmit

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[48] In our analyses, Maine's heat pump-specific rate was the most effective for keep rates low after electrification in that state. However, the winter discount was still insufficient to close the gap between gas-heated homes and those with heat pumps. Nevertheless, specifying that the rate be specifically for heat pumps is effective for encouraging heat pump adoption.

[49] This resource includes fuel-switching policies from 2022. The 2025 *State Energy Efficiency Scorecard* (forthcoming) will provide more up-to-date information on states with fuel-switching restrictions.

and distribute this electricity, the effect of a better grid on electricity prices has not been as widely studied. However, the relationship between grid investment and transmission prices has been observed empirically, with interconnection between renewable production centers and urban demand centers causing a decline in the per-unit electricity cost (Gonzales, Ito, and Reguant 2022).

A key assumption underpinning this paper—that electricity demand is lower during the winter, justifying utilities offering a discount during this time—will no longer be the case with a fully electrified housing stock. Therefore, a comprehensive solution must reach beyond rate designs.

It is important to understand the relationship between infrastructure and cost. Without significant investment in grid infrastructure, transmission and distribution capacity will still exist, but it will be much scarcer, with competition for capacity driving up the price. The outdated equipment requires more maintenance and, since it is older, is less efficient than more current technology. Although it is widely accepted that the United States needs a newer, better grid, yet grid upgrades are typically presented as an infrastructure issue, and not a cost issue. However, the effects of an outdated grid do show up in the marketplace as higher prices relative to what we could have under greater public infrastructure investment.

Implement clean heat standards and carbon pricing

Clean heat standards are a policy tool that "places performance requirements on heating market actors to increase the uptake of clean heat products and services"(Santini et al. 2024, p. 2). This policy tool is effective because it provides flexibility within a range of possible actions. It may thus provide a faster and easier pathway to decarbonization than equipment standards alone. It can also be paired with wider policy and market reforms that support clean heating, such as carbon pricing, phaseout policies, and energy efficiency obligations. Colorado, Maryland, Massachusetts, and Vermont have implemented some version of these standards (Santini et al. 2024).

In Connecticut, natural gas heat is encouraged through a winter discount in prices. Removing this discount in Connecticut and other similar states could also be a useful policy step toward supporting clean heat.

As demonstrated by an analysis of Maryland gas prices, electrification is likely to drive up residential gas prices in the coming decades, even without clean heat standards. This is largely because a declining natural gas customer base will lead to increased costs for remaining customers (OPC Maryland 2022). Given installation of gas central heating in new construction is more expensive than heat pump installation (and gas backup systems are not needed in most regions), electrification is likely to naturally continue (OPC Maryland 2022). Clean heat standards, carbon pricing, and other related policies could help support this trend and further accelerate the change in gas prices relative to electricity. A handbook for implementing clean heat standards is available from the Regulatory Assistance Project (Santini et al. 2024).

Program administrators and implementers

Use behavioral strategies to encourage electrification and shift consumption patterns

In terms of behavior change and adoption, consumers who are still hesitant to electrify when the math works may be encouraged to switch through behavioral science–based strategies. Although cost and lack of awareness are the top barriers for electrification and efficiency, issues of trust in the utility, misperceptions of savings, extra effort required of the customer and overwhelm from the complexities and uncertainties of rate structures and potential future outcomes can also slow adoption. Behavioral science offers recommendations for overcoming these barriers and provides guidance for taking these nonfinancial issues into account when designing and marketing electrification programs. Working with contractors could be a critical avenue to increase uptake of heat pumps.

Residential electrification is economically feasible

Our analysis finds that only a handful of U.S. states have challenging economics for electrification—and even in those states, the economics of electrification can be improved with energy efficiency and heat pump–specific electricity rates (including winter discounts). Nevertheless, long-term investment in infrastructure and energy policy is also critical. With these investments and rates, along with behavioral science insights, many Americans can be moved to power their homes with electricity without increasing their costs. The future is bright for electrification in the United States.

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Appendix A. Upfront costs

Electrification and efficiency upgrades (also known as retrofits) for residential properties are expensive and out of reach for many homeowners (Sussman, Lewallen, and Conrad 2024). Although retrofit prices vary, the most significant barrier for prospective customers is usually upfront costs.[50] Therefore, defraying upfront costs is the primary target of most electrification and energy efficiency policies. In this section, we provide a brief overview of the main incentives that are currently available to U.S. homeowners.

Tax credits and rebates

Homeowners can get up to a $2,000 tax credit on a heat pump via the Energy Efficient Home Improvement Credit (Internal Revenue Service 2025).[51] Other energy efficiency costs, such as panel upgrades, insulation, windows and doors, and home energy audits, can be redeemed for up to $1,200 in additional credits. These tax credits can be combined with other incentives on a state or utility level, allowing homeowners to stack the funds. Although these are tax credits and not upfront incentives (and therefore require homeowners have a tax liability and can front the $2,000 until filing their taxes the following year), they are nonetheless important in helping to make the upfront electrification math work.

The Home Efficiency Rebate program (HOMES) is another federal financial incentive for energy efficiency and electrification. This program includes $4.3 billion to be spent on performance-based energy upgrades of single family homes and multifamily buildings. States can offer rebates based on modeled energy savings, measured energy savings, or both. Additionally, contractors can receive a $200 incentive for projects completed in disadvantaged communities.

Further, state-level programs receive IRA and the IIJA funding from the federal government. The State Energy Program (SEP), administered by the Department of Energy (DOE), provides annual funding to states, territories, and DC to support state-level energy initiatives. DOE's Weatherization Assistance Program (WAP) provides no-cost whole-home energy upgrades for low-income households (usually including insulation, air sealing, and other energy efficiency measures). This helps electrification efforts, as many low-income households have insulation and weatherization issues that must be solved before further electrification upgrades can take place. Thus, while WAP funding does not directly fund electrification, it can be quite useful for electrification efforts.

Other DOE programs include funding for states to establish revolving loan funds (U.S. DOE 2021) for energy efficiency upgrades,[52] funds for states to establish point-of-sale rebates (U.S. DOE 2024b) to provide instant savings without a tax credit, and funds to develop their own separate rebate programs (U.S. DOE 2024c). Beyond DOE, competitive home energy upgrade grants for states, as well as territories, tribal governments, municipalities, and nonprofits are available from the Environmental Protection Agency (EPA). The Department of Health and Human Services (HHS) allows 15% of funds from the Low-Income Home Energy Assistance Program (LIHEAP) to be spent on weatherization, assisting low-income households in the prerequisite upgrades for electrification. The Department of Housing and Urban Development (HUD) and the Office of Indian Economic Development (OIED) offer funds for

[50] For general price estimates of various retrofit packages, see Nadel and Fadali (2022).

[51] This credit is located in Section 25C of the Internal Revenue Code.

[52] Revolving loan funds (RLFs) are pools of capital from which loans are made and to which the loan repayments are returned and lent out again (ACEEE 2017).

energy improvement on HUD-subsidized multifamily properties and Tribal communities, respectively. For more information on these programs and more, see Appendix A of Amann and Saul-Rinaldi (2024).

After all the tax credits and rebates are accounted for, some of the most important (and expensive) energy upgrades may still be too expensive for liquidity-constrained homeowners, but these incentives nevertheless make the electrification math work better for many customers.

PACE loans

Property-Assessed Clean Energy (PACE) loans are a tool that can be used to encourage clean energy investment but that, if not implemented effectively, can also result in negative consequences for homeowners. PACE loans are specifically created for financing energy upgrades, electrification, and renewable energy. The difference between a PACE loan and a standard loan is that PACE loans are attached to the property itself, not the homeowner, and are paid back through higher property taxes. This allows the homeowner to receive the upgrade for no money down and does not impact the credit score of the homeowner. However, a property with an active PACE loan can be more difficult to sell because the loan goes to the next property owner. Attaching the loan to the property circumvents the risk that a loan will not be repaid if the homeowner sells (a risk that makes traditional loans unlikely or impossible) but it could also create challenges for home sellers.

Selling is particularly challenging because homebuyers have difficulty securing a mortgage to buy a home with an active unpaid PACE loan. Many banks will not approve these mortgages because Freddie Mac and Fannie Mae will not buy them (Fannie Mae 2020; Freddie Mac 2024; Wrapp 2013). These mortgage buyers are concerned that if a home forecloses, the PACE loan must be paid before the mortgage.[53] The problem may be alleviated with a reserve fund model that allows the government to step in and pay the PACE loan on behalf of the seller (Charin 2014), but this nevertheless shows the complexity of implementing PACE programs with proper guard rails.

If the PACE energy efficiency upgrades pay for themselves in savings, as they are meant to do, then the program can be an effective method to increase homeowner investments in energy upgrades. However, the lack of a federal mandate to require a home energy assessment prior to securing the PACE loan means that in some states homeowners may not be required to perform an assessment, and therefore property tax bills can go up without a concurrent decrease in energy bills. Requiring a validated home energy audit prior to receiving a PACE loan is, therefore, another key attribute that states should consider when implementing a residential PACE program.

PACE loans are a useful solution for many owners, though PACE loans face challenges for their further adoption. PACE loans must first be enabled by state-level legislation and then the state energy office or some other entity must set up a PACE program; only three states (California, Florida, and Missouri) have active PACE programs for residential buildings.[54] Residential PACE programs have been stifled by controversy over California's program, where insufficient consumer protections allowed for the defrauding of homeowners through the loans (NCLC 2020; DFPI 2020). DOE provides best practice guidelines for implementing PACE programs that, if followed, could help states protect homeowners while delivering energy efficiency, solar, and electrification (U.S. DOE 2024d).

[53] PACE loans take priority over mortgages. Therefore, the mortgage lender must approve the PACE loan.

[54] As of July 2024, 38 states have passed enabling legislation and 31 of these have set up PACE programs, though almost all these programs are for commercial buildings.

Energy efficiency services

Historically, customers in the municipalities, universities, schools, and hospitals (MUSH) sector have managed the costs of energy upgrades using an Energy Savings Performance Contract (ESPC; U.S. DOE 2024a). This is a contract where a customer hires a contractor to perform an upgrade without paying for the full down payment cost, and the customer pays back the value of the upgrade through future savings. Thus, the customer lowers their upfront cost while still saving energy.

This type of contracting is typically limited to the MUSH sector because of the high per-contract cost for the energy service company (ESCO). ESPCs are financially viable for large individual buildings, or even several buildings, but not usually individual homes. An improved version of the model, known as energy efficiency as a service (EEaaS) has no down payment for the customer,[55] but is nevertheless rarely available to single family homes.

Although EEaaS has potential as a novel solution for defraying upfront energy efficiency costs, only one provider (to our knowledge) makes it available to homeowners,[56] and this provider, BlocPower, has a less-than-stellar track record (Harris 2023b, 2023a). A large part of BlocPower's business model involves taking on large contracts with cities to achieve economies of scale when implementing multiple retrofits (though these results have yet to be seen), as one-off single family home projects alone are not financially feasible for ESCOs.

As the City of Ithaca found when trying to retrofit its building stock through an ambitious initiative involving its own recruitment of state-level funding, community development financial institutions (CDFIs), and green banks, these funds are insufficient for such a project. As a result, the city contracted with BlocPower, which secured financing from institutional investors such as Goldman Sachs (Mooney 2023). Still, financial conditions remain tight and, as of 2024, progress on the plan has been slow, with only 10 commercial and nonprofit buildings fully electrified as of March 2024 (Brady 2024) and BlocPower's work on single family homes not yet started.[57]

Making the upfront costs math work

For most homeowners using fossil fuels for heat, hot water, or cooking, a new system using electricity would have a higher upfront cost. Although many homeowners will save money in the long run through electrification (as discussed in the body of this report), the upfront cost could nonetheless be a barrier. The best way to make the math work for these customers is to offer point of sale rebates, tax credits, and, if possible, low- or no-interest financing. Fortunately, tax credits and rebates are being offered through IRA and IIJA and other state and utility programs. These will make the upfront costs math work better for a substantial number of homeowners. PACE and EEaaS are imperfect but have potential for laying the groundwork for effective financing program models in the future.

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[55] For more on the EEaaS model, see ACEEE's report Utilities and Energy Efficiency as a Service: The Potential for Win-Win Partnerships.

[56] A 2022 ACEEE report that highlighted 19 EEaaS providers included two providers that service single family homes, one of which has stopped since then.

[57] Personal communication with Rebecca Evans, director of sustainability, City of Ithaca. Notably, while BlocPower has electrified 10 buildings, nearly 200 have been electrified by the residents themselves.

Appendix B. Utility rates

Price structures for each state were based on the largest electric and gas utility, which for Minnesota and Colorado served at least 50% of customers and the largest metropolitan area. In Connecticut, two utility providers serve over 80% of power customers, while three separate natural gas providers serve nearly all

gas customers. To provide conservative assumptions, we chose the lower of the electricity rates and the median of the three natural gas rates. Fuel oil and propane prices were estimated via the average prices over 2019–2022 as published by the U.S. Energy Information Administration (EIA).

Note: highlights show updated rates since initial publication.

State	Season		Time-of-Use Rate: Monthly charge	Peak rate	Shoulder rate	Offpeak rate	Time period definitions
Connecticut	Summer	June - September					
	Winter	October - May	$ 9.620	$ 0.413	N/A	$ 0.237	Peak: 12-8 p.m. weekdays; Offpeak: all other hours
Colorado	Summer	June - September		$ 0.319	$ 0.219	$ 0.117	Peak: 3-7 p.m. weekdays; Shoulder: 1-3 p.m. weekdays; Offpeak: all other hours
	Winter	October - May	$ 8.050	$ 0.202	$ 0.161	$ 0.120	
Maine	Summer	May - October					Peak: 7 a.m. - 8 p.m. weekdays; Offpeak: all other hours
	Winter	November - April	$ 24.150	$ 0.260	N/A	$ 0.178	
Minnesota			See attached table				

State	Season		Demand-Based Rate: Monthly charge	Peak rate	Offpeak rate	Peak demand charge	Offpeak demand charge
Connecticut	Summer	June - September					
	Winter	October - May	$ 9.620	$ 0.300	$ 0.150	$ 4.394	$ 13.181
Colorado	Summer	June - September					
	Winter	October - May	See attached table				
Maine	Summer	May - October					
	Winter	November - April	N/A				
Minnesota			See attached table				

State	Season		Discounted Heat Pump Rate: Monthly charge	Peak rate: Heat pump	Peak rate: Non-heat pump	Shoulder rate: Heat pump	Shoulder rate: Non-heat pump	Offpeak rate: Heat pump	Offpeak rate: Non-heat pump
Connecticut	Summer	June - September		$ 0.413					
	Winter	October - May	$ 9.620	$ 0.285	$ 0.413	N/A		$ 0.237	
Colorado	Summer	June - September		$ 0.319		$ 0.219		$ 0.117	
	Winter	October - May	$ 8.050	$ 0.140	$ 0.202	$ 0.161		$ 0.120	
Maine	Summer	May - October						$ 0.307	
	Winter	November - April	$ 40.670	N/A				$ 0.118	N/A
Minnesota			N/A						

State	Season		Flat rate: Monthly charge	Flat rate: Per-unit charge	Gas: Monthly charge	Gas: Per-unit rate	Fuel Oil	Propane
Connecticut	Summer	June - September						
	Winter	October - May	$ 9.620	$ 0.288	See attached table		$ 3.839	$ 3.671
Colorado	Summer	June - September		$ 0.153				
	Winter	October - May	$ 8.050	$ 0.136	$ 12.300	$ 0.830	N/A	$ 2.446
Maine	Summer	May - October						
	Winter	November - April	$ 26.600	$ 0.215	See attached table		$ 3.560	$ 3.399
Minnesota			See attached table		See attached table		$ 3.744	$ 2.141

Highlighted areas are rates simulated for this report	Fuel oil and propane prices are in $/gallon
Electricity per-unit prices are in $/kWh	Gas per-unit prices are in $/therm.
Electricity demand charges are in $/kW	The first 50 kWh of this plan are covered in the monthly flat rate

Figure B1. Most utility rates

Colorado Demand-Based Rate		Monthly Charge	Peak rate	Shoulder rate	Offpeak rate	Demand charge
Summer	June - September		$ 0.280	$ 0.180		$ 5.789
Winter	October - May	$ 8.050	$ 0.160	$ 0.110	$ 0.090	$ 3.860

Figure B2. Colorado demand-based rate

Minnesota Flat Electric Rate		Monthly charge	Per-unit rate	
			Electric space heating customers	Non-electric space heating customers
Summer	June - September		$ 0.175	
Winter	October - May	$ 6.000	$ 0.126	$ 0.158

Figure B3. Minnesota flat electric rate

Minnesota Electric Time-of-Use Rate		Monthly cost	Peak rate		Offpeak rate	Time period definitions
			Electric heating customers	Non-electric heating customers		
Summer	June - September		$ 0.305			Peak: 9 a.m. - 9 p.m. weekdays;
Winter	October - May	$ 6.000	$ 0.180	$ 0.260	$ 0.096	Offpeak: all other times

Figure B4. Minnesota electric time-of-use rate

Minnesota Demand-Based Rate		Monthly cost	Peak rate		Offpeak rate	Demand charge	Time period definitions
			Electric heating customers	Non-electric heating customers			
Summer	June - September		$ 0.245			$ 5.466	Peak: 9 a.m. - 9 p.m. weekdays; Offpeak:
Winter	October - May	$ 6.000	$ 0.154	$ 0.225	$ 0.094	$ 1.367	all other times

Figure B5. Minnesota electric demand-based rate

Maine Gas Rate	Monthly charge	Per-unit rates			
		Gas heating customers	Non-gas heating customers	Gas heating customers	Non-gas heating customers
		First 40 therms		Above 40 therms	
	$ 32.870	$ 1.100	$ 1.162	$ 0.854	$ 0.765

Figure B6. Maine gas rate

Connecticut Gas Rate

Month	Gas Heating			No Gas Heating	
	Monthly charge	First 30 ccf	Above 30 ccf	Monthly charge	per ccf
1	$18.000	$1.675	$1.199	$20.350	$2.677
2		$1.722	$1.245		$2.724
3		$1.762	$1.285		$2.763
4		$1.709	$1.232		$2.711
5		$1.698	$1.221		$2.700
6		$1.646	$1.169		$2.648
7		$1.510	$1.034		$2.512
8		$1.510	$1.034		$2.512
9		$1.629	$1.152		$2.686
10		$1.681	$1.205		$2.739
11		$1.681	$1.205		$2.739
12		$1.682	$1.205		$2.739

Figure B7. Connecticut gas rate; note that this rate is in hundred cubic feet, which is roughly equivalent to therms. (1 CCF ≈ 1.038 therms)

Minnesota Gas Rate

Monthly charge	Month	Per-unit rate
$ 10.830	1	$ 0.910
	2	$ 0.938
	3	$ 0.775
	4	$ 0.745
	5	$ 0.788
	6	$ 0.847
	7	$ 0.877
	8	$ 0.833
	9	$ 0.905
	10	$ 0.952
	11	$ 0.862
	12	$ 1.094

Figure B7. Minnesota gas rate;

Appendix C. Energy cost modeling details

The energy usage data for this study were taken from ResStock™, a dataset of simulated building energy usage for U.S. residential housing stock, developed and maintained by the National Renewable Energy Laboratory (NREL). We used the simulation data published in March 2024, using weather data from the meteorological data from 2018 (AMY 2018). The three datasets we used were for the baseline data without energy upgrades (upgrade #0), a cold-weather air-source heat pump (upgrade #2), and a cold-weather air-source heat pump with insulation improvements (upgrade #7). We chose three states based primarily on which had challenging economics as estimated by the aggregate state profiles from ResStock™. Connecticut had the most challenging economics of any state, followed by other New England states. Minnesota had challenging economics similar to nearby Michigan and Wisconsin and was chosen for its relative simplicity in its energy markets. Colorado had the most challenging economics of its region and was chosen for greater geographic diversity. Maine was chosen as a northeastern state with better economics for electrification. State-by-state analysis was then conducted on the individual time-series housing profiles.

Data analysis was computed with R through R Studio, utilizing the packages Tidyverse, data.table, Futureverse, and Rfast. From the complete set of simulations, we removed the ~1% in each state which used a heating source outside of fuel oil, electricity, natural gas, and propane. While not specified, this can refer to houses with wood-burning stoves or no heating at all. Using fuel costs and usage data, annual bills for each of the simulated households were calculated for baseline data and both upgrade packages.