Massachusetts Study on Time-Varying Rate Design to Enable Electrification

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About Advanced Energy United

Advanced Energy United (United) is a national association of businesses that works to accelerate the move to 100% clean energy and electrified transportation in the U.S. The term advanced energy encompasses a broad range of products and services that constitute the best available technologies for meeting our energy needs today and tomorrow. These include electric vehicles (EVs), energy efficiency, demand response (DR), energy storage, solar, wind, hydro, nuclear, heat pumps (air- and ground-sourced), and smart grid technologies. United represents more than 100 companies in the $374 billion U.S. advanced energy industry, which employs 4.1 million U.S. workers and over 135,000 in the Commonwealth of Massachusetts.

About Demand Side Analytics

Demand Side Analytics (DSA) helps utilities, regulatory agencies, and system operators navigate the technical, economic, and policy challenges of building a smarter and cleaner energy future. We focus on data-driven research and insights and predictive and causal analytics. We deliver data-driven insights into how various technologies and interventions affect the way homes and businesses use energy and how those, in turn, affect grid and system planning. We have a proven record for conducting insightful, high-quality, accurate and unbiased analysis and are meticulous about ensuring that research is useful for policy decisions, operations, and implementation.

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Executive Summary

Massachusetts is a leading state on clean energy metrics with a long history of aggressive energy efficiency programs and bold investments in renewable energy projects. However, the Commonwealth's growing policy emphasis on electrification of transportation and buildings is hindered by some of the highest electric rates in the country. For this reason, United engaged DSA to develop the *Massachusetts Study on Time-Varying Rate Design to Enable Electrification*. The study finds that a time-of-use (TOU) electric rate structure, paired with enhanced energy efficiency efforts, can significantly reduce residential energy bills for electrified homes.

Because not all alternative rate structures satisfy other related Commonwealth policy objectives related to distributed generation, energy efficiency, and long-term system cost containment, the study primarily examined the customer-level bill impacts of a basic time-of-use (TOU) design. This rate design encourages customers to modify their electricity consumption patterns through energy efficiency, load shifting, and distributed energy, while also mitigating system cost increases that are borne by ratepayers. We estimate that under current electric and gas rates, converting from a natural gas furnace to a minimum efficiency heat pump system increases annual energy costs by approximately $2,000 for a typical Massachusetts home. This magnitude of utility bill increase curbs adoption and creates a serious headwind to the Commonwealth's climate goals. A shift to the modeled TOU rate, however, can offset the bill increase by about $570, or 9%. In contrast, TOU confers less than $90 (2%) in savings to the gas-heated home as less of their energy consumption is electric and thus subject to the rate's benefits. As the customer further electrifies and becomes more efficient, energy and cost savings increase, while the TOU rate affords a steady savings rate of roughly 8-9% per year. Overall, this rate offers preferential bill savings to electrified customers, while also mitigating electrification's contributions to peak load and the associated capacity costs.

Though this report focuses on the impact of TOU rates and energy efficient upgrades on individual customer bills and avoided system costs, we also consider how gas rates might change in parallel given market electrification trends. Finally, we compare the effects of TOU with several other rate designs inspired by the Massachusetts Interagency Rates Working Group (IRWG). For all rates considered, we look at the effects of rate changes on electric bills, gas bills, and avoided system costs to understand their pros and cons.[1]

[1] The Massachusetts Interagency Rates Working Group provided Near-Term Rate Strategy Recommendations on December 20, 2024 and Long-Term Ratemaking Recommendations on March 7, 2025. The reports can be found at the IRWG's website.

In the study, we focus on long-term solutions to be implemented when Massachusetts has completed their rollout of Advanced Metering Infrastructure (AMI), which is expected to be completed in 2025 for Unitil, 2028 for National Grid, and 2029 for Eversource.[2]

Part 1: Impacts of TOU rates on bills and avoided costs

To compare the effect of TOU rates on homes with gas heating versus homes with electric heating, the study uses energy consumption data for five representative Massachusetts households – one with gas heating (baseline home), and four with varying degrees of electrification and energy efficiency measures. The proposed rate is then applied to these model home profiles, generating bills which show how different homes could be affected by TOU. We also discuss the rate's impact on avoided costs at the individual customer and system levels, including a consideration of the shift from a summer peaking system to a winter peaking system.

As mentioned above, we estimate that TOU would save customers who electrify with minimum-efficiency heat pumps approximately $570 annually compared to the current rate. For a fully electrified home with a high-efficiency heat pump, annual bills on current rates would approximately break-even with pre-electrification bills, though the TOU rate could save an additional few hundred dollars.

Regarding avoided costs, the modeled TOU rate could be expected to reduce electric system cost increases from a partially electrified home with a minimum-efficiency heat pump by approximately 7.8% or $148, in a winter peaking system.

Part 2: Impacts of advanced energy efficiency measures on bills and avoided costs

Using the same representative Massachusetts household profiles, this section compares electric, gas, and combined fuel bill savings that customers can expect given higher levels of electrification and efficiency on both the current rate and our modeled TOU rate. It also discusses how various levels of full electrification may raise costs for those who remain connected to the gas system, and how increasing gas delivery rates change bolsters the economics of electrifying. Finally, the section contemplates how the various electrification and efficiency scenarios impact avoided costs.

From the results it is clear that only the scenario using a minimum-efficiency heat pump drive total bill increases. Upgrade levels that used a high-efficiency heat pump were able to at least match or pay less than current pre-electrification bills, on both current rates and our modeled TOU rate. The addition of enhanced insulation to a fully electrified home with a high-efficiency heat pump saves an extra $765 annually, from energy savings alone. By design, TOU builds on those savings, offering additional savings over the current rate.

[2] Massachusetts Interagency Rates Working Group, *Near-Term Rate Strategy Recommendations*, p. 23. December 2024.

Electricity avoided cost increases range from approximately $1,000 per electrification customer in the minimum-efficiency heat pump scenarios down to less than $300 per customer in the highest efficiency scenario before the system switches to winter peak. After the switch, avoided cost increases range from just under $700 to just under $2,000.

Our gas delivery cost analysis illustrates that at 5% full electrification, wherein 5% of customers have disconnected entirely from gas, remaining customers will experience an increase of around $65 annually. That increase escalates as the percentage of customers electrifying escalates, reaching an additional $1,200 per year at 50% penetration.

Part 3: Examination of other alternative rate options

The third section of this study contrasts the impact of various alternative rate designs on annual bills and avoided costs. The alternative rates were chosen to align with the Massachusetts IRWG's near-term rate design study – a Universal Fixed Charge Rate of $25, a $25 Fixed Charge Rate available only to electrifiers, and a Decreasing Tiered Rate. However, the modeling inputs and assumption are our own, which leads to directionally similar but not identical findings as the IRWG. We also consider the different advantages and disadvantages of each rate option as they relate to other interrelated energy goals and discuss additional considerations for the Commonwealth as it considers these options.

The analysis shows that the $25 Universal Fixed Charge Rate performs the worst across all electrification scenarios, and that the Electrifier-only Fixed Charge Rate and Decreasing Tiered Rate perform best; however, these rates have noteworthy disadvantages. Further, the magnitude of benefits of the Electrifier-only Fixed Charge and Decreasing Tiered Rates is reduced when using a high-efficiency heat pump, and much reduced when using a high-efficiency heat pump alongside other building shell improvements. Only the TOU rate has any effect on avoided costs, because it is the only rate that encourages shifting load away from peak periods that drive system costs.

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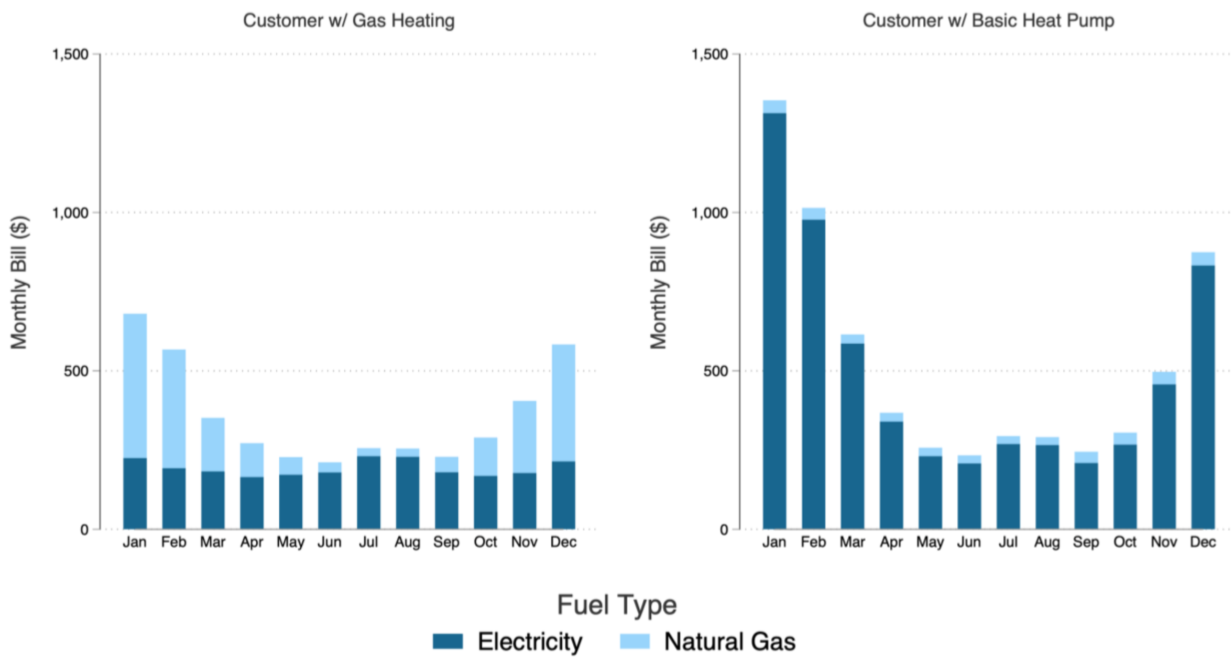
Introduction

Massachusetts is widely recognized as a leading state with respect to clean energy policy and energy conservation programming. Electrification will be a key focus as Mass Save programs shift focus from kilowatt hour (kWh) reductions to greenhouse gas emissions reductions and obligations from the Massachusetts Clean Heat Standard ramp up. While Massachusetts has a variety of innovative initiatives to bolster adoption of EVs and heat pump technologies, the high retail rates faced by customers of the Commonwealth's two largest investor-owned utilities (IOUs) present a strong headwind to electrification.

Figure 1 shows the change in annual energy costs for a home that transitions from natural gas heat to an air-source heat pump under current rates, with no other electrification or efficiency measures. The left-hand panel shows monthly energy bills under current rates before electrification, and the right-hand panel shows monthly energy bills after electrification. When we compare bills in each month across the panels and sum over the months, we estimate that the electrified customer pays around $3,600 more on electricity annually compared to their non-electrified counterpart due to increased electricity consumption being applied to a high, volumetric rate. Though that customer avoids around $1,600 on their gas bill after electrifying, they still net an overall energy cost increase of over $2,000 per year. As such, even with programs that help offset upfront capital costs, electrification under current rates is a costly proposition for the typical home. The prospect of decades of increased energy burdens will limit market adoption of heat pump technologies and hinder progress towards the Commonwealth's climate goals.

While the focus of this study is on the impacts of air source heat pumps and other electrification measures, ground source heat pumps are a higher efficiency electrification option that can produce significant consumer bill reductions.

Figure 1: Monthly Bills Under Current Rate, by Heating System Type (National Grid)



Massachusetts is also deploying AMI statewide and expects this to be complete in the next five years. Once in place, more complex rate structures, such as those that vary the cost of electricity by hour, can be implemented. Until then, the Commonwealth has limited options to address this problem.

In 2023 the IRWG was formed to advance near- and long-term rate designs that align with the Commonwealth's decarbonization goals. The goals of the group were to understand the current rate landscape, address barriers to near-term electrification through rate design, as well as consider what rate structures could look like in a decarbonized future. The group stresses *"electric ratemaking and rate design must prioritize the reduction of energy burden and incentivize transportation and building electrification to facilitate the transition to a distributed grid."*[3]

United retained DSA to perform an analysis of electric rate design options that could help accelerate electrification without disadvantaging ratepayers or complementary advanced energy technologies that are a necessary part of affordable decarbonization. To that end, the goals of the study were to:

[3] Massachusetts Interagency Rates Working Group. "Background." Commonwealth of Massachusetts, [24 April 2025 of Access], mass.gov/info-details/interagency-rates-working-group.

- Design a TOU electricity rate structure and estimate monthly bills under multiple efficiency scenarios;
- Understand how varying levels of electrified heating and home efficiency improvements impact bills and changes in avoided costs under current and alternative rates;
- Consider how increasing natural gas rates might impact the attractiveness of electrification, and;
- Examine additional rate structures like those considered by the IRWG, including higher fixed charges, seasonal heat pump rates, and a decreasing tiered rate.

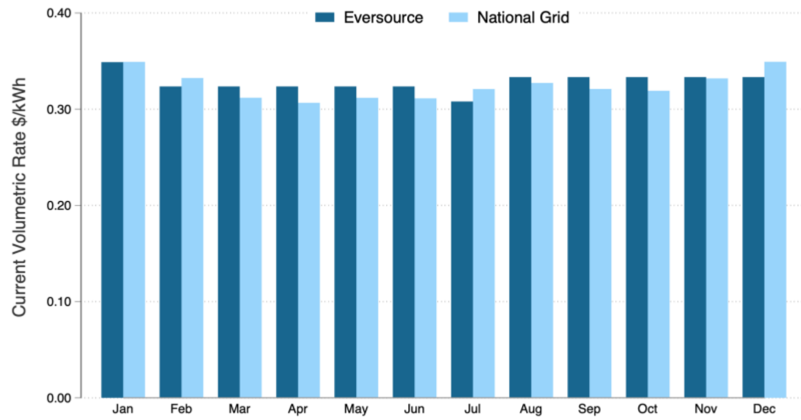
Current Rates

The study aims to contrast energy bills under current Massachusetts rates[4] to bills under alternative rate structures like those considered by the IRWG. To do so, we first need to understand the current rate landscape, including electricity and gas volumetric charges ($/kWh and $/therm, respectively) and fixed charges ($/month). After collecting published rates for the most recent 12 months for National Grid and Eversource (henceforth "the IOUs") we applied them to average household consumption data to project typical monthly bills. Specifically, delivery and supply rates are combined to get total volumetric rate by IOU by month. Figure 2 shows monthly volumetric electricity rates by IOU, and Figure 3 shows monthly volumetric natural gas rates by IOU. Generally, energy prices are highest in the winter.

In the main body of the report, figures and surrounding text are based in National Grid rates (although some figures contain both National Grid and Eversource information). The two IOUs report similar rates, and thus the sets of figures resemble each other closely. United is open to providing analogous Eversource results at request.

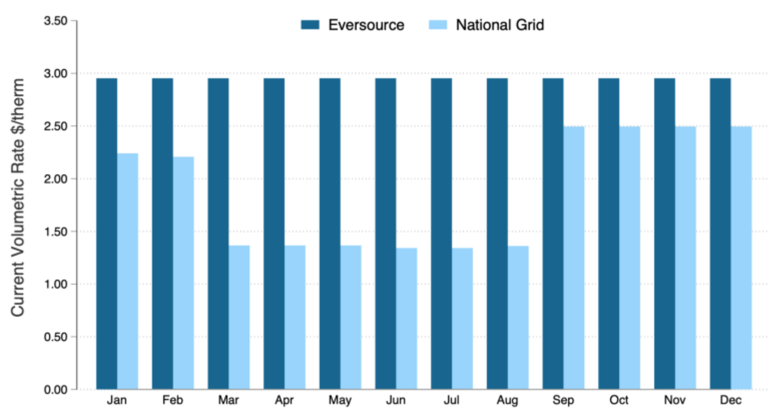
[4] Massachusetts's Basic Service current electricity rates from Eversource and National Grid were pulled from the companies' websites for the following periods: National Grid – electricity: supply (Aug. 2024 – Jul. 2025); delivery (Jan. 2024 – Dec. 2024); natural gas: supply (Mar. 2024- Feb. 2025); delivery (Mar. 2024 – Feb. 2025); Eversource electricity: supply (Aug. 2024 – Jul. 2025); delivery (Jul. 2024-Jun. 2025); natural gas: supply (May 2024, Feb. 2025); delivery (Mar. 2025 – Oct. 2025). This included fixed and volumetric rates for both electricity and natural gas. Where a choice was presented, the Boston area rates were used because the Boston metropolitan statistical area holds two-thirds of the state's population. The most recent year of rates was pulled.

Figure 2: Current Electric Monthly Volumetric Rate by Utility



Includes supply and delivery. Monthly electric fixed charges of $10 for National Grid and Eversource, respectively, are not included here.[5]

Figure 3: Current Natural Gas Monthly Volumetric Rate by Utility



Includes supply and delivery. Monthly natural gas fixed charges of $12 and $9.75 for National Grid and Eversource, respectively, are not included here.

Natural gas supply costs affect both electricity and natural gas rates to different extents and can fluctuate greatly over time. They present a significant challenge to accurately project. The correlation between natural gas supply costs and the ultimate natural gas or electricity rates paid by customers is outside of scope of this study. For that reason, this report does not project the impact of changes to natural gas supply rates. However, the study includes a

[5] To simplify analysis, we have omitted the small opt-in discounts on delivery rates offered to homes with electrified heating.

section called Increasing Gas Delivery Rates that projects increases to natural gas delivery rates under various scenarios of customer declines due to electrification.

Methods

Household Energy Consumption: NREL Energy Consumption Data

In each of the three sections of this paper, we reference various “Upgrade Levels” to distinguish between electrification and efficiency household scenarios. Typical Massachusetts electricity and natural gas consumption was primarily estimated using National Renewable Energy Laboratory (NREL) End Use Load Profiles 2022 data for Massachusetts.[6] This dataset provides average energy usage by end use (appliance), as well as for the whole home. Usage is broken out into electricity and natural gas components.[7] Furthermore, NREL supplies load profiles for various levels of home electrification, referred to here as “Upgrade Levels” and described in Table 1. Upgrade Level 0 was used as the baseline fossil-fuel heated home, and is contrasted with Upgrade Levels 3, 7, 8, and 10 representing the increasingly electrified and efficient home, throughout this report. The main difference between the baseline home and upgrade levels 3, 7, 8, and 10 is higher electricity usage and lower natural gas usage, as the latter homes have heat pumps which replace the need for fossil fuel heating. Upgrade Level 3 retains a gas connection for non-heating uses, while Upgrade Level 7 uses the same minimum-efficiency heat pump as Upgrade Level 3 but assumes whole-home electrification. Upgrade Levels 8 and 10 homes are more efficient than their Upgrade Level 3 and 7 counterparts and use less electricity. The heat pump efficiency levels in Upgrade Levels 8 and 10 approach the current technical limits of air source heat pump efficiency. At various points, we examine an alternative Upgrade Level 3 scenario where we remove the load caused by air conditioning (cooling units) in order to avoid comparing the impact to bills of including an entirely new service to previous bills without that service, thereby isolating the cost of the new air conditioning benefit. Over 20% of Massachusetts households today do not have air conditioning.[8]

Although not included in the study, ground source heat pumps – both individually and as part of looped networks – represent an even more efficient electrification option than those considered here, but also have higher upfront equipment and installation costs compared to air source heat pumps.

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[6] Specifically, the residential, TMY3 (Typical Meteorological Year) source version was used. Data starts out unique by home type (Single Family Detached, Multifamily, etc.), date and hour, but was collapsed to be the weighted mean by date and hour, weighted by percentage of Massachusetts homes which fall into each home type bucket (~51% Single Family Homes).
[7] Other fuel types, such as wood, propane, and fuel oil are also included, but are converted to therms and grouped with natural gas here.
[8] https://www.eia.gov/consumption/residential/reports/2009/state_briefs/pdf/ma.pdf

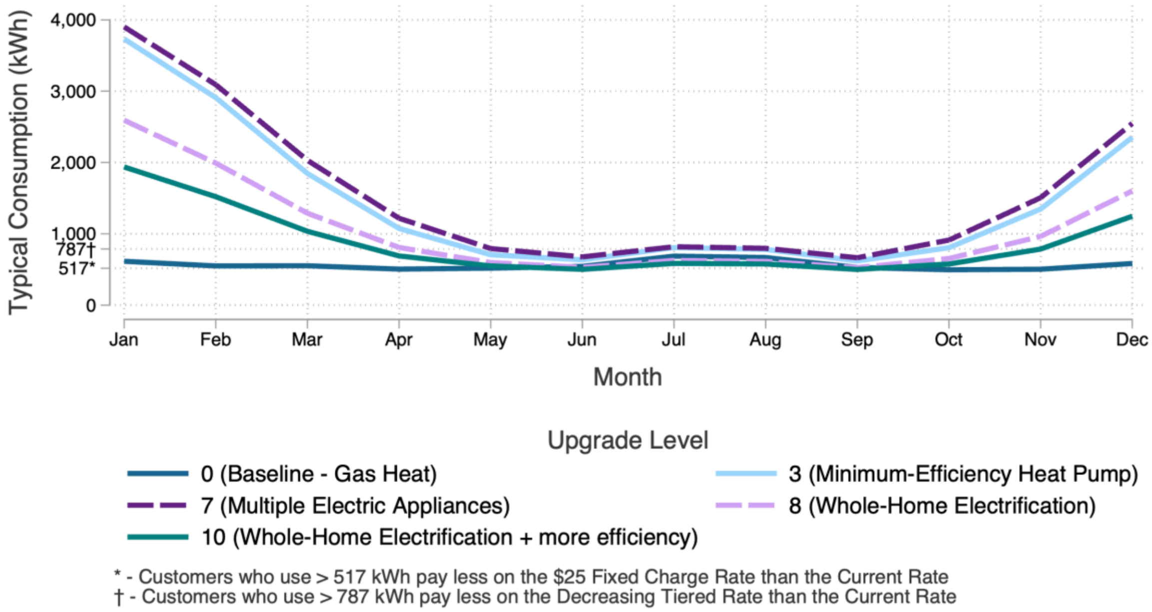
Table 1: Description of NREL Upgrade Levels (levels used are shaded in purple)

Upgrade Level	Definition	Specifications
0	Baseline	2018 U.S. housing stock
1	Basic enclosure	Attic floor insulation, wall insulation, duct sealing, general air sealing
2	Enhanced enclosure	Basic enclosure (Upgrade 1) + foundation wall and rim joist insulation, finished attic and cathedral ceiling insulation
3	Heat pumps, minimum-efficiency, electric backup	Homes with HVAC ducts: centrally ducted heat pump (SEER 15, 9 HSPF) for homes with HVAC ducts Homes without HVAC ducts: ductless mini-split heat pump (SEER 15, 9 HSPF) Electric resistance backup heating
4	Heat pumps, high-efficiency, electric backup	Homes with HVAC ducts: centrally ducted heat pump (SEER 24, 14 HSPF) for homes with HVAC ducts Homes without HVAC ducts: ductless mini-split heat pump (SEER 29.3, 14 HSPF) Electric resistance backup heating
5	Heat pumps, minimum-efficiency, existing heating as backup	Same heat pumps as Upgrade 3 + existing heating system retained as backup
6	Heat pump water heaters	1-3 bedroom homes: 50-gallon, 3.45 UEF HPWH 4-bedroom homes: 66-gallon, 3.35 UEF HPWH > 4-bedroom homes: 80-gallon, 3.45 UEF HPWH
7	Whole-home electrification, minimum efficiency	Heating: minimum-efficiency heat pump and electric resistance backup (Upgrade 3) Water Heating: heat pump water heater from Upgrade 6 Dryer: electric resistance dryer

		Cooking: electric range & oven
8	Whole-home electrification, high efficiency	Heating: high-efficiency heat pump and electric resistance backup from Upgrade 4 Water Heating: heat pump water heater from Upgrade 6 Dryer: Ventless heat pump dryer Cooking: Induction range & electric oven
9	Whole-home electrification, high efficiency + basic enclosure package (packages 1 & 8)	Basic enclosure package (Upgrade 1) + whole-home electrification, high efficiency (Upgrade 8)
10	Whole-home electrification, high efficiency + enhanced enclosure package (packages 2 & 8)	Enhanced enclosure package (Upgrade 2) + whole-home electrification, high efficiency (Upgrade 8)

To visualize the difference in electricity consumption between Upgrade Levels, refer to Figure 4. We note that peak summer usage does not differ hugely between all Upgrade Levels and actually increases slightly in Upgrade Level 3 versus Upgrade Level 0 because installing a heat pump adds air conditioning (summer load) to the households either not using air conditioning today or using window air conditioning units, therefore increasing the amount of space cooled with a central unit. The increase in cooling load after adding a heat pump from these households (over 20% of Massachusetts households) is enough to increase the summer consumption of the average household.

Figure 4: Typical Monthly Electricity Consumption by Upgrade Level



Upgrade 0 has gas heating; higher levels have electric heating, plus increasingly efficient technology and insulation. Upgrade 3 (and all those above it) includes air conditioning benefits, which some Upgrade 0 households do not have.

To visualize the change in gas and electricity consumption by Upgrade Level, refer to Table 2.

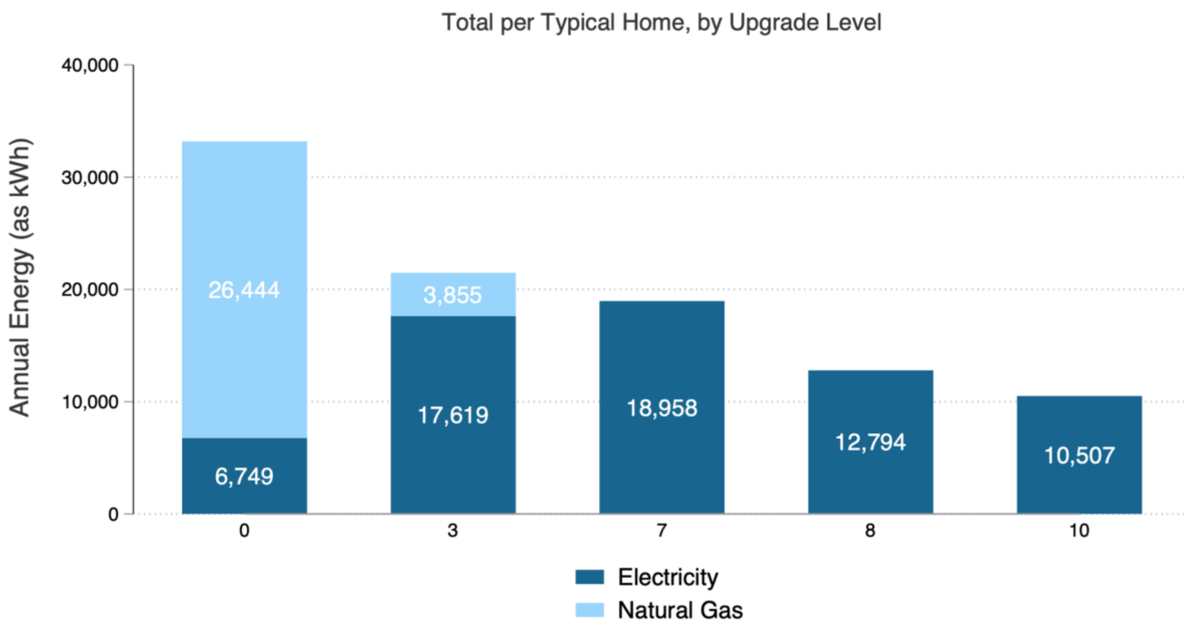
Table 2: Annual Energy Consumption by NREL Upgrade Level

Upgrade Level	Annual Electricity Consumption (kWh)	Annual Natural Gas Consumption (Therms)
0	6,748	902
3	17,620	132
7	18,958	0[9]
8	12,794	0
10	10,507	0

[9] For Upgrade Levels 7, 8, and 10, the NREL data showed fewer than 3 therms of natural gas used per year, and those were zeroed out in this report for simplicity.

For total energy consumption, Figure 5 compares Upgrade Levels with therms expressed in kWh. Between Upgrade Level 0 and Upgrade Level 3, there is a 35.2% decrease in total energy consumed. Between Upgrade Level 0 and Upgrade Levels 8 and 10, there are 61.47% and 68.33% decreases, respectively.

Figure 5: Annual Energy Consumption by Upgrade Level[10]



[10] Therms were multiplied by 29.3 to arrive at equivalent kWh.

Part 1: Understanding time-varying rate options

Time-of-Use Rate

TOU rates are characterized by higher volumetric prices during peak demand periods and lower volumetric prices during off-peak periods to better reflect system costs. These rates differ based on hour of day and day type. Throughout our analysis, the on-peak period is defined as 3pm through 8pm on non-holiday weekdays. This period was chosen because it is easily interpreted and captures the highest grid-stress hours across all months. A more complex TOU peak schedule might be expanded to include winter mornings or trimmed to only cover the hottest summer months. TOU rate parameters directly influence the magnitude of demand reductions and should be chosen carefully.

For this primary alternative rate scenario, we assumed that the seasonal ratio of on-peak to off-peak prices was 3-to-1, meaning that the on-peak price is three times the off-peak price.[11] We also let the monthly fixed charge remain unchanged from the current rate. Using this price ratio and assuming revenue-neutrality[12], the following equation can be solved, for the off-peak volumetric price:

$$\begin{aligned}\text{volumetricBil}l_s = {} & \left(\text{kW}h_{off,s} \times v\text{olumetricPrice}_{off,s}\right) \\ & + \left(\text{kW}h_{on,s} \times v\text{olumetricPrice}_{off,s} \times p\text{riceRatio}_s\right)\end{aligned}$$

Subsequently, the on-peak volumetric price can be computed:

$$volumetricPrice_{on,s} = volumetricPrice_{off,s} \times priceRatio_s$$

Time-varying rates (TVR) in general can act as a demand management strategy by incentivizing reductions in electricity consumption during grid stress periods, which occur when system demand is high. While other rates shown in this study aim to propel home electrification with reduced volumetric rates, TOU rates are commonly used to reduce demand during peak periods, when it matters the most by improving system utilization. Though reducing peak electricity demand can lower reliance on fossil fuel energy sources, this effect is secondary. Periods with higher marginal prices tend to also be when the marginal emissions rate of the grid is most carbon-intensive so optimization of loads to price signals will generally have environmental benefits, but these benefits are not evaluated in the study.

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[11] For reference, the average analogous price ratio for ISO New England – Northeast Massachusetts load zones from 2021 through 2023 was found to be 1.5 in summer, and 1.25 in winter.

[12] Revenue neutrality describes a change to rates that does not change the revenue collected from an average customer, assuming no consumption changes.

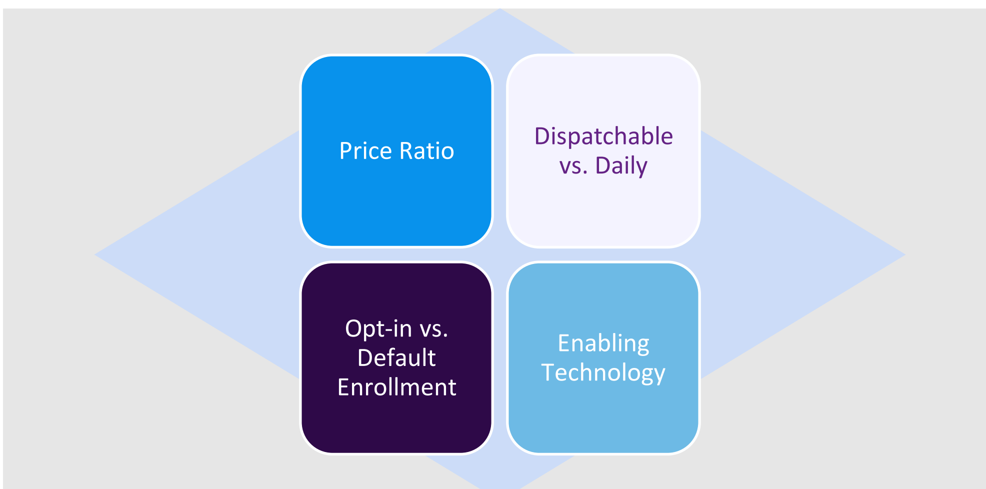
In our analysis, TOU rates were solved to be the following values in Table 3: Prices Under a TOU Rate:

Table 3: Prices Under a TOU Rate

Utility	Season	Fixed Charge	Volumetric Price ($/kWh)	
			On-Peak	Off-Peak
Eversource	Summer	$10	0.699	0.233
	Winter	$10	0.733	0.244
National Grid	Summer	$10	0.686	0.228
	Winter	$10	0.732	0.244

The wider universe of TVR includes rates differing on four key dimensions shown in Figure 6. Impacts will vary significantly based on chosen parameters.

Figure 6: TOU Rate Dimensions



- **Price Ratio**. The ratio of the on-peak rate to the off-peak rate. The larger the price ratio, the stronger the incentive for consumers to shift their consumption.
- **Dispatchable versus Daily**. Utilities can choose to implement "on-peak" pricing on a daily or event basis. Often utilities elect for steeper price ratios with dispatchable rates since the on-peak price only takes effect for a limited number of event days (sometimes referred to as critical peak pricing).

- **Opt-In versus Default Enrollment**. An opt-in rate is offered to consumers for voluntary adoption. Conversely, a default rate is assigned to all customers (can be paired with the ability to opt out). Adoption levels are much higher with default enrollment.
- **Enabling Technology**. Smart devices capable of storing and managing operations based on price signals lead to larger load impacts than TVR alone.

Our illustrative rate is opt-in, applied daily, with technology, with a price ratio of 3:1 in all months.

Price Response Assumptions

Given the underlying premise that electricity is an elastic product, a percent increase in price should result in a percentage decrease in the quantity demanded. We derive our load impact assumptions for each rate from the regression coefficients shown in Table 4. These model coefficients come from a meta-analysis of 335 TVRs compiled by the Brattle Group in its Arcturus 2.0 database. We use the second model specification, which includes an indicator variable for opt-out designs (default enrollment). The practical interpretation of the regression coefficient for the 'Opt-Out Binary' term is that a default enrollment results in a 3.9% lower peak demand reduction compared to the same rate offered on an opt-in basis. Because the rate considered here is an opt-in rate, that term is ignored in our calculations.

Table 4: Arcturus 2.0 Regression Coefficients Estimating TOU Load-Shifting

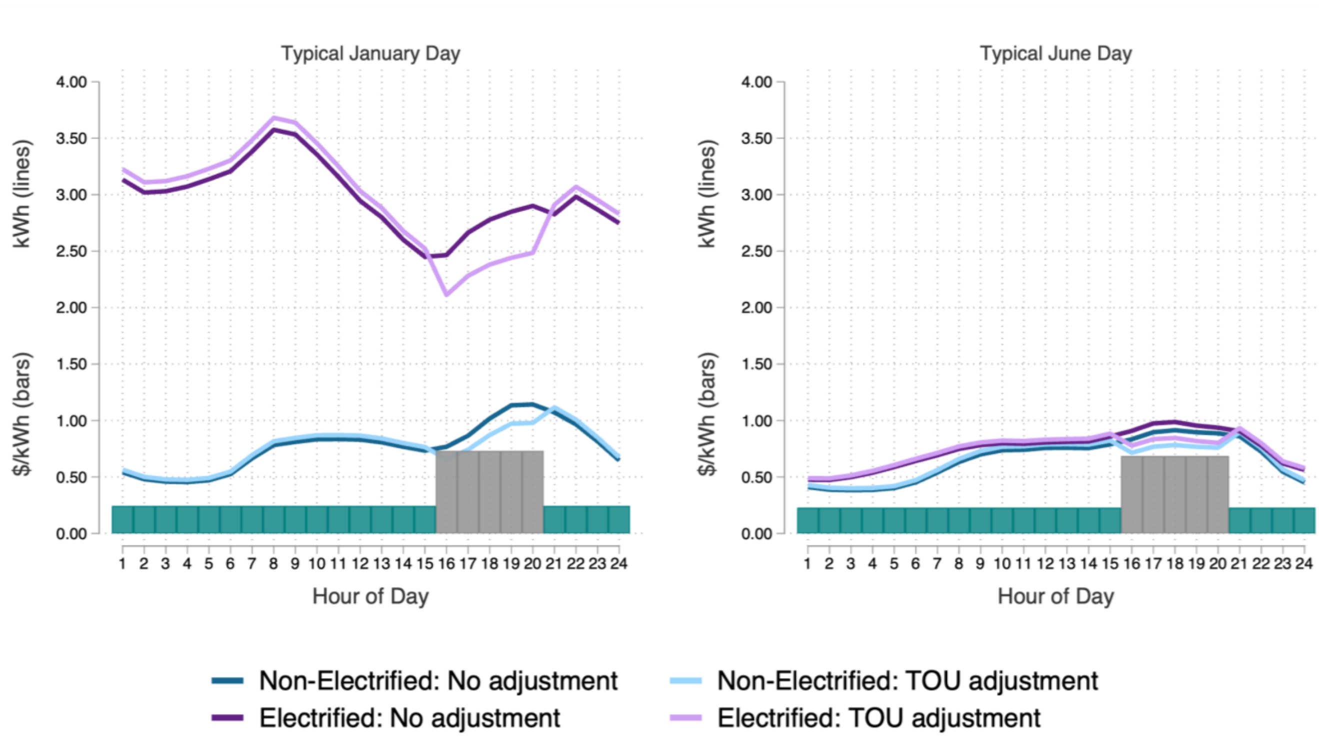
	Dependent variable:	
	Peak Impact	
	(1)	(2)
Log of Peak/Off-Peak Ratio	-0.065***	-0.058***
	(0.007)	(0.007)
Log of Peak/Off-Peak Ratio x Technology	-0.046***	-0.047***
	(0.008)	(0.008)
Opt-Out Binary		0.039***
		(0.009)
Constant	-0.011	-0.028***
	(0.007)	(0.009)
Observations	335	335
R^2	0.569	0.588
Adjusted R^2	0.566	0.584
Residual Std. Error	0.064 (df = 332)	0.063 (df = 331)

Given a price ratio of 3:1, Table 4 regression suggests that the reduction in on-peak consumption is roughly 14.5%. In our analysis, we assume all on-peak reduction is shifted to off-peak consumption. Again, a larger price ratio would likely lead to more load shifting and greater bill savings.

Typical seasonal load profiles for electricity-only are shown in Figure 7, and highlight the elevated winter usage of the electrified home which replaced winter gas heat with an electric heat pump. Summer electricity usage at the average electrified home causes a small increase due to more cooling following heat pump installation as some households have no cooling or just window air-conditioning unit(s) prior to electrification. For this report, we added a scenario that removes increased loads from air-conditioning. Since a heat pump used for *air conditioning* increases home comfort in the summer and is an added benefit, this added scenario is helpful for direct comparison purposes.

Overlaid on Figure 7 is the TOU rate (grey bars), and the load-shifting effect of the TOU rate ("adjusted", lighter-colored lines). The TOU effect in winter is considerable for the electrified home which has more winter electricity load to shift, compared to the non-electrified home. The effect of TOU rate pressure on energy bills is explored further in Table 5.

Figure 7: Time-of-Use Load Profiles and Volumetric Rates, by Season (National Grid)



Findings

Based on the chosen electrification scenarios, which are described in more detail in Table 1, under the current rate, households that replace their natural gas heating with a minimum-efficiency heat pump with minimum code efficiency will experience combined energy bill increases of over $2,000 per year. On the TOU rate modeled in this paper, that increase would be only just over $1,500 – a savings of over $500 from the current rate. If these households decide to fully electrify by replacing all natural gas appliances with high-efficiency electric appliances (Upgrade Level 8), they would, approximately, break even on today's rate. On the TOU rate, they will save, on average, an additional $271 per year on their energy bills while also reducing avoided cost increases (discussed later in this study). If they take the additional step to weatherize their home with insulation and air-sealing, their annual energy bill savings triple to $930 on the TOU rate, a $185 savings over the same efficiency scenario on current rates. Table 5 below compares gas and electric bills under each electrification scenario between current rates and TOU rates. Notably, TOU savings are higher when electricity consumption is higher because consumers have more to gain by moving more kilowatt-hours from the higher on-peak rate to the lower off-peak rate.

Table 5: Bill Impacts by Upgrade Scenario, Current Rates vs. TOU rates ($2024)

Current Rate				
Upgrade Level	**Gas**	**Electric**	**Combined**	**Difference from Upgrade 0**
3	$393	$5,954	$6,347	$2,021
3 no AC	$393	$5,868	$6,260	$1,934
7	$-	$6,393	$6,393	$2,067
8	$-	$4,347	$4,347	$21
10	$-	$3,582	$3,582	$(745)

TOU Rate				
Upgrade Level	**Gas**	**Electric**	**Combined**	**Difference from Upgrade 0**
3	$393	$5,384	$5,777	$1,537
3 no AC	$393	$5,291	$5,684	$1,444
7	$-	$5,791	$5,791	$1,551
8	$-	$3,969	$3,969	$(271)
10	$-	$3,310	$3,310	$(930)

System Costs

AESC 2024 - Avoided Cost Data by Fuel Type

Avoided costs, or the cost to the system to produce additional energy units, are estimated using Synapse Energy Economics' *Avoided Energy Supply Costs in New England* report.[13] The 2024 report provides projections of avoided costs of electricity and natural gas by season, peak period indicator, and year from 2024 through 2050. Both energy (kWh) and capacity (kW-year) avoided costs of electricity were pulled, with a couple of omissions due to unnecessary or questionable data. Non-embedded GHG costs were excluded from energy avoided costs ($/kWh). Only future capacity market costs were counted in capacity energy costs ($/kW-year), and all Demand Reduction Induced Price Effects (DRIPE)-related energy and capacity costs were omitted due to significant variability over the study horizon. All "Cleared" costs were not counted. Lastly, to simplify the cost trend, "Uncleared" energy capacity figures were omitted as well. What remained is transmission and distribution costs, as well as a few dollars' worth of reliability costs.

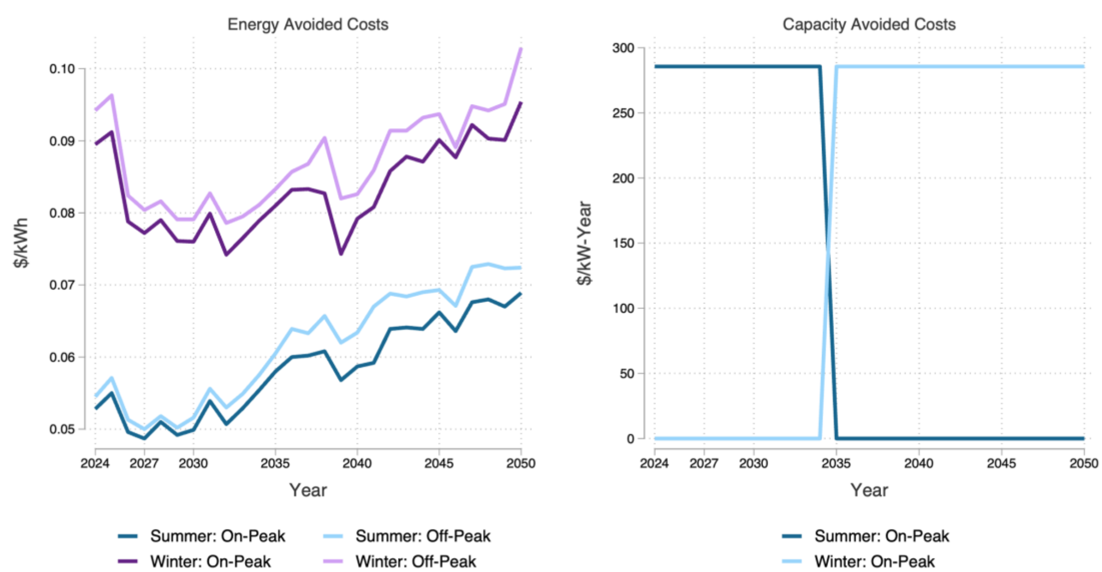
Figure 8 graph electricity and gas avoided costs, respectively. Electricity energy costs rise over time, though year-to-year oscillations are non-trivial. Next, electricity capacity costs start at around $280 per kW in the summer, zero dollars in the winter and remain this way until the system switches from being summer-peaking to winter-peaking. After the winter-peaking shift in 2035, the capacity costs swap to winter. Natural gas energy costs are more stable over the time period. These avoided cost changes, specifically as the system changes to winter peaking, are important considerations when designing rates to enable electrification. Any rate design options that do not take into account this change risk unnecessary rate increases to all ratepayers.

[13] Data used can be found here: https://www.synapse-energy.com/aesc-2024-materials

The AESC 2024 study assumes that New England becomes winter-peaking in 2035, causing the switch in seasonal capacity costs shown on the right-hand graph.

For interpretive purposes, a higher avoided cost value means that adding load at peak (whether in summer before 2035 or in winter post-2035) is more expensive. Higher avoided costs make peak demand reduction measures, including TOU rates that shift demand from on-peak to off-peak, more valuable. Therefore, the higher the avoided cost value, the higher a customer's rates may become absent behavior changes and the more a household may save via an effective TVR.

Figure 8: Electricity Avoided Costs by Year ($2024)



Shift to Winter-Peaking System

Many of the alternative rate scenarios we consider in the study have the potential to accelerate the shift to a winter peaking system, and, except for the TOU rate, are designed to incentivize increased electricity consumption rather than manage system costs. As shown in Figure 8, after 2034, the 2024 AESC report predicts that the Massachusetts electricity system will change from summer-peaking to winter-peaking because of increased adoption of electric heating. While the system remains summer-peaking, winter electricity consumption rises but does not affect capacity costs.

Once the grid becomes winter peaking, rates that provide favorable winter per-kilowatt hour rates and incentivize consumption at the expense of conservation will no longer be reflective of system costs, nor beneficial from a long-term system cost-containment perspective.

Using DSA's System Cost Change Simulator, we are able to estimate that an individual customer upgrading from a baseline home to an Upgrade Level 3 minimum-efficiency heat pump home on current rates in 2034 (when the grid is assumed to be summer-peaking) will drive the household's individual electric system costs up 111%. If the customer moves to a TOU rate as it upgrades to the Upgrade Level 3 home, its individual system costs only increase by 104%.

However, once the system becomes winter-peaking, the same heat pump installation increases household electric system costs by 246%, as seen in Figure 9. If the customer also switches to a TOU rate as it installs the minimum efficiency heat pump, this increase to system costs is reduced to 222% because load is shifted away from peak hours.

Figure 9: Electric System Annual Avoided Costs ($2024)

Single Customer to Upgrade Level 3				
		Baseline Home	**Upgrade Level 3 Home**	**Percent Change**
Current Rates	**2034**	$820	$1,734	111%
	2035	$766	$2,658	246%
TOU Rates	**2034**	$767	$1,670	118%
	2035	$723	$2,467	241%

30% Electrification to Upgrade Level 3				
		Baseline Home	**Upgrade Level 3 Home**	**Percent Change**
Current Rates	**2034**	$295,212,608	$624,226,432	111%
	2035	$275,878,496	$956,750,016	246%
TOU Rates	**2034**	$276,200,256	$601,202,112	118%
	2035	$260,457,824	$888,080,320	241%

For an aggregate perspective, see Figure 9 and Figure 10. In the final year presumed to be summer-peaking, 30% electrification penetration at Upgrade Level 3 (minimum-efficiency heat pump) will cost $624,226,432 in energy and capacity (2024 dollars) if no load shifting is incentivized. This is $329,013,824 above the system costs to serve baseline homes. In 2035, the system with 30% penetration of Upgrade Level 3 homes will cost $956,750,016. This is $680,781,520 above the system costs to serve baseline homes. 95.7% of this increase comes from new capacity needs. If rates that encourage load-shifting are in effect with 30% penetration of Upgrade Level 3 homes, the 2034 system costs are $601,202,112, and our 2035 system costs are $888,080,320 (of which 95% are capacity-driven).

Figure 10: Electric System Annual Avoided Cost Increases – Baseline to Upgrade Level 3 ($2024)

Single Customer Electrification to Upgrade Level 3			
	2034	**2035**	**% Increase due to Shift to Winter Peaking**
Current Rates	$914	$1,891	106.9%
TOU Rates	$903	$1,743	93%
System Savings % from TOU	**1.2%**	**7.8%**	

30% Electrification at Upgrade Level 3			
	2034	**2035**	**% Increase due to Shift to Winter Peaking**
Current Rates	$329,013,824	$680,871,520	106.9%
TOU Rates	$325,001,856	$627,622,496	93%
System Savings % from TOU	**1.2%**	**7.8%**	

At 30% penetration of Upgrade Level 3 homes, the avoided cost increase between 2034 and 2035 on current rates is $351,857,696. On the TOU rate, the increase is $302,620,640. The TOU rate increase is 14% less than the increase in the non-TOU scenario.

In sum, the modeled TOU rate can be expected to reduce electric system cost increases by approximately 7.8% in a winter peaking system when the cost of additional minimum-efficiency electrification on current rates could otherwise be expected to drive up system costs by almost $2,000 per customer.

While analyzing the system cost impacts of all Upgrade Levels was beyond the scope of this study, we can predict that Upgrade Levels 8 and 10 would have a lower impact on system costs given that they increase electricity consumption by 6,045 kWh and 3,758 kWh, respectively, compared to the 10,871 new kWh driven by Upgrade Level 3.

Part 2: Understanding the Impact of Advanced Efficiency Measures

In this section, we compare both current and TOU rates against various levels of home and appliance efficiency.

Changes in Electricity Bills

The Upgrade Level 3 load profile represents the installation of minimum-efficiency heat pump(s) in an otherwise representative Massachusetts home. Table 1 provides a more detailed description of each home type that we consider. Compared to the baseline home (Upgrade Level 0), this home type consumes over 160% more electricity, and 85% less natural gas.

Compared to the baseline home, the Upgrade Level 8 home type (with a high-efficiency heat pump) consumes over 90% more electricity. Since this upgrade replaces all natural gas appliances, it consumes no natural gas. Further, we assume they disconnect from the natural gas service, thus incurring no gas fixed charge on their monthly energy bill. Upgrade Level 8 homes utilize high-efficiency heat pumps and heat pump water heaters and are roughly 27% more efficient in terms of electricity usage relative to the code-minimum electrified home type.

The Upgrade Level 10 home builds on Upgrade Level 8 with various measures to improve insulation and reduce air infiltration. It consumes only 55% more electricity than the baseline home, and is 18% more efficient than the Upgrade Level 8 home. Refer to Figure 11 for annual energy consumption values by Upgrade Level. See Table 6: Comparing Energy Usage by Electrification Level for a summary of changes in electricity bills.

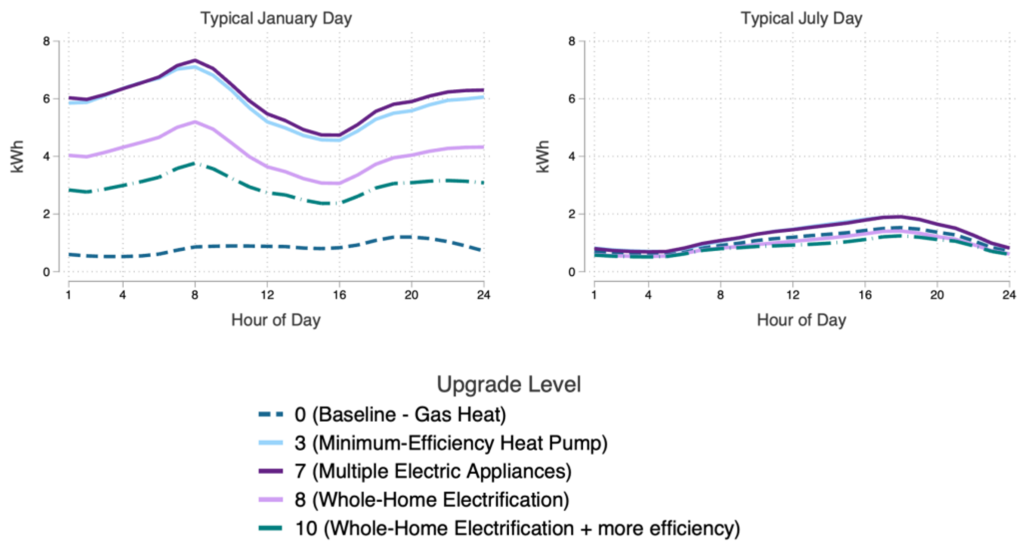
Table 6: Comparing Energy Usage by Electrification Level

Upgrade Level 3	Upgrade Level 8	Upgrade Level 10
160% more **electricity** than the baseline home (Upgrade Level 0) 85% less **gas** than the baseline home (Upgrade Level 0)	90% more **electricity** than the baseline home (Upgrade Level 0) 27% less **electricity** than the code-minimum electrified home (Upgrade Level 3) 100% less **gas** than the baseline home (Upgrade Level 0)	55% more **electricity** than the baseline home (Upgrade Level 0) 18% less **electricity** than Upgrade Level 8 100% less **gas** than the baseline home (Upgrade Level 0)

Figure 11 shows electric load profiles for a typical January and July day for different electrification scenarios. Relative to the code-minimum electrification scenario, the efficient electrification scenarios yield modest reductions in electricity usage that are more significant in January than July. The load shape does not change substantively across electrification scenarios (people increase energy usage when they wake up and when they return from work), but the curve is shifted down as the home becomes more electrified and efficient and the level of consumption changes. That said, even at the highest electrification efficiency level, electricity usage is roughly three times higher than that of the baseline home in January. Of course, a reduction in energy results in both a lower energy bill for the customer, and lower system costs for the utility.

In Upgrade Level 3 under current electricity rates, a home installing a minimum-efficiency heat pump experiences annual electric bill increases of $3,641, though this is partially offset by a $1,621 reduction in gas bills. We note here that Upgrade Level 3 includes adding air conditioning as a benefit to the 20%+ of Massachusetts households that do not currently have it. This new benefit adds approximately $100 to bills annually.

Figure 11: Typical Electric Load Profiles by Electrification Level, Seasonal



In the highly-efficient scenarios of Upgrade Levels 8 and 10, bills are reduced because of the lower level of electricity consumption than Upgrade 3. Under current electricity rates, a fully electrified home with a high-efficiency heat pump incurs an annual electric bill increase of $2,034 (a net increase of only $21 when subtracting savings from no gas consumption). When additional insulation and air-sealing measures are added, the home only experiences an electric bill increase of $1,269 (more than offset by the reduction of $2,013 in gas bills, for a net *reduction* of $744). A fully electric home relying upon a minimum-efficiency heat pump (Upgrade Level 7) would experience the highest annual electric bill increases of over $4,000 (a net increase of $2,067 when considering combined gas and electric bills). The efficiency measures, which we note entail a high upfront capital investment, mitigate both electric and combined bill increases under electrification.

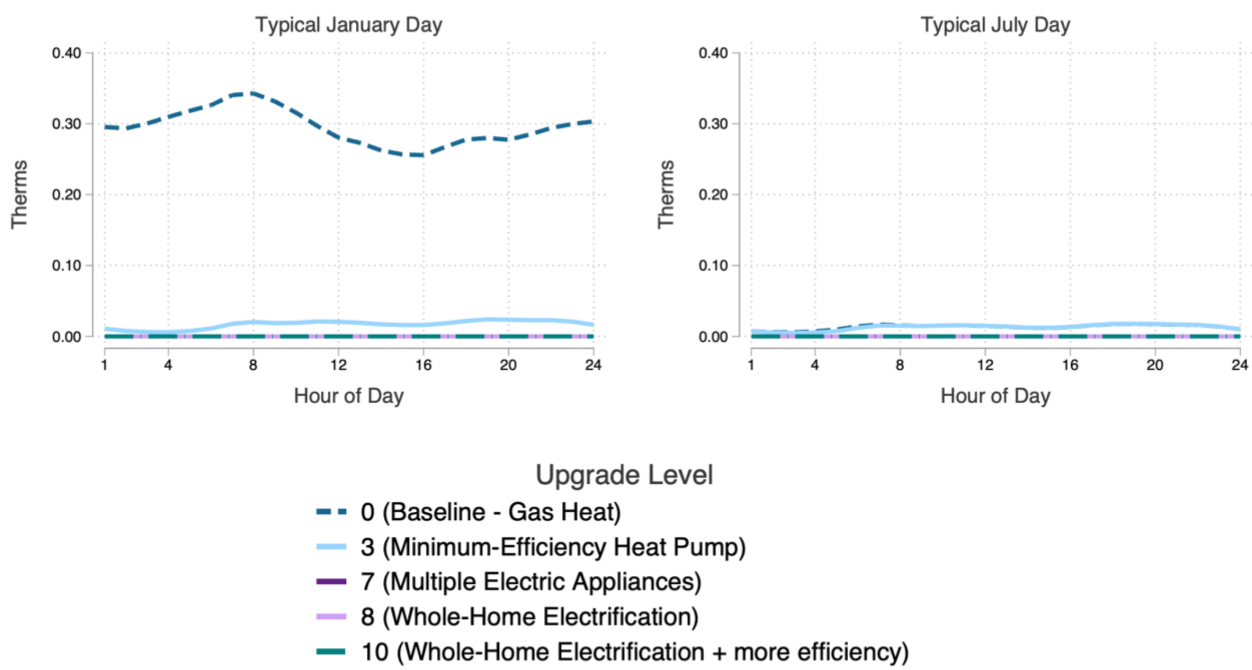
Changes in Gas Bills

Under the code-minimum electrification scenario (Upgrade Level 3), some natural gas heating exists as a backup for when the heat pump has reached its maximum capacity, and for use in other appliances. In the highly efficient electrification scenarios, the backup gas heating is removed, and the home's heating service is solely provided by the heat pump. The result, shown in Figure 12 that no gas is consumed in the high-efficiency homes. Gas demand is typically at its highest on January mornings in a baseline home. For homes that have upgraded to a minimum efficiency heat pump, but not fully electrified (Upgrade Level 3), gas usage is low but steady throughout the waking hours of the day in both January and July. Upgrade Level 7, 8, and 10 homes are fully electrified and therefore have no gas demand.

In Upgrade Level 3, the annual gas bill decreases by $1,621 due to electrification, while annual avoided cost decreases by $607. Since the majority of a household's natural gas consumption was used for heating, the avoided cost changes occur in the winter and colder shoulder season months.

The gas bill reductions in Upgrade Levels 8 and 10 are identical between the low and high efficiency whole-home electrification scenarios because both entail complete electrification and no natural gas consumption. In total, the annual gas bill decreases by $2,013, while the annual avoided costs recovered decrease by $695.

Figure 12: Typical Gas Load Profile by Electrification Level, Seasonal



Large bill reductions relative to avoided cost reductions are a consequence of the fixed costs of gas service being recovered volumetrically. A concern, as more homes electrify, is that those fixed costs must now be borne by fewer gas ratepayers, less gas throughput, or both. This in turn results in higher gas rates and a stronger incentive for gas-powered households to electrify. This self-perpetuating phenomenon is known as a utility "death-spiral." While a thorough examination of this scenario is beyond the scope of this study, the results of the simple electrification scenario considered here are instructive in so far as they show the gas utility shortfall between revenues and costs as an incremental home electrifies its heating source.

Increasing Gas Delivery Rates

If electric rates are set such that electrification becomes more attractive, natural gas consumption will fall. Because a majority of costs of gas delivery service are recovered volumetrically, gas rates must then rise to recover those costs. The higher gas rates then provide a stronger incentive for households with natural gas to electrify, which results in more gas rate increases. The issue of a natural gas utility death-spiral – on both the gas and electric systems – is a long-term concern for policy makers.

Assuming all costs collected through natural gas delivery rates (this excludes gas supply costs) are fixed in nature and remain costs regardless of natural gas throughout and customer count, as customers leave the gas system or reduce gas consumption due to converting appliances to electricity, natural gas delivery rates must increase to cover gas system costs. Our simplified analysis to project those increases, shown in Table 7: Natural Gas Delivery Cost Increases per Customer by Percentage of Customer Decline (National Grid),holds constant the residential revenues collected by National Grid,[14] based on current delivery rates and residential customer count, and then divides those constant revenues by declining customer counts.

Table 7: Natural Gas Delivery Cost Increases per Customer by Percentage of Customer Decline (National Grid)

Percent of Residential Customer Decline	Annual Bill Increase
5%	$64.90
10%	$137.01
15%	$217.60
25%	$411.02
50%	$1,233.05

As can be seen in above in Table 7, if five percent of residential customers electrify and therefore no longer pay a natural gas bill, the annual bill increase for the average customer who remains on the system is around $65. If customer declines reach 50%, that bill increase goes up to over $1,200. The more natural gas customers who leave the system, the higher natural gas bills become for the remaining customers, making electrification more financially

[14] This also assumes that the utility's rate base remains constant. Capital expenditures that increase rate base, like pipeline replacement, would add to the rate increases from declines in customer count or natural gas throughput.

appealing, under any electric rate design scenario. This analysis also holds gas supply costs constant.

We note here that these increases will alter the differential between annual bills for a baseline home with gas and an electrified home under all Upgrade Levels and electric rate structures, including current rates. Said another way, a home moving from Upgrade Level 0 to Upgrade Level 7 (with no gas usage) on current rates can expect to pay approximately $4,000 more annually in electric bills today. Because annual gas bills of approximately $2,000 zero out, the customer may see a $2,000 annual "combined" bill increase. In a hypothetical future scenario wherein 25% of gas customers have already fully electrified and gas bills for those remaining baseline homes are paying approximately $400 more per year ($2,400 total), Upgrading to Level 7 would only increase combined bills by $1,600. As the percentage of fully electrified customers increases, the escalating increase in gas delivery costs for those remaining on the gas system may eliminate the challenge of annual bill increases from electrification, even under current rates and lower-efficiency Upgrade Levels. Of course, this is not a desirable outcome for customers heating with either gas or electricity, and the focus should remain on alternative rates and efficiency measures to lower bills.

While we did not embed these hypotheticals in the rest of this analysis, we note that the economics of electrifying is related to changes in gas bills and rates and cannot be truly understood in isolation.

Changes in Combined Bills with TOU Rate

In terms of annual combined bills, customers electrifying with a minimum efficiency heat pump – either partially via Upgrade Level 3, or fully via Upgrade Level 7 – can be expected to pay approximately $2,000 more. Still, the increased electricity consumption brings the opportunity to shift more demand from on-peak to off-peak hours. The TOU rate we modeled for this study, detailed in **Time-of-Use Rate**, can save minimum efficiency electrified households (Upgrade Level 7) around $600 per year compared to current rates. Even with these TOU rate savings, these households can expect to pay approximately $1,500 more annually than a baseline gas and electric house on current rates. Household bills from a high-efficiency heat pump as part of a fully electrified home (Upgrade Level 8), on the other hand, can be expected to match the annual bills of Upgrade Level 0 on today's current rates. On the modeled TOU rate, the Level 8 household can save approximately $250 annually compared to today's current rate. Households on both current rates and TOU rates would save about $750 and $1,000 from a baseline home on current rates, respectively, by adding an enhanced enclosure package to their whole-home electrification with a high-efficiency heat pump. This includes additional attic and wall insulation, and duct and air sealing. Figure 13 shows the savings on the TOU rate on a monthly basis, wherein a household's combined energy bill in January, February, March, April and December are significantly higher in Upgrade Levels 3 and 7. With a high-efficiency heat pump from Upgrade Level 8, only one month shows a significant bill increase (January) while others, including October, November, and December offer small to medium savings. In every month, Upgrade Level 10 offers small to medium bill savings, demonstrating the additional benefits of insulation and air sealing measures across seasons.

Figure 13: Annual Combined Energy Bills by Upgrade Level

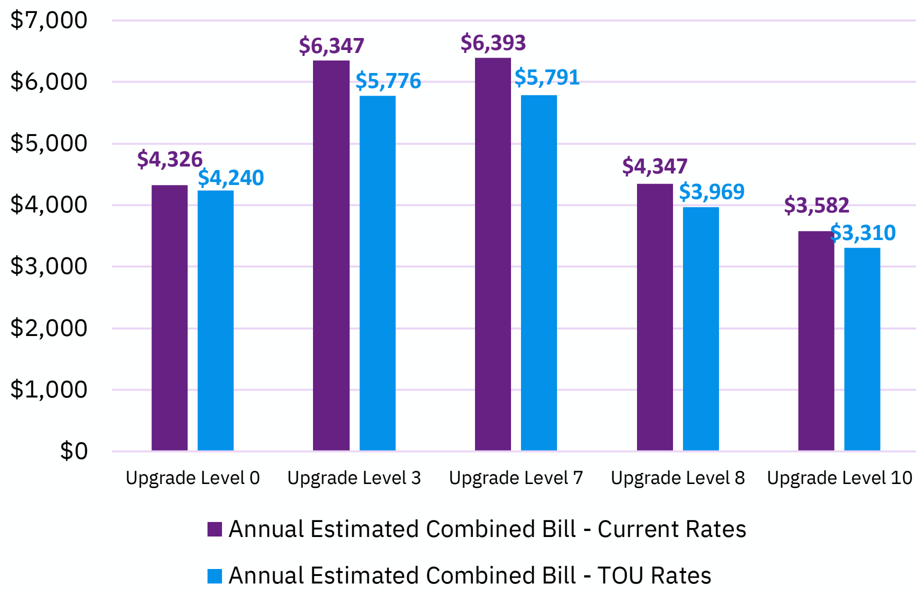
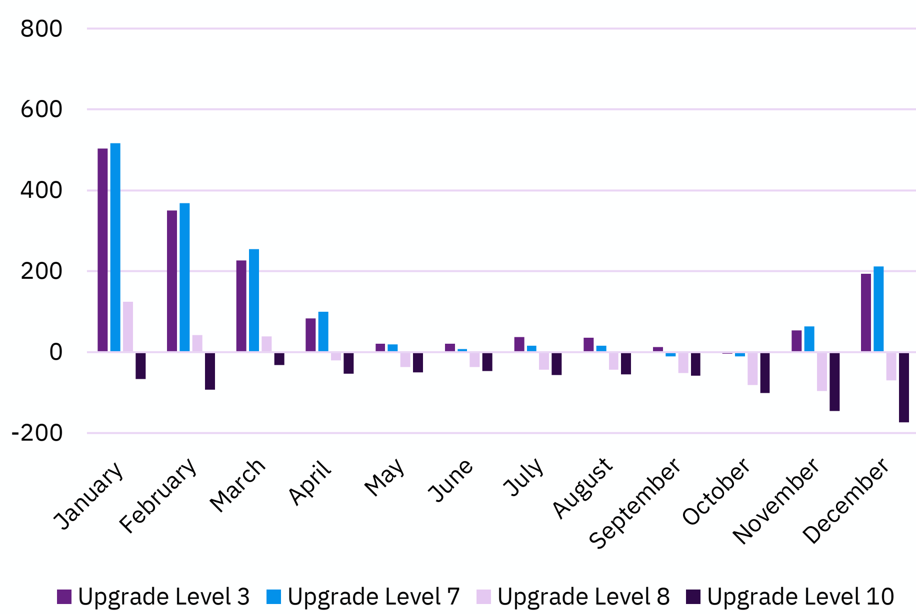
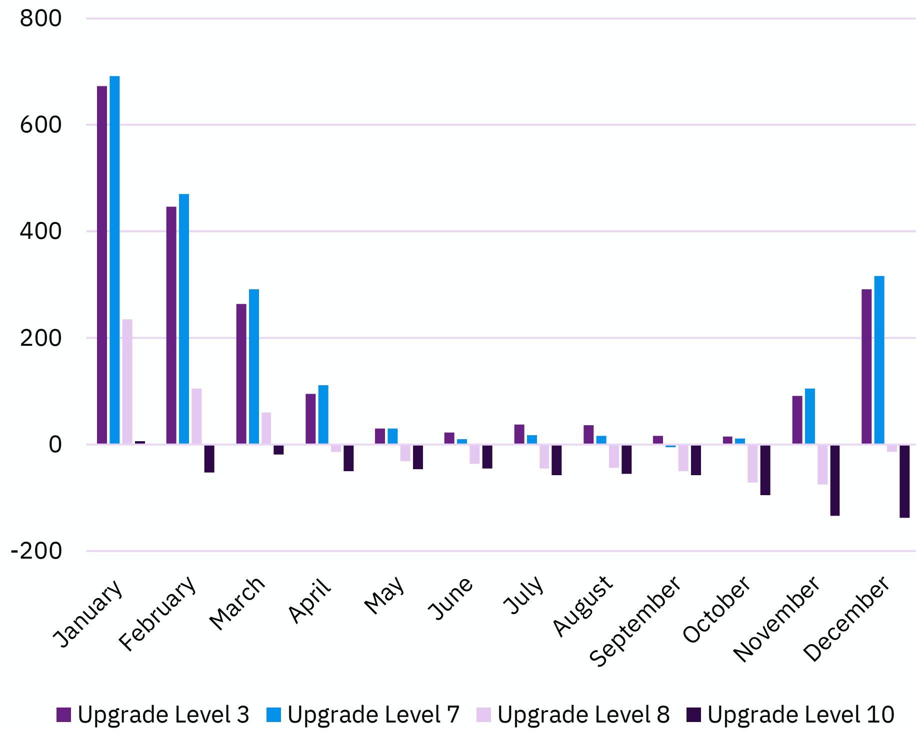


Figure 14: Monthly Bill Changes Compared to Baseline, by Upgrade Level – with TOU Rate



The current, non-TOU rate puts additional pressure on bills in January, February, March, November, and December on households with Upgrade Levels 3, 7, and 8 as compared to the TOU rate. Upgrade level 10 continues to provide savings in all months except for January, where bills are essentially level with today's Upgrade Level 0 on current rates.

Figure 15: Monthly Bill Changes Compared to Baseline, by Upgrade Level – Current Rate



How Impact Avoided Costs Vary by Upgrade Level

In 2024, the increase in electric avoided costs borne by the utility per electrification customer is approximately $1,000 for the code-minimum scenario (Upgrade Level 3), slightly higher for Upgrade Level 7 (more electrification; same efficiency), $516 in the high-efficiency heat pump scenario (Upgrade Level 8), and $291 in the high-efficiency heat pump and enhanced efficiency scenario (Upgrade Level 10). The lower the avoided cost value, the less it costs to the system to add additional load to peak. Intuitively, high-efficiency heat pumps have the least impact on the grid and even less impact when paired with additional efficiency measures.

In 2035, when we anticipate that the Massachusetts grid becomes winter peaking, the avoided cost increases from electrification increase further; however, the increases are still mitigated by high-efficiency heat pumps and additional efficiency measures. The avoided cost increase at Upgrade Level 7 is $1,915/year, versus $1,031/year for Upgrade Level 8 and $682/year for Upgrade Level 10.

Figure 16 compares the avoided cost increases in 2035 from Upgrade Level 7 electrification (whole home electrification, minimum efficiency heat pump) and from Upgrade Level 10 electrification on a monthly basis (whole home electrification, high-efficiency heat pump, and additional insulation and air sealing). Though the installation of a heat pump in both scenarios drives avoided costs up, Upgrade Level 10's impacts are less than half of Upgrade Level 7's impacts in January and negligible in most other months.

Figure 16: Annual Electric Avoided Cost Increases by Upgrade Level - 2034 vs. 2035

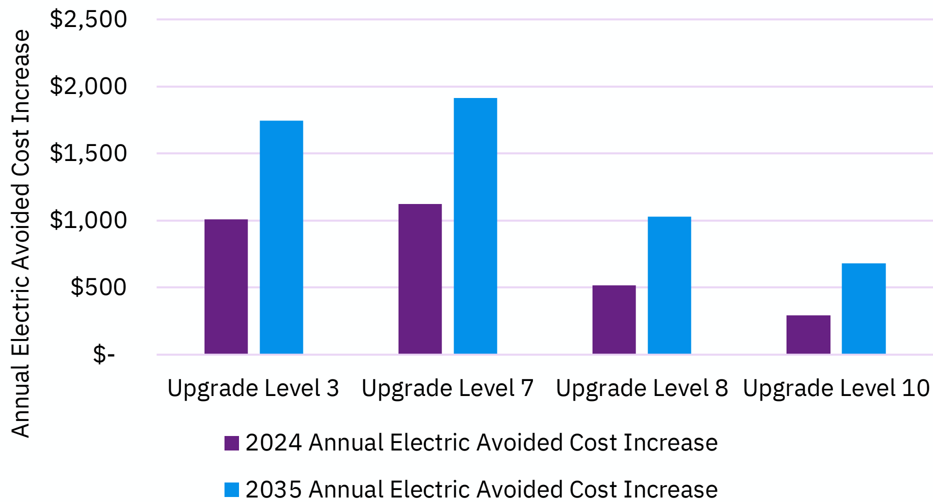
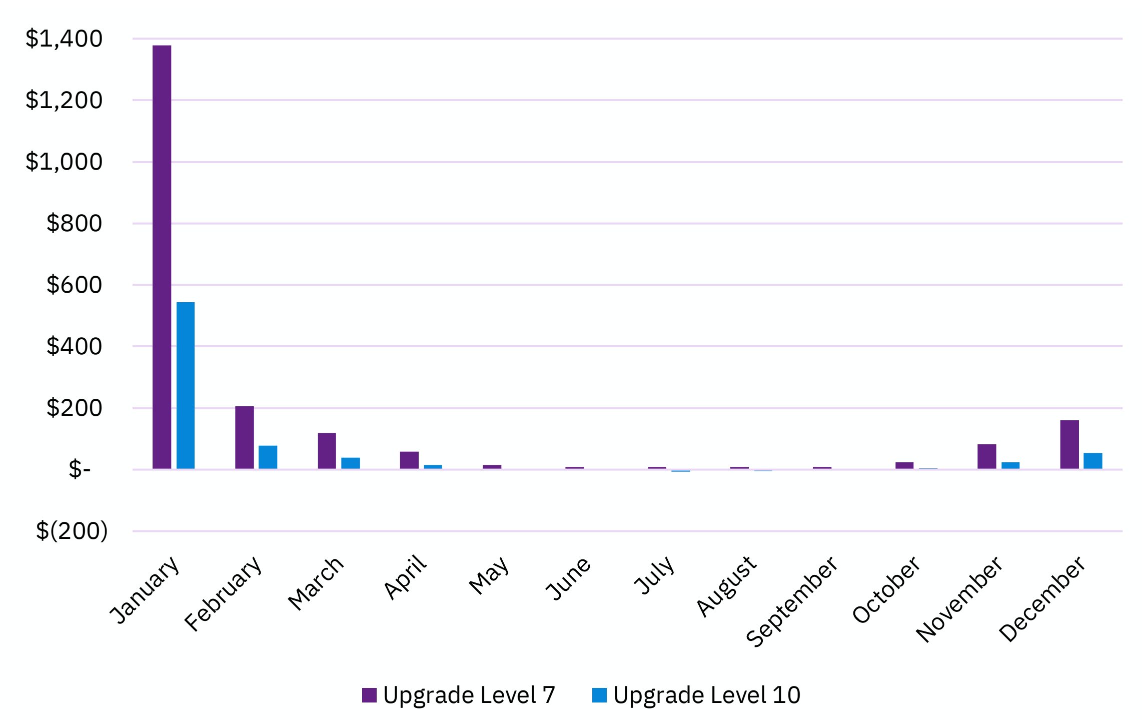


Figure 17: 2035 Monthly Electric Avoided Cost Increases - Upgrade Level 7 vs. 10



Because the increase in bills is significantly above increases in avoided costs in both 2034 and 2035 in all efficiency scenarios (Figure 18 and Figure 19), the electric arm of the utility earns revenue far in excess of the cost increase they experience when a customer electrifies. This cost recovery gap means that electrifying customers bear an inefficiently high share of fixed costs under the current rate structure. Even with high-efficiency heat pumps and additional efficiency measures that support lower or equivalent annual total energy bills (Upgrades 8 and 10), customers are still overpaying compared to a more efficient rate design. Over time, rates might fall as fixed costs are spread over a larger base of consumption, but for the incremental household considering electrifying under the current structure, the disincentive they face is significant. Most household purchase decisions will be based on the current rates without consideration of future downward pressure on rates from electrification.

Figure 18: Bill Increases vs. Avoided Cost Increases Compared to Baseline (2024)

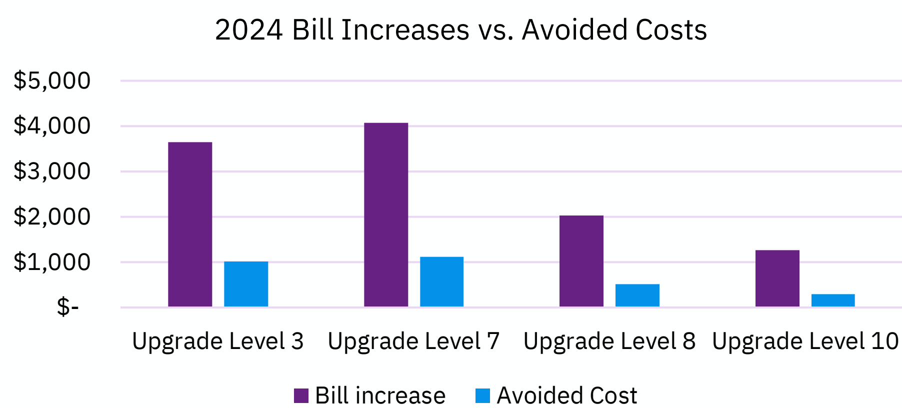
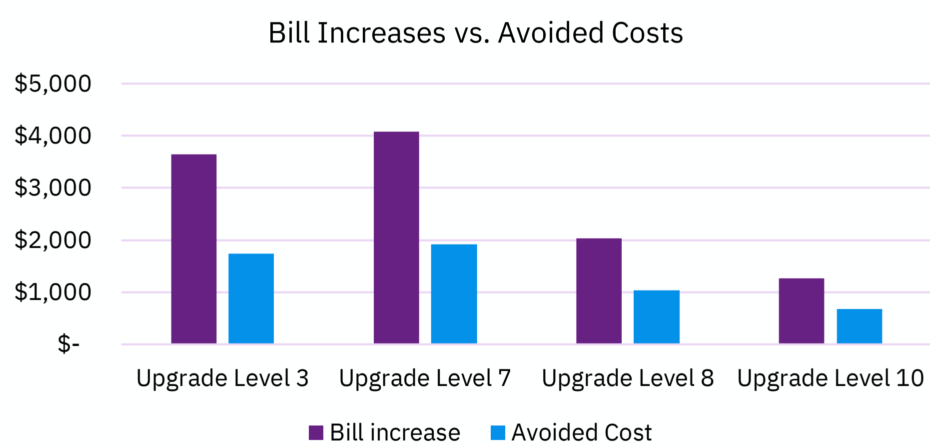


Figure 19: Monthly Electric Avoided Cost Increases (2035)



One option to address this gap is with optional heat pump specific rates that better match utility revenue increases with avoided cost increases. Further examination of these technology-specific rates are not within the scope of this study.

Part 3: Other Near-Term Rate Options

This section compares the bill impacts of electrification across various Upgrade Levels across three additional rate design options and discusses their long-term impacts on the electric system.

For this analysis, alternative rates similar to those used within the IRWG were determined by solving rate design equations which assumed revenue-neutrality. Revenue neutrality is a rate design principle that requires the total expected revenue under an alternative rate to be equal to the total expected revenue under current electricity rates, assuming no changes to how much and when energy is consumed.[15] See **Current Rates** for a discussion of how rates were collected.

Importantly, the findings below are heavily dependent on how high or low the proposed rates are set. For example, the higher fixed charge rate seen here includes an increased monthly fixed charge of $25, which allows volumetric rates to be lowered. A utility could instead choose an even higher fixed charge, permitting the volumetric rate to be further reduced and offering increased savings to the high-consumption customer.

Also, although the electricity rates are changing in the rates delineated in Figure 2, the accompanying natural gas rate remains unchanged from the current rate to keep analysis simple. In other words, this section does not consider any of the findings from the section above: **Increasing Gas Delivery Rates**. Further, we assume changes in electricity rates do not affect gas bills or consumption. Thus, gas bills and avoided costs are identical under current and alternative electricity rates, within Upgrade Level. Thus, across all rates, whole-home electrification (Upgrade Levels 7 , 8, and 10) leads to a decrease in the annual gas bill of $2,013 due to the elimination of gas consumption, while annual avoided costs decrease by $695.

For electricity, we designed rate alternatives to have volumetric charges greater than or equal to avoided cost of energy to ensure their economic viability. As a result, annual bill increases are always above, or commensurate with, annual system cost increases due to electrification. Notably, the TOU rate triggers customers to shift load from on-peak periods to off-peak periods which can reduce grid stress. This type of rate lowers capacity requirements on the electricity system and could ease grid strain from electrification. This will be especially important once New England’s electric grid becomes winter-peaking – which this study assumes to occur in 2035 based on AESC projections.

[15] Basing revenue-neutrality calculations on an individual, representative household, is equivalent to the entire residential class when bills are a linear function of consumption, which is the case for most rates considered in this report.

Table 8 provides an overview of our findings: the advantages and disadvantages of each alternative rate offering that we analyzed.

Table 8: Overview of Alternative Rate Findings

Rate	Advantages	Disadvantages	Impact on Avoided Costs
$25 Fixed Charge Rate – Universal Version	Incentivizes electrification by reducing bill increases from higher consumption for all customers.	Could lead to an overall increase in electricity consumption without a decrease in fossil fuel consumption; can be regressive and penalize households with lower usage. Lower volumetric rates reduce the benefits of energy efficiency and distributed energy resource.	Upward pressure via increased electricity consumption at peak
$25 Fixed Charge Rate – Seasonal Electrified Version	Incentivizes electrification by reducing bill increases from higher consumption for electrified homes; leaves standard rate offering unchanged.	Higher administrative burden than a rate that does not require qualifying technology due to customer education, outreach, and qualification; benefits limited to qualifying technologies. Lower volumetric rates reduce the benefits of energy efficiency and distributed energy resources.	Upward pressure via increased electricity consumption at peak
Decreasing Tiered Rate	Incentivizes electrification by dramatically reducing bill increases from higher consumption for all customers.	Could lead to overall increase in electricity consumption without decrease in fossil fuel consumption; more complex than other offerings; can be regressive. Can also reduce the benefits of energy efficiency and distributed energy resources.	Upward pressure via increased electricity consumption at peak
Time-of-Use Rate	Improves system utilization and can help mitigate capacity expansion requirements due to electric load growth.	Does not make electrification more affordable on its own but can be used to support long-term cost containment. Higher kilowatt-hour consumption can increase the potential of TOU rates to benefit bills and lower system costs.	Downward pressure via incentives to shift consumption away from peak

Higher Fixed Charge, Lower Volumetric Price Rates

$25 Fixed Charge - Universal Rate

The first alternative electric rate considered here is one with a higher monthly fixed charge but a lower volumetric price for all ratepayers. Historically, policy makers have been hesitant to adopt rates that lower the volumetric price, because they disincentivize energy efficiency relative to rates with higher volumetric charges. On the other hand, making electrification cheaper is theorized to catalyze fuel-switching away from fossil fuels.[16]

Setting a lower volumetric rate can lead to decreases in total bills for high-electricity consumption customers. Conversely, the total bill for customers that consume relatively little electricity will increase because they now pay a larger compulsory fixed charge. On this rate, the volumetric price is the same no matter the level of consumption.

Under current rates, the monthly electric fixed charges are set to $10. In this exercise, a $25 fixed charge was chosen arbitrarily, and volumetric prices were solved accordingly to maintain revenue neutrality. This rate is calculated seasonally (one rate calculated for winter, separate one for summer). The following equation can be solved for the volumetric price, where $totalFixedCharge_s$ is the new higher fixed charge (e.g. $25) multiplied by the number of months in season s (6):

$$totalBill_s = (kWh_s \times volumetricPrice_s) + totalFixedCharge_s$$

Table 9 shows how volumetric prices look under a $25 Fixed Charge Rate:

Table 9: Prices Under a $25 Fixed Charge Rate, by Utility

Utility	Season	Fixed Charge	Volumetric Price ($/kWh)
Eversource	Summer	$25	0.299
	Winter	$25	0.304
National Grid	Summer	$25	0.293
	Winter	$25	0.304

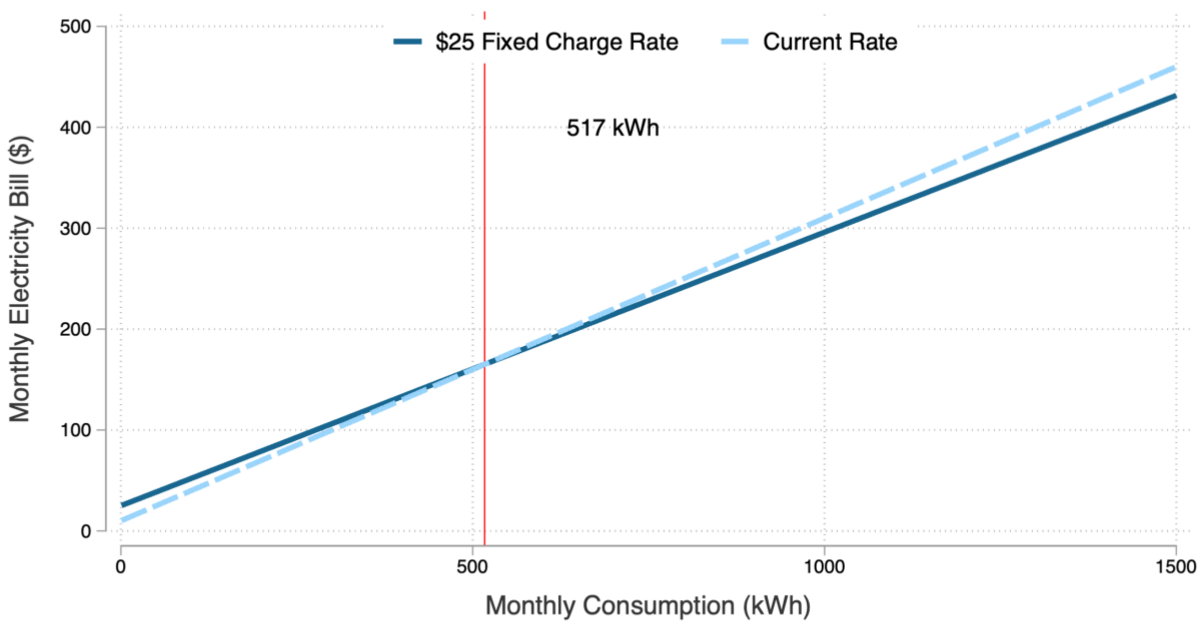
Figure 20 compares electricity bills under the $25 Fixed Charge Rate and the current rate. For monthly consumption under 517 kWh (vertical red line), the $25 Fixed Charge Rate is more

[16] Recent evidence (https://jesse-buchsbaum.com/files/job_market_paper.pdf) suggests that residential electricity consumers are highly price-responsive in the long run.

expensive than current rates, but over 517 kWh the $25 Fixed Charge Rate is cheaper. Based on this analysis, roughly half of electric customers in Massachusetts use less than 517 kWh per month.

Under the fixed charge rate, fixed charges make up a higher proportion of bills for low consumption customers. As consumption increases, the average rate declines more quickly for the fixed charge rate. For example, if a customer uses 1 kWh a month, they are billed at just over $25/kWh and their bill is almost exclusively composed of the fixed charge. As consumption increases, more of their bill is composed of the lower volumetric price, accruing them more savings relative to the current rate. The $25 Fixed Charge Rate thus confers savings to customers with electrified heating, who use more electricity. Refer to Table 2 for typical consumption figures by electrification level.

Figure 20: Example Comparison of Bill Under $25 Fixed Charge Rate vs. Current Rate



Note: The example rate used in the figure is for summer under the $25 Fixed Charge Rate version.

$25 Fixed Charge - Seasonal Electrified Rate

A second version of this rate targets customers with electric heating (heat pumps) while customers with gas heating remain on the current rate. Construction of this rate also differs from the $25 Fixed Charge Rate in that the winter volumetric prices are set to reflect Avoided Energy Supply Costs (AESC) 2024 avoided costs. This rate is the lowest value which still recovers costs,[17] proffering maximal savings unto the electrified customer. Then, still assuming revenue neutrality and choosing a monthly fixed charge (e.g., $25), the following equation was solved for summer volumetric price:

$$totalBill = (volumetricPrice_{winter} \times kWh_{winter}) + (volumetricPrice_{summer} \times kWh_{summer}) + (fixedCharge \times 12)$$

Because winter rates are so low (nine cents), the alternative summer volumetric price must be higher than the current summer price to recoup costs and remain revenue neutral.

The bill impacts from this rate are similar, but amplified, compared to the $25 Fixed Charge version. Electrified customers end up with a lower total bill (electric and gas) than under current rates, and non-electrified customers experience no bill change. Table 10 displays the volumetric prices under this scenario, where winter volumetric prices are set to 2024 avoided costs:

Table 10: 2024 Prices Under a $25 Fixed Charge Rate - Seasonal Electrified Version

Utility	Season	Fixed Charge	Volumetric Price ($/kWh)
Eversource	Summer	$25	0.504
	Winter	$25	0.090
National Grid	Summer	$25	0.498
	Winter	$25	0.090

Decreasing Tiered Rate

Finally, the IRWG considered the bill impacts of a Decreasing Tiered Rate (also known as a declining “block” rate), wherein marginal consumption units are priced incrementally lower. This type of rate has traditionally been discouraged because it disincentivizes energy efficiency, but deserves renewed consideration when electrification is a policy objective. The first 0 to N units of consumption, or the first tier, are on one volumetric rate, while the next N + 1 to M units of consumption are on a second rate, and any units M + 1 and above are billed using a third rate. Each subsequent rate is lower than the last, and the third rate is set to electricity energy avoided costs. This rate construction choice means that energy costs will

[17]Avoided costs start as unique by on and off-peak periods, so weighting by NREL load was necessary to arrive at a mean avoided cost for all winter hours.

always be covered. Customers who have high electricity consumption, because of fuel-switching from gas, could save money overall, as the mean per-unit rate they will be charged is lower than the current volumetric rate.

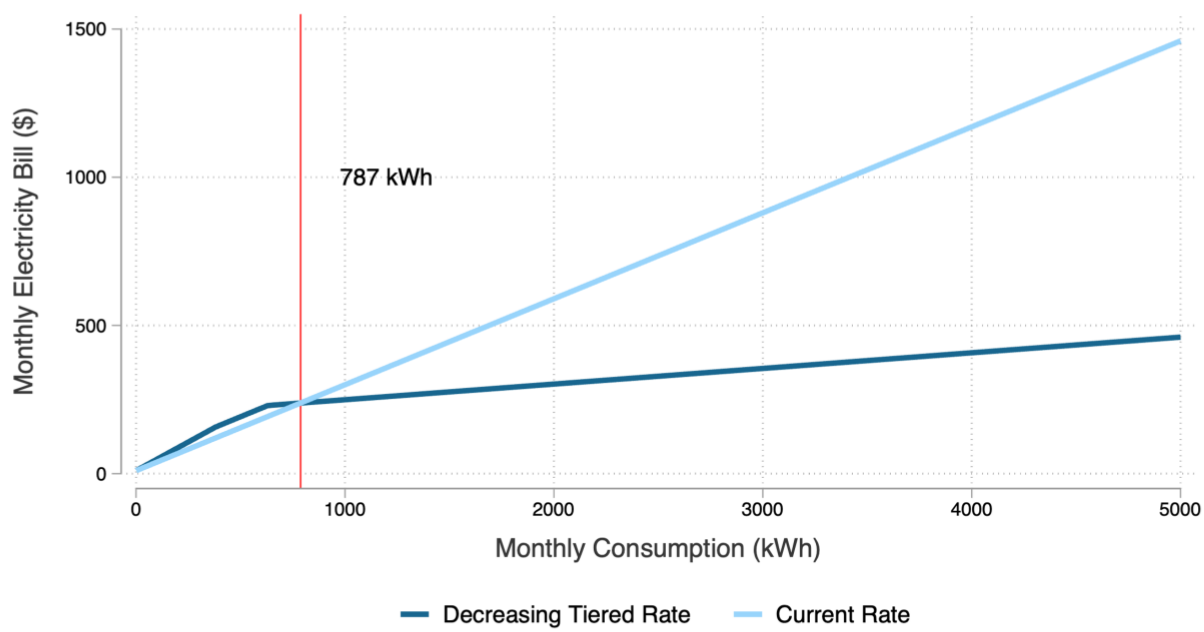
In more technical terms, this alternative rate is made up of three tiers (one set of tiers for each season), wherein the expected total consumption in each tier is one-third of overall system consumption. In other words, the first, second and third tiers are defined as the 0^{th} – 33^{rd}, 34^{th} – 66^{th}, and 67^{th} to 100th percentile of consumption, respectively. To calculate these boundaries, an electricity consumption distribution was retrieved from 2020 RECS data and scaled to fit the NREL consumption mean.[18] Next, the second tier volumetric price was set to the current load-weighted electricity rate, and the third tier was set to load-weighted avoided costs, both tier rates set by season. Lastly, we let fixed cost remain unchanged from the current rate. The following equation could then be solved for the first tier volumetric price:

$$\text{volumetricBill}_s = \left(kWh_{tier1,s} \times volumetricPrice_{tier1,s}\right) + \left(kWh_{tier2,s} \times volumetricPrice_{tier2,s}\right) + \left(kWh_{tier3,s} \times volumetricPrice_{tier3,s}\right)$$

More specifically, during summer and using Eversource rate inputs, a customer's electricity bill under this Tiered Rate would be lower if they consumed over 787 kWh in the month, compared to current rates. Figure 21 expounds on this point, showing that as consumption increases above 787 kWh (vertical red line), the hypothetical tiered rate customer pays increasingly less per unit on average, compared to the same customer billed under the current rate. For context, the typical low-efficiency electrified home (Upgrade Level 3) uses 2,000 – 4,000 kWh per month in winter and would thus pay roughly half of their current electricity bill if this Tiered Rate were imposed (see Figure 4 for more information on typical electric load by month). Bill impacts to low-consumption income-qualified homes are a concern with Decreasing Tiered Rates as electric bills will increase for homes using less than a certain 'break even' quantity per month. While both the IOUs offer rate discounts to low-income customers, this analysis is restricted to standard rate offerings. Discounts for low-income customers could easily be applied to the alternative rates that we consider and would help to mitigate concerns about regressivity.

[18] Residential Energy Consumption Survey (RECS) data from the U.S. Energy Information Administration contains energy consumption data from a representative sample of US households, showing variation across households. To calculate the consumption boundaries for the Decreasing Tiered Rate, the distribution of electricity consumption was required. The NREL data, which only provides mean consumption statistics, did not satisfy this requirement, so the RECS distribution was shifted to center on the NREL mean. Tier boundaries were drawn from that shifted distribution.

Figure 21: Example Comparison of Bill Under Tiered and Current Rates



Note: Uses Eversource rate inputs and summer tier boundaries.

Both increasing and decreasing tiered rates exist, where increasing tiered rates (also known as block rates) disincentivize higher electricity consumption and decreasing tiered rates do the opposite but are theorized to spur fuel-switching to electricity. A version of this rate structure with increasing block rates (third-tier rate is highest) has been in place for residential customers in California since the 1970s and was originally adopted to encourage conservation.[19]

The details of this rate for Massachusetts are specified in Table 11. Note that because the avoided costs are lower than the current rates, the first-tier price is necessarily higher to recoup costs and remain revenue-neutral.

[19] https://docs.cpuc.ca.gov/PublishedDocs/PUBLISHED/FINAL_DECISION/169782-01.htm

Table 11: 2024 Prices Under a Decreasing Tiered Rate, by Utility

Utility	Tier Range	Volumetric Price ($/kWh)	
		Summer	Winter
Eversource	Tier 1: 0 – 370 kWh	0.425	0.418
	Tier 2: 371 – 612 kWh[20]	0.326	0.331
	Tier 3: 613+ kWh[21]	0.053	0.090
National Grid	Tier 1: 0 – 370 kWh	0.417	0.418
	Tier 2: 371 – 612 kWh	0.319	0.330
	Tier 3: 613+ kWh	0.053	0.090

The Impact of Alternative Rates on Bills: Gas & Electricity Combined

Figure 22 and Figure 23 show annual combined gas and electric energy bills under the efficient electrification scenarios (compared to the baseline home) for a representative household under current rates and our alternative electricity rates. Figure 22 expresses this in total bills, and Figure 23 expresses it in a dollar change from today's baseline home under current rates. Under current electricity rates, the lower-efficiency home with whole-home electrification (Upgrade Level 7) experiences an annual bill increase of $2,067. In contrast, the home with highest efficiency retrofits (Upgrade Level 10) *saves* $745 under current electricity rates due to its low electricity consumption. This means that the highest-efficiency home pays over $2,812 less per year than the code-minimum full electrification home (Upgrade Level 7). While the high-efficiency home experiences bill reductions, the level of efficiency and electrification here

[20] These rates are electric load-weighted averages of the collected rates in that season. The same methodology applies to the winter tier 2 prices.
[21] The third tier rates are set to avoided cost ($/kWh), which do not include capacity avoided costs ($/kW-year).

would require a sizable upfront capital investment. Such homes are unlikely to represent a large share of customers for years to come.

For both Upgrade Level 3 homes, which uses a minimum efficiency heat pump and retains gas service for other home appliances, and Upgrade Level 7 homes, which uses the minimum efficiency heat pump in a fully electrified home, the alternative rate design that drives the highest bills will be the $25 Fixed Charge – Universal Rate. In both of these scenarios, the TOU rate offers modest savings over current rates. Both the $25 Fixed Charge – Seasonal Electrified Rate and the Decreasing Tiered Rate save the most on customers' near-term bills.

In the high-efficiency scenarios (Upgrade Levels 8 and 10), all alternative rates lead to additional decreases in combined energy bills, which are already lower than the bills of the baseline home under the current rate. The $25 Fixed Charge – Seasonal Electrified Rate and the Decreasing Tiered Rate yielded the largest bill decreases because the reduction in annual gas bills is substantially larger than the increase in annual electricity bills. In Upgrade Level 8, the $25 Fixed Charge Rate and the TOU rate result in bills that are very comparable to the baseline home, because the reductions in gas bills only slightly outweigh the increases in electricity bills. In Upgrade Level 10, both of those same rates offer meaningful savings.

In all scenarios, the $25 Fixed Charge – Universal Rate performs the worst, and the rates that reduce volumetric charges perform the best. This is understandable, as electrified homes add most load in the winter and winter volumetrics charges are as low as $0.090/kWh in both the $25 Fixed Charge – Seasonal Electrified Rate and Decreasing Tiered Rate. In so far as the system remains summer peaking, the kilowatt-hours added to system demand during winter reflect a more efficient use of existing grid resources and the low cost may be justified.

However, both rates incentivize increased consumption without incentivizing load-shifting away for peak periods that drive higher avoided costs, or without encouraging the use of efficiency measures or distributed resources that offset a customers' grid impact. The marginal gains in annual bill savings from upgrading from Upgrade Level 3 electrification to Upgrade Level 10 electrification under the $25 Fixed Charge – Seasonal Electrified Rate and Decreasing Tiered Rates are $1,469 and $1,018, respectively. Under the TOU rate, the benefit from the move from Upgrade Level 3 to Level 10 is $2,466 annually. These increased savings could be used to justify and help finance the capital-intensive efficiency and equipment upgrades needed to move from a Level 3 home to an Upgrade Level 8 or 10 home.

Figure 22: Annual Energy Bills by Rate for Electrified Upgrade Levels (2024)

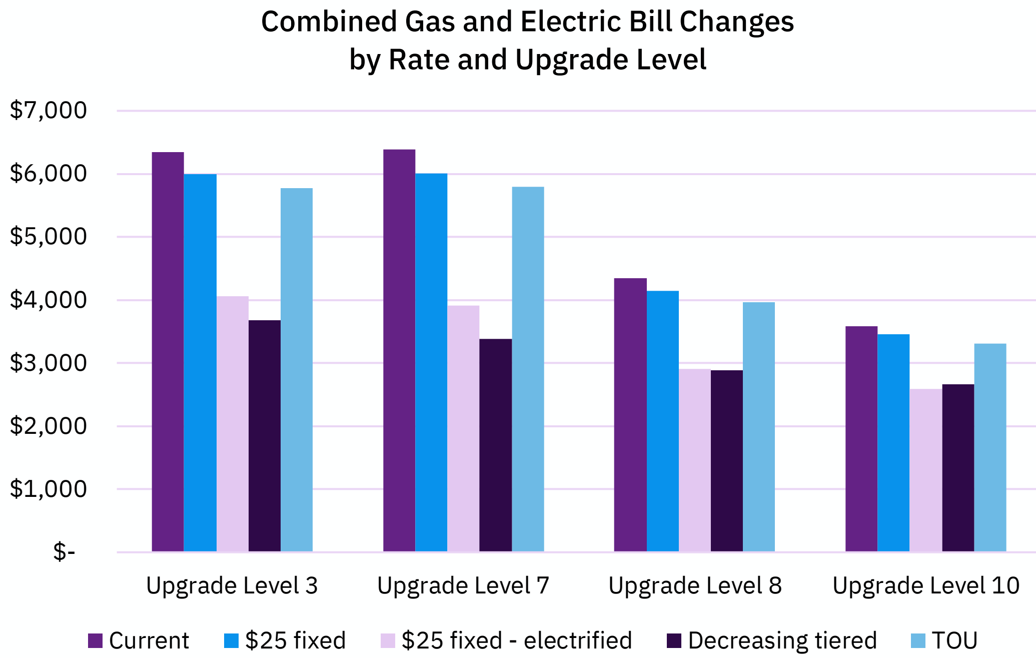
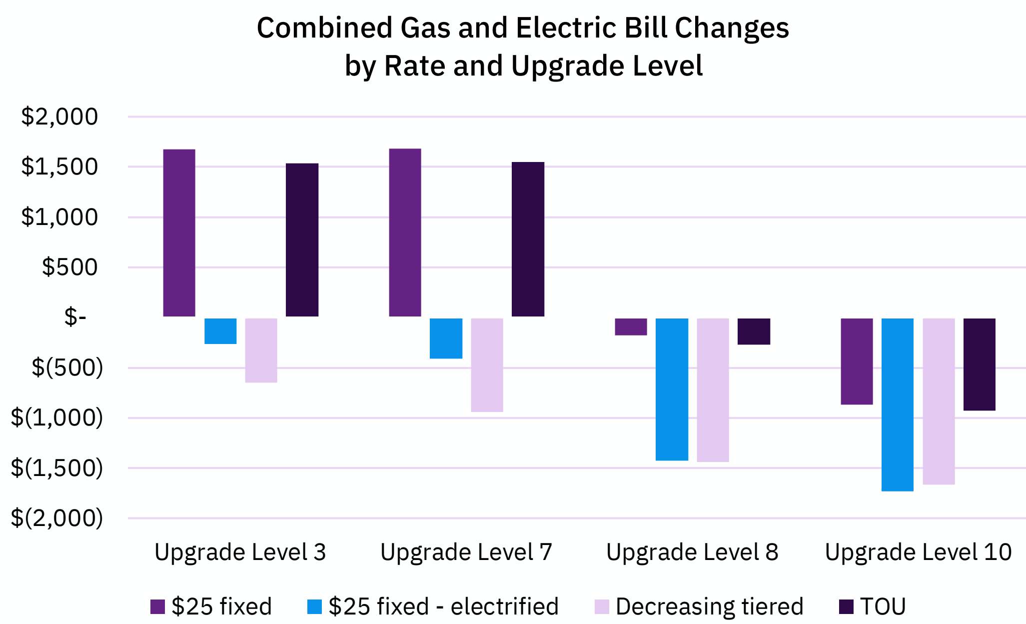


Figure 23: Change in Annual Energy Bills by Rate for Electrified Upgrade Levels (2024)



To date in Massachusetts, both Unitil and National Grid have proposed, and the Department of Public Utilities has approved, seasonal heat pump rates that are most similar to the $25 Fixed Charge – Seasonal Electrified Rate modeled in this study. Since then, the Department of Energy Resources has filed a petition to open an investigation into seasonal heat pump rates and direct all electric utilities to establish or modify optional seasonal heat pump rates for residential customers.[22] In the near term before AMI deployment is widespread and before the system becomes winter peaking, an optional heat pump customer rate can be used to more squarely address the discrepancy between heat pump bill increases and avoided cost increases identified in Figure 18. Notably, these seasonal rates can be *combined* with TOU rates that encourage load shifting once AMI is available, and cost-reflective differentiation by season and by peak hour may mitigate the need for this rate to be accompanied by an increase in fixed charges that have the potential discourage DER adoption. Though we did not study these variations for this report, the newly opened Docket 25-08 may be an appropriate place to examine these combined rates.

Given the high system costs to deliver electricity in the Commonwealth today and the anticipated escalation in system costs per additional heat pump when the system switches to winter peaking, utilities setting heat pump-specific rates today should be prepared – and prepare the relevant customers – for adjustments to those rates as TOU is enabled and as the system cost dynamics shift. We recognize that there is a cost to the marketing, education, and re-education of customers about changes to rates, and potential customer fatigue in learning new, increasingly complex rate designs and adjusting their behavior every few years. These factors should be taken into consideration as the Commonwealth makes changes to balance its many objectives, including affordability, electrification, and system efficiency.

The Impact of Alternative Rates on Avoided Costs

The change in avoided costs does not vary meaningfully across rates because total consumption is unchanged by rate under all but the TOU rate, as illustrated in Figure 24.[23] Said another way, TOU rates are the only rate of those considered by the IRWG that have any direct impact on system costs (see Figure 24: Annual Electric Avoided Cost Increases by Rate and Upgrade Level (2035). As avoided costs increase, each additional unit of electrification used at peak becomes more expensive to provide. Given Massachusetts's high rates driven by a high revenue requirement, mitigating avoided cost increases can help prevent future bill pressures.

[22] https://eeaonline.eea.state.ma.us/dpu/fileroom/#/dockets/docket/11542
[23] The behavior change (shifting) that we model under the TOU rate yields a small reduction in avoided costs, though TOU rates designed for to incent more dramatic behavioral changes may yield more significant results.

For this reason, any consideration of rate design changes to promote electrification should also be mindful of how and when added energy consumption will impact system costs.

Figure 24: Annual Electric Avoided Cost Increases by Rate and Upgrade Level (2035)