Neighborhood-Based Analysis of Building Electrification Policies in Massachusetts

Aimee Powelka, Daniel Engelberg, Massachusetts Executive Office of Energy and Environmental Affairs
Darya Guettler, Sam Wolk, Christoph Reinhart, Massachusetts Institute of Technology
Samuel Letellier-Duchesne, David Righter, Introba
Elizabeth A. Stanton, Sagal Alisalad, Applied Economics Clinic

ABSTRACT

Building energy use has produced an average of 53% of Massachusetts's annual greenhouse gas (GHG) emissions over the past decade. Over ¾ of state's 2.7 million buildings rely on fossil fuel heating. To meet net zero GHG emissions by 2050, nearly every residential building and most commercial and industrial buildings must be electrified.

A central policy question is how Massachusetts will transition away from the gas system. The transition presents several challenges including shifting building heating loads to the electric grid, minimizing impacts on rising utility rates, and addressing the costs of maintaining the gas system during a period of declining use. To evaluate these tradeoffs, a geographically based building model was commissioned by the Energy and Environmental Affairs Executive Office and developed by Introba, MIT's Sustainable Design Lab, and Applied Economics Clinic.

We analyzed the cost and emissions impacts of electrification in three areas identified as sites for replacement of leaking gas mains in a Gas System Enhancement Plan as one demonstration of the model's capabilities. We compared the lifetime costs of the pipeline replacement to costs from 50%, 75% or 100% building electrification. In one area, we found clear cost savings and emissions reductions from electrification. In the other two areas, we found comparable costs with reduced GHG emissions. This geographically based modeling approach is a new tool to advance integrated energy planning for the building sector for state policymakers.

Introduction

Massachusetts operates under binding, declining greenhouse gas (GHG) emissions limits established pursuant to the Global Warming Solutions Act and strengthened by subsequent climate legislation. The Commonwealth is legally required to reduce economy-wide emissions by at least 50 percent below 1990 levels by 2030, 75 percent by 2040, and to achieve net-zero and a minimum 85 percent GHG emissions reduction by 2050. These limits are implemented through sector-specific strategies in the Clean Energy and Climate Plans (CECPs) which are required to be published by the Massachusetts Executive Office of Energy and Environmental Affairs every five years.

Within this statutory framework, the building sector represents a significant decarbonization challenge. Over the past decade, direct fossil fuel combustion in residential, commercial, and industrial buildings has resulted in an average of 32 percent of Massachusetts's GHG emissions inventory (MassDEP). When combined with indirect emissions from electricity use, buildings account for approximately 53 percent of statewide GHG emissions. More than three-quarters of Massachusetts's 2.7 million buildings rely on fossil fuels for space and water heating. Accordingly, the CECP for 2025 and 2030 (EEA 2022) establishes that nearly all residential buildings and most commercial and industrial buildings will require electrification by mid-century to comply with statutory emissions limits (Roadmap 2021).

The CECP determined that the Mass Save® ratepayer-funded energy efficiency programs (Mass Save) would serve as the main policy lever for building electrification. These programs have incentivized energy efficiency since 2008 and are familiar to most residents. Recent Mass Save programs have provided incentives for electrification as well as for energy efficiency, with over 134,000 homes with heat pump installations supported between 2021 and 2025. However, historic participation has not been equitably distributed with many more homeowners and affluent residents receiving Mass Save incentives than renters and lower income residents (DNV-GL 2020; Navigant, Illume, and Cadeo 2020). The current Mass Save programs are beginning to address this inequity in part by designating certain communities as eligible for enhanced incentives (Mass Save 2025).

Complicating the decarbonization transition, energy affordability has become a challenge for residents in Massachusetts. Investments in aging gas and electric infrastructure have driven costs up, leading to less support for Mass Save ratepayer funding. The need to decarbonize by electrifying and transitioning off of the gas systems raises critical questions regarding affordability, electric distribution system impacts, and equity. The challenges of affordability and equity are central to developing building electrification policies that will inform the next CECP.

A major policy question is how Massachusetts will transition off the gas system to mitigate climate change. The transition presents multiple challenges including shifting building heating loads to the electric grid, preventing fixed gas system costs from dramatically increasing rates for those who cannot afford to electrify, and the costs required to maintain the gas system during this transition. The ~21,000 miles of gas mains in Massachusetts (DOER 2026) are old and leak-prone and concentrated in older urban areas. Regulators have substantively been discussing how to transition off the gas system beginning with the Future of Gas investigation in Order 20-80 (DPU 2023). That order requires gas utilities to file Climate Compliance Plans (CCPs) every five years. The CCPs must demonstrate that non-gas pipeline alternatives (NPAs), such as energy efficiency, demand response, targeted electrification and networked geothermal, have been considered for future cost recovery for new distribution system investments.

To reduce gas leaks, the Massachusetts legislature requires the gas distribution companies to annually file a five-year Gas System Enhancement Plan (GSEP; Gas Leaks Act 2014). The gas companies are investing billions of dollars annually to replace the leaking pipes. This presents the question of how much we should be investing in a gas system that will ultimately be decommissioned. NPAs, such as building electrification, are required to be assessed for all leak prone pipe repairs to ensure that ratepayers are not supporting infrastructure that may at one point support few or no customers.

Emerging analytics such as stock-level building-by-building energy models now allow us to explore the impacts of building electrification by community characteristics (e.g., for equity analyses), on the electric distribution grid (e.g., impacts on capacity) and for NPA potential. Working with Introba, MIT's Sustainable Design Lab, and Applied Economics Clinic, we developed a modeling approach to support the exploration of electrification policy and its impacts.

In this paper, we apply the model to analyze the cost and emissions impacts of electrification in three areas identified as sites for replacement of leaking gas mains as a demonstration of the model's capabilities. We compare the lifetime costs and GHG emissions of the pipeline replacement under a BAU scenario to scenarios of 50%, 75% or 100% building electrification.

Methods

Building Stock

To generate the stock model of all buildings in Massachusetts, the Semantic Building Energy Modeling (SBEM) approach described by Wolk and Reinhart (2025) was used. This methodology enables building-level energy modeling even when there is some uncertainty about the characteristics of a building by applying probability distributions to each building conditioned on the deterministic features available.

The MassGIS tax assessor database allowed derivation of census-tract level information on building components (MassGIS). Other inputs include federal building energy surveys (e.g., RECS, CBECS, PNNL Prototype Buildings), and the 2020 American Census Survey. These sources together enabled differentiation in energy usage and building components for the desired semantic fields of building age, typology, height, and components (e.g., lighting, appliances, heating and cooling types, insulation levels, etc.). A clustering approach was applied to identify which granularity of typology had the greatest impact on energy usage intensity for the building stock. Using the National Laboratory of the Rockies (NRL) ResStock dataset, k-means clustering was utilized to identify the largest clusters of MA buildings according to their energy use intensity (EUI), and the typologies were mapped accordingly. This approach entails reviewing all known features about a building (e.g., age, typology, location, owner, height, property value, ratio of building footprint to property footprint) and using buildings with known energy usage to identify which of the known features have the largest impact on energy usage. Beyond typology, age and height were deterministic factors that affected the chosen building energy components. For example, even though only two building typologies exist for residential buildings, three different height buckets (1, 2-4, and 4-7 story) and three different age buckets (pre-1975, 1975-2002, 2003 and later) were used for commercial buildings.

Building retrofits

Building retrofit packages were designed to explore the impacts of electrification and efficiency measures on total and peak energy usage (Figure 1). For this case study, with the focus on electrification, we tested the following two most likely building retrofits for NPA areas. For reference, we also include efficiency (controls, LEDs and high efficiency appliances) and insulation alone. While other retrofits are technically possible, such as a heat pump without insulation, the current policy and incentive structures require insulation and air sealing whenever heat pumps are installed.

ASHP + insulation: Air source heat pump (ASHP) installation, heat pump or electric water heating, and market-standard insulation and air sealing.

Full electrification: ASHP installation, heat pump or electric water heating, market-standard insulation and air sealing, and electrification of cooking and clothes-drying appliances.

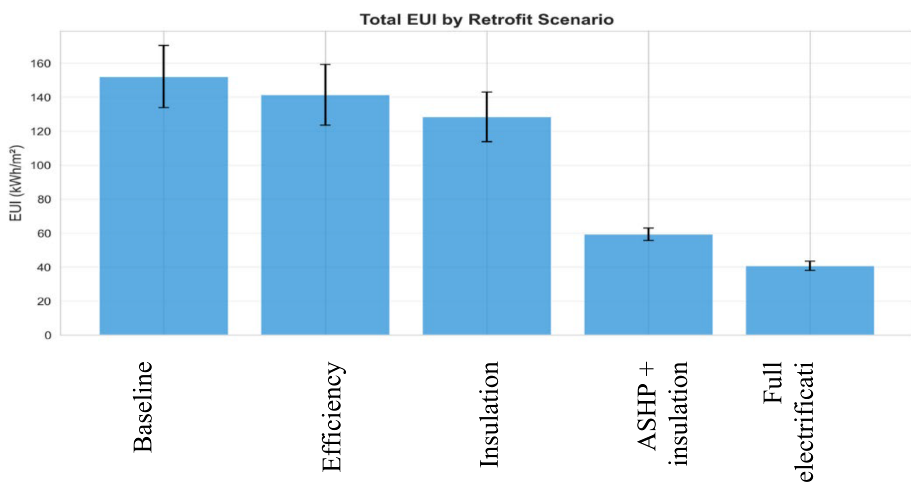

Figure 1: Energy use intensity changes from building retrofits for all NPA area buildings.

For every building, we applied a consistent set of upgrades based on their current state. Every building that was not assigned a high probability of already having a heat pump was retrofit with an ASHP. The coefficient of performance was calculated dynamically based on local TMY3 (Typical Meteorological Year) weather data for each city, accounting for the efficiency degradation of ASHPs during Massachusetts' peak winter design days.

Adoption curves

To determine whether an owner of their residential building is in principal willing to pay for a given retrofit package, the "deal/no deal" framework built by Berzolla, Meng, and Reinhart (2025) for retrofits was adopted. The underlying regression model requires seven attributes for each building, household income, education, concern about the climate, space characteristics (e.g., number of rooms), perception of neighbors' retrofit adoption, upfront costs, and energy costs. The model then yields a likelihood score for a given household to go ahead with the retrofit. A logistic model was created to align the data from the 2020 American Census Survey and the Yale Climate Communications survey for the seven input attributes and assign a willingness-to-pay (WTP) likelihood for each building. A limitation of this method is that this WTP framework was built upon data solely from owner-occupied buildings. In the absence of better data, we applied the WTP criteria to all the NPA area buildings. This will increase uptake more than would be expected for rented homes given the split incentive challenge of tenant-occupied buildings. The WTP model is applied to estimate the base propensity of a household to pay for a retrofit and is then layered with a second uptake model to project the timing of future retrofit projects based upon historic Mass Save participation trends over the years 2013-2024.

Policy levers

To explore their influence on electrification adoption, policies were divided into three categories: regulatory, distributive, and constitutive policies (Table 1). Regulatory policies such as a clean heat standard would set required benchmarks and the model changes energy savings until the benchmark is achieved. Distributive policies such as Mass Save incentive programs change the model's cost equation through reduced capital and/or operating costs. Constitutive policies such as targeting incentives based upon geographic or demographic factors change the model's adoption curve by focusing on the delivery of policies to priority areas.

Table 1. Overview of policy types, their implementation and examples.

Policy Type	Implementation	Example policies	Potential set of retrofits
Regulatory	Define objective and choose retrofits until objective is met.	Clean Heat Standard Energy code Efficiency standards	Technical potential: all possible retrofits
Distributive	Change underlying system costs or energy costs based on possible incentives.	Electrification / efficiency incentives Market transformation programs	Economic potential: financially feasible retrofits
Constitutive	Identify potential projects for clustering and alter the overall adoption rate and network effects of the policies.	Geographic targeting: Equity communities Gas pipeline pruning Electric load availability	Realistic potential: retrofits likely to be implemented

Choosing specific case studies to evaluate

This model is a powerful step forward for building energy and emissions analysis in Massachusetts. As a first test, we wished to apply the model to a very specific and relevant policy question. We chose to analyze the potential costs of building retrofits in potential NPA areas for which specific natural gas grid upgrades have been proposed. The comparison is timely given the current concerns regarding energy affordability and massive planned investments in pipeline repairs in the GSEPs. The GSEPs are required to include the estimated costs for a NPA and an estimated cost for the gas pipeline replacement.

The specific NPA areas in this paper were selected according to the following criteria from a utility-filed GSEP (DPU 2025a). First, the gas utility determined if a pipeline section were to be decommissioned rather than repaired, then it would maintain system integrity and ensure continued safety. Second, we ensured that we were selecting some projects designated as within a Massachusetts environmental justice (EJ) neighborhood to represent sociodemographic diversity and the state's policy priorities (EJ, 2020). Finally, we examined project locations to assess their geography with a preference for projects that appeared to have fairly distinct bounds, for example being limited by an intersecting main road. The selected NPA areas are listed in Table 2.

Table 2. Gas system attributes of NPA areas.

City	GSEP footage	Pipe diameter	Operating pressure	Existing material	Mapped addresses
Arlington	2,985	12”	LP to 25	Cast iron	Robinhood Rd, Parker Rd, Cheviot Rd, Intervale Rd, Lakeshore Dr
Braintree	345	2”	60	Steel	12-26 Randall Ave
Newton	2,565	6”	LP	Cast iron	Pearl St

Defining the spatial bounds of the problem

The GSEP filings do not contain the specific buildings served by the gas main in our three NPA areas. Instead, we used the location (exact latitude and longitude) and subdivision number from the GSEP data to identify the physical clusters of buildings serviced by specific gas mains. We chose to estimate a lower and upper bound based on the scope of the gas line we are focused on, using the line length and pressure to estimate this.

This assessment was done qualitatively and quantitatively. Quantitatively, we used GSEP footage to create a linear search radius. We then applied a 50-100m parcel buffer perpendicular to the line to capture all buildings with a direct service connection. Using the operating pressure attribute, we adjusted the cluster size. Low-pressure systems often require larger integrated sections to be decommissioned together to maintain the pressure balance of the surrounding network. For higher-pressure segments, we used the line diameter and pressure to estimate the total load capacity of the segment. If a segment serves as a pass-through for a larger neighborhood, the upper bound was extended to include all buildings within that specific subdivision number to ensure no customers are left stranded without a feed. While this radius approach is unlikely to identify the exact buildings served by the gas main, the establishment of lower and upper bounds for the buildings within the service area establishes a reasonable range that should resemble the actual customers served.

Qualitatively, we prioritized segments ending in "dead ends" as these would likely be hydraulically isolated. Decommissioning a dead-end segment requires only the electrification of buildings directly fronting that specific GSEP footage with no impact on downstream reliability. The resulting set of buildings for each NPA area, with their upper and lower bounds, are shown in Figure 2.

Figure 2: Upper and lower spatial bounds of selected NPA areas.

Results

Table 3 provides an overview of characteristics of the three selected NPA areas. Sociodemographic data are from the American Census Survey (2020), heating fuel and air conditioning availability from the American Communities Survey, and Mass Save participation rates by block group from the Mass Save program administrators (pers. comm., March 3, 2026). In Massachusetts as a whole, about 50 percent of homes are heated with natural gas, 24 percent with delivered fuels (heating oil, propane), and 20 percent with electricity (ACS, 2024). The NPA areas have higher proportions of gas heating than the statewide averages.

Table 3: Characteristics of the block groups containing a NPA area.

	Arlington	Braintree	Newton
Designated EJ	No	Yes, income	Yes, minority
Block Group	365400	419800	373100
Median income	$179,348	$96,043	$179,455
Education level (% with bachelor's degree or higher)	77%	43.1%	76.7%
Percent renters	39%	23%	30%
Family Size	2.95	2.84	2.52
Gas heating fuel proportion	59.4%	56.3%	75%
Delivered fuels proportion	29.6%	29.7%	18%
Electric heating fuel proportion	11%	17%	7%
Air-conditioning prevalence	91%	91%	91%
Average Mass Save participation rate over 5 years	10%	5%	6%
Mean age of buildings (lower bound / upper bound)	84 / 88 years	10 / 66 years	109 / 132 years

To explore the existing investments in building retrofits, Mass Save participation rates, available at block group, were statistically allocated to the projects. We see a relatively high level of participation in Arlington, a relatively affluent community with extensive existing community-based clean heating outreach. The block groups in Braintree and Newton each illustrate a lower level of participation.

We assessed the timeline for electrification of the homes in the three NPA areas using existing programs and incentives. Electrification curves here represent the "natural" electrification that would occur for any building that has not already converted to a heat pump, without any incentives beyond what is currently available (a maximum of $8,500 for an ASHP). Homes within each NPA area electrify on different timelines and exhibit a range of uncertainty (shading) for the specific year of their upgrade (Figure 3). The Braintree and Newton adoption curves exhibit a step-function due to the small number of buildings with each building's conversion as a step.

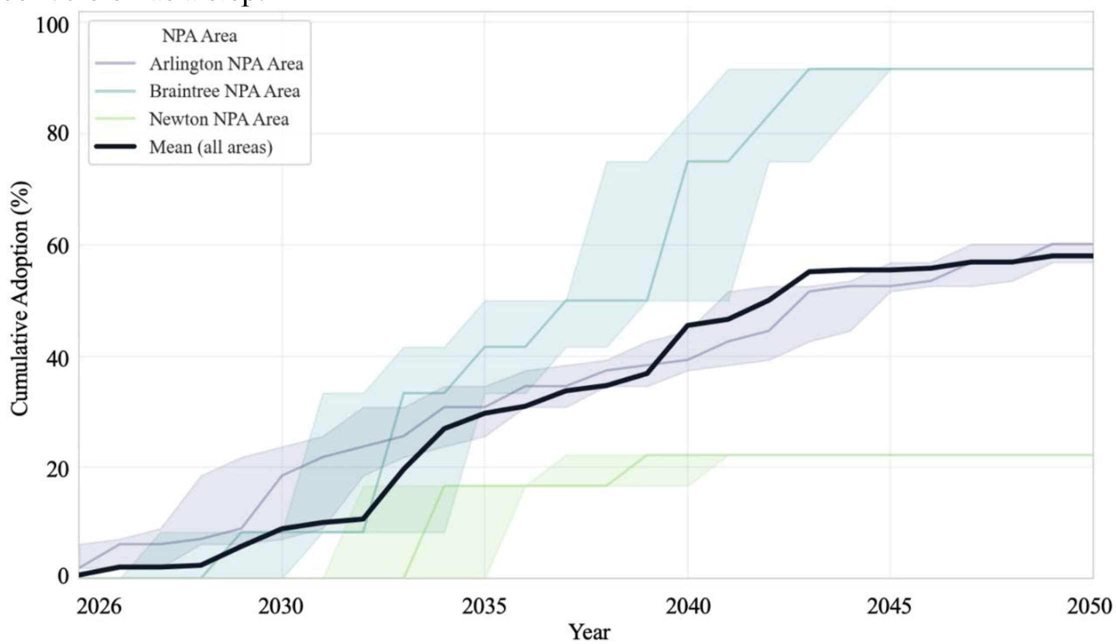

Figure 3: Adoption curves of electrification (ASHP + insulation retrofit) with current incentives in three NPA areas.

The primary determinants for the timing of building electrification are the age of the existing heating and cooling systems, the upfront capital expense and the cost comparison between the existing heating fuel and the retrofit fuel. Gas heating costs are less than ASHP heating costs, which in turn are less than propane or oil heating costs. These comparative costs influence the economics of the choices that building owners make when replacing their heating system.

Other determinants for electrification are based upon demographic factors including income, education, concern about the climate, space characteristics (e.g., room numbers), and perception of neighbors' adoption of electrification. In contrast to expectations given the sociodemographic data indicated in Table 3, we see that Braintree, the least affluent and least educated NPA area, electrifies the most rapidly and extensively in the long-term through 2050. This can be explained in part by the low electricity rates in Braintree, which is served by a municipal lighting plant rather than an investor-owned utility. Other factors include Braintree's relatively higher level of electric heating and its newer buildings that are less expensive to retrofit than in other communities. Newton has the slowest and lowest amount of electrification, likely due to its highest proportion of gas heating among the three communities.

Even in the most likely-to-electrify neighborhoods or communities, 100% electrification is unlikely to occur in the current market. Indeed, we see in Figure 3 that none of the NPA areas reaches complete electrification by 2050. We hypothesize that even if all costs were covered and residents were paid to convert, some households would not choose to electrify. Instead, we expect that as the heating equipment market changes over time, finding replacements for fossil heating equipment will become increasingly difficult and so force the remaining non-electrified households to convert when their existing heating equipment fails.

Every NPA area building was modeled for the two energy retrofits: "ASHP + insulation" and "full electrification." The range of capital costs for building retrofits with ASHP + insulation is illustrated in Figure 4. Table 4 includes the total modeled building upgrade costs for the upper and lower spatial bounds of each NPA area. It also includes the costs provided by the utility in their GSEP filing for the NPA and the gas pipeline replacement for comparison. In all NPA areas, our modeled building upgrade costs are lower than the GSEP costs (GSEP NPA cost). In contrast, the GSEP pipeline replacement costs do not exhibit a consistent pattern (i.e., not all higher or lower) when compared to the modeled building upgrade costs. These costs represent only upfront capital needs and not the full impact of lifecycle or ratepayer costs.

Figure 4: Capital expenses for ASHP + insulation building upgrades (ASHP, HPWH, insulation and air sealing).

To determine if these NPA upgrades would be able to proceed without an electric system upgrade, we queried local feeder data to determine the available headroom (kVA) at the nearest substation. For this initial case study, we confirmed that the total coincidental peak load of the new heat pumps does not exceed existing substation or feeder capacity, effectively setting the required capital costs for substation or feeder upgrades to zero for these specific sites.

Table 4: Building age, upgrade costs and operating expenses for ASHP + insulation upgrades.

NPA Area	Number of buildings	Total modeled building upgrade capital costs	GSEP NPA cost	GSEP pipeline replacement cost
Arlington	15 - 53	$541,400 - $1,734,130	$2,435,119	$ 1,283,021
Braintree	2 - 6	$157,508 - $318,970	$ 335,535	$ 155,201
Newton	3 - 9	$140,870 - $335,760	$ 1,629,173	$ 509,911

Modeled Scenarios

How to finance the cost of the transition from the gas system to electrified buildings is a major question being explored by policy makers. We chose to examine lifetime costs as a fair representation of societal costs. We assess only direct costs including utility-born costs for pipeline replacements that are funded by gas ratepayers, electrification and efficiency incentives paid by electric and gas ratepayers (e.g., Mass Save incentives), costs borne by building owners for upgrades, and the operating expenses over the lifetime of the heating system. We did not include costs for electric distribution system upgrades due to a lack of significant impact on the associated feeders and substation; this is detailed further in the discussion.

To explore the relationship between the scale of electrification and the total costs, we modeled the four scenarios indicated below. In all scenarios, we first modeled "naturally occurring" electrification that represent the current adoption rates for electrification as shown in Figure 3. For the partial, hybrid and full electrification scenarios, we then increased available incentives by an amount sufficient to achieve the electrification threshold (50%, 75%, 100%) in the five years prior to the gas main replacement. To estimate the uptake trajectories for the different scenarios, we started with the Mass Save Participation trends per year. To represent a realistic timeline for NPA area electrification, we limited the timeline for current electrification rates to five years before requiring the threshold for electrification in each scenario to be met upon pipeline replacement (BAU) or decommissioning (electrification scenarios).

Scenario 1: Gas BAU

Utility Action: Full replacement of the gas main using the GSEP-filed capital estimate (e.g., $1.2M for Arlington).

Building Action: Households electrify all end-uses and retrofit building envelopes at the current adoption rates. Replacements for heating, hot water and appliances occur only at the end of the equipment's life cycle.

Methodology: We apply a probability-based adoption curve where households switch to heat pumps annually during furnace failure:

$$NPV = \sum CapEx_{BAU\ Replacement} + \sum CapEx_{Natural\ Retrofit} + \sum OpEx_{BAU\ Energy\ Costs} + \sum OpEx_{Retrofit\ Energy\ Costs} + \sum CapEx_{Natural\ incentive}$$

Partial Electrification (50%) and **Hybrid Electrification (75%)**

Utility Action: The gas main is decommissioned after five years.

Building Action: We modeled naturally occurring electrification using current Massachusetts adoption rates and Mass Save incentives. Additional incentives were provided to electrify 50% (Partial) or 75% (Hybrid) of the NPA area buildings within the five-year timeframe. Customers that did not electrify fully were converted to propane upon decommissioning of the gas main. While conversion to fuel oil is also a potential retrofit choice, propane is gaining in use whereas fuel oil is diminishing in use (Census Bureau 2024).

Methodology: We apply a probability-based adoption curve where households switch to heat pumps annually during furnace failure. The net present value (NPV) of the system cost is based only on the cost of electrification and retrofitting:

$$NPV = \sum CapEx_{Retrofit} + \sum OpEx_{Retrofit\ Energy\ Costs} + \sum CapEx_{Natural\ incentives} + \sum CapEx_{Added\ Incentives}$$

Full Electrification (100%)

Utility Action: The gas main is decommissioned after five years.

Building Action: Every building in the NPA areas is retrofitted with an ASHP and envelope improvements within five years.

Methodology: The net present value (NPV) of the system cost is based only on the cost of electrification and retrofitting as shown above for the partial and hybrid electrification scenarios.

Given a five-year timeline for gas pipeline decommissioning, we forced buildings to electrify sooner than otherwise would have occurred under BAU in the three electrification scenarios (i.e., the adoption curves would shift left in Fig. 4). Under all scenarios, the natural electrification adoption rates continue beyond the five-year transition period and so within the 20 years shown in Figure 5, greater electrification rates are seen in some NPA areas. For Arlington, this resulted in the 50% electrification scenario reaching 60% electrified buildings. For Braintree, this resulted in both the 50 and 75% electrification scenarios ending at 83% electrified buildings. For Newton, there was no additional electrification beyond the level set by the scenario. As stated above, this is likely due to the higher proportion of gas heating in Newton.

The cumulative 20-year costs for the scenarios are shown in Figure 5. Error bars represent the range in the electrification capital costs for the lower and upper bounds of buildings included in the NPA area. Error bars also include the uncertainty in future fuel prices with electricity price variation set at 20%, gas at 10% and delivered fuels at 5%; these are based upon historic values. Electricity costs are from flat basic service residential rates for these communities and do not include time-of-use or demand charges; these assumptions represent the current electricity rate structure in Massachusetts. Notably, these electricity rates are an overestimate of the cost to operate the ASHPs in Arlington and Newton because lower heat pump winter rates went into effect following this modeling effort.

Total costs, inclusive of both building owner and rate-payer costs, are lower in the three electrification scenarios in Arlington. In Braintree and Newton, the costs may be lower, but we cannot conclude this given the relatively large error bars. To definitively compare total costs, particularly in these NPA areas with few buildings, requires us to know specifically which buildings should be included. In NPA areas with comparable costs, the electrification options have the additional benefits of reducing GHG emissions and reducing the potential for stranded gas assets.

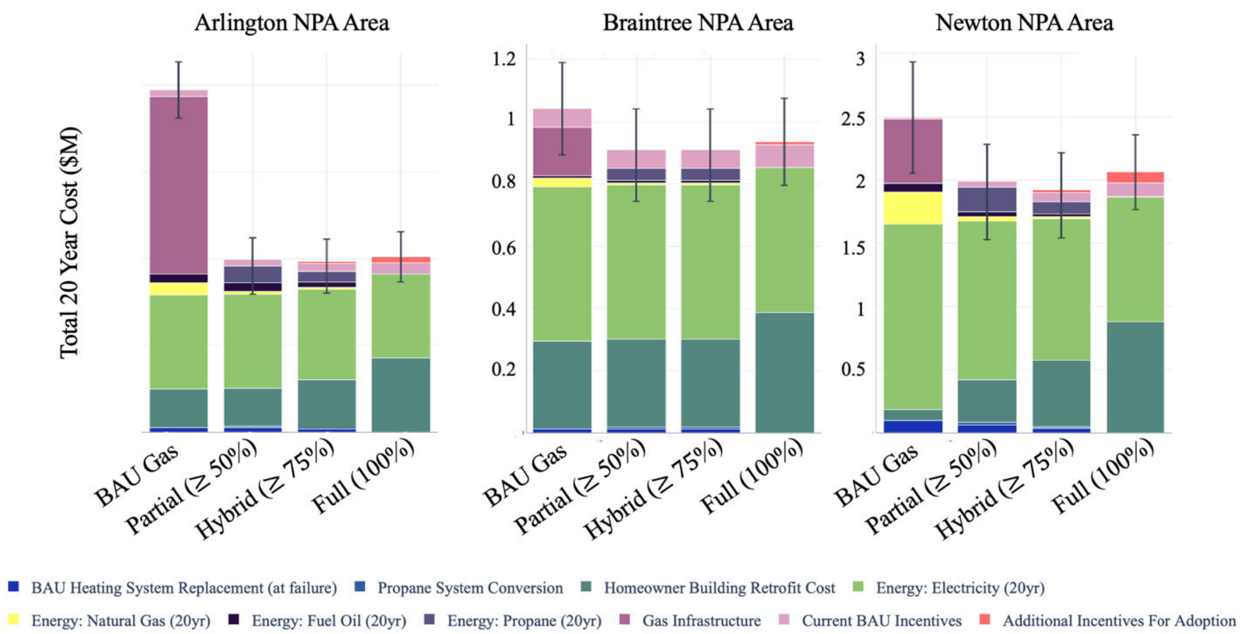

Figure 5: Total costs for NPA areas under BAU or electrification scenarios.

Looking at fuel costs, we see that 20-year fuel costs, including electricity alone, fossil fuels alone (gas and propane), and electricity plus fossil fuels, are lowest in the full electrification scenario. Operational savings that accrue to the building owner or tenant are countered by the increased need for capital for the retrofits in the full electrification scenario.

Finally, we examined the GHG emissions impacts of the different NPA area electrification scenarios (Figure 6). The shading represents the emissions for the lower and upper bounds of buildings included in the NPA areas as well as the inherent uncertainty in the rate of electrification that is seen particularly in the BAU scenario. We assume that the electricity grid transitions to net zero emissions in 2050 with a 5% reduction in the year-over-year emissions factor. We assume no changes in refrigerant leakage, the GWP of refrigerants, or gas leakage. We see that scenarios that increase the rate and extent of electrification result in the highest level of cumulative GHG emission reductions. These are especially evident in the near-term years through 2035.

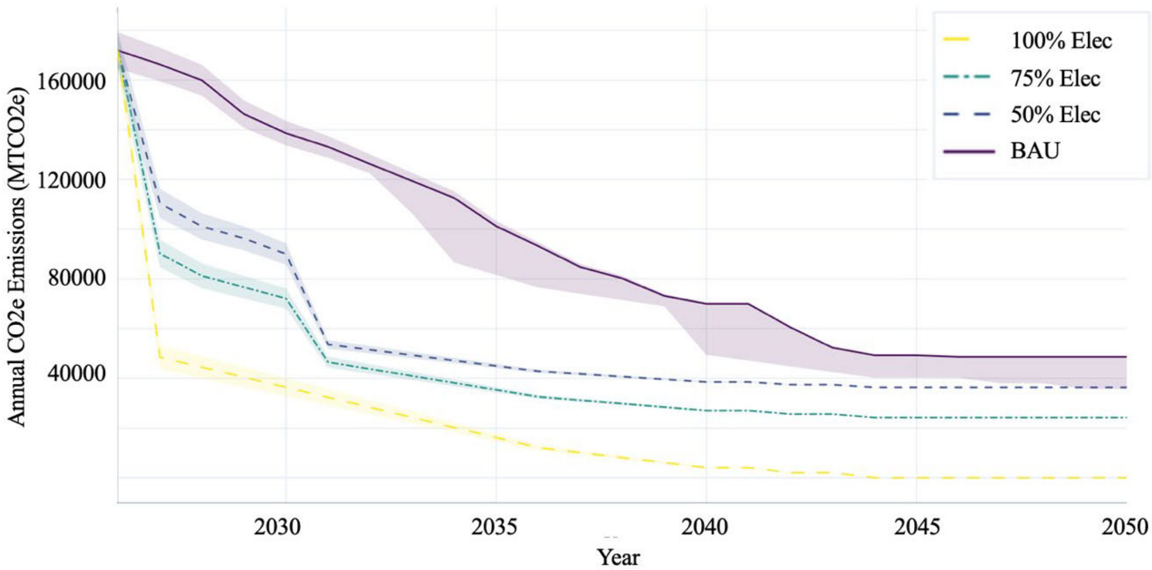

Figure 6: GHG emissions impact of BAU and electrification scenarios for all three NPA areas.

Discussion

In this paper, we have found that we can apply a new model for building energy and emissions analysis in Massachusetts to advance integrated energy planning. We find that our modeled costs of building electrification are lower than the utility's GSEP NPA cost estimate in three areas (Table 4). Our finding of a lower NPA cost than the GSEP is the opposite that of the gas utility which found a NPA to be more expensive than pipeline replacement. The cost of a gas main replacement or building electrification in NPA areas is determined by the upfront capital expenses, the lifetime operational costs, and the socialized costs of the pipe replacement or electrification incentives that are paid by electric and gas ratepayers, respectively. The cost data and assumptions in the gas utility analysis are not publicly available. A recently filed targeted electrification demonstration project included both direct and indirect cost categories (DPU 2025c). Without knowing if the indirect costs beyond participant incentives are included in the NPA cost estimate, we are unable to determine conclusively if our modeled costs are a true cost comparison. However, this model provides the first means for the state to explore the costs associated with specific NPA areas and suggests that common assumptions about the cost of building retrofits could be shared among different stakeholders to advance conversations about integrated energy planning.

Another uncertainty in our model is which specific buildings are connected to a gas main within each NPA area. Specific building and customer information is confidential and not disclosed. We addressed this uncertainty by modeling upper and lower bounds for buildings included in the NPA analysis (Figure 2). The lack of shared information is a barrier here as well.

The demonstration of this analytical method is limited to the three NPA areas assessed and does not represent all potential NPA area cases. Two variables are clearly omitted from our analysis: areas served fully by the gas system and non-urban settings. At current gas prices, we speculate that it is likely that BAU would be cost-competitive with the electrification scenarios in a fully gas heated NPA area. However, that speculation must be tempered by the knowledge that future gas rates must increase to cover the system costs as increasing numbers of customers electrify and reduce the number of gas ratepayers. For non-urban settings, two variables likely to be most important include the mix of heating fuels serving the buildings (which is different in urban, suburban and rural areas) and the length of the gas pipeline to be replaced. Additionally, our model's adoption curves are informed only by the willingness-to-pay of owner-occupied buildings. This greatly simplifies the existing building environment with its mix of owner-occupant arrangements. Further work needs to be undertaken to better understand landlords' willingness-to-pay and to apply the resulting adoption curves.

An important consideration for NPAs is their impact on the electric grid. In each of the NPA areas examined, building electrification did not create a need for capacity upgrades to the associated feeders and substations, likely due to the small number of buildings. Building electrification can also trigger the need for a transformer upgrade, a cost typically borne by the building owner. The need for a local transformer upgrade is highly dependent upon the electric loads of other connected customers and especially for electric vehicle charging. We did not have data on local transformer loading profiles. Given these multiple variables, the costs for a transformer upgrade were not included in the cost of building electrification.

The rate of electrification in NPA areas is a key consideration for determining whether a gas main replacement is justifiable. We see that the three NPA areas in our analysis show different rates of electrification that would occur with the current incentive levels. In Arlington and Braintree, more than half the customers choose to electrify within 20 years (Figure 3). This is less than the timeline for gas pipe depreciation and so the undepreciated value would be passed onto remaining gas customers. The gas pipe would remain an "underutilized asset" as the customer base slowly erodes, leading to higher per-therm delivery costs for remaining residents. We have not modeled the impact of the higher per-therm delivery costs. However, evaluations have shown that less affluent customers electrify slower than more affluent customers (NMR 2024). This creates an equity challenge that will focus stranded gas costs and increasing gas rates on customers unable or unwilling to electrify.

For long-term decommissioning of the gas system, the pace of building electrification must align with integrated gas and electric planning to minimize overall system costs to ratepayers. We modeled total costs with and without gas pipeline replacement with varying levels of electrification (Figure 5). We clearly see a cost savings from electrification in one NPA area (Arlington). For the other two NPA areas, the costs of pipeline replacement and the three levels of electrification are comparable. The electrification scenarios all demonstrate a reduction in GHG emissions in comparison to BAU (Figure 6). The electrification scenarios also avoid the gas system investment that has a high likelihood of becoming a stranded asset. We conclude that electrification can help us achieve our goals of keeping energy affordable and reducing our GHG emissions.

The results of this and future analyses using this model to compare NPAs to pipeline replacement can be used to inform policy development. To encourage electrification in specific areas, it is likely that increased incentives and/or different programs might be required. Massachusetts has a precedent for geotargeted incentives in the current Mass Save energy efficiency programs. Designated equity communities, communities with a history of Mass Save program under participation and a high percentage of renters, receive increased incentives and prioritized support. The concept of geotargeting resources, therefore, can be explored as one potential mechanism to encourage the electrification of gas customers in NPA areas.

Conclusion

This model helps fill a data gap: it provides detailed, geographic information that was previously unavailable to state policymakers to explore building decarbonization policies, including the potential for NPAs. Potential NPA areas can be identified by mapping leaking gas pipes in areas with sufficient electric capacity and then assessing building owners' propensity to electrify. Our building model provides an integrated energy planning tool to help coordinate a logical, cost-effective and equitable clean energy transition off the gas system to mitigate climate change.

References

Berzolla, Z., T. Meng, and C. Reinhart. 2025. "Deal or no deal: U.S. homeowners' willingness to pay for residential building retrofits." *Environmental Research: Infrastructure and Sustainability* 5(1). Available at: https://doi.org/10.1088/2634-4505/adac09.

Census Bureau. 2020.

———. 2024. " S2504: Physical Housing Characteristics for Occupied Housing Units." https://www.census.gov/programs-surveys/acs

DNV-GL. 2020. *Residential Nonparticipant Customer Profile Study.* Mass Save, MA. https://ma-eeac.org/wp-content/uploads/MA19X06-B-RESNONPART_Report_FINAL_v20200228.pdf

DOER (Department of Energy Resources). Natural Gas Distribution. https://www.mass.gov/info-details/natural-gas-distribution. Accessed March 2026.

DPU (Department of Public Utilities). 2023. *Order On Regulatory Principles and Framework.* Order 20-80-B. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/18297602

———. 2025a. Petition of Boston Gas Company d/b/a National Grid for Approval of 2026 Gas System Enhancement Plans. Docket 25-GSEP-03. https://eeaonline.eea.state.ma.us/dpu/fileroom/#/dockets/docket/12570

———. 2025b. Joint Brief On Legal Issues Associated with Local Gas Distribution Companies' Obligation to Serve Existing Customers. https://bit.ly/3Rq4jZc

———. 2025c. Initial Brief of Boston Gas Company, Massachusetts Electric Company and Nantucket Electric Company each D/B/A National Grid. https://bit.ly/4peSxx7

EEA (Massachusetts Executive Office of Energy and Environmental Affairs). 2022. *Massachusetts Clean Energy and Climate Plan for 2025 and 2030.* Boston, MA. https://www.mass.gov/doc/clean-energy-and-climate-plan-for-2025-and-2030/download

EJ (Environmental Justice Criteria and Map). 2020. Environmental Justice Populations in Massachusetts. https://www.mass.gov/info-details/environmental-justice-populations-in-massachusetts

Gas Leaks Act. 2014. (Plan for replacement or improvement of aging or leaking natural gas infrastructure.) Mass General Law - Part I, Title XXII, Chapter 164, Section 145. https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section145

MassDEP (Massachusetts Department of Environmental Protection). Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2022. https://www.mass.gov/lists/massdep-emissions-inventories

MassGIS Data: Property Tax Parcels https://www.mass.gov/info-details/massgis-data-property-tax-parcels

Mass Save. 2025. 2025-2027 Three-Year Plan. https://ma-eeac.org/wp-content/uploads/Exhibit-1-2025-2027-Three-Year-Plan.pdf

Navigant, Illume, and Cadeo. 2020. *Residential Nonparticipant Market Characterization and Barriers Study.* Mass Save, MA. https://ma-eeac.org/wp-content/uploads/MA19R04-A-NP-Nonpart-MarketBarriersStudy_Final.pdf

NMR. 2024. *MA22X06-B-HPMEIB Heat Pump Adoption Rates by Income Group.* Mass Save, MA. https://ma-eeac.org/wp-content/uploads/MA22X06-HPMEIB-In-Program-HP-Adoption-Memo_31may2024-clean.pdf

Roadmap (An Act Creating A Next-Generation Roadmap for Massachusetts Climate Policy). 2021. Mass. Acts ch. 8 (enacted March 26).

RMI, National Grid. 2024. Non-Pipeline Alternatives: Emerging Opportunities in Planning for U.S. Gas System Decarbonization. https://www.nationalgridus.com/media/pdfs/other/CM9904-RMI_NG-May-2024.pdf

Disclosure of AI Assistance
AI-assisted tools used: ChatGPT. Used for: preliminary drafting of the introduction and refining the abstract to reach 250 words. Extent: two, one-time interactions.
Human review: The authors reviewed and verified all content, calculations, and citations.