GETTING OFF GAS

TRANSFORMING HOME HEATING IN MASSACHUSETTS

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This report describes a path forward to reduce greenhouse gas (GHG) emissions from the gas used for residential heating in Massachusetts. Nearly half of Massachusetts homes use gas for heating, which contributes significantly to total statewide GHG emissions. It is vital to address a path forward to reduce gas use now, as a transition away from this heavy residential use of gas and toward the increased use of non-fossil fuel-based heating sources may take decades to accomplish. The path, described below, summarizes the Commonwealth's climate policy, legal mandates, and economic bases to reduce harmful GHG emissions from residential gas use. It also suggests policy options to effectively achieve these necessary reductions while meeting the needs of customers and utilities.

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COVER PHOTO: Winter in Brighton, Massachusetts

To solve climate change,

we need to move quickly away from using fossil fuels such as gas to heat and power our homes. Here in Massachusetts, nearly half of all homes rely on gas for heating, which contributes significantly to the state's greenhouse gas emissions.

Ending our reliance on this climate-damaging fossil fuel could take decades. That's why the work must start now, especially if the Commonwealth is going to meet its 2050 targets for cutting its overall carbon emissions.

Ultimately, residential heating needs in Massachusetts can be met by transitioning from oil and gas furnaces to heat pumps. They're both cost-effective and provide a lower-carbon form of home heating.

This transition will require a set of practical policy solutions that will cut emissions and transform how we heat our homes, including:

1. Requiring gas utilities to explore new business models so they no longer rely on building new polluting infrastructure for revenue.
2. Prioritizing low-income, rental, and other residents in the transition from oil and gas furnaces to cleaner options such as heat pumps. Ensuring these populations can afford to make this switch will lead to significant emissions reductions.
3. Expanding all rebate programs for air source heat pumps and ending rebates for gas upgrades to jump-start the transition to clean technology.
4. Revising building codes and establishing carbon footprint standards for residential buildings to lower their emissions – both when new homes are being built and existing homes are up for sale.
5. Maintaining a high priority on replacing leak-prone gas pipes that contribute to the state's overall emissions. This will both lower emissions and improve public health and safety.
6. Modifying the way gas utilities recoup money and retire outdated pipes to address the anticipated retirement of fossil fuel infrastructure as the state moves to meet its climate goals.

Implementing these policy options over the next 10 years is an efficient, economical way to reduce Massachusetts's greenhouse gas emissions, meet the needs of local utilities, and improve the lives of residents. With the right policies in place, utilities have the opportunity to replace polluting, dangerous infrastructure with cleaner, safer options. They will also be incentivized to invest in cleaner sources of energy, rather than fossil fuel infrastructure that will become obsolete before Massachusetts families and businesses have even finished paying for its construction.

But these are just the start. More research on utility needs and customer incentive programs will also be needed to ensure programs are designed and targeted effectively.

The policies outlined in this report can also serve as a model for other states in New England to reduce their own greenhouse gas emissions.

I. CLIMATE NEEDS, LEGAL MANDATES, AND PROGRESS MADE TO DATE

Climate change presents a pressing environmental, economic, and equity challenge for Massachusetts and the world. The impacts of climate change diminish our health, cost billions in needed repairs, and place unfair burdens on vulnerable communities.

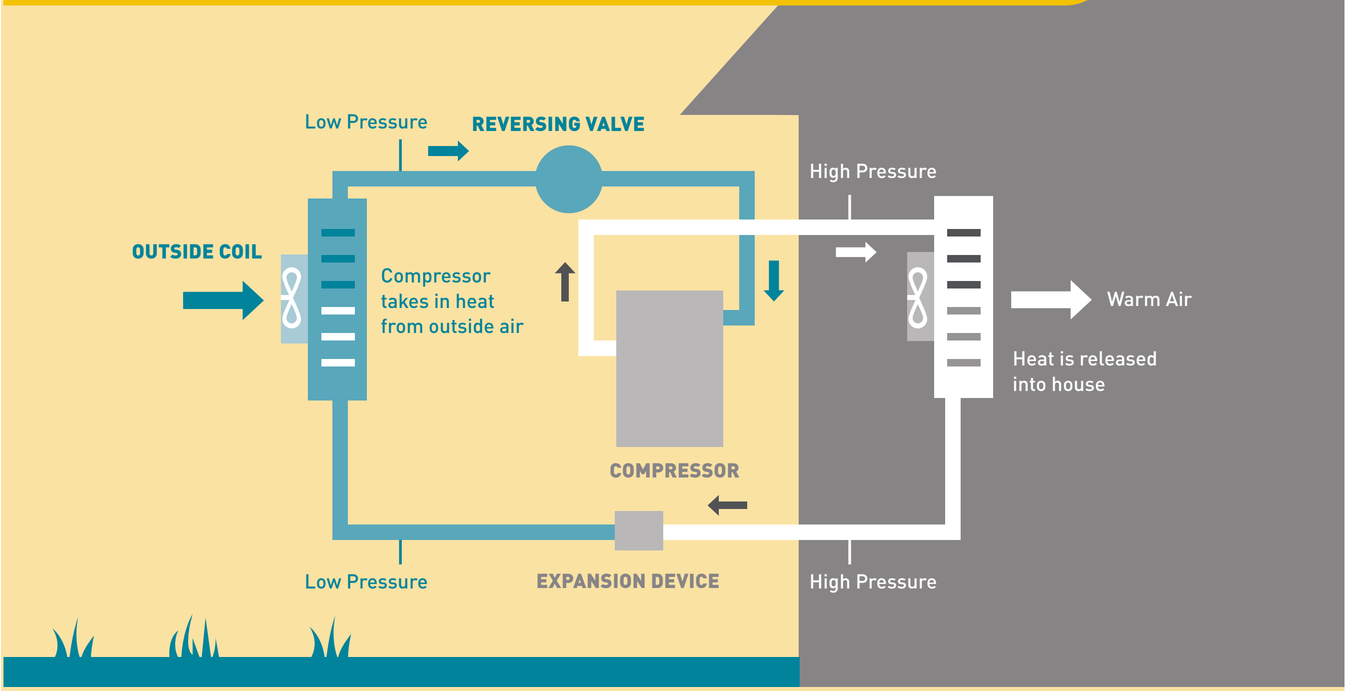
To mitigate these impacts, in 2008, Massachusetts enacted the Global Warming Solutions Act (GWSA), which requires the reduction of GHG emission levels by at least 80 percent below 1990 levels by 2050.[1] Further, an April 2020 determination issued by the Baker-Polito administration established net zero GHG emissions as Massachusetts' new legal emissions limit for 2050.[2]

Additional laws, executive orders, and policies in Massachusetts focus on strategies for reducing GHG emissions and call for reduced energy use. These also call for increased energy efficiency, decarbonization of the electric grid, and end-use electrification.[3]

While progress has been made to reduce GHG emissions, far more action is needed to meet the Commonwealth's 2050 goals. In its 10-year progress report issued in 2018, the Commonwealth reported that substantial GHG emissions reductions have resulted from the increased decarbonization of the electric grid. To further reduce emissions over the five-year period 2018–2023, the report recommended expanding energy-efficiency programs and promoting the switch to more efficient and lower-GHG-emitting energy sources – such as electricity – for residential heating.[4]

The remainder of this report will address home heating as a significant source of emissions. Specifically, we will offer recommendations on how Massachusetts can drastically reduce residents' reliance on gas over the next 10 years by **1)** promoting the widespread adoption of electric-powered air source heat pumps in homes and **2)** ensuring that work to fix methane leaks in existing infrastructure is done effectively and strategically. We also make recommendations for how gas utilities can adapt their business models as gas usage declines as a result.

What are heat pumps and how do they work?



Instead of burning a fuel like gas or oil, heat pumps warm a home like an air conditioner in reverse, pulling heat from the air (even in winter). In summer, heat pumps operate as highly efficient air conditioners. This process is driven by an electric condenser. Air source heat pumps can be central systems (which use house ductwork to circulate warm and cool air) or ductless systems (where an outdoor unit is connected to one or more indoor air handling units). Ductless air source heat pumps are also referred to as ductless mini-splits.

Ground source heat pumps (or geothermal heat pumps) transfer heat between the ground outside and indoor air for building heating and cooling. Heat pumps are highly energy efficient. Because they move energy rather than create it, for every one unit of energy they use, they can move three or more units of energy into or out of a home. In doing so, they use 60% to 75% less energy than gas or oil furnaces and approximately 35% less electricity than traditional air conditioners to keep your home comfortable.[5]

Heat pumps can now be installed with electric-powered backup resistance heat, which in Massachusetts may be needed for a small number of hours each winter. The backup resistance heat kicks in at very low temperatures and offsets a concern some customers may have that homes with heat pumps may feel cold on very cold days.[6] This approach should be paired with insulation and other weatherization measures to ensure the less-efficient backup system is needed as little as possible.

Although air source heat pumps are currently installed in a low percentage of homes in Massachusetts, their popularity is growing. Heat pump installation is also increasing nationwide. An industry research group reported that in 2019, 45% of new heating equipment installations in the U.S. were heat pumps.[7]

II. WHY FOCUS ON HOME GAS USE?

Reducing gas from other sources will not be enough. Gas is used widely in Massachusetts for power generation, building uses such as heating, and industrial uses such as chemical manufacturing.

Massachusetts has a program called the Gas System Enhancement Program (GSEP), which requires gas utilities to replace or retire leak-prone cast-iron or unprotected steel pipes in their service areas over the next 15 years.[9]

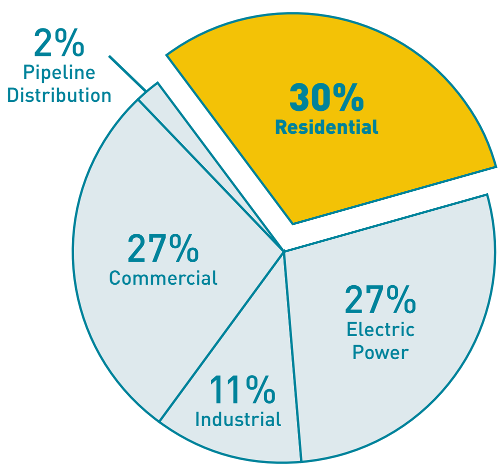
However, residential building uses account for 30% of gas consumption in the Commonwealth.[10] Addressing gas leaks will not be enough to achieve the GHG emissions reductions mandated by the GWSA. Additional actions are needed to address gas use in homes.

We rely heavily on gas in our homes. Approximately 50% of the Commonwealth's 2.9+ million residential housing units use gas for heating and often for water heating, cooking, and clothes drying as well. The statewide availability of gas and its historically low prices have led to the heavy and growing reliance on this climate-damaging fossil fuel in homes.

The use of electricity as a "fuel" to power heating sources has become a viable alternative over the past 10 years. As the increased use of solar and wind decarbonizes the electric grid, electricity is becoming a cleaner and healthier energy source. The cost of electricity is expected to rise more slowly than the cost of gas rises in the future. Approximately 50% of the electricity used in Massachusetts does not emit GHGs, and this will increase to approximately 75% by 2030.[14]

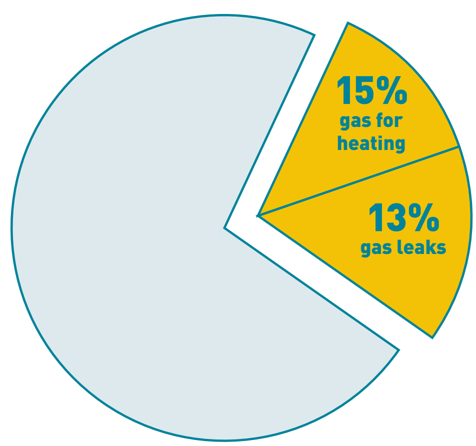
30% of gas use in 2018 was for home heating

2018 MASSACHUSETTS NATURAL GAS CONSUMPTION



27% of total GHG emissions are attributable to gas usage in buildings[8]

BASED ON 2016 – PARTIAL 2017 DATA GHG EMISSIONS IN MASSACHUSETTS



Massachusetts gas utilities and gas leaks

In Massachusetts, gas utilities supply gas to more than one million residences along 21,000 miles of pipeline. Under the Gas System Enhancement Program, gas utilities are required to replace or retire leak-prone pipes in their service areas. Leaked gas is largely comprised of methane – a particularly strong GHG that is approximately 85 times more climate-damaging than carbon dioxide emissions over a 20-year period.[11] Research shows that 2.7% of gas distributed in Massachusetts never makes its way to homes or businesses but is lost through leaks.[12] If leak-prone gas pipes are not replaced or retired, additional leaks will occur. Replacing these pipes under the current framework will require an investment of $9 billion to $12 billion between now and 2035. At the end of 2018, approximately 1,600 miles of leak-prone pipe had been replaced or retired, with 5,400 miles remaining.[13] Massachusetts policy-makers will need to take into account this cost relative to the costs of alternative energy technologies when determining the role of gas utilities in the state's path to decarbonization.

2.7% of gas
distributed in Massachusetts is lost through leaks

The electrification of the residential building sector will lead to sizable reductions of GHG emissions plus improved indoor air quality and increased safety. Energy-efficient electric-powered air source heat pumps are an important component of the transition away from heavy gas use in homes.[15]

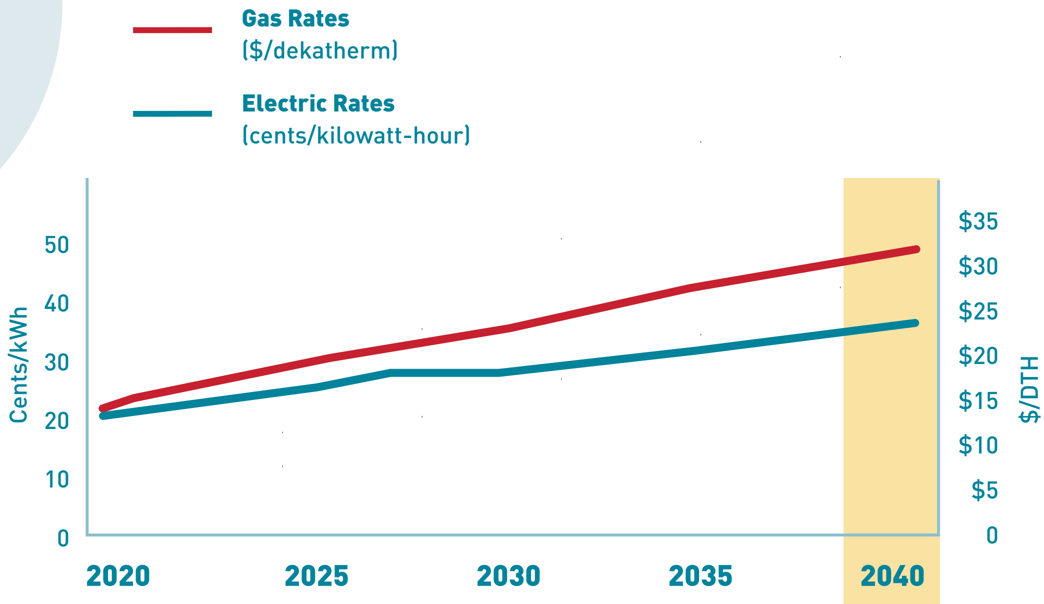
Long-term investments in gas come with high financial risk. To provide gas service to their customers, gas utilities continually invest in their distribution systems and customer service connections. Gas utilities pass the costs of these investments on to their customers through utility bill charges, and they can recover those costs for as many as 50 years.

Although gas is currently less expensive than other forms of energy, it will become more expensive over time due to the additional billions of dollars that must be spent to replace leaking pipes. Gas utilities will pass along these costs to their customers.

Our forecast of Massachusetts residential gas and electricity rates over the next 20 years bears out this anticipated increase (see chart). Residential gas rates are forecast to increase by more than 100%, while electricity rates are forecast to increase by approximately 50%.[16]

By 2040, the increasing costs of gas for heat will have far outpaced electricity.

FORECAST MASSACHUSETTS RESIDENTIAL GAS AND ELECTRIC RATES (WITH IMPACT OF GSEP FROM 2015)



CAPITAL COSTS OF HEAT PUMPS AND GAS FURNACES

	Central Heat Pump	Mini-Split Heat Pump	Gas Replacement
Heating	$9,600 – $11,750	$8,900	$5,500 – $5,750
Cooling	included	included	$3,750 – $4,500
TOTAL	**$9,600 – $11,750**	**$8,900**	**$9,500 – $10,000**

Up front costs for heat pumps are **comparable or less than** for gas furnaces.

As gas prices rise, electric-powered heating systems will become more financially attractive to operate. As more customers move away from gas to take advantage of cleaner and lower-cost energy supplies, a smaller customer base will be left behind to pay for the pipes in the ground as well as their maintenance and repair. This will increase costs for the remaining customers, many of whom may be low-income homeowners, renters, or others unable to switch because of high upfront costs or landlords unwilling to invest in conversions that benefit renters. These remaining customers will be burdened with paying more than their fair share for a system that is increasingly expensive as well as less viable over the long term than systems using cleaner and lower-cost energy.

Opportunities to reduce GHG emissions and to lower cost. Gas furnaces typically are replaced every 15 to 20 years.[17] The time of replacement creates an opportunity to transition to electric-powered heat pumps. Providing incentives that equalize the upfront costs of heat pumps and gas furnaces will allow more customers to make this transition to heat pumps and will help customers avoid investing in a system that actually costs more over its lifespan due to higher operating costs. With equalized incentives, a residential customer who needs to replace a failed gas furnace today could instead install an air source heat pump, while a residential customer with a 10-year-old gas furnace could consider adding an air source heat pump as a partial conversion.

III. HEAT PUMPS CAN MEET RESIDENTIAL CUSTOMER NEEDS

Residential customer cost and performance needs can be met by heat pumps. When combining the upfront and annual operating costs associated with heat pumps over their life spans, these costs are likely to be lower than those associated with gas furnaces. Upfront costs as well as operating costs are examined in more detail below. Regarding performance, the detail below shows that heat pumps can heat efficiently in cold climates and can cool efficiently in hot, humid climates. This makes them a good investment for customers in New England.

UPFRONT COSTS

In terms of upfront costs, which include equipment and installation costs, air source heat pumps cost less than oil or propane-powered residential heating systems. Currently, upfront costs for air source heat pumps are higher than those for gas furnaces.

A typical Massachusetts home (approximately 1,800 square feet in size) would require two mini-split air source heat pumps for a ductless home, or a three-ton central air source heat pump for a ducted home. Upfront costs for a mini-split air source heat pump range from $3,500 to $5,000 per indoor unit (this includes an outdoor unit), with the median cost being approximately $8,900 for a home with one outdoor and two indoor units.[18] Upfront costs for a three-ton central air source heat pump system range from $9,600 to $11,750.[19] Upfront costs for a high-efficiency gas furnace are approximately $5,500 to $5,750. If air conditioning is added, the combined cost for a gas furnace plus a central air conditioning system ranges from $9,500 to $10,000.[20]

Rebate programs can promote the wider adoption of energy-efficient heating systems by reducing upfront costs. Currently, Massachusetts rebate programs make it more financially attractive to upgrade from a forced hot water boiler or a lower-efficiency gas furnace to a higher-efficiency gas furnace than to an air source heat pump. Expanded rebate programs can level the playing field and equalize air source heat pump upfront costs to those for gas systems.

OPERATING COSTS

Air source heat pumps cost less to operate than oil or propane systems. As the price of gas increases due to pipeline replacement costs, air source heat pumps will cost less to operate in the future than gas heating plus air conditioning systems.

For an 1,800-square-foot home, the current estimated annual operating cost for a three-ton air source heat pump (heating, cooling, and maintenance costs) is approximately $1,700. For an equivalent-sized gas furnace plus air conditioning, the annual cost is approximately $1,500. In 2026, we estimate that these operating costs will be roughly the same. By 2035, the estimated annual operating cost for these will be approximately $2,400 for the same heat pump system and $2,700 for the equivalent-size gas system.[25] Actual heat pump operating costs will vary depending on the floor plan of the home, the level of insulation, and the location in the Commonwealth.

Massachusetts rebate programs for air source heat pumps

Massachusetts currently offers rebates to residential customers for air source heat pumps through MassSave and the Alternative Portfolio Standard.[21]

MassSave is an energy-efficiency program funded by utility customers. MassSave currently offers:

- $250-per-ton rebate for central and mini-split heat pumps (or $750 for a three-ton heat pump) to replace a gas furnace;
- fuel optimization rebates of $1,250 per ton to customers who switch from oil, propane, or electric resistance heat to central or mini-split air source heat pumps;
- the MassSave HEAT Loan program, which provides no-interest seven-year loans of up to $25,000 to finance the purchase of high-efficiency heating and cooling equipment, including air source heat pumps.

Landlords and renters may be eligible for MassSave rebates and programs.[22]

Run by the Massachusetts Department of Energy Resources, the Alternative Portfolio Standard (APS) is a market-based program that requires a portion of the electric load in Massachusetts to be met by eligible energy systems that lower GHG emissions and increase energy efficiency.[23] In 2014, the APS added air source heat pumps as potentially eligible energy systems. Currently, the APS rewards homeowners and landlords for installing air source heat pumps that supply 100% of the heating load of a home. The credits awarded depend on the size of the home (for an 1,800-square-foot house, the credits may be worth approximately $2,160). The credits are doubled for a zero-energy home, which is a home that creates as much energy as it uses. As a practical matter, however, these credits have proven difficult for homeowners to earn.[24]

PERFORMANCE

Heat pumps not only provide ample heat, but they do so efficiently. Recent advances in air source heat pump technology and design have improved their heating efficiency in cold climates. Current products are as much as 25% more efficient than products introduced four to five years ago and perform well even in very low temperatures (as low as -10 degrees Fahrenheit).[26]

Air source heat pumps can be used as primary heating systems or as a partial solution to supplement an existing system. During this transition period, adding a heat pump as a partial solution can be a good option from an economic as well as an energy-efficiency perspective. A device called an integrated control can be used to switch between systems to provide optimal heating and control operating costs.

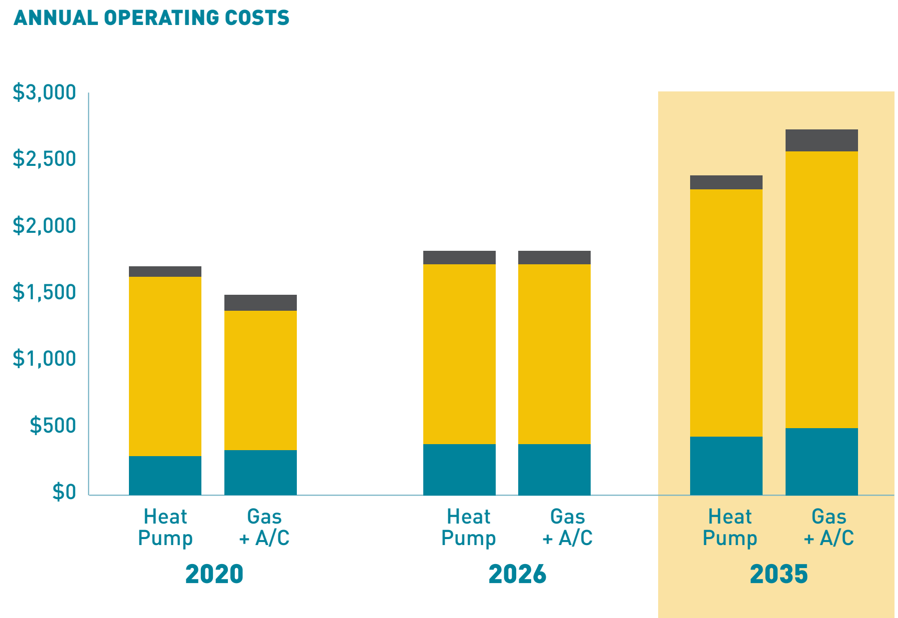
Heat pumps also cool homes well. Heat pumps are more efficient and less expensive to operate than window air conditioning units or central air conditioning systems. They are widely used in very hot, humid climates.

Heat pump rebates by state

As of December 2020, state-and utility-funded programs in other New England states and in New York state offer rebates to residential customers for installing air source heat pumps. No state currently provides sufficient incentives to bridge the upfront cost barriers to switching customers from fossil fuel heating to heat pumps.

EFFICIENCY MAINE efficiencymaine.com	$1,500 to residential customers and up to $2,000 to low- and moderate-income residential customers who install air source heat pumps
NH SAVES nhsaves.com	$400 per ton for air source heat pumps
ENERGIZE CONNECTICUT energizect.com	Rebates of up to $500 available for mini-split heat pump unit installations and up to $1,200 for ENERGY STAR- certified central air source heat pump installations
EFFICIENCY VERMONT efficiencyvermont.com	offers rebates of up to $650 for the installation of mini-split heat pumps and up to $800 per ton for the installation of central air source heat pumps (plus a $500 low- to moderate-income bonus)
RHODE ISLAND energy.ri.gov	Rebates of up to $750 for the installation of air source heat pumps
NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY nyserda.ny.gov	Rebates of up to $1,000 available for the installation of air source heat pumps

By 2035, annual costs to run a gas-based system will be 12.5% higher than those for a heat pump system.



IV. POLICY OPTIONS TO REDUCE HOME GAS USE

To reduce GHG emissions from gas use in homes, the following policy recommendations should be evaluated today and implemented over the next 10 years.

1. Require gas utilities to explore new business models, including pathways to electrification.
2. Prioritize low- and moderate-income and rental customers in the transition to electrification.
3. Expand air source heat pump rebate programs.
4. Revise building codes and establish carbon footprint standards for residential buildings.
5. Maintain a high priority on strategically triaging and replacing leak-prone gas pipes and gas infrastructure that cannot be retired in the near term.
6. Modify gas utility cost recovery rules.
7. Conduct additional research.

1. REQUIRE GAS UTILITIES TO EXPLORE NEW BUSINESS MODELS

The traditional utility business model involves utilities providing energy to residential customers, who have purchased heating and cooling systems for their homes. However, gas utilities will need new or different business models to meet GHG emissions reduction mandates. These investor-owned companies must prepare for a decline in the demand for gas by developing alternative uses for their existing infrastructure, redefining customer relationships, and adjusting organizational capabilities. During this time of transition, gas utilities should be authorized and required to identify and evaluate new business opportunities.

A potential new business model is for utilities to become heating and cooling service providers as well as energy suppliers. As an example, utilities could supply both energy and utility-owned heating and cooling systems (such as air source heat pumps) to their customers, billing monthly for the combined services. A pilot program of this model using ground source heat pump technology has been proposed by Eversource.[27] Future pilots should also compare the cost and efficacy of an air source heat pump-based approach.

If pilot programs demonstrate positive results, gas utilities can stop expanding distribution systems and installing new gas infrastructure and begin to transition to full deployment of heating and cooling as a service programs. Heating and cooling as a service has the potential to provide all customers (including moderate-income homeowners and renters) with the benefits of more efficient and lower-GHG-emitting heating and cooling. Our analysis suggests that the life-cycle costs for gas utilities to provide customers with both equipment and service are similar to what customers would pay to buy and operate a gas furnace and air conditioner if the full costs of the GSEP are incurred.[28]

Expanded heating and cooling as a service programs could provide gas utilities with a new return on their investment base. At the end of 2018, gas utilities had a net investment of approximately $4,400 per customer.[29] If gas utilities installed heat pumps in a customer's home, the investment per customer would more than double while operating costs for energy would decline. As gas utilities earn profits for their shareholders based on their investment in assets, this model provides the utility with a pathway to offer services and earn a return for shareholders while reducing GHGs.

2. PRIORITIZE LOW- AND MODERATE-INCOME AND RENTAL CUSTOMERS

Gas customers who cannot switch to heat pumps (primarily moderate-income and rental customers) should not be penalized by having to pay increasing gas rates – which will be made even higher as the gas customer base erodes over time.

Full Incentives for Low-Income Customers, Expanded Rebates for Moderate-Income Customers

Low-income customers (households with incomes below 60% of the median family income in Massachusetts)[30] comprise a significant portion of the gas customer base and are typically unable to afford energy-efficiency upgrades.[31] When these customers are reached by the Mass Save program, the full costs of energy-efficiency measures are covered. This model should be extended into the gas system-to-heat pump transition recommended here. The Mass Save approach, however, leaves behind "moderate-income" customers, whose incomes are above the low income threshold but are not high enough to afford the upfront costs of new energy technology or added monthly costs from HEAT Loan 0% interest financing.

Targeted rebates and other incentive programs are needed to reduce barriers for moderate-income customers. Rebates should be provided on a sliding scale, so those paid to moderate-income customers to convert to air source heat pumps would be much higher than those paid to higher income customers.[32] Moderate-income incentives should also be offered at the point of purchase to increase access for moderate-income customers who otherwise may have difficulty paying the upfront costs and waiting several weeks or more to receive a rebate.

Giving Renters An Option

Renters comprise 38% of Massachusetts households.[33] Renters typically pay for utility costs, not residential unit owners. Because renters do not own the unit they are occupying, may not live in the unit for long periods of time, and may have fewer financial resources, they are unlikely to pay to upgrade to a more efficient heating system that reduces GHG emissions and energy costs. On-bill financing of air source heat pump upgrades would provide a viable option for renters to reap the benefits of heat pumps and accompanying energy-efficiency measures without having to pay upfront costs all at once. We strongly encourage programs that would enable utilities to install heat pumps to replace oil, propane, or gas furnaces and electric resistance heat systems and then charge whichever customer is currently living in the unit for the upfront and operating costs of the heat pump over time. Other states allow utilities and electric co-ops to use on-bill financing programs to enable their rental customers to take advantage of more efficient heat pumps.[34] In Massachusetts, allowing utilities to use on-bill financing would require new legislation and likely require funds for utilities to upgrade their billing systems.

3. JUMP-START THE TRANSITION BY EXPANDING AIR SOURCE HEAT PUMP REBATE PROGRAMS AND ELIMINATING REBATES FOR GAS FURNACE UPGRADES

Mass Save rebates for upgrading furnaces and boilers to more efficient gas models should be reduced and eliminated entirely by 2025, with those funds reallocated to heat pumps. Rebates for converting oil, propane, and electric resistance systems to heat pumps should be maintained. Rebates for heat pump installation to replace gas should at least be doubled to account for the current difference in the upfront costs of low-carbon, energy-efficient air source heat pumps.

Mass Save currently offers rebates of up to $1,250 to replace a warm air furnace with a high-efficiency gas furnace. It also offers rebates of up to $2,750 to replace a forced hot water boiler with a high-efficiency gas furnace. In comparison, Mass Save currently offers a $250 per ton rebate for central and mini-split heat pumps (or $750 for a three-ton heat pump) to replace a gas furnace.

Expanded rebate programs for existing homes as well as for new construction will help promote the growth of heat pump installation plus the transition to lower-emitting energy sources. Over the next decade, the rebates associated with installing high-efficiency gas furnaces should be eliminated. These changes to the Mass Save program could be accomplished through regulatory action by the Department of Energy Resources and the Department of Public Utilities.

At the same time, the Massachusetts Department of Energy Resources should consider modifying the Alternative Portfolio Standard (APS) to promote the expanded use of air source heat pumps. Currently, APS-related credits are only attractive if a home generates 100% of its heat from heat pumps and the old gas, oil, or propane furnace is removed. If the requirements to earn credits were modified to allow homes that generate a large majority of the heating load, perhaps 70%, from a heat pump (i.e., a partial conversion to a heat pump), this would likely provide a sufficient incentive for residential customers to switch.

4. REVISE BUILDING CODES AND ESTABLISH CARBON FOOTPRINT STANDARDS FOR RESIDENTIAL BUILDINGS

Building codes for existing residential buildings should be revised to encourage energy efficiency and to incentivize the early retirement of inefficient HVAC systems. For new construction, building codes can be updated to meet 2050 GWSA mandates.[35] New standards can be strong enough to require the use of heat pumps (both air source and ground source) or other solutions that are similarly low carbon and energy efficient.

Carbon footprint standards for residential buildings should be established to require homeowners to meet low GHG emissions requirements before a home can be sold or transferred. Such standards would require changes to building codes, and legislation would be needed to direct their creation. Title 5, which requires residential septic systems to meet certain standards at transfer, provides a precedent for this type of legislation.[36] We recommend that the new standards be announced well ahead of their effective date so that customers can take them into account when replacing home heating systems. With approximately 5% of homes sold each year, up to 25% of homes sold during the 10 years following the standards' implementation will have converted to heat pumps.

5. MAINTAIN A HIGH PRIORITY ON STRATEGICALLY TRIAGING AND REPAIRING OR REPLACING LEAK-PRONE GAS PIPES

In addition to accounting for almost half of the greenhouse gas emissions from the building sector in Massachusetts, gas leaks damage and kill trees – reducing the ability of trees to be natural carbon sinks that offset fossil fuel emissions.

Continuing to replace leaking gas pipes, absent the policy interventions recommended in this report, would ultimately overburden a small set of customers who are unable to afford the upfront costs to switch from gas to a more affordable heat pump system. Gas leak repair and replacement work must continue for health and safety reasons, as well as to reduce emissions from the gas system, for as long as utilities are allowed to deliver gas through those pipes. Given the cost to replace pipes – and that the majority of leaked methane emissions come from a small percentage of existing leaks – strategic identification and sequencing of leaks for repair or replacement is essential.[37]

6. MODIFY GAS UTILITY COST RECOVERY AND ASSET RETIREMENT RULES

Massachusetts should modify its gas utility cost recovery rules to both meet GHG emissions reduction mandates and lower the risk of investments in gas infrastructure becoming stranded assets. As some current gas infrastructure investments are depreciated over 50 or more years, gas utilities will not be able to recover the costs of these assets before they need to be taken out of service. New and existing infrastructure investments by gas utilities should instead be placed on a schedule resulting in the investment being depreciated during its useful life – that is, by the time Massachusetts needs to have eliminated the use of gas in buildings. We estimate that depreciating the entire distribution system would have a very modest impact on gas rates.[38]

As residential customers transition away from the use of gas, an increasing portion of the gas distribution system will no longer be fully used.[39] To lower costs to gas customers still paying for these utility assets, Massachusetts should consider the use of securitization to retire them. This approach, which has been employed by electricity generation plants, would remove unused assets from the rate base of the gas utility. The utility is then compensated for the value of those assets with funds generated by state bonds. Even though the bonds are paid off over time through a charge placed on gas customer bills, customers would save money in the long term.[40]

Modifying gas utility cost recovery rules and asset retirement rules would require new legislation.

7. CONDUCT ADDITIONAL RESEARCH

Merging Gas and Electric Utilities
Additional research is needed to evaluate the regulatory and legislative changes necessary to allow gas and electric utility assets in the same service areas to merge. This merger would facilitate the transition from gas furnaces to electric-powered heat pumps by allowing a single entity to offset the loss of a gas customer with an increase in the customer's electric load.

Better Targeting of and Fewer Barriers to Incentive Programs
Research is also needed on how to target incentive programs more effectively and reduce the eligibility paperwork associated with program implementation. In addition to the dedicated incentive programs for low- and moderate-income customers discussed above, other incentive programs may be needed based on the type of home heating system, the efficiency levels of installed heating and air conditioning systems, and particular locations in Massachusetts.

V. CONCLUSIONS

A strategy for transitioning Massachusetts residents away from gas is required now to meet climate needs as well as the GHG emissions reductions mandated by the GWSA. In addition to these top-line goals, this transition strategy should be calibrated to ensure the following:

- Replacing fossil fuel-based heating systems with heat pumps over time as current systems approach the end of their useful lives and using heat pumps for all possible new builds.
- Alleviating negative impacts on both customers and gas utilities from the reduced demand for and use of gas.
- Ensuring low-income, rental, and other residential customers who may not be able to pay out of pocket to switch to heat pumps have the financial support to do so.
- Identifying gas leaks and triaging the biggest leaks for priority repair or replacement.

Developing and implementing this transition strategy requires both legislators and utilities to consider many important factors, including the widespread use of gas for residential heating, the current and future cost of gas relative to the cost of electricity, current energy rebate programs, and Massachusetts' obligations to gas utilities.

Lessons for Other States

Nearly every New England state has GHG reduction goals (some mandated by law) that will require transitioning away from gas for home heating. **All New England states have efficiency programs in place that can facilitate the transition to cleaner and more energy-efficient heat pumps.**

The format of this analysis can be useful and replicated for other states. (The cost and break-even calculations will differ depending on the size and age of the state's gas distribution system and whether they have a program like Massachusetts' Gas System Enhancement Program.) **Some examples of how this analysis can be used in other states include:**

CONNECTICUT

The Governor's Council on Climate change is evaluating opportunities and strategies to achieve the state's mandated 45% GHG reduction by 2030. The analysis provided here can assist the council in equitably incorporating strategies to transition away from gas for home heating.

MAINE

Maine has the highest per capita heat pump use, but there's room to improve. As the state's Climate Council develops the implementation of its 2019 climate legislation and its goal to install 100,000 new heat pumps by 2025, it can set plans in place now to transition from gas to electricity that will help Maine meet these requirements.

VERMONT

Vermont can use this analysis as it explores opportunities to revamp its energy-efficiency programs to include better incentives to update fossil fuel heating systems to electric ones. The analysis can also inform Vermont's choices as the state looks to implement programs and rules to achieve the state's GHG emission goals.

NEW HAMPSHIRE

New Hampshire can use this analysis to build on current efficiency incentives for heat pumps. This analysis may also be helpful to the state's home battery storage pilot (designed to reduce overall demand for electricity during peak times and to serve as backups during power outages) and its ongoing investigation into grid modernization.

RHODE ISLAND

In 2020, Rhode Island completed a study addressing pathways to decarbonization and transforming the heating sector. The study highlights the need to move home heating away from gas and transitioning to cleaner electricity. The analysis provided here can facilitate the steady transition away from gas while ensuring equity and meeting the needed GHG reductions.

APPENDIX – METHODOLOGY

Impact of Carbon Emissions from Gas in Massachusetts. When methane gas (CH4) is leaked it is a particularly potent greenhouse gas (GHG). Over a 20-year period, according to the Intergovernmental Panel on Climate Change, it is 85 times more powerful than CO2 emissions. (When measured over longer periods of 100 years, the gas is 24 times more powerful than CO2 emissions).[49] The 20-year measurement period is more appropriate for our use because **1)** Massachusetts is working toward 80%–100% reduction in greenhouse gases by 2050 (30 years away); and **2)** methane only lasts 12.4 years in the atmosphere.

According to a study approved in 2014, 2.7% of natural gas by the transmission, distribution, and end uses in the Boston metro area are leaked[50], which means that the leaked gas can have a greater impact on global warming than the gas consumed in residences. This measurement is much more significant than the 1.1% used in another emissions inventory. This measurement does not include the significant impact of leaks from fracking natural gas, storing it, and transporting it to Massachusetts, which further contribute to greenhouse gas emissions.

When the Massachusetts Greenhouse Gas Inventory (for 2016) is adjusted for the impact of the gas leaks, 15% of Massachusetts GHG emissions come from burning natural gas in residential and commercial buildings and another 13% of GHG emissions come from the leaks, with over a quarter of GHG emissions coming from the burning and leaked natural gas from the building sector.

Causes of the Leaks. Many of the pipes that carry gas to residential and commercial properties in Massachusetts were installed long ago. Some are over 100 years old. Cast-iron and non-cathodically protected steel, cast-iron, and wrought-iron mains are leak-prone. Plastic pipe, installed more recently, is less prone to leaks. Approximately 5,400 miles of pipe (at the end of 2018) were leak-prone, representing roughly one-quarter of the natural gas mains in Massachusetts. In addition to fixing the leaks that are discovered, gas utilities are replacing the leak-prone pipes.

Replacing the Pipes. In 2014 the Massachusetts legislature passed An Act Relative to Natural Gas Leaks, (MGL 164), also known as the Gas System Enhancement Program (GSEP), that mandated the replacement of leak-prone pipes by 2035. By the end of 2018, approximately 1,600 miles of pipe had been replaced. The six gas utilities covered by GSEP (Blackstone is not covered) plan to replace approximately 270 miles per year of leak prone pipes until the project is complete. In their 2019 GSEP plans, the average cost per mile for replacing the pipes is approximately $1.9 million, and the cost per mile of replacement has been rising. Over the next 15-18 years, we expect the gas utilities to spend $9 billion to $12 billion on pipe replacement, and the cost could be much higher.

Why Electricity is Becoming Increasingly Non-Emitting. New England electricity is becoming increasingly non-emitting as the region invests in offshore wind, imported hydro (largely from Quebec), energy efficiency, and demand response. These estimates also include nuclear and existing hydro capacity. Massachusetts has committed to purchase 1,600 MW of offshore wind.[51] It has also committed to purchase 1,200 MW of Quebec hydro capacity.[52] Other states in New England are also pursuing additional offshore wind. Massachusetts invests aggressively in energy efficiency. Regulatory roadblocks set up by the federal government may slow some of these investments.

How Customers Pay for the Leak Repairs. We estimate that the six gas utilities – Eversource, National Grid (Boston Gas and Colonial), Bay State, Berkshire, Liberty, and Fitchburg – will invest some $12 billion between 2019 and 2038 to replace leak-prone pipe. In addition, these same utilities spent $1.4 billion from 2015 through 2018 on leak-prone pipe replacement. In estimating the cost of these investments, we used the average cost per mile estimated in the utilities' GSEP filings for 2020 of $1.9 million per mile installed, adjusted upward 2% per year for inflation starting in 2021.

Customers pay for these investments over the life of the investments. The utilities earn a rate of return on the investments, they earn cash flow as the investments are depreciated, and they pay real estate taxes to local jurisdictions. CLF found the spending weighted rates of return, rates of depreciation, and real estate tax rates from the utilities' 2019 GSEP filings with the Massachusetts Department of Public Utilities. Partially offsetting these rates are deferred tax reserves and operating and maintenance cost savings from the newly installed pipes relative to the existing pipes. These can be found at https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bynumber and entering 19-GSEP-01 to 19-GSEP-06.

The weighted rates are as follows:

RATE OF RETURN (PRETAX): 9.25%

DEPRECIATION RATE: 2.78% (36 years)

PROPERTY TAX RATE: 2.18%

DEFERRED TAX RESERVES:10% of the return

OPERATION AND MAINTENANCE OFFSET: $3,300 per mile installed per year

The rate of return can vary over time as interest rates, income tax rates, and the cost of equity change.

The depreciation rate is an investment weighted average of the depreciation rate for mains and services. Mains are the pipes in the streets. Services are the connections to homes and buildings. Mains are typically depreciated over 40+ years; services are depreciated over a shorter period.

The deferred tax reserves vary significantly from year to year as tax laws change. We used a slightly higher reserve than the average for 2019, but a smaller reserve than in some earlier years.

The operating and maintenance offset is $3,300 per mile installed (adjusted 2% per year for inflation) in 2019. This is a minor factor. These costs build up over time. In 2018, customers were paying under $180 million for GSEP replacements. By 2035, we expect customers will pay well over $1.1 billion per year (including 2% annual inflation).

Estimating Future Gas Rates. To fully estimate future gas rates, we estimate the other costs and sources of revenues for the Massachusetts gas utilities. To do so, we took the 2017 and 2018 income statements of the Massachusetts gas utilities, including commodity costs (gas that comes into Massachusetts, including leaked gas), the return, depreciation and property taxes from non-GSEP capital spending, and other operating expenses and estimated them for each year to add to the GSEP-related expenses.

Below are some of the key expense data and assumptions:

NON-GSEP CAPITAL SPENDING IN 2019: $565 million.

OTHER FIXED COSTS: $962 million

COMMODITY COSTS: $1,016 million

For non-GSEP capital expenditures, the depreciation rate, rate of return, and property tax rate are the same as for GSEP and the investment grows at 2% annually.

Other fixed costs are escalated at 2% annually.

Commodity costs are escalated at the annual growth rate, in nominal terms for residential gas rates in New England, based on data from the U.S. Energy Information Administration (EIA).

Non-GSEP capital spending and other fixed costs for Bay State Gas are normalized to remove the impact of the gas explosions in Lawrence and adjacent communities.

These costs, along with the GSEP costs, are totaled.

The volume of gas delivered by the utilities is assumed to be stable over time, leading to total gas costs incurred by consumers.

By 2035, the cost per therm, including GSEP costs, is estimated to rise to $2.82 per therm versus $2.33 per therm without GSEP.

Estimating Future Electric Rates. The EIA estimates that electric rates will grow far more slowly than our estimated natural gas rates will rise.

We estimated future Massachusetts residential electric rates using the EIA forecast of nominal residential electric rates for New England from the 2020 Annual Energy Outlook Reference Case, adjusted for the 2019 difference between Massachusetts residential electric rates and New England residential electric rates.
We converted electric prices from $/MMBTU to cents/kWh at 293 kWh/MMBTU.

Air Source Heat Pump Operating Costs. Air source heat pumps operating costs are estimated for an 1,814-square-foot home, the average size home heated by natural gas. (https://www.mass.gov/info-details/household-heating-costs).

For air source heat pumps, the energy consumption is for a 3-ton unit and equivalent gas furnaces.

For an air source heat pump, we estimate the following energy consumption: 5,976 kWh for heating, a net of 158 kWh for backup heat, and 1,328 kWh for cooling. In addition, these costs include $77 for annual maintenance.

The comparable gas furnace uses 69 MMBTU of gas for heating, 328 kWh to operate the furnace, and 1,530 kWh for cooling. In addition, these costs include $120 for maintenance of both heating and cooling.

The energy consumption numbers are from Applied Economics Clinic's study on Home Heat Pumps in Massachusetts (2019), adjusted for the size of the units and adjusted for inflation.

For future installations of heat pumps used for heating, we have assumed an improvement in performance from 11 to 12 HSPF to reflect the improvement in efficiency of heat pumps.

Future gas and electric rates are based on the methodology described above.

Air Source Heat Pump, Ground Source Heat Pump, Efficient Gas Furnace, and Air Conditioner Upfront Costs. The air source heat pump and ground source heat pump capital costs come from Mass CEC databases, https://www.masscec.com/clean-heating-and-cooling/ground-source-heat-pump-installer-resources, as well as from the Applied Economics Clinic's study on Home Heat Pumps in Massachusetts (2019). All costs exclude rebates. The replacement gas furnace and air conditioner estimates also come from this study.

A typical Massachusetts home (approximately 1,800 square feet in size) would require two mini-split air source heat pumps (for a ductless home) or a 3-ton central air source heat pump (for a ducted home). Upfront costs for a mini-split air source heat pump range from $3,500 to $5,000 per indoor unit (this includes an outdoor unit), with the median cost being approximately $8,900 for a home with one outdoor and two indoor units. Upfront costs for a 3-ton central air source heat pump system range from $9,600 to $11,750. Upfront costs for a high-efficiency gas furnace are approximately $5,500 to $5,750. If air conditioning is added, the combined cost for a gas furnace plus a central air conditioning system range from approximately $9,500 to $10,550.

Accelerated Cost Recovery. As Massachusetts now has a goal of reaching carbon neutrality by 2050, the Department of Public Utilities should consider accelerated recovery of the investment in its gas plant, so that at least 80% of the investment in the gas system and perhaps as much as 100% is recovered from ratepayers by 2050. If the depreciation schedule for all investments in the gas system were modified so that the entire investment is depreciated by 2050, then the Commonwealth's commitment to gas utilities to recover their costs would be accomplished. Our estimate is that accelerating the depreciation to accomplish this goal would have only a modest, 5%–6% impact on residential gas rates. This occurs because the increased depreciation would be partially offset by a lower investment base (reflecting the increased depreciation) for return on capital and property taxes. In fact, the impact on consumers would likely be even smaller because the gas utilities could not prudently continue to reinvest in their infrastructure as they approach 2050.

Securitization. As an increasing proportion of the gas utilities' infrastructure becomes underutilized or unutilized, lowering the costs for remaining customers will be critical. One approach to lowering costs would be to securitize the underutilized proportion of the gas distribution assets. Under this approach, the gas utility would be paid book value for the assets. The assets would be removed from the rate base of the utility and the utility would no longer earn return on capital or depreciation from the asset. The unused assets would also no longer incur property taxes. The investment to acquire the assets would be paid off over a period of time, which we assume to be 15 years, and supported by a charge paid by ratepayers. Because the cost of municipal debt is much lower than the cost of return on capital, depreciation, and property taxes, ratepayers would save money by securitization. Instead of paying over 9% return on capital, just under 3% depreciation, and just over 2% in property taxes on these assets each year, ratepayers would pay about 3% on municipal bond interest plus principal payments for a total payment of just over 8% (versus 14% in return on capital, depreciation, and property taxes) for 15-year loan terms. As we get closer to 2050, the loan terms would need to be shorter and the savings would be smaller.

To achieve the low interest rate on municipal debt, the Commonwealth would need to legislatively mandate payments, placed on consumers' gas bills, to cover the debt. We estimate that a securitization program could potentially save rate payers close to 20% on their utility bills. A significant uncertainty in this approach is whether the state could buy the underutilized assets at book value.

Heating and Cooling as a Service. The heating-and-cooling-as-a-service model has no upfront costs for the customer. Instead, the customer pays for the cost of converting to a heat pump, over time, through payments to the utility. This enables renters and moderate-income customers to take advantage of heat pumps without the large upfront investment.

We estimated costs to customers and returns to the gas utility of delivering heating and cooling as a service. Specifically, we project that the utility buys a heat pump in 2035 and operates it for 15 years, collecting return on capital, depreciation, property taxes, and energy costs. In addition, we project that the utility pays a carbon tax (starting at $55 per ton of carbon equivalent) on the carbon from the electric generation, but credit the utility with the capacity value of the savings in summer from reducing cooling load (using FCA 14 capacity value of $2/kW-month), assuming that half of the cooling load is coincident load. We also credit the gas utility with the overhead absorption in the electric system. This will only be available if the same utility provides both electricity and gas. The electricity prices from EIA Annual Energy Outlook 2019 are based on the EIA nominal forecast for New England residential electricity, adjusted to Massachusetts prices (see Estimating Future Electric Rates, above). The net cost of the service is discounted at 5% annually.

We then compared the service cost of the heat pump with the cost to the customer of buying a new high-efficiency gas furnace and a new air conditioner and operating them over 15 years, including the costs of gas and electricity plus a carbon tax on the gas and electricity used. The gas rates come from Estimating Future Gas Rates, above.

The heating-and-cooling-as-a-service model shows that it would be attractive for both the utility and the customer to deliver heating and cooling via an air source heat pump as a service relative to buying a new gas furnace once gas prices are driven higher by GSEP costs.

END NOTES

[1] M.G.L. c. 21N.

[2] *See* https://www.mass.gov/doc/final-signed-letter-of-determination-for-2050-emissions-limit.

[3] *See, e.g.,* Green Communities Act of 2008, M.G.L c. 169; Executive Order No. 569 Establishing an Integrated Climate Charge Strategy for the Commonwealth 2016, https://www.mass.gov/executive-orders/no-569-establishing-an-integrated-climate-change-strategy-for-the-commonwealth.

[4] Global Warming Solutions Act: 10-Year Progress Report, https://www.mass.gov/doc/gwsa-10-year-progress-report, p. 16 (2018).

[5] Estimates derived from New York State Energy Research and Development Authority, New Efficiency: New York, Analysis of Residential Heat Pump Potential and Economics, January 2019, and The Cadmus Group, Inc., Ductless Mini-Split Heat Pump Impact Evaluation, December 2016. Estimates adjust the cooling SEER to 20 and use Heat COP of 2.5 -3.0 v. .76 for gas heat.

[6] *See* http://ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20 Shipments/2019/December_2019.pdf.

[7] *See* http://ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20 Shipments/2018/December_2018.pdf.

[8] Massachusetts Greenhouse Gas Baseline Inventory and Projection, https://www.mass.gov/doc/appendix-c-massachusetts-annual-green house-gas-emissions-inventory-1990-2017-with-partial-2018/download or https://www.mass.gov/lists/massdep-emissions-inventories, Appendix C under "Greenhouse Gas Baseline, Inventory & Projection". *See also* Cleveland, S., Into Thin Air: How Leaking Gas Infrastructure is Harming our Environment and Wasting a Valuable Resource (2015).

[9] *See* An Act Relative to Natural Gas Leaks, https://malegislature.gov/Laws/SessionLaws/Acts/2014/Chapter149.

[10] *See* https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_sma_a.htm.

[11] United States Environmental Protection Agency, Understanding Global Warming Potentials, https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

[12] *See* McKain, K. et al., Methane emissions from gas infrastructure and use in the urban region of Boston, Massachusetts, https://www.pnas.org/content/112/7/1941

[13] *See* 2019 GSEP reports filed with the Massachusetts Department of Public Utilities, 15-GSEP-01 through 15-GSEP-06, https://eeaonline.eea.state.ma.us/DPU/Fileroom/dockets/bynumber.

[14] *See* https://www.iso-ne.com/about/key-stats/resource-mix; ISO New England, Inc. (Imports are largely renewables), 2017 Economic Study: Exploration of Least-Cost Emissions-Compliant Scenarios, 2018, p. 50. Includes the impact of energy efficiency, demand response, and imports. *See* Massachusetts Decarbonization Roadmap Study, https://www.mass.gov/info-details/ma-decarbonization-roadmap.

[15] *See* Massachusetts Decarbonization Roadmap Study, https://www.mass.gov/info-details/ma-decarbonization-roadmap.

[16] Electric rate forecasts are based on the U.S. Energy Information Administration's (EIA) forecast of residential electric rates in New England adjusted for Massachusetts electric rates. Gas commodity rate forecasts also are based on EIA projections. *See* 2020 EIA Annual Energy Outlook, https://www.eia.gov/outlooks/aeo/tables_ref.php. All projections are in nominal dollars, assuming 2% inflation. Gas commodity forecasts are based on EIA projections. The cost of GSEP was estimated using the total miles of pipeline replaced annually at the cost per mile estimated for 2020 in the 2019 GSEP plans ($1.85 million per mile), depreciation at the average rate for pipes and services over 36 years, and a 9.25% pre-tax cost of capital reduced by an estimated 10% for deferred taxes. Property taxes are estimated at 2.18% of depreciated capital deployed. Gas utility operating expenses are inflated at 2% annually.

[17] *See* http://homeenergycenter.com/8-furnance-warning-signs.html.

[18] Applied Economics Clinic, Home Heat Pumps in Massachusetts 2019, https://www.aeclinic.org, p. 3.

[19] Data from Applied Economics Clinic, Home Heat Pumps in Massachusetts 2019, https://aeclinic.org/publicationpages/2019/5/29/home-heat-pumps-in-massachusetts, and MassCEC air source heat pump 2014-2019 rebate program, https://www.masscec.com/cost-residential-air-source-heat-pumps (includes $400 for cost of backup heat; rebates not included). Although ground source heat pumps provide an additional option for climate-friendly heating and cooling, their upfront costs are significantly more expensive. For an 1,800-square-foot home, the average cost for a 3-ton ground source heat pump is approximately $40,000.

[20] *See* HVAC.com; Applied Economics Clinic, Home Heat Pumps in Massachusetts 2019, https://www.aeclinic.org, p. 3.

[21] The Massachusetts Clean Energy Center (MassCEC) has offered rebates for air source heat pumps over the years. The MassCEC air source heat pump 2014–2019 rebate program returned rebates to 20,085 residential customers (rebates ranged from $625 to $3,500, with the average rebate being $1,794). MassCEC recently introduced a small pilot program for the installation of central air source heat pumps for new construction and for replacement systems in homes with gas heat. Rebates start at $2,500 per residence and go up to $5,000 for low-income households. For more information, *see* https://www.masscec.com.

[22] *See* https://www.masssave.com/en/saving/residential-rebates/electric-heating-and-cooling.

[23] *See* https://www.mass.gov/alternative-energy-portfolio-standard.

[24] APS credits are doubled for homes that meet any of the following criteria: Home Energy Rating System of 50 or less, meets the Department of Energy definition of "Zero Energy," achieves PHIUS+ certification by the Passive House Institute of the United States, or registers as a Passive House Building or EnerPHit Retrofit by the International Passive House Association (iPHA). *See* DOER Massachusetts Renewable Thermal Stakeholders Session, January 11, 2018.

[25] Estimates for 2020 are based on kWh and BTU data and maintenance costs from Applied Economics Clinic, Home Heat Pumps in Massachusetts 2019, https://www.aeclinic.org, updated for inflation for 2020. For heat pumps, a 158-kWh increase is included for backup heat (50% of the total backup heat use, with the remaining amount reducing the consumption of electricity by the heat pump). Estimates for heat pump costs for 2035 include an efficiency increase from 11 HSPF to 12 HSPF. 2035 gas and electricity rates are calculated as described in Footnote 16.

[26] Northeast Energy Efficiency Partnerships (NEEP), which is one of six regional energy-efficiency organizations funded by the U.S. Department of Energy, has developed a specification for these cold-climate air source heat pumps, and maintains product lists for those that meet its performance standards. *See* https://neep.org/ASHP-Specification.

[27] In its 2020 rate case filing, Eversource has proposed a pilot program using geothermal networks to provide piped warm water for heating and cold water for air conditioning to selected neighborhoods, mixed-use buildings, and larger multifamily buildings over the next five years. The company also proposes to provide the in-home equipment (including heat pumps) needed to connect to the customer's ductwork or hot water heating system. D.P.U. 19-120 (2020).

[28] These estimates for air source heat pumps operated as a service provide the utility with a return on capital, depreciation, and property tax at rates equal to those available in 2019. Gas and electric rates are calculated as described in Footnote 16 for years starting in 2035. Maintenance costs are those estimated in Applied Economics Clinic, Home Heat Pumps in Massachusetts 2019, www.aeclinic.org, escalated at 2% annually. The estimates also include the value of additional overhead absorption in the electric system, the reduction in summer peak capacity from more efficient heat pumps in place of air conditioners and the cost of carbon. The prices paid by the customer that provide the utility with a return on capital for installing the heat pump are compared to those paid by a customer for replacing a gas furnace and existing air conditioner with more efficient ones and operating them for a 15-year period. The difference in annual costs is discounted at 5% annually.

[29] Data from annual returns filed by gas utilities with the Massachusetts DPU for the year ended 12/31/2018, net of accumulated depreciation.

[30] The Massachusetts median family income in 2018 was $77,378 (average 2014-2018) in 2018 dollars. US Census Bureau ACS. https://www.census.gov/quickfacts/fact/table/MA/INC110218.

[31] *Three Year Energy Efficiency Plans*, 2019-2021, D.P.U. 18-110 – D.P.U 18-119, pp. 43-44 (2019).

[32] The Massachusetts Clean Energy Center currently runs a pilot program that doubles the rebates paid to low-income customers for installing heat pumps. *See* https://www.masscec.com/air-source-heat-pumps-1.

[33] *See* https://www.census.gov/quickfacts/MA.

[34] Hawaii and Washington have on-bill programs and Alaska law allows for such programs. The City of Holland Michigan, the State of Illinois, NYSERDA, and South Jersey Gas also have on-bill programs.

[35] *See* Massachusetts Decarbonization Roadmap Study, https://www.mass.gov/info-details/ma-decarbonization-roadmap. The Green Communities Act requires Massachusetts to adopt the latest edition of the International Energy Conservation Code (IECC) and update it within 1 year of any IECC revision. M.G.L. ch. 169, sec. 55.

[36] *See* M.G.L. ch. 21A. See also 310 CMR 15.

[37] *See* Hendrick, et al., "Fugitive methane emissions from leak-prone natural gas distribution infrastructure in urban environments," Environmental Pollution [Volume 213, June 2016, Pages 710-716]. Where repair is chosen over replacement, utilities must track whether new leaks appear within 500–1,000 feet of existing leaks on the same main, or mains on the same interconnect, for a period of two to three years. This will ensure that repairs actually reduce leaks rather than push the leak to another location on bad pipe. The data available to date in MA indicate that new leaks are occurring at roughly the rate of repairs through 2018 and that methane emissions from lost and unaccounted for gas are increasing through 2019. We won't be able to fully evaluate the impact of repairing Significant Environmental Impact (SEI) leaks under GL 164 Section 144 and DPU16-31-C until at least 2022. If the SEI strategy successfully addresses the so-called "super-emitter" leaks, a strategy emphasizing repair as a course of first action will be more cost effective than replacing gas pipes for reducing methane emissions. However, the data currently suggest that, in the absence of pipe replacement, old pipes will persist with new leaks despite an ongoing and aggressive repair program.

[38] We estimate that placing new as well as existing gas infrastructure on an 80 to 100 percent depreciation schedule by 2050 would have a 4% to 5% impact on gas rates, as the increase in depreciation would largely be offset by decreased return on capital and real estate taxes on the gas utility plant.

[39] Efforts to replace gas from fracked sources with farm, landfill, or hydrogen gas have significant climate and pollution impacts and cost far more than electrifying heating systems. https://earthjustice.org/sites/default/files/feature/2020/report-decarb/Report_Building-Decarbonization-2020.pdf

[40] The costs attributable to these underutilized assets would be replaced by bond interest and principal repayment. Instead of paying approximately 13.5% of the assets each year for return on capital, depreciation, and property taxes, ratepayers would pay bond interest plus principal repayments, saving about 20 percent of the asset-related costs as we approach 2050. This would save customers about $13 per month by 2048.

[41] Approximately 34% of Massachusetts customers are served by Eversource for both gas and electric service or by National Grid for both gas and electric service. Merging gas and electric utilities could lead to overhead savings with one set of billing and administrative functions, instead of two, and allow costs to be spread among a larger base of sales.

[42] LD 1679 An Act to Promote Clean energy Jobs and To Establish the Maine Climate Council. http://legislature.maine.gov/bills/display_ps.asp?PID=1456&snum=129&paper=SP0550

[43] LD 1766 An Act to Transform Maine's Heat Pump Market to Advance Economic Security and Climate Objectives. https://www.mainelegislature.org/legis/bills/display_ps.asp?LD=1766&snum=129

[44] Brattle Group, *Heating Sector Transformation in Rhode Island: Pathways to Decarbonization by 2050*, http://www.energy.ri.gov/documents/HST/RI%20HST%20Final%20Pathways%20Report%204-22-20.pdf

[45] https://neep.org/sites/default/files/resources/2019ASHPProgramSummaryUpdatedFeb2019.pdf

[46] https://new-hampshire.libertyutilities.com/alstead/liberty-utilities-home-battery-storage-pilot-approved-.html

[47] NH Investigation into Grid Modernization, Docket IR 15-296, https://puc.nh.gov/Regulatory/Docketbk/2015/15-296.html

[48] https://portal.ct.gov/DEEP/Climate-Change/GC3/Governors-Council-on-Climate-Change

[49] Myhre, G., Shindell, F-M Breon, W Collins, J. Fuglestvedt, J. Huang, D. Koch, J-F Lamarque, D. Lee, B Medoza, T Nakajima, A Robock, G. Stephens, T. Takemure and H Zhang, 2013: Anthropogenic and Natural Raidative Forcing In: Climate Change 2013: the Physical Basis Contribution of Working Group to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, page 714.

[50] Kathryn McKain, Adrian Down, Steve Raciti, John Nudney, Lucy R. Hutyra, Cody Floerchinger, Scott C. Herndon, Thomas Nehrkorn, Mark S. Zahniser, Robert B. Jackson, Nathan Phillips, and Steve C. Wofsy, "Methane Emissions from Natural Gas Infrastructure and Use in the Urban Region of Boston, Massachusetts, PNAS early edition, approved December 2014

[51] https://www.mass.gov/news/department-of-public-utilities-approves-offshore-wind-energy-contracts.

[52] https://www.utilitydive.com/news/massachusetts-utilities-sign-contracts-to-import-canadian-hydropower/528802/#:~:text=Dive%20Brief%3A,which%20will%20deliver%20the%20power.

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