Lawrence, Massachusetts, Residential Building Efficiency and Electrification Analysis

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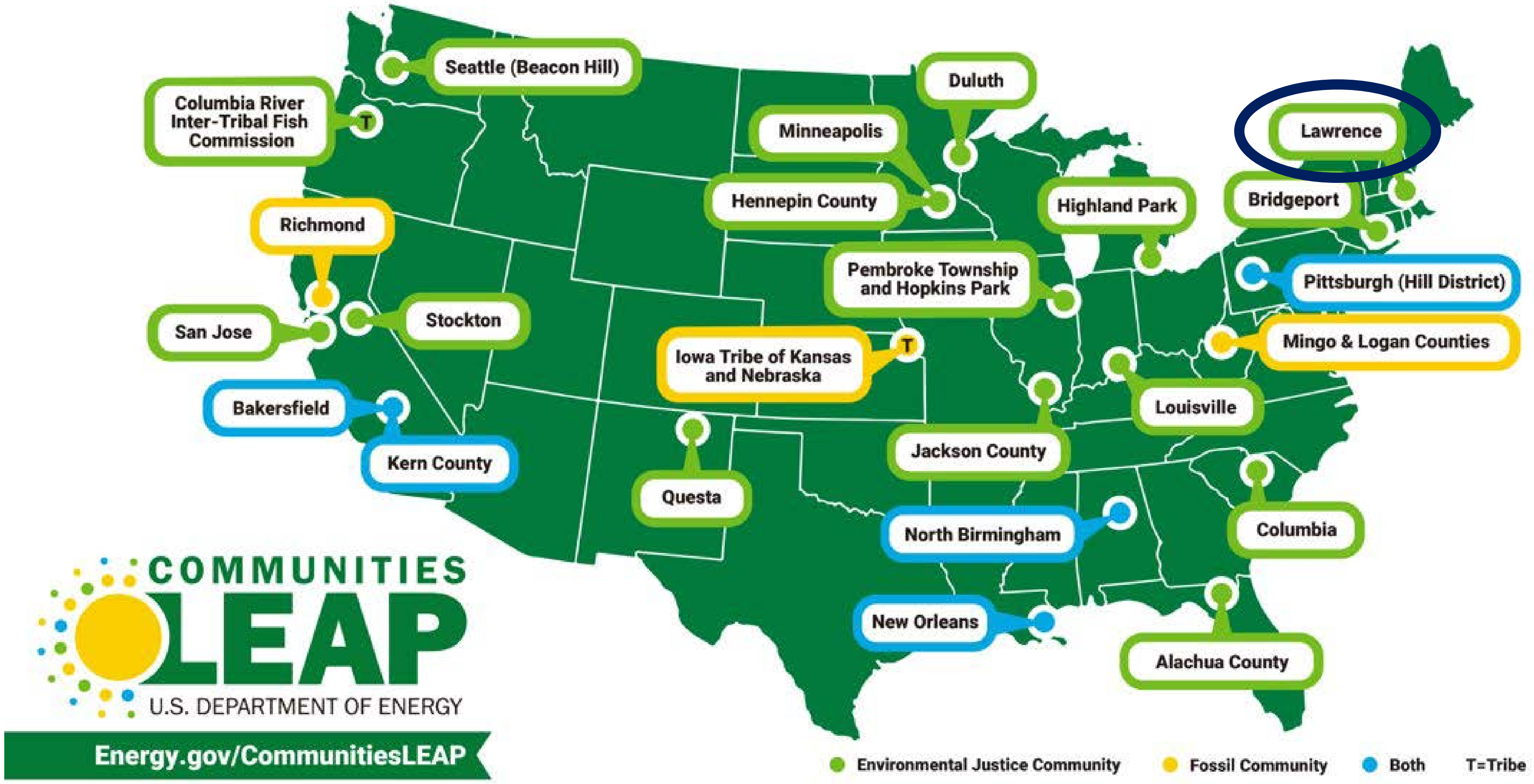
Communities LEAP Pilot Technical Assistance Opportunity

The Communities Local Energy Action Program (Communities LEAP) Pilot Competitive Technical Assistance opportunity aims to facilitate sustained community-wide economic empowerment through clean energy, improve local environmental conditions, and open the way for other benefits, primarily through DOE's clean energy deployment work.

This opportunity was open to low-income, energy-burdened communities that are also experiencing either direct environmental justice impacts, or direct economic impacts from a shift away from historical reliance on fossil fuels.

Map of LEAP Communities



Contents

Abbreviations

- AC: Air Conditioning
- AMI: Area Median Income
- ASHP: Air-Source Heat Pump
- DOE: U.S. Department of Energy
- IRA: Inflation Reduction Act (2022)
- HP: Heat Pump
- HPWH: Heat Pump Water Heater
- HSPF: Heating Seasonal Performance Factor
- NREL: National Renewable Energy Laboratory
- SEER: Seasonal Energy Efficiency Ratio
- WAP: Weatherization Assistance Program

Glossary

- Air-Source Heat Pump (ASHP): An air-source heat pump can provide efficient heating and cooling for a home. When properly installed, an air-source heat pump can deliver up to three times more heat energy to a home than the electrical energy it consumes. This is possible because a heat pump transfers heat rather than converting it from a fuel, like combustion heating systems (Energy Saver: Air-Source Heat Pumps).
- Annual Fuel Utilization Efficiency (AFUE): A measure of how efficient a furnace or boiler is in converting the energy from fuel to heat over the course of a typical year. Specifically, AFUE is the ratio of the furnace's or boiler's annual heat output compared to its total annual fossil fuel energy consumed (Energy Saver: Furnaces and Boilers).
- Energy Burden: The percentage of gross household income spent on energy costs. Households that spend 6% or more of their income in energy bills are considered energy-burdened (Office of State and Community Energy Programs).
- Energy Efficiency: Energy efficiency is the use of less energy to perform the same task or produce the same result. (DOE Office of Energy Efficiency and Renewable Energy).
- Energy Efficiency Ratio (EER) (Room Air Conditioner): The ratio of the cooling capacity (in British thermal units (Btu) per hour) to the power input (in watts) (Energy Savers: Room Air Conditioners).
- Thermal envelope/enclosure**:** The thermal envelope is everything about the house that serves to shield the living space from the outdoors. It includes the wall and roof assemblies, insulation, air/vapor retarders, windows, and weatherstripping and caulking (NREL 2000).
- Geothermal Heat Pump: Geothermal (ground-source or water-source) heat pumps achieve higher efficiencies by transferring heat between a home and the ground or a nearby water source (Energy Saver: Heat Pump Systems).
- Heating Seasonal Performance Factor (HSPF): The HSPF is a measure over an average heating season of the total heat provided to the conditioned space, expressed in Btu, divided by the total electrical energy consumed by the heat pump system, expressed in watt-hours (Energy Saver: Air-Source Heat Pumps).

Glossary (cont.)

- Infiltration: Air leakage occurs when outside air enters and conditioned air leaves your house uncontrollably through cracks and openings (Energy Saver: Air Sealing Your Home).
- Insulation: Insulation provides resistance to heat flow and lowers heating and cooling costs. Properly insulating a home not only reduces heating and cooling costs, but also improves comfort (Energy Saver: Insulation).
- Mini-Split Heat Pump: Ductless heat pumps, or mini-split heat pumps, are an alternative to radiator or baseboard heating, as well as a replacement for window units for cooling. No duct work is needed. Instead, a head unit, or multiple head units, are mounted on an interior wall or ceiling, with an accompanying unit outside (ENERGY STAR®: Ductless Heating and Cooling).
- Retrofit: A retrofit is the addition of new technology or features to an older system.
- R-Value: An insulating material's resistance to conductive heat flow is measured or rated in terms of its thermal resistance, or R-value. The higher the R-value, the greater the insulating effectiveness (Energy Saver: Insulation).
- Seasonal Energy Efficiency Ratio (SEER): SEER is a measure over an average cooling season of the total heat removed from the conditioned space, expressed in Btu, divided by the total electrical energy consumed by the heat pump, expressed in watt-hours (Energy Saver: Air-Source Heat Pumps).
- Weatherization: Weatherization refers to improvements to a building to protect the inside from the outside weather and to increase energy efficiency (Energy Saver: Weatherization).

Lawrence, MA, Residential Building Efficiency and Electrification Analysis Overview

Residential Building Efficiency and Electrification in Lawrence, MA

The Lawrence Stakeholders Coalition (LSC) is interested in assessing and understanding the potential for and pathways to electrification for the City of Lawrence.

The LSC's main questions are:

- What is the impact of various electrification packages on residential electricity bills?
- What types of buildings should the LSC target for electrification plus efficiency and weatherization packages?

This technical assistance aims to assist the LSC in electrification and energy-burden reduction planning by:

- Providing cross-cutting data on modeled housing stock characteristics (e.g., insulation levels, fuel types, equipment efficiencies), energy-burden characteristics, and energy consumption.
- Providing information on potential upgrade package costs, emissions reductions, and energy reductions by prioritized housing segment.

Background Information

The ResStock analysis presented here focuses on opportunities to reduce energy burden, energy consumption, and energy bills for single-family homes, multifamily buildings, and mobile/manufactured homes.

Using results from the Low-Income Energy Affordability Data (LEAD) tool report, *Household Energy Burden in Lawrence, Massachusetts*, and feedback from the LSC, NREL researchers identified 4 priority housing segments for deeper analysis:

- Segment 1: Multifamily buildings with 2-4 units, pre-1940
- Segment 2: Multifamily buildings with 5+ units, pre-1940
- Segment 3: Mobile homes, 1940-1979
- Segment 4: Single-family (attached and detached), pre-1940.

These segments prioritize the most energy-burdened households and the housing types with the most housing units in Lawrence. ResStock (used in this report) utilizes census-level data to determine the geographical area and the housing unit count. The LEAD tool report focuses on the 0-30% AMI group, and it maps energy burden by census tract.

All ResStock graphs and packages come from cited source: Liu, Lixi, Jes Brosman and Yingli Lou 2023: Data for Lawrence, MA.

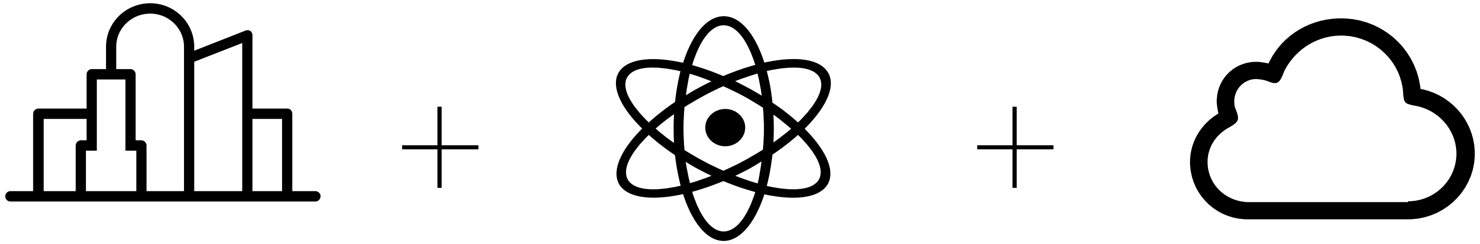
Source: City of Lawrence 2024

ResStock

Background

ResStock Process for Analyzing Building Upgrade Opportunities

ResStock



Building stock characteristics database + Physics-based computer modeling + High-performance computing

This is where Communities LEAP comes in!

1. Describe the U.S. building stock quantitatively
2. Sample the description to create statistical representation – in reality, these values may be different for each community
3. Model the samples
4. Model changes to the building stock, including energy efficiency packages, electrification, etc.
5. Publish description, samples, models, results, aggregations, visualizations, and documentation.

ResStock Workflow

Collect community housing analysis needs

- Collect housing segments of interest, utility costs, and local material and labor costs. Bring costs to 2023 USD. Determine geography of interest and dwelling unit count.

Filter national dataset to community level

- Downselect national dataset to defined geography of interest. If the downselection has too few samples, perform downsampling by finding ≥1,000 best matched samples within a wider region and reweighting the samples so they approximate the housing diversity in the original geography. Renormalize sample weights to dwelling unit count of the community.

Estimate impacts of 16 efficiency and electrification retrofit measures

- Process retrofit measures from EUSS 2022.1 and derive 6 additional measures
- Process annual or time series simulation data to determine energy bill, carbon, and energy savings.

Modeling Assumptions and Limitations

Modeling is imperfect.

- Analysis is based on ResStock-modeled energy consumption; all models have uncertainties.
- Modeling is aggregated across collections of housing units; results for individual housing units can vary substantially.
- For the most part, national average costs, scaled based on a local cost/inflation adjustment factor, were used; costs do not include rebates; costs for any individual project can vary substantially.
- Average utility rates for National Grid residential customers were used.
- Energy bill information and income are from the 2019 American Community Survey.
- Weather year used for the simulations is AMY 2018.

Not all technology options were considered.

- Specific measures and measure packages were modeled (not all potential technologies/performance levels and packages).

Modeling Assumptions and Limitations (cont.)

Cooling With Heat Pumps

- Households without existing cooling systems were assumed to use cooling after a heat pump upgrade, which adds a new service and improved thermal comfort, but can also substantially affect the cost-effectiveness of the packages.
- Heat pumps were modeled with existing heating system as backup and, also, separately modeled with electric backup; heat pumps were sized for cooling loads, which can produce more conservative estimates.

Housing Stock Considerations

- Building upgrades that are needed before electrification (remediation or a new electric panel) were not considered. These upgrades are particularly important in 0-80% AMI communities.
- Vacant housing was included in the analysis.

See the ResStock methodology document for a more detailed list of key modeling assumptions and limitations.

What Can ResStock Data Be Used To Inform?

Future grant applications	Program and Policy Development	Outreach	Coalition Priority Setting
Highlight the specific needs and how funding could be used	Inform program development, including where to direct incentives or technical assistance	Community outreach around energy cost reductions upgrades and potential funding	Identifying future priorities for energy audits or other efforts

Fuel Use and Housing Types in Lawrence, MA

Main Types of Heating Systems in Lawrence, MA

Natural Gas

Furnace: Furnaces heat air and distribute the heated air through the house using ducts.

Boiler: Boilers heat water and provide either hot water or steam for heating. Steam is distributed via pipes to steam radiators, and hot water can be distributed via baseboard radiators or radiant floor systems or can heat air via a coil (Energy Saver: Furnaces and Boilers).

Electric

Furnace: Blowers (large fans) in electric furnaces move air over a stack of electric resistance coils called elements. Heated air is delivered throughout the home through ducts.

Baseboard: Electric baseboard heaters are electric resistance heaters controlled by thermostats located within each room (Energy Saver: Electric Resistance Heater).

Heat pump: Heat pumps use electricity to transfer heat from a cool space to a warm space, making the cool space cooler and the warm space warmer. Because they transfer heat rather than generate heat, heat pumps can efficiently provide comfortable temperatures for your home (Energy Saver: Heat Pump Systems).

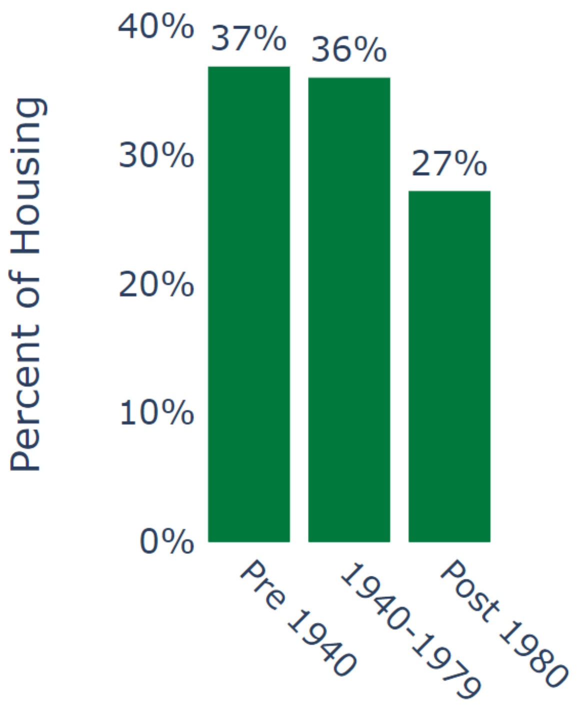
Heating (Fuel) Oil

Heating oil is used for space and water heating.

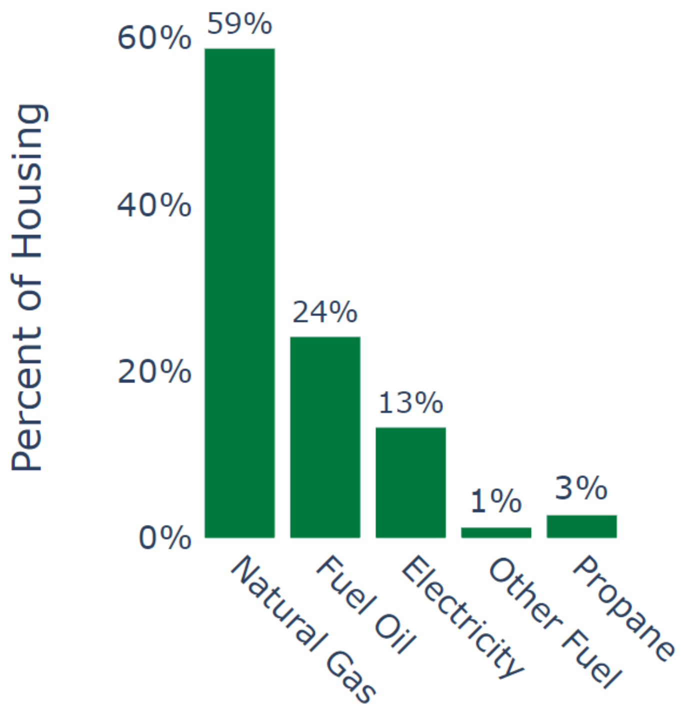
Heating oil and diesel fuel are closely related petroleum products called distillates. Heating oil is sold mainly for use in boilers and furnaces (for space heating) and in water heaters (Energy Information Administration 2023).

Building Age and Heating Fuel Source

Lawrence Housing Unit Age



Lawrence Fuel Type

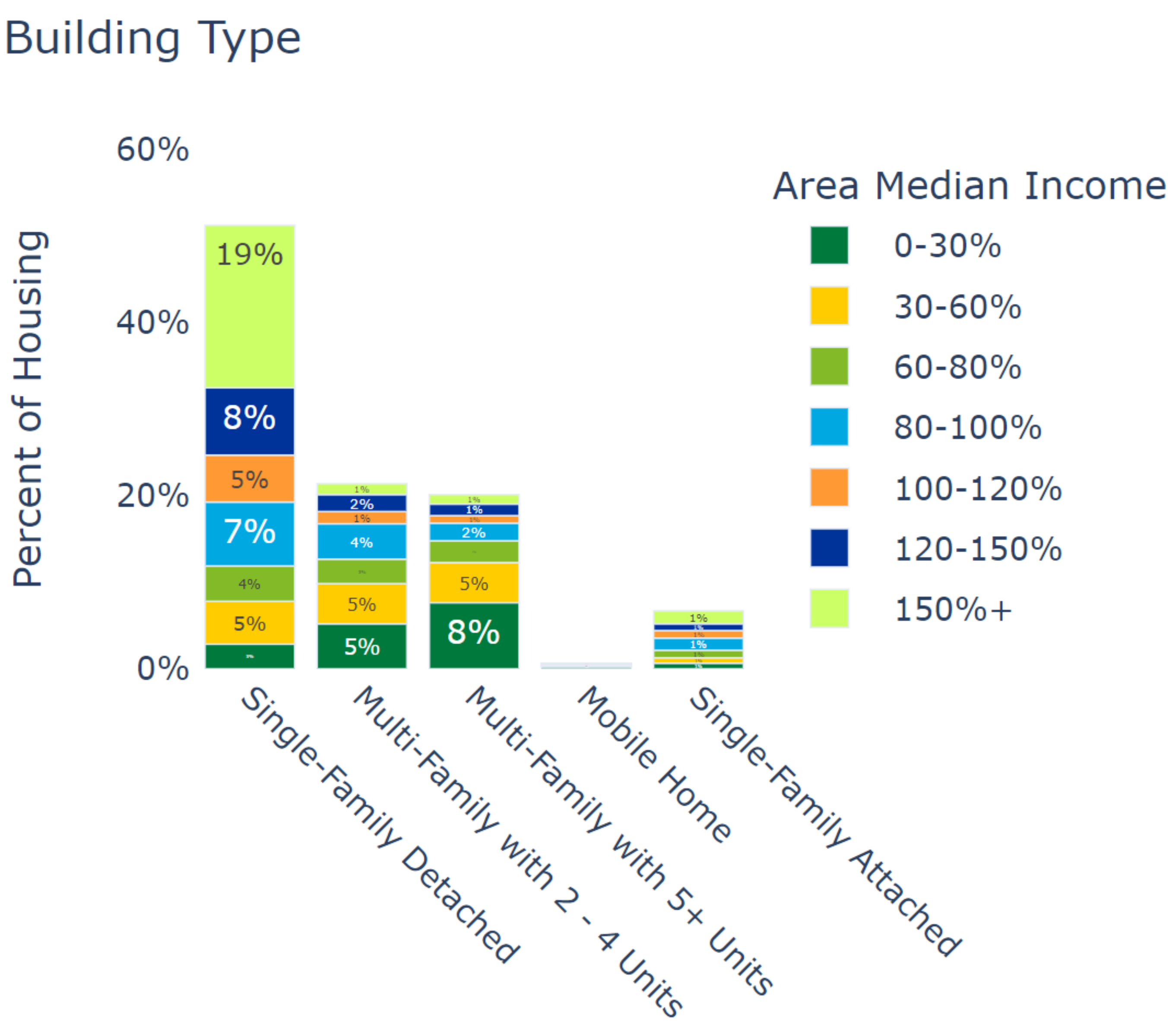


- 37% of the housing stock in Lawrence, MA, was built before 1940, which was before building energy codes were established.
- 59% of the housing stock in Lawrence, MA, uses natural gas as the primary heating fuel.

Housing Types in Lawrence, MA

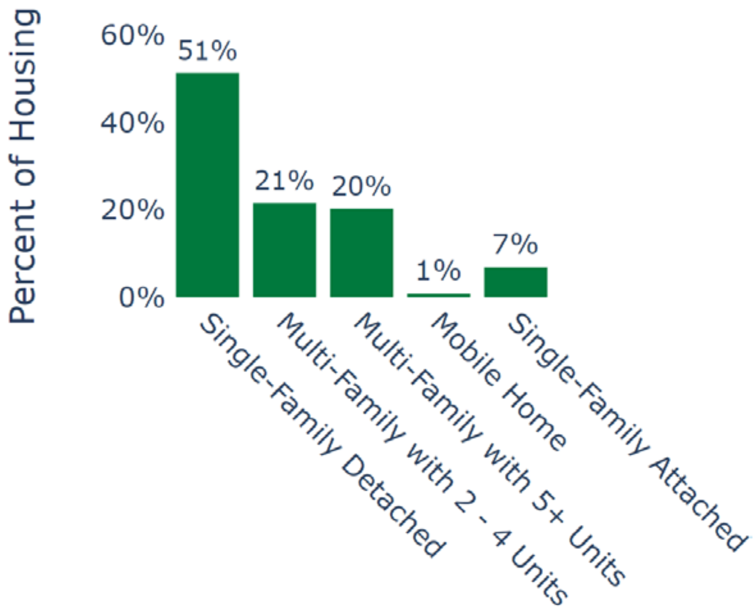
- Households in the 0-30% AMI group, which are the most energy-burdened, often live in multifamily housing with 5+ units (8% of all housing units) and multifamily housing with 2-4 units (5%).
- Households in the 30-60% AMI category mostly live in single-family detached (5%), multifamily housing with 5+ units (5%), and multifamily housing with 2-4 units (5%).

Lawrence Area Median Income and Housing Type Segment

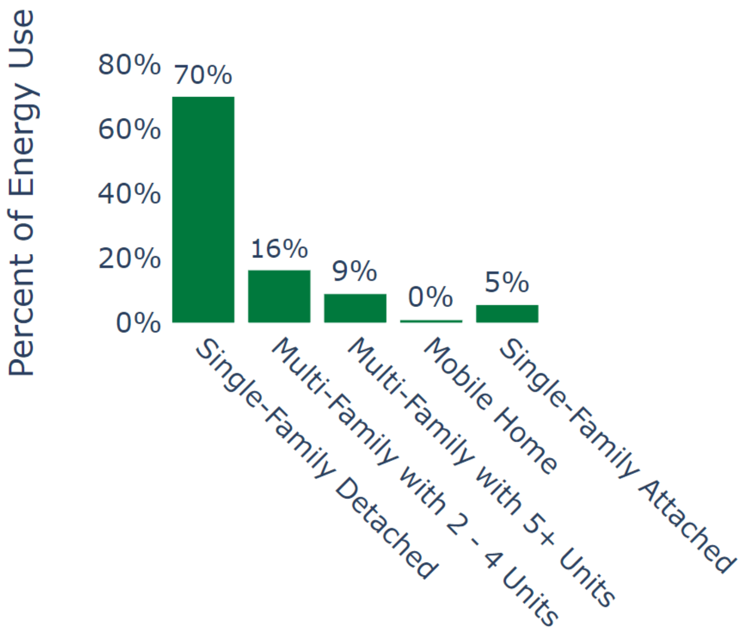


Building Type and Energy Consumption by Segment

Lawrence Housing Type Segments



Lawrence Energy Use and Housing Type Segments

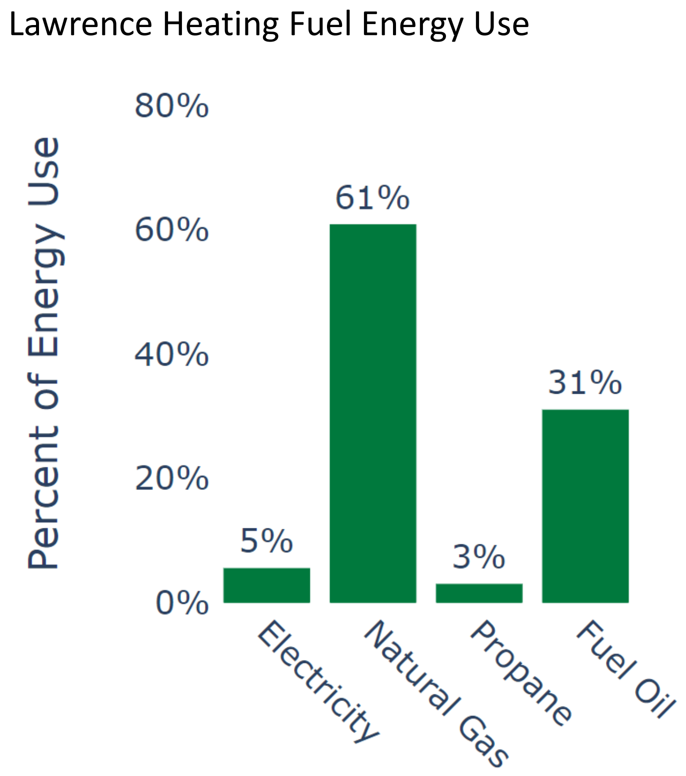


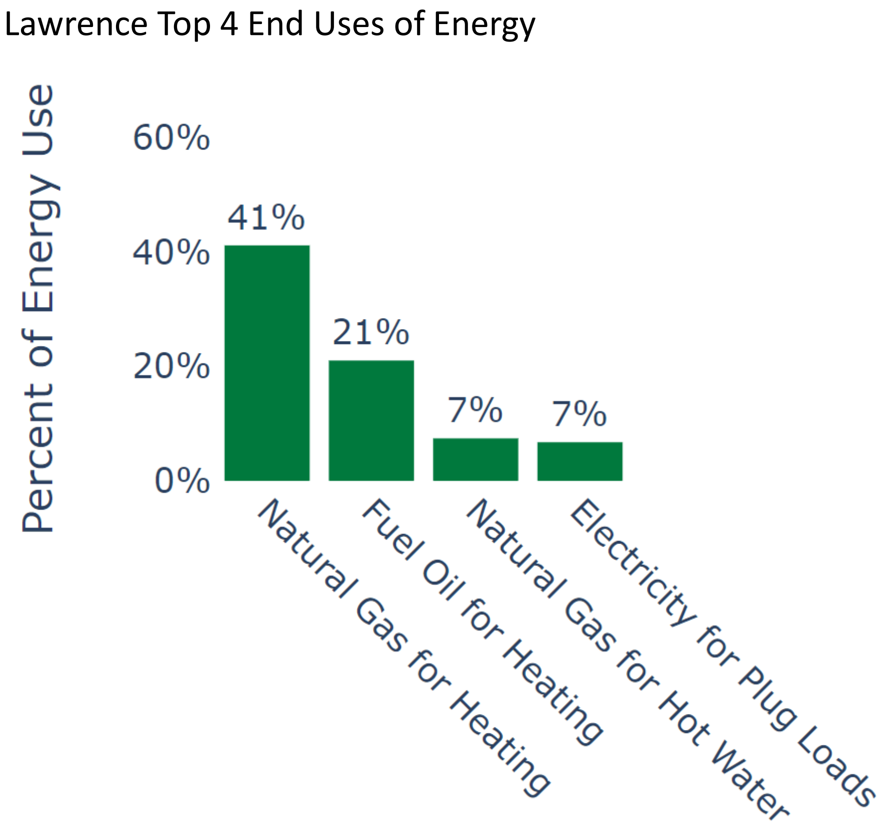
- Single-family detached homes are the most common (51% of housing units).
- Multifamily buildings comprise 41% and single-family homes 58% of the building stock in Lawrence, MA.

- Based on modeled results, single-family detached homes consume most of the residential building energy (70%) in Lawrence, MA.*

*When referring to energy consumption, this analysis is referring to site energy here and throughout the report.

Heating Fuel Energy Use and End Use

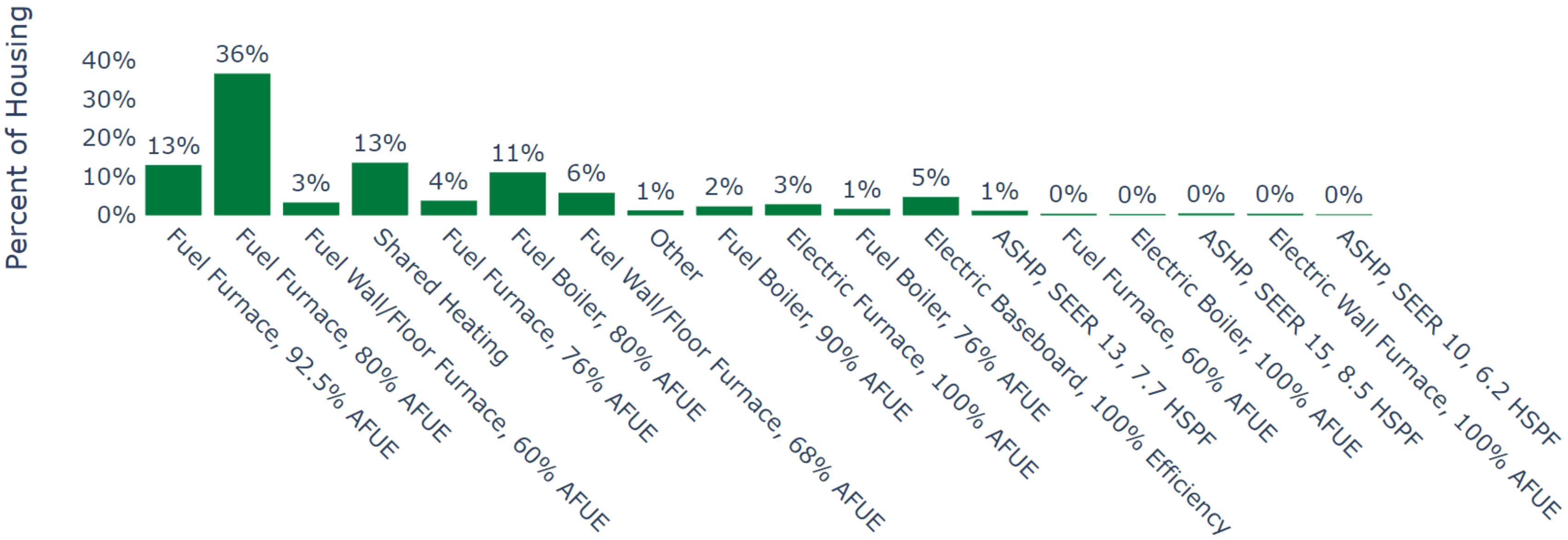




- Based on modeled results, 61% of the residential heating energy consumed in Lawrence, MA, comes from natural gas while 31% comes from fuel oil. This generally follows the percentage of housing stock that uses those heating sources.
- Based on modeled results, 41% of total residential energy used in Lawrence, MA, is used for natural gas heating while 7% of all energy used for natural gas is for hot water.

Heating System Efficiency

Lawrence Modeled Efficiency of Heating Systems



<u>Annual Fuel Utilization Efficiency (AFUE)</u>: A measure of how efficient a furnace or boiler is in converting the energy from fuel to heat over the course of a typical year (Energy Saver: Furnaces and Boilers).

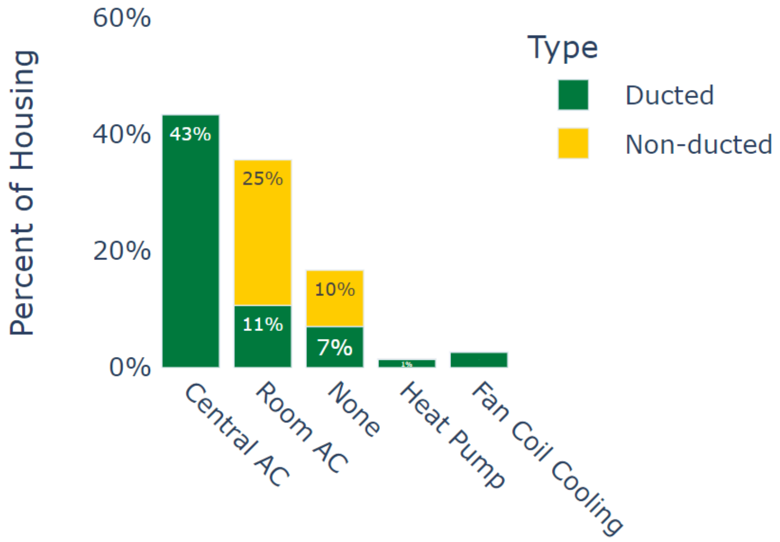
- Based on ResStock modeled characteristics, it is estimated that 3% of the homes in Lawrence have a low-efficiency 60% AFUE fuel wall/floor furnace, while 6% have a 68% AFUE wall/floor furnace. These can cause higher energy bills, making these households good targets for efficiency improvements.
- Based on ResStock modeled characteristics, it is estimated that 36% of the homes in Lawrence have a fuel furnace with 80% AFUE rating (mid-efficiency*) and 13% of them have a 92.5% (higher-efficiency) AFUE.

* https://www.energy.gov/energysaver/furnaces-and-boilers

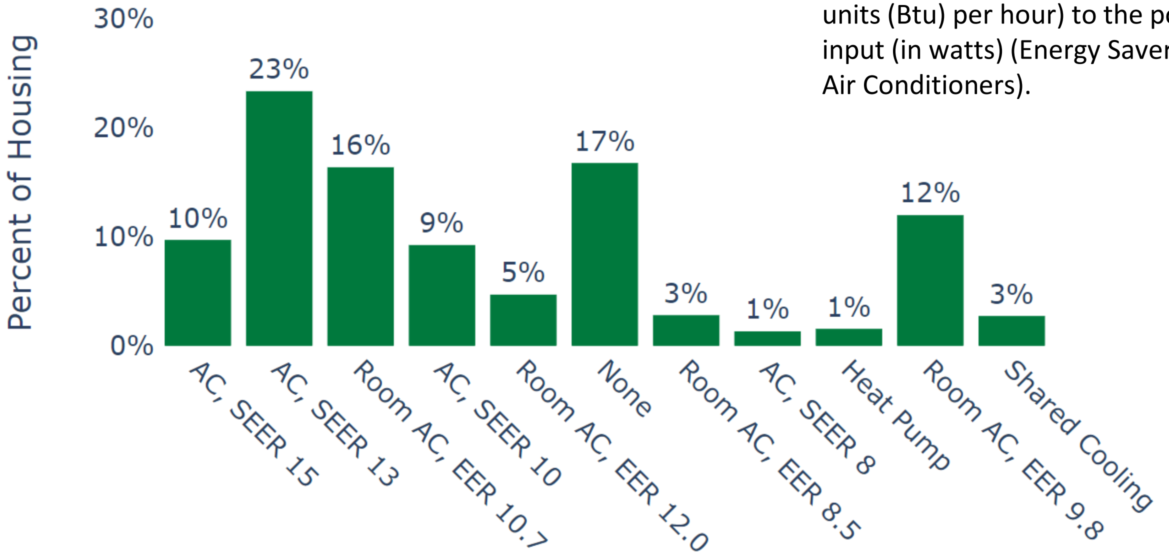
Cooling Systems in Lawrence, MA

<u>Seasonal Energy Efficiency Ratio (SEER):</u> a measure over an average cooling season of the total heat removed from the conditioned space (Energy Saver: Air-Source Heat Pumps).
<u>Energy Efficiency Ratio (EER) (Room Air Conditioner):</u> The ratio of the cooling capacity (in British thermal units (Btu) per hour) to the power input (in watts) (Energy Savers: Room Air Conditioners).

Lawrence Modeled Cooling Systems



Lawrence Modeled Efficiency of Cooling Systems



Based on ResStock modeling, it is estimated that:

- 17% of homes in Lawrence do not have a cooling system.
- 43% of homes in Lawrence have central AC; 1% of homes have heat pumps.

- 23% of the homes in Lawrence have an AC with a 13 SEER efficiency, while 16% and 10% have efficiencies of 10.7 EER and 15 SEER, respectively.

Fuel Use and Housing Type Summary

In Lawrence, MA, an estimated 41% of households live in multifamily buildings and 58% live in single-family homes.

- A small, energy-burdened segment of the population, lives in mobile homes (1%).

Heating

- In Lawrence, MA, 59% of households use natural gas as their primary source of heating; natural gas represents 61% of residential energy consumption. Based on modeled results, natural gas is mostly used for heating (41% of all residential energy use) and some for hot water (7% of all residential energy use).

Cooling

- Based on modeled results in Lawrence, MA, 43% of homes in Lawrence have central AC and 1% have heat pumps. It is estimated that about 17% of the households do not have a cooling system.

Lawrence, MA, Housing Envelope

Home Envelope Overview

Building Envelope: Everything that separates your home from the outside, including walls, windows, attic and roof, and foundation floors and walls.

Envelope Status: Definitions for the purpose of this analysis:

- Good: Meets current [IECC 2021 building codes] building code performance levels
- Inadequate: Above average for the climate, but not meeting the International Energy Conservation Code of 2021
- Poor: Below average for the climate.

Notes about homes with inadequate or poor envelope status:

- They are harder and more expensive to heat and cool.
- They can bring in more outdoor pollutants.
- They can be less comfortable for occupants, and poor infiltration is linked to home health hazards such as asthma triggers like mold and pests (HUD 2016).

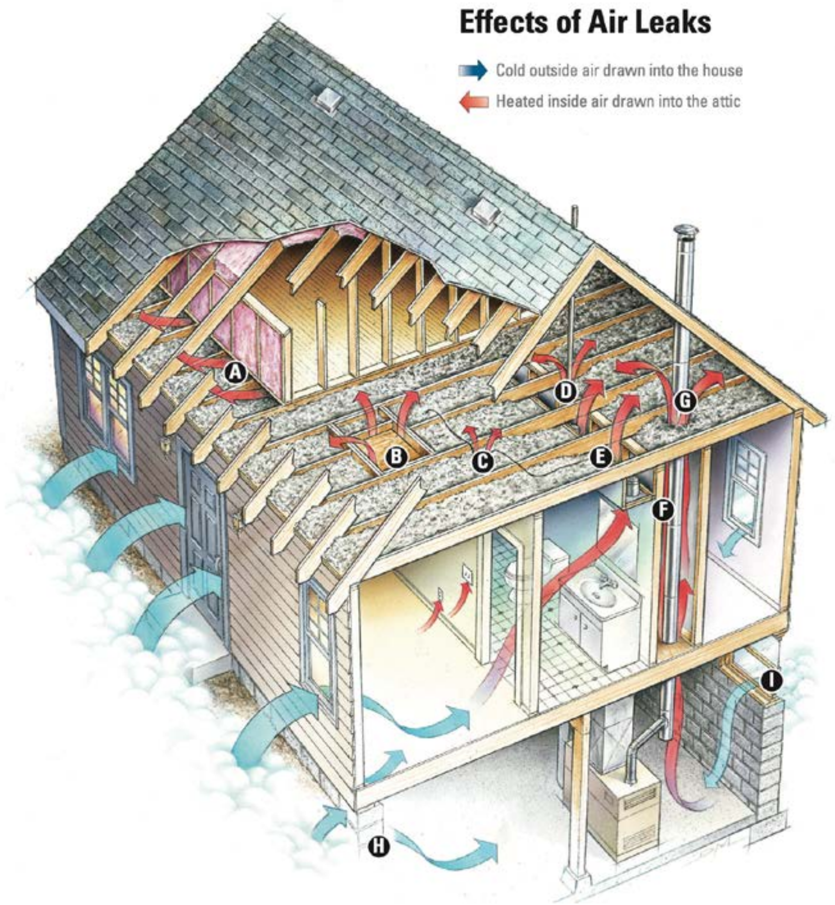
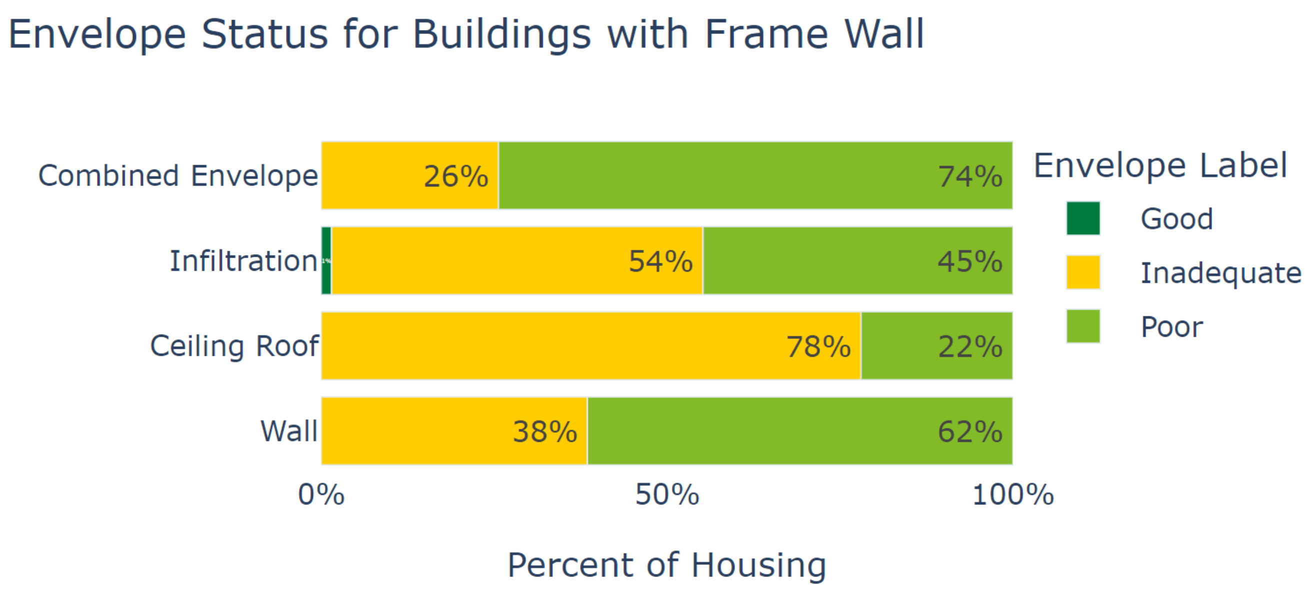


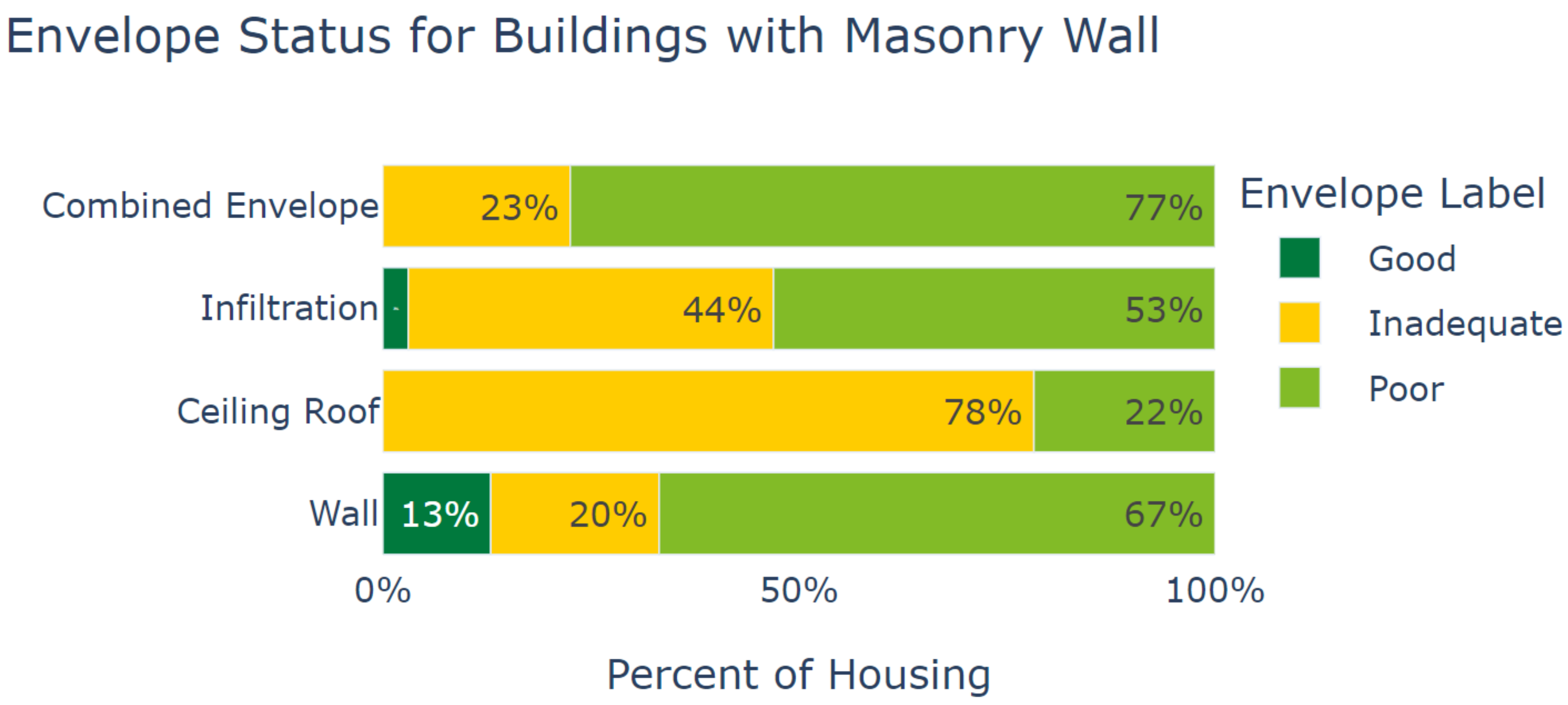
Image Source: ENERGY STAR n.d.: Seal and Insulate with ENERGY STAR

Envelope Status for Buildings With Frame Wall



- Frame wall is wood framing with a cavity with or without insulation between studs, siding on the outside, and an interior finish like drywall or plaster.
- Overall, 74% of the homes in Lawrence with frame wall have a poor envelope status, while 26% are characterized as inadequate.

Envelope Status for Buildings With Masonry Wall



77% of homes with masonry wall have poor envelope status, while 23% have inadequate status.

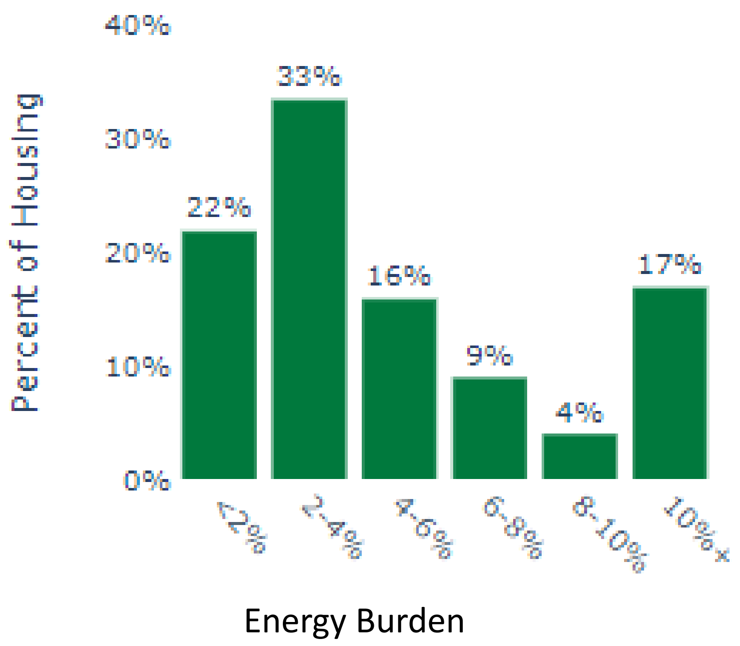
Envelope Status Key Takeaways

- Most homes in Lawrence, MA, have a poor envelope status for both masonry and frame wall homes.
- Poor wall insulation is the main envelope characteristic that is most prominent for both housing types.

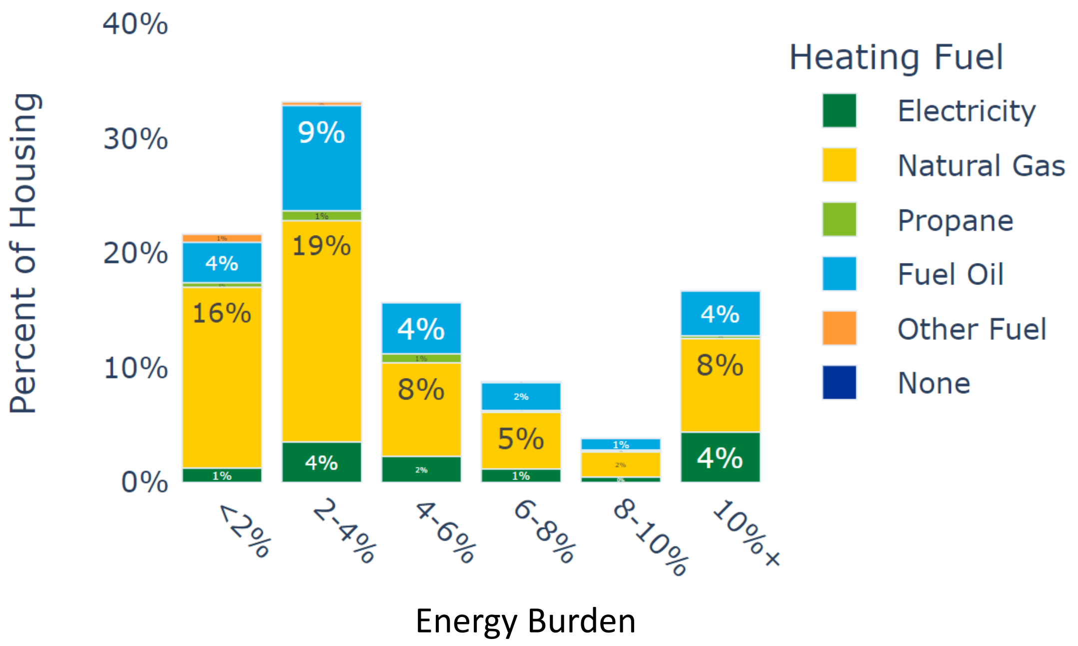
Energy Burden in Lawrence, MA

Energy Burden and Heating Fuel

Lawrence Modeled Energy Burden by Percent of Housing



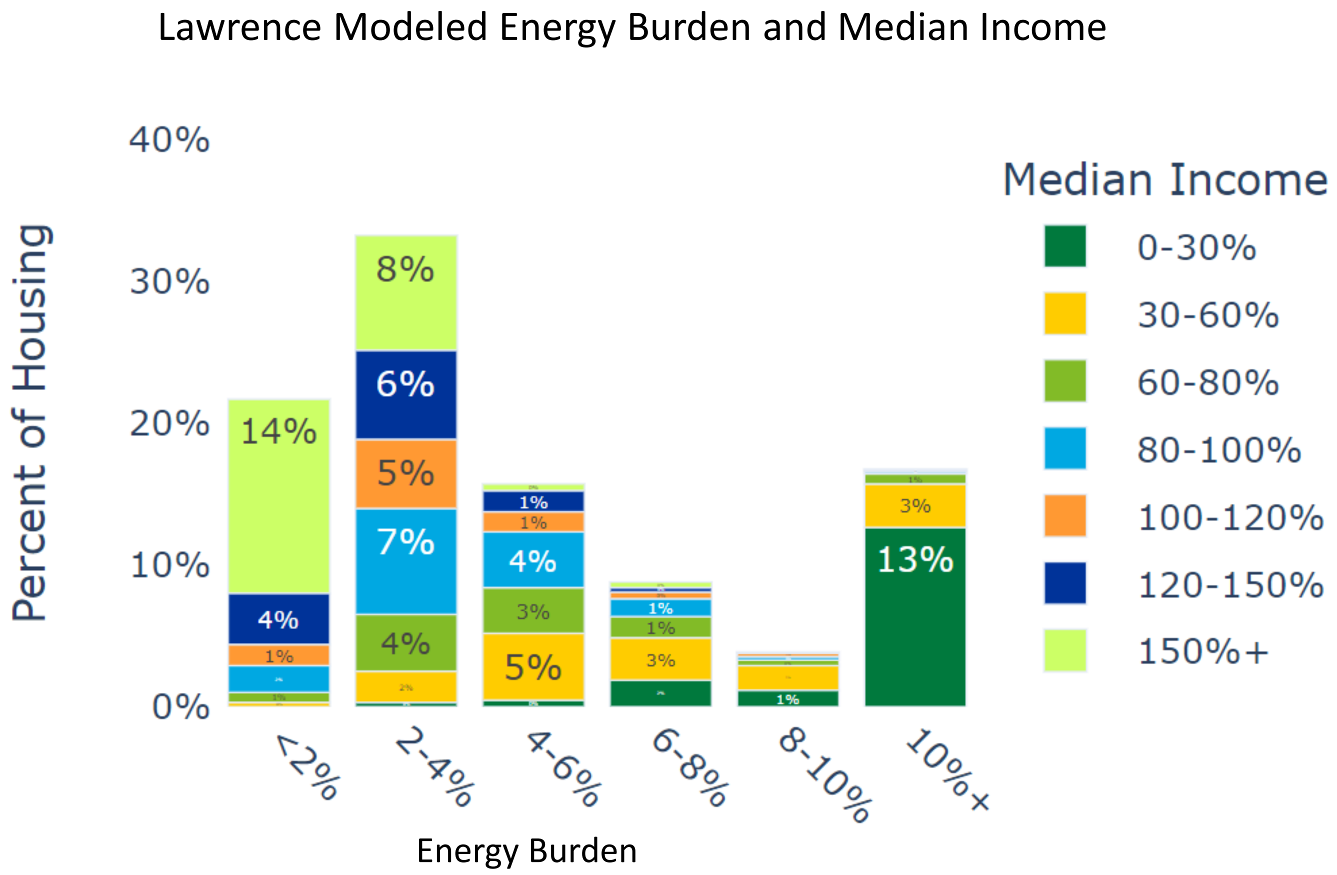
Lawrence Modeled Energy Burden and Heating Fuel



- Based on modeled results, it is estimated that about 30% of Lawrence's households are energy-burdened and about 17% are severely energy-burdened.

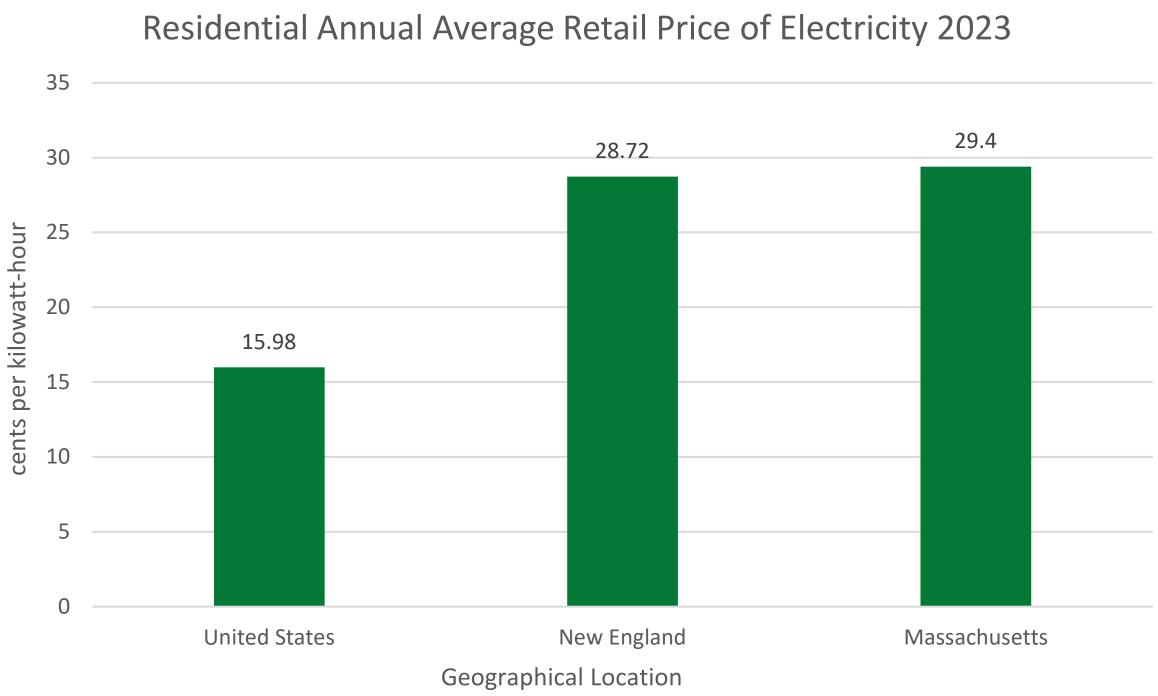
- Of all households in Lawrence, it is estimated that about 27% (15% using natural gas, 6% using electricity, and 5% using fuel oil as their primary heating source) are energy-burdened.

Energy Burden and AMI



- Although most income groups have a percentage of energy-burdened households, those in the 0-30% AMI group have the highest percentage of households that are *severely energy-burdened,* representing an estimated 13% of all households.
- The second most energy-burdened income group is the 30-60% AMI group. Over half of those households in the 30-60% AMI group (representing about 8% of all households) are energy-burdened.

Energy Burden and Electricity Prices



On average, the electricity price in Massachusetts is 0.68 cents/kWh higher than the New England average and 13.42 cents/kWh higher than the average across the United States.

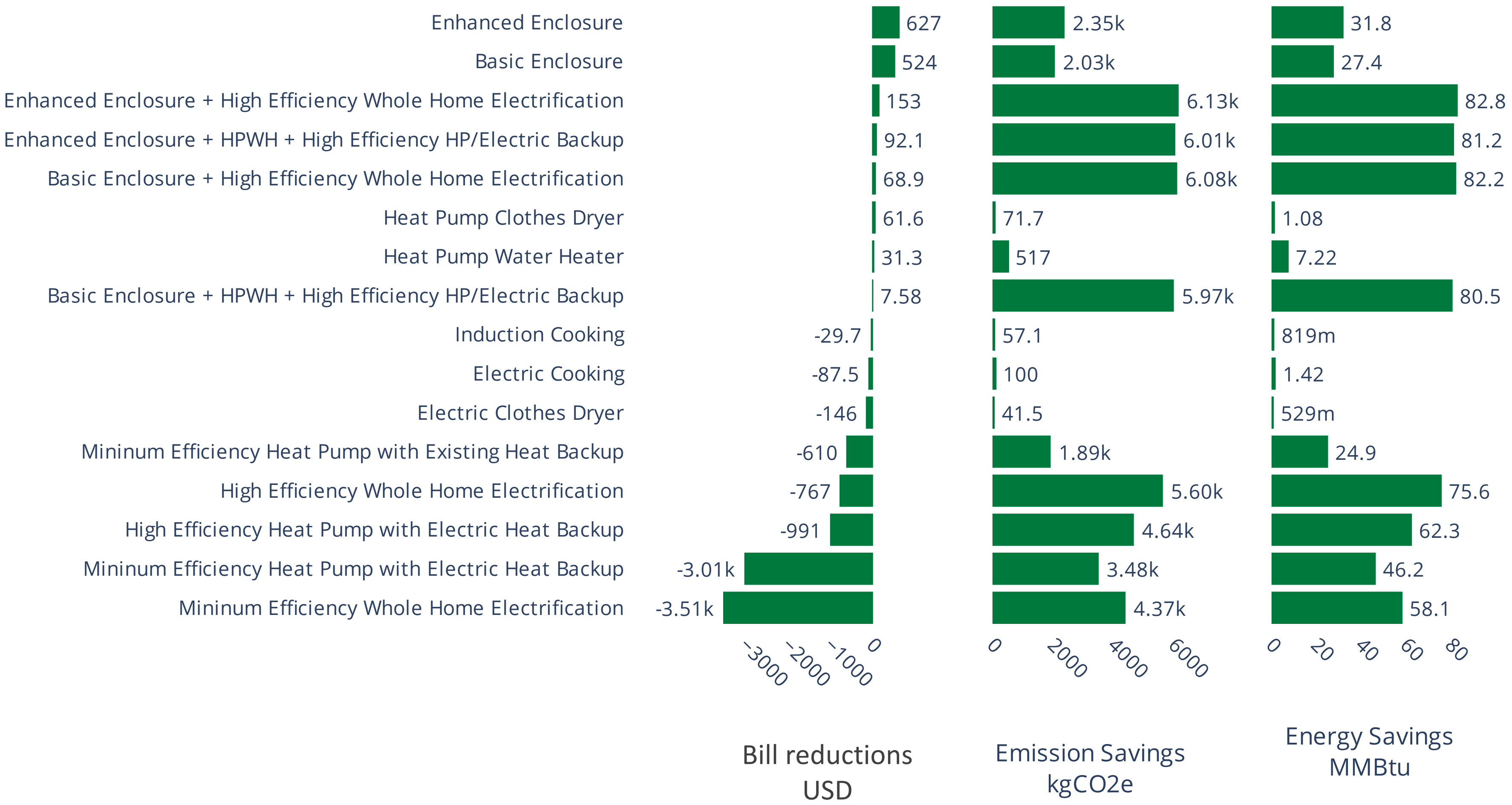
High electricity costs contribute to high energy burden, especially in low-income populations in Lawrence, MA.

Source: Energy Information Administration n.d.: Electricity Data Browser

Housing Energy Efficiency Upgrade Strategies in Lawrence, MA

Pathways for reducing energy use, energy costs, and associated emissions

Modeled Annual Average Reductions Potential Per Dwelling Unit, Lawrence, MA



This table shows how different electrification and energy efficiency upgrade “packages” impact how much is spent on energy bills (bill reductions), how much emissions are reduced (emission savings), and how much energy consumption is reduced (energy savings) after homes are upgraded with these packages.

Understanding the Electrification and Energy Efficiency Packages

Based on the modeled results for Lawrence, MA, presented on slide 37:

- Some upgrade "packages," such as **Enhanced and Basic Enclosure, provide *only*** envelope upgrades. These packages provide energy bill reductions because they decrease heating and cooling loads, decreasing the magnitude and frequency that cooling and heating systems operate, using less energy overall.
- Packages that *add* new electrification technologies, such as **Electric Cooking and Heat Pumps, generally increase the amount of electricity utilized while reducing the use of gas**, and thus can result in higher energy bills due to the increased electricity consumption.
- Other packages include *both* envelope upgrades and new electrification technologies, such as **Enhanced Enclosure + High Efficiency Whole Home Electrification, *moderately* decreasing energy bills while providing higher emission reductions** than when adding only new electrification technologies without envelope upgrade measures. This combination can be advantageous because upgrading the envelope reduces the amount of electricity used by the new electric cooling and heating systems, keeping energy bill costs lower than without envelope upgrades while creating a cleaner and healthier living environment (Lee and Billimoria 2021).

Understanding the Electrification and Energy Efficiency Packages

Based on the modeled results for Lawrence, MA, presented on slide 37:

- While electrification generally increases the consumption of electricity, **by switching to more *efficient* electrification technologies that replace other sources of energy such as natural gas, overall energy consumption and associated emissions can be reduced**. Energy consumption and emissions can be further reduced through enclosure upgrades.
- Electricity prices are key in determining the costs of energy bills when electrification upgrades have been installed. **High electricity costs in Massachusetts, including Lawrence, MA, is the key driver of increased energy bills seen for various packages when a home is electrified.**

Example Deep Dive on Upgrade Strategies

ResStock Modeled Upgrades

1. Basic Enclosure
2. Enhanced Enclosure
3. Heat Pump Water Heater
4. Minimum Efficiency Heat Pump with Electric Heat Backup
5. High Efficiency Heat Pump with Electric Heat Backup
6. Basic Enclosure + Heat Pump Water Heater (HPWH) + High Efficiency Heat Pump with Electric Backup
7. Enhanced Enclosure + High Efficiency Home Electrification.

Disclaimers

- The upgrade costs presented do not account for any rebates or incentives.
- The upgrade packages represent average modeled costs for *all* housing types in the City of Lawrence. More specific costs are dependent on the type of housing (e.g., single-family or multifamily), vintage, and other factors. Actual costs for any specific project will vary greatly based on these and other factors.

1. Basic Enclosure: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Upgrade attic insulation to modern building codes (IECC 2021)

Reduce air leakage (infiltration) by 30%

Seal ducts to 10% leakage, add R-8 insulation

Drill-and-fill wall insulation to R-13 for frame houses with no insulation

Average Upgrade Cost: $5,590

Average Annual Energy Bill Reductions $524

Average Annual Emissions Reduction: 2,031 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

The average upgrade cost, energy bill reductions, and emissions reductions are an average value for all building types in Lawrence. These values will change based on building type, vintage, and more.

2. Enhanced Enclosure: Modeled Reductions Potential for Lawrence, MA, Residential Buildings

Everything in the Basic Enclosure Package, and…

Add R-10 to foundation walls and rim joists

Seal crawlspace vents

Insulate finished attic and cathedral ceilings to R-30

Average Upgrade Cost: $7,543

Average Annual Energy Bill Reductions: $627 per year

Average Annual Emissions Reduction: 2,352 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

3. Heat Pump Water Heater: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Replace existing water heater with heat pump water heater (HPWH)

Note: As previously noted in the limitations, the full cost of the measure was modeled; installing a heat pump water heater at or near the end of life of an existing water heater can be more cost-effective.

Average Upgrade Cost: $3,585

Average Annual Energy Bill Reductions: $31 per year

Average Annual Emissions Reduction: 517 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

4. Minimum Efficiency Heat Pump With Electric Heat Backup: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Air-source heat pump with SEER 15 and 9.0 HSPF ratings if the house has ducts

Mini-split heat pump with SEER 15 and 9.0 HSPF ratings if the house does not have ducts

Average Upgrade Cost: $21,292

Average Annual Energy Bill Reductions: -$3,013 per year (negative energy bill reductions are bill increases*)

Average Annual Emissions Reduction: 3,481 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

*See Packages 6 and 7 for examples of where combining high-efficiency heat pumps with other enclosure and electrification measures is estimated to yield near neutral or positive reductions in utility bills and substantial emissions reductions.

5. High Efficiency Heat Pump With Electric Heat Backup: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Air-source heat pump with SEER 24 and 13.0 HSPF ratings if the house has ducts

Mini-split heat pump with SEER 24 and 13.0 HSPF ratings if the house does not have ducts

Average Upgrade Cost: $30,072

Average Annual Energy Bill Reductions: -$991 per year (negative energy bill reductions are bill increases*)

Average Annual Emissions Reduction: 4,643 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

*See Packages 6 and 7 for examples of where combining high-efficiency heat pumps with other enclosure and electrification measures is estimated to yield near neutral or positive reductions in utility bills and substantial emissions reductions.

6. Basic Enclosure + HPWH + High Efficiency HP/Electric Backup: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Everything in the Basic Enclosure Package, and…

Heat pump water heater

High-efficiency heat pump with electric backup

Average Upgrade Cost: $35,450

Average Annual Energy Bill Reductions: $7 per year

Average Annual Emissions Reduction: 5,966 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

7. Enhanced Enclosure + High Efficiency Home Electrification: Modeled Reduction Potential for Lawrence, MA, Residential Buildings

Everything in the Enhanced Enclosure Package, and…

Heat pump water heater

High-efficiency heat pump with electric backup

Heat pump clothes dryer and induction range with electric oven

Average Upgrade Cost: $40,548

Average Annual Energy Bill Reductions: $153 per year

Average Annual Emissions Reduction: 6,125 kg CO_2

Source: Liu, Lixi, Jes Brosman and Yingli Lou 2023

Key Findings for Upgrade Options

Based on modeled results for Lawrence, MA:

- The results highlight the impact of enclosure upgrades in terms of annual energy bill reductions, with lower upfront costs than heat pump measures. Basic enclosure upgrades have the highest weighted average cost-effectiveness* (average annual bill reductions of $524 with an average upgrade cost of $5,590) among the 7 packages presented in this report. In certain cases, performing enclosure upgrades first can also allow for HVAC systems to be sized smaller, saving people money on their future projects.
- The greatest predicted emissions reductions come from enhanced enclosure + high-efficiency whole-home electrification (6,125 kg CO_2 annually).
- Certain electrification upgrades are not predicted to yield annual utility bill reductions by themselves and require pairing with enclosure upgrades and other electrification upgrades to save customers money on annual energy bills and lower energy burden from energy bills. However, it should be noted that these combined packages have substantial upfront costs and will likely require strategies for further reducing and financing the costs, even after available rebates, credits, etc. are accounted for.
- Overall, there is an opportunity for high-impact investment for energy consumption, energy bill, and emissions reductions through envelope retrofits in Lawrence, MA.

*This is the average modeled bill reduction for this measure across all modeled units, divided by the average modeled cost for this measure across all modeled units.

Segment-Level Data Highlights

Segments and Highlights

- Segment highlights in the following slides include:
  - The upgrade with the highest modeled energy bill reduction
  - The upgrade with the greatest modeled emissions reduction
  - The upgrade with the lowest modeled energy bill reduction.
- Full raw data includes a larger set of fields.

Lawrence, MA, Highest Modeled Energy Bill Reductions: Basic Enclosure

Segment 0-80%	Average Upgrade Costs	Average Energy Bill Reductions (annual)	Average Energy-Burden Reductions* (pre→post)	Average Site Energy Reductions (%)	Average Emissions Reductions (KgCO2e)
Multifamily buildings with 2-4 units, pre-1940	$2,950	**$323**	11.5% → 10.2%	22.2%	1,466
Multifamily buildings with 5+ units, pre-1940	$2,040	**$462**	14.9% →12.5%	18.8%	882
Mobile homes, 1940-1979	$5,320	**$57**	8.8% → 8.6%	21.7%	1,810
Single-family (attached and detached), pre-1940	$7,900	**$749**	15% → 12.1%	25.8%	3,208

- All segments showed energy bill reductions.
- Single-family homes show the highest energy bill reductions from basic enclosure upgrades ($749).
- Mobile homes see the least energy bill reductions and energy-burden impacts from bill reductions.

* Does not include energy-burden impacts of upgrade costs.

Lawrence, MA, Highest Modeled Emissions Reductions: Enhanced Enclosure + High Efficiency Home Electrification

Segment 0-80% AMI	Average Upgrade Costs	Average Energy Bill Reductions (annual)	Average Energy-Burden Reduction* (pre→post)	Average Site Energy Reductions (%)	Average Emissions Reductions (KgCO2e)
Multifamily buildings with 2-4 units, pre-1940	$34,040	$410	11.5% → 10.1%	70.2	**4,551**
Multifamily buildings with 5+ units, pre-1940	$28,520	$872	14.6% → 9.9%	63.1	**2,837**
Mobile homes, 1940-1979	$39,540	$-550	8.8% → 11.2%	68.4	**5,555**
Single-family (attached and detached), pre-1940	$48,220	$393	15% → 10.8%	72.1	**8,845**

- Even with enclosure upgrades, mobile homes experience average energy bill and energy-burden increases for the electrification packages modeled. Thus, an increase in electricity use due to electrification is greater than energy use reduction due to enclosure upgrades.
- All other segments show positive energy bill reductions.
- All segments show substantial modeled emissions reductions associated with the upgrades. The largest average reductions per household are estimated to be from single-family homes (8845 KgCO2e).

* Does not include energy-burden impact of upgrade costs.

Lawrence, MA, Lowest Modeled Cost Reductions: Minimum Efficiency Whole-Home Electrification

Segment 0-80% AMI	Average Upgrade Costs	Average Energy Bill Reductions (annual)	Average Energy-Burden Reduction* (pre→post)	Average Site Energy Reductions (%)	Average Emissions Reductions (KgCO2e)
Multifamily buildings with 2-4 units, pre-1940	$24,170	**$-1527**	11.5% → 17.9%	47.8	3,259
Multifamily buildings with 5+ units, pre-1940	$16,010	**$-831**	13% → 17.5%	44.2	2,100
Mobile homes, 1940-1979	$22,470	**$-2463**	8.8% → 19.1%	45.5	4,060
Single-family (attached and detached), pre-1940	$40,010	**$-3534**	15% → 24.7%	49.2	6,602

- All segments showed increased average energy bill costs and energy burden.
- See package on prior slide where combining high-efficiency heat pumps with other enclosure and electrification measures is estimated to yield positive reductions in utility bills for all segments except mobile homes.
- All segments still show substantial emissions reductions and site energy reductions.

* Does not include energy-burden impact of upgrade costs.

Navigating Segment-Level Data

upgrade_name Basic Enclosure

Values	
Segment 1 Energy Burden After Upgrade (%)	10.2
Segment 2 Energy Burden Before Upgrade (%)	14.9
Segment 2 Energy Burden After Upgrade (%)	12.5
Segment 3 Energy Burden Before Upgrade(%)	8.8
Segment 3 Energy Burden After Upgrade (%)	8.6
Segment 4 Energy Burden Before Upgrade (%)	15
Segment 4 Energy Burden After Upgrade (%)	12.1
Segment 1 Energy Reductions Average (%)	22.2
Segment 2 Average Energy Reductions Percent	18.8
Segment 3 Average Energy Reductions (%)	21.7
Segment 4 Average Energy Reductions (%)	25.8
Segment 1 Energy Bill Reductions 10th Percentile	32.38407532
Segment 1 Energy Bill Reductions 90th Percentile	592.9239903
Segment 2 Energy Bill Reductions 10th Percentile	22.2444302
Segment 2 Energy Bill Reductions 90th Percentile	1292.473302
Segment 3 Energy Bill Reductions 10th Percentile	20.08753013
Segment 3 Energy Bill Reductions 90th Percentile	128.1860556
Segment 4 Energy Bill Reductions 10th Percentile	35.69310337
Segment 4 Energy Bill Reductions 90th Percentile	1708.121385
Segment 1 Average Upgrade Cost	2954
Segment 2 Average Upgrade Cost	2035.5
Segment 3 Average Upgrade Cost	5322.6
Segment 4 Average Upgrade Cost	7904.2
Average Upgrade Cost (full community)	5592.6

Segment Key
segment1_0-80%AMI: multifamily with 2-4 units, constructed before 1940, 0-80%AMI income level
segment2_0-80%AMI: multifamily with 5+ units, constructed before 1940, 0-80%AMI income level
segment3_0-80%AMI: mobile home, constructed in 1940-1979, 0-80%AMI income level
segment4_0-80%AMI: single family, constructed before 1940,0-80%AMI income level

- Summary tables are being provided to the LSC as a companion spreadsheet with pivot tables to navigate all upgrades across the segments.
- Can filter by upgrade type.
- A community-wide sheet and a segment-level sheet are being provided.
- Raw data is also included and available online.

Using This Data Moving Forward

- Public Lawrence Dataset: Lawrence ResStock results data are public.
- Lawrence Data Sheet: Included as a separate attachment.
- Methodology Document: This document describes the methodology, tools, and processes used to analyze the potential impacts of the energy efficiency and electrification retrofit packages on communities' housing stocks.
- Data Guidance: File with description of data and figures for each community that used ResStock.
- Policy and Programs Example Resource: Provides different policy and/or program approaches that have been used by communities to support community-scale electrification of existing buildings.

Thank You

www.energy.gov/communitiesLEAP

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