Credit: Mikhail Haramati

DECARBONIZING NEW YORK STATE'S HOMES

An evaluation of GasFreeNY's Bucks for Boilers proposal

WiN CLiMATE

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TABLE OF CONTENTS

WiN CLiMATE

INTRODUCTION

New York State has set ambitious, legally-mandated targets to decarbonize the state; however, few concrete steps have been taken to reduce emissions from existing buildings.

New York City's Local Law 97 of 2019, which applies to the city's large buildings, is currently the state's only law that mandates existing properties to transition away from fossil fuels. New York State's Climate Scoping Plan proposes a mix of subsidies and mandates to drive the weatherization and electrification of the rest of the state's buildings by 2050. These recommendations would replace virtually all fossil-fueled heating systems with heat pumps in the coming decades.

Governor Hochul has previously supported phasing out installation of new boilers and furnaces by 2030 in Executive Budget proposals, and signaled continued support by committing New York to the U.S. Climate Alliance's goal of installing 200 million heat pumps nationwide.[1] However, there are currently no state laws to implement these policies at scale.

[1] See the Governor's announcement on Sept. 21, 2023.

A **statewide mandate** is necessary to reach the 2050 net-zero emission target. The key to decarbonizing buildings is an end-of-life intervention: every time a boiler or furnace dies, it should be replaced by a heat pump.

To ensure that all households can afford to install heat pumps, and experience decreased energy bills when they do so, this mandate must be paired with **subsidies**. This is the goal of **Bucks for Boilers**, a decarbonization plan recently announced by the GasFreeNY coalition.

This report analyzes Bucks for Boilers to answer key questions posed by the initiative:

1. If enacted, what impact would the proposal have on the finances of New York households?
2. What level of public investment would be required from the State to achieve the proposal's goals?

What is Bucks for Boilers?

Bucks for Boilers consists of two complementary policies: mandates and subsidies.

Mandates

Bucks for Boilers mandates that all heating systems installed in existing buildings must run on electricity, not combustible fuels, after 2030.

A statewide mandate is essential to electrifying, and thus decarbonizing, New York's buildings by 2050: because new boilers and furnaces typically operate for 20 to 30 years, all new heaters installed after 2030 must be electric in order to initiate a gradual transition that completes by mid-century.

And the only realistic way to guarantee 100% customer adoption of heat pumps after 2030 is through a legal requirement. Without meeting this milestone of 100-by-30, New York's largest source of climate pollution simply won't be eliminated in time.

Subsidies

With the mandate is in place, many households would need subsidies to afford the switch to heat pumps, and to cut their energy bills after doing so.

Bucks for Boiler proposes expanded subsidies for the heat pumps themselves, bringing their up-front cost in line with those of boilers and furnaces.

Much of New York's building stock is old and in varying states of disrepair, particularly in low-income communities that have experienced decades of disinvestment. As a result, some households require weatherization and repairs to experience lower bills after installing heat pumps. Bucks for Boilers subsidizes these too.

Bucks for Boilers would subsidize three distinct types of homes across both single and multifamily buildings:

1. **Heat pump only**: units that would benefit immediately from a transition off fossil fuel heating, with lower monthly energy bills right away;
2. **Weatherization first**: units that would require some weatherization work alongside heat pumps installation to lower their bills;
3. **Repairs needed**: units that would require repair and remediation of mold, asbestos, roof leaks, and other health & safety issues before weatherization and heat pumps.

Different units would need different upgrades to electrify with savings. But in order to ensure that all households can afford these upgrades to begin with, Bucks for Boilers would offer up-front subsidies according to their income level:

- **Low** and **moderate-income** households would have their upgrades—over and above the cost of replacing their boiler or furnace—fully paid for, allowing them to benefit from lower energy bills immediately.

- **Medium** and **high-income** households would receive whatever dollar amount allows their upgrades to pay for themselves (with the resulting savings) after four and seven years, respectively.

There is a category of homes that cannot currently benefit financially (by way of lower heating bills) when switching from fossil fuels to clean heat, even when heat pumps, weatherization and repairs are fully subsidized.

This may change as utility rates, heat pump costs, electricity and gas prices evolve in coming years. In order to provide conservative estimates, the analysis assumes that today's costs continue unchangingly into the future, and does not rely on forecasts of commodity prices, technological progress, or policy changes.

Who commissioned this report?

This report was commissioned by Spring Street Climate Fund, a non-profit organization working to win climate policy in New York that makes a difference on a global scale.

Who is Win Climate?

Win Climate is a think tank that provides legislators and advocates with rigorous and actionable data on state climate policy.

Our team of data scientists and policy experts brings evidence-based insight to climate and energy issues.

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EXECUTIVE SUMMARY

New York's single largest source of climate pollution is buildings. Statewide, buildings are responsible for approximately one-third of total emissions, primarily from burning fossil fuels to produce heat and hot water. [2]

[2] According to the NYS Department of Environmental Conservation's 2022 Statewide GHG Emissions Report (NYS DEC 2022)

To decarbonize New York's most polluting sector, over 5 million homes will have to replace their fossil-fueled heating systems in the coming decades with electric heat pumps. Many must also weatherize, insulating and air sealing to stop wasting heat.[3]

[3] See NY Climate Scoping Plan Integration Analysis (NYSERDA 2022)

In 2019, New York State passed the Climate Leadership and Community Protection Act (CLCPA), which enacted ambitious statewide targets to reduce greenhouse gas emissions and transition to a clean economy. The law requires New York to reduce emissions by 40% from 1990 levels by 2030 and 85% by 2050.

Recent laws passed by the State of New York require that all new buildings be properly insulated[4] and heated with electricity[5]. To meet its climate goals, New York will need to heavily subsidize and streamline pathways for building electrification and weatherization. If done successfully, New York will manage to decarbonize the building sector while cutting energy bills for residents.

[4] The Advanced Building and Appliance Codes Act of 2022 (Parker and Fahy 2022)

[5] The All-Electric Building Act of 2023 (Kavanagh and Gallagher 2023), a version of which was enacted in the state's FY '23-24 budget.

To realize this vision, the GasFreeNY Coalition has announced Bucks for Boilers, a proposal that realizes the Scoping Plan's key recommendations by implementing two complementary policies:

- A **mandate** that heating systems installed in existing buildings must run on electricity, not combustible fuels, after 2030;
- **Subsidies** for heat pumps, weatherization, and repairs, ensuring that every household can afford the upgrades needed to electrify their heat while saving money on their energy bills.

The proposal, described in more detail in the introduction, envisions a combination of State regulation and financial support that would electrify buildings at the speed and scale required to achieve the CLCPA's legally-binding decarbonization targets, while ensuring that New Yorkers benefit financially from the transition.

This report evaluates Bucks for Boilers and finds that:

- **88% of New York households would save money** through Bucks for Boilers. Of these households, we show that, upon completion of the subsidized upgrades described above:
    - **Low-income households would save a median of $510 (20%)**

Bucks for Boilers uses these income levels:
Low: <60% of Area Median Income
Moderate: 60-120% AMI
Medium: 120-180% AMI
High: >180% AMI

annually on their energy bills, and would realize those savings immediately.

- **Moderate-income households would save a median of $630 (20%) annually on their energy bills**, and would also realize those savings right away.
- **Medium income households would save a median of $890 (24%)** annually on their energy bills. These households recoup their up-front investments through bill savings after **4** years, and then save money in subsequent years.
- **High income households would save a median of $900 (26%) annually on their energy bills.** High income households would pay the highest up-front cost, which would pay for itself after **7** years, and then save money thereafter.

In order to meet the state's mandated climate goals, **94%** of homes in New York State must install cold-climate heat pumps in the coming decades. Of these homes, our research finds that:

- **40% of these homes would save money immediately on monthly energy bills** by switching from fossil-fueled heating to heat pumps;
- **48% would require weatherization** alongside heat pump installation to realize monthly savings on energy bills;
- **12% would not see savings even after being weatherized** given today's electric and gas prices, and would need alternative compensation to ensure an equitable transition;
- **Savings are greatest for homes heated with electric resistance or delivered fuels** (propane, oil), which would save a median of **$1,400 per year** after switching to heat pumps. The median home heated by natural gas save **$380** per year, on average.

To ensure that all **residential buildings** can afford to electrify with savings when their fossil fuel heating dies out, we estimate that the State of New York would need to spend an average of **$4.5B** per year between 2025 and 2050. This study looks at residential buildings only—we do not estimate the additional cost to electrifying the state's commercial buildings.

These subsidies are designed so that low- and moderate-income households incur no up-front costs[6], medium- and high-income households enjoy reasonable payback periods, and all New Yorkers experience the transition to heat pumps as an upgrade, not a burden. This level of investment from the State, combined with Federal support, would ensure the vast majority of residences save money annually in a fossil-free New York.

[6] Over and above the cost of replacing their existing boiler, furnace, or other heating system.

Since heat pumps are currently more expensive than boilers and furnaces, public funds would help pay for the cost difference between replacing the fossil fuel equipment and upgrading to a cold-climate air source heat pump.

In cases where building envelopes must be tightened to produce lower bills after electrification—and only in those cases—weatherization and, when needed, pre-weatherization repairs, would also be covered.

Note on our spending estimates

Our annual spending estimate of **$4.5B** for New York State is specific to achieving Bucks for Boiler's proposed **payback periods**:

- Low- and moderate-income New Yorkers would be able to benefit from lower energy bills immediately, which requires that they spend no more out-of-pocket, on whatever upgrades they need to electrify-with-savings, than they would have paid for a new boiler or furnace.
- While moderate and high income people would also receive subsidies for their upgrades, they would pay more out-of-pocket.

This estimate also assumes that today's gas and electricity prices remain stable, and does not account for projected decreases in the cost premium for heat pumps.

It also does not include the state's existing energy efficiency spending, or any funding that might available through the state's forthcoming cap-and-trade program.

FINDINGS

Today, only **6%** of New York State' apartments and houses have heat pumps. By 2050, nearly all homes must install them to meet New York's legally-binding target of net-zero climate pollution.[7]

[7] See NY Climate Scoping Plan Integration Analysis (NYSERDA 2022)

In order for New Yorkers to experience heat pumps as an upgrade, not a sacrifice, proponents of Bucks for Boilers want to ensure that energy bills decrease after residential buildings install heat pumps.

In cases where installing a heat pump does not produce lower energy bills, the proposal envisions heat pumps combined with **weatherization** as the core tool to ensure that households experience ongoing cost savings. (Other methods, such as carbon pricing or redesigned electric rates, are outside the proposal's scope.)

Weatherization
Reducing heat loss in a building by sealing air leaks and insulating attics, walls, and basements

This report takes a conservative approach to estimating the benefits and costs of Bucks for Boilers: we assume that today's utility rates, gas prices, and electricity prices remain fixed, and do not attempt to forecast likely decreases in the price of heat pumps.

To shed light on what New York State must do to cut home energy costs as the state electrifies, we answer the following questions:

- *How many of New York's households would save money after they electrify?*
- *How many must weatherize before they see bill savings?*
- *How many of these units require pre-weatherization repairs?*
- *How large would the savings resulting from these upgrades be?*
- *How much would the upgrades cost?*
- *So that everyone can afford these upgrades, how much of the cost must be covered by the government?*
- *How much would be paid for by the federal Inflation Reduction Act (2023)?*

Overview of our model

To answer these questions, we employ state-of-the-art energy simulations on a representative sample of New York's buildings.[8]

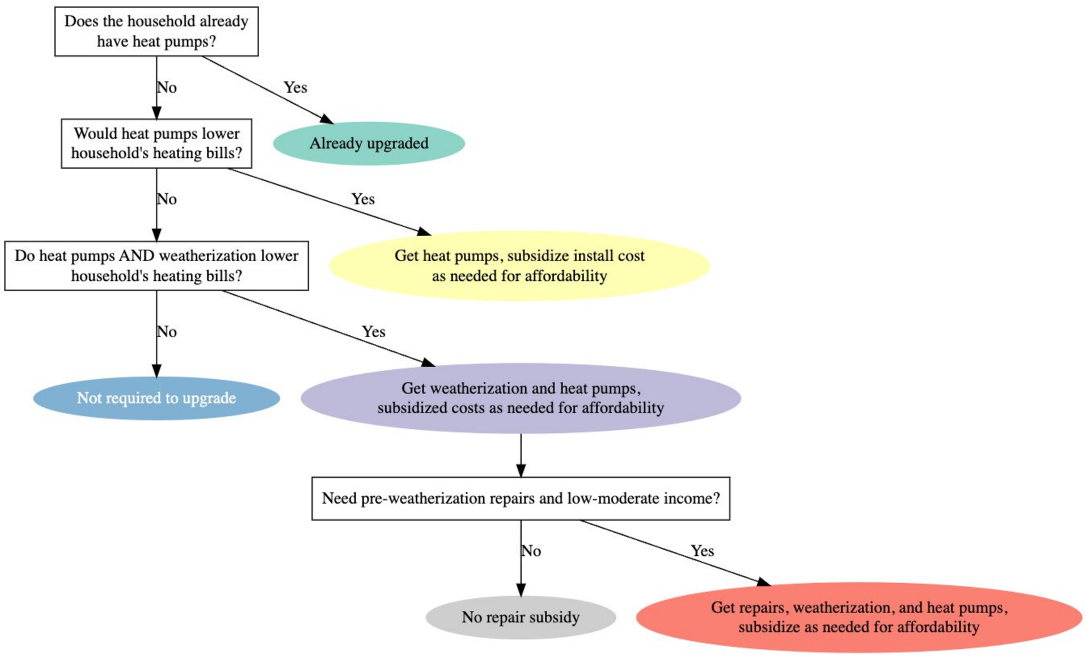
[8] Using NREL's End-Use Load Profiles for the U.S. Building Stock (EULP, Wilson and Li 2021) dataset. See Section 4.3.2 in appendix for technical details.

For each household in the sample, we:

1. **Identify upgrades**: determine which upgrades are needed for the household to save money after installing cold-climate air source heat pumps, and

2. **Calculate subsidies**: compute the subsidy needed for the household to afford these upgrades, based on their annual income.

Our model's logic is outlined below:



Identifying necessary homes upgrades

To start, we identify the specific upgrades each housing unit needs: would heat pumps be sufficient, or must they also weatherize? Are health & safety repairs required before weatherization can proceed?

For every housing unit in New York State, we simulate how much energy it would consume per year before and after switching to heat pumps (with and without weatherization) and calculate the resulting impact on gas and electricity bills. Then, we estimate how likely the households is to need repairs, and assign it to one of five **outcomes**:

Scenario outcomes

1. **Already sufficient**: homes that already have heat pumps (or wood stoves), so no further upgrades are needed.
2. **Electrification**: homes that could buy heat pumps tomorrow and instantly see savings.
3. **Electrification + Weatherization**: homes that need weatherization before they see savings with heat pumps.
4. **Electrification + Weatherization + Repair**: homes that need weatherization to see savings and also require repairs before weatherization.
5. **Not required to upgrade**: homes where heat pumps increase bills even after being weatherized.

Findings: what upgrades do homes need to save money with heat pumps?

Given today's heat pump, weatherization, and fuel costs, where do each of New York's **8,149,600** households end up?

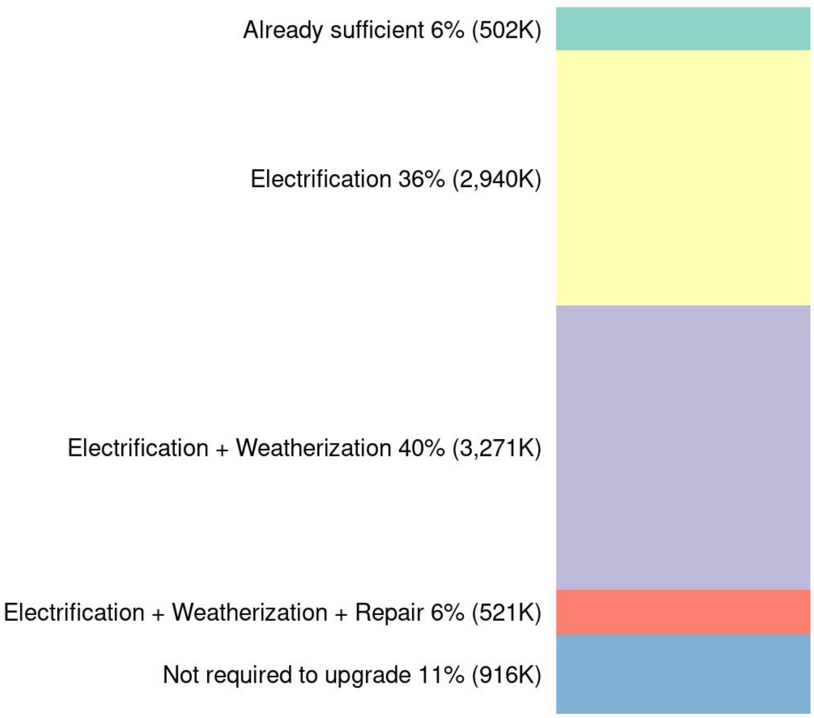


Figure 1: NYS households by scenario outcome

A fraction of New York's homes have already upgraded, so we analyze the remaining **94%** of households across the state that are still heated by fossil fuels or electric resistance.

Heat pumps can lower bills in **88%** of the homes that have yet to adopt them. Of these 88%, **46%** would see savings immediately, while **54%** would need to be weatherized first.

Of the homes that need weatherization to see lower heating bills, an estimated **14%** require pre-weatherization repairs. These expensive repairs are needed most often by low-income New Yorkers, who can least afford them.

Can these outcomes be improved?

Our analysis uses 2023 heat pump prices and efficiencies[9] and assumes these will persist through 2050. This is a highly conservative assumption. Heat pump prices are expected to drop with increased manufacturing and more installers competing in the market, reducing the need for subsidies.

[9] See Section 4.3.4.1 in our technical appendix for details.

Heat pump efficiency is also expected to continue improving, increasing savings, reducing the need for weatherization, and shrinking the pool of homes that can't upgrade without their bills going up. This would further reduce the need for subsidies, while increasing benefits to households.

Our findings also reflect the availability of cheap fracked gas and the high cost of electricity in New York. Cutting the price of electricity by building out renewable energy, or raising the price of fracked gas, as New York's planned cap-and-trade system would likely do, would have the same effect as better heat pumps: savings would go up, and subsidies would go down.

Finally, these outcomes reflect the design of New York's electric rates, which handicap heat pumps. Recent studies by ESIG[10] and ConEd [11] suggest heat pump-friendly rates could also increase household savings and decrease needed subsidies.

[10] ESIG's simulated study (Sergici et al. 2023) suggested that MA customers with heat pumps would save money by switching to time-of-use and demand rates

[11] ConEd's real-world experiment (ConEd 2023) concluded that NY customers switching to demand rates saw bill savings.

How much would households save after upgrading?

If installed as envisioned in the Bucks for Boilers proposal, with weatherization included for homes that need it to realize bill savings, heat pumps would cut energy costs for **6,731,700** households, saving them a median of **$730** a year.

Since every building is different, some households would save more than others. The single biggest determinant of savings, however, is how the building is currently heated:

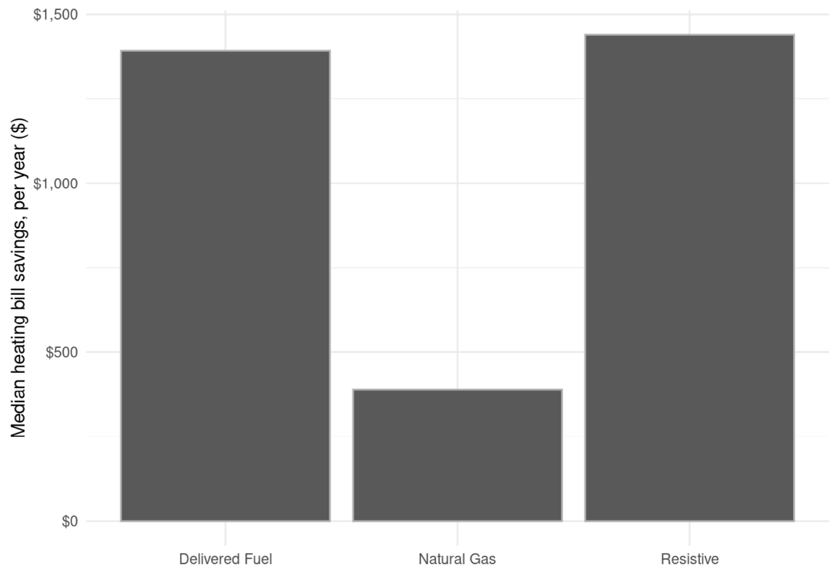


Figure 2: Median heating bill savings, by heating system

Electric resistance and delivered fuels heat **34%** of New York's households. These **2,755,400** homes would save a median of **$1,440** and **$1,390** a year, respectively.

Homes that are currently heated by natural gas, around **60%** of the state, would save a median of **$380** annually.

Electric resistance
An inefficient—and therefore expensive—form of electric heating that warms air by running a current through a resistive element

Delivered fuels
Fossil fuels like propane or heating oil, which must be delivered by trucks when homes lack natural gas hookups

How much would it cost for households to upgrade?

Today's heat pumps cost thousands of dollars more to purchase than new boilers or furnaces, the so-called heat pump premium. Weatherization can cost thousands of dollars more. Pre-weatherization repairs range from relatively affordable (roof leaks) to eye-wateringly expensive (asbestos removal).

Heat pump premium
The added cost of replacing a boiler or furnace with a heat pump, e.g. if a new boiler costs $3K, and an equivalent heat pump costs $7K, the premium is $4K

When heat pumps and weatherization produce lower bills, these investments pay for themselves over time. But if households cannot afford these up-front costs when the time comes to replace their heating systems, then the lower energy costs that would result are inaccessible.

How much would it cost, then, to upgrade each housing unit in the state so it can electrify-with-savings?

Below is the median upgrade cost for each income level, beyond the cost of replacing a broken boiler or furnace which has reached the end of its life.

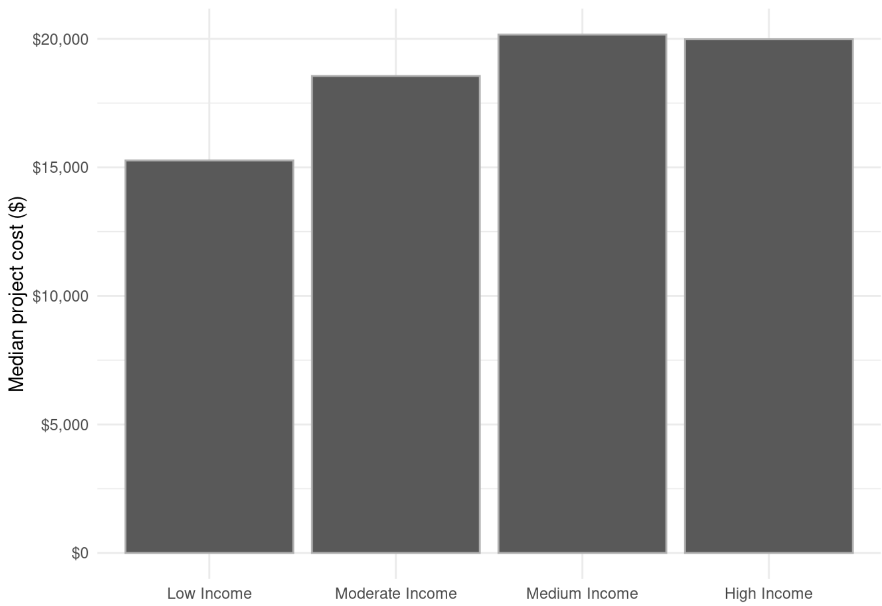


Figure 3: Median up-front upgrade costs, by income level

Bucks for Boilers uses these income levels:
- **Low**: <60% of Area Median Income
- **Moderate**: 60-120% AMI
- **Medium**: 120-180% AMI
- **High**: >180% AMI

Our findings reveal that low-income homes require a median investment of **$15,260** to electrify with lower bills, while high-income homes require a median investment of **$19,980**.

Wealthier households have greater up-front upgrades costs because they tend to have larger homes, which require larger heat pumps and more weatherization. While low and moderate-income households are more likely to need pre-weatherization repairs, their median up-front costs still tend to be lower.

What subsidies are needed for households to afford upgrades?

While these up-front costs would be largely recouped through bill savings, many households would need subsidies to pay for them in the first place.

Bucks for Boilers would subsidize households using a sliding-scale. This is because high income households can likely afford to pay for a heat pump in cash, and wait a few years to get a return their investment, whereas low income households, who would derive much greater benefit from cheaper bills, may struggle to even qualify for a loan.

After a household upgrades their home, their bills would decrease by a set amount, which would be used to "pay back" the up-front cost. The bigger the subsidy, the larger the savings. The larger the savings, the shorter the payback period, and the sooner a household can benefit from lower bills.

Payback period
The amount of time required for the lower energy bills resulting from an energy efficiency measure to pay back the measure's up-front cost

Bucks for Boilers subsidy scheme

Our model implements the subsidy scheme proposed by Bucks for Boilers, subsidizing each household up to the point where it can achieve the payback period corresponding to its income level:

Income level	Definition	Payback period
Low	0-60% AMI	0 years
Moderate	60-120% AMI	0 years
Medium	120-180% AMI	4 years
High	180%+ AMI	7 years

Recall that Bucks for Boilers only subsidizes a household's upgrades if their energy bills are expected to decrease after installing heat pumps.

In order to benefit from those savings immediately, low and moderate income households would have their upgrade costs—over and above the cost of replacing their boiler or furnace—completely paid for.

Medium income households would be subsidized up to a 4 year payback period, meaning that lower bills would pay back the initial out-of-pocket costs after 4 years. High income households would be subsidized up to whatever level achieves a 7 year payback period.

Findings: out-of-pocket and subsidy costs

The following charts break down what share of each income level's upgrade costs would be paid for by property owners, the federal Inflation Reduction Act, and the State of New York:

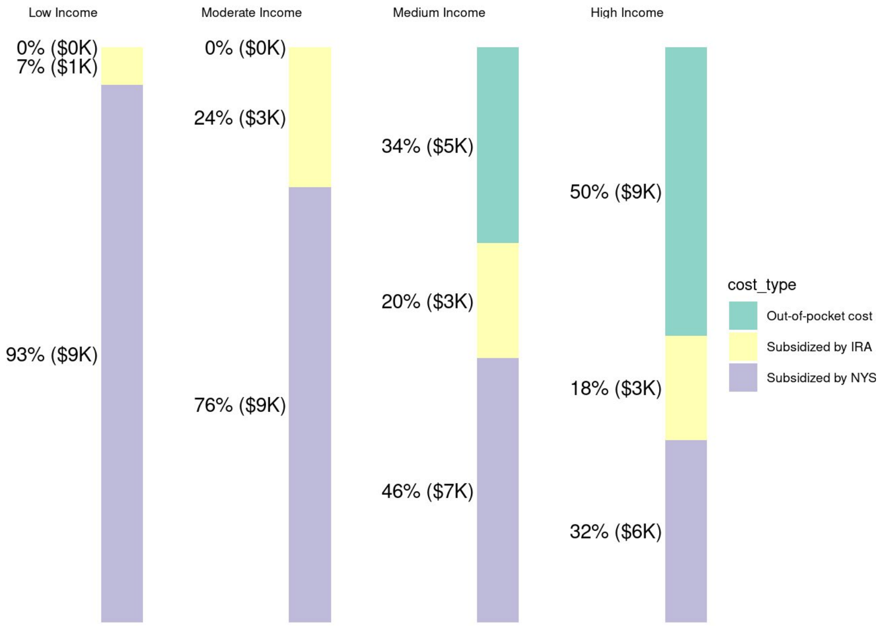


Figure 4: Average up-front upgrade costs and subsidies per household, by income level

If New York State were to implement Bucks for Boilers, low and moderate income households would pay nothing out of pocket above the cost of replacing their existing systems. Medium income households would have a median of 61% of their up-front costs subsidized, and pay a median of $6K out-of-pocket. High income households would pay a median of $9K more up-front, and have 55% of their upgrades paid for by federal and state government.

The federal Inflation Reduction Act (2023) includes tax credits for heat pumps and weatherization, which would cover about 20% of the upgrade cost for moderate, low, and high income households. Low income owner-occupied households, who often don't have tax liability, benefit less on average. Rental properties are covered under a different tax break related to energy efficient building properties, which we also model.

After applying these federal incentives, the remaining needed would be paid for by state government.

All costs in this section are in 2023 dollars.

How much would these subsidies cost the State of New York?

Bucks for Boilers boils down to mandates and subsidies: the mandates required for New York's buildings to gradually electrify by 2050, and the subsidies needed, given current energy and equipment prices, to ensure that consumers benefit financially from the transition.

This building-by-building transformation would largely unfold over the next 30 years, particularly after boilers and furnaces are phased out in 2030. Given when each home's current heating system is expected to die, and the subsidy needed for it to electrify-with-savings, we calculated how much it would cost New York State to enact Bucks for Boilers.

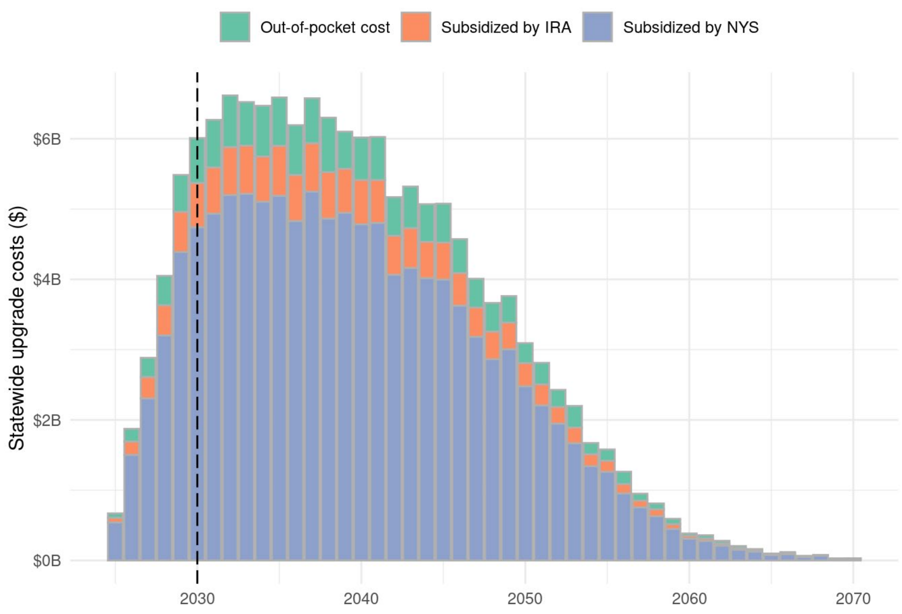


Figure 5: Total upgrade costs and government subsidies, by year

Between 2025 and 2050, the IRA would provide an average of **$436M** per year, in the form of leaving an average of **$4.1B** per year that New York State would need to spend on heat pump, weatherization, and repair subsidies in order to equitably decarbonize residential buildings.

Where would this money come from?

Under the New Efficiency: New York initiative, New York State already spends $1B in ratepayers dollars every year on energy efficiency programs. While these programs provide heat pump and weatherization incentives, around half of the money is spent on other gas and electrical efficiency measures, and pre-weatherization repairs are largely ineligible.

These existing subsidies are not reflected in the chart above: our goal in this study was to estimate how much state funding would be required to realize the Bucks for Boilers subsidy scheme *after the IRA is accounted for*. During implementation, this state revenue could be collected from any number of sources: ratepayers, taxpayers, cap-and-trade program revenues, and so on.

Finally, this is how much the program would cost in total over the next few decades:

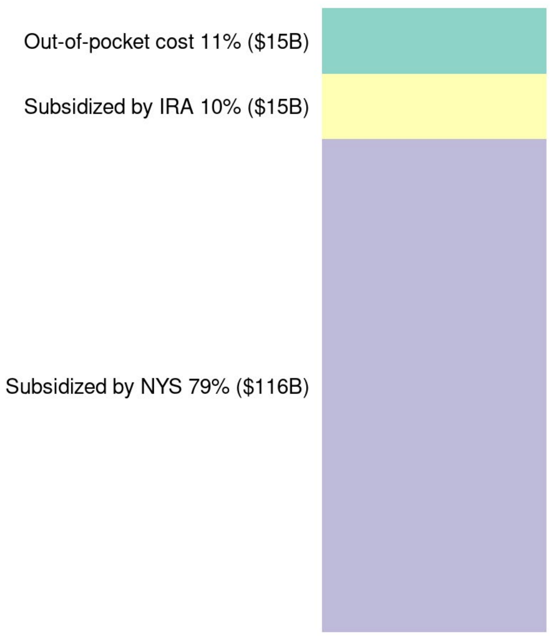


Figure 6: Total costs of transition (2025-2070), by payee

Table 1: Cost to New York State of implementing Bucks for Boilers, by year

Replacement Year	Yearly Cost (millions)
2025	$548
2026	$1,534
2027	$2,366
2028	$3,260
2029	$4,472
2030	$4,837
2031	$5,041
2032	$5,309
2033	$5,334
2034	$5,192
2035	$5,305
2036	$4,948
2037	$5,359
2038	$4,962
2039	$5,054
2040	$4,876
2041	$4,879
2042	$4,159
2043	$4,254
2044	$4,083
2045	$4,083
2046	$3,697
2047	$3,250
2048	$2,916
2049	$3,064
2050	$2,533
2051	$2,250
2052	$1,970
2053	$1,691
2054	$1,370
2055	$1,279
2056	$974
2057	$770
2058	$647
2059	$465
2060	$314
2061	$281
2062	$220
2063	$154
2064	$134
2065	$78
2066	$94
2067	$52
2068	$69
2069	$25
2070	$25

TECHNICAL APPENDIX: DATA & METHODS

Background

94% of households in New York state are heated with fossil fuels or inefficient resistance heating. At present prices and efficiencies, 88% of them would save money on their annual utility bills by switching to **cold-climate Air Source Heat Pumps** (ccASHPs). Before they could see savings, some of these units would need to **weatherize**, and some units would need **repairs** before they can weatherize.

At the moment, however, many households struggle to afford the high up-front costs of these **upgrades**: ccASHPs, weatherization and repairs can each costs tens of thousands of dollars. Prices for ccASHPs may come down over time, but depending on cost declines could mean waiting too long to hit the CLCPA's emissions targets.

Home heating systems typically last between 15-25 years. Installing ccASHPs when currently systems die, weatherizing and repairing homes when necessary, and offering sufficient subsidies so households can afford these upgrades smoothly electrify New York's building heat, cutting energy bills and emissions.

In this report, we analyze **Bucks for Boilers**, a proposal by the GasFreeNY coalition that fleshes out this vision. Subsidies would be available voluntarily starting in 2025. Starting in 2030, whenever a household's heating system reached end of life, they'd be required to replace it with electric heat, ideally ccASHPs, unless projections showed that the household would lose money on their yearly bills from the switch.

Concepts

Upgrades

Some households would cut their energy bills just from switching to ccASHPs.

Others might only save money if their home is also weatherized, or would save enough from weatherization to justify the cost.

In addition, some households would require repairs to make weatherization possible (such as remediating mold or asbestos). **Bucks for Boilers** would subsidize these repairs for low and moderate income households when weatherization is indicated.

Up-front costs

The up-front costs of whatever **upgrades** each home needs to electrify-with-savings, over and above the cost of replacing the home's current heating system, would be paid by three sources:

1. **Federal tax credits** from the Inflation Reduction Act
2. **State subsidies**
3. Household **out-of-pocket expenses**, paid back by energy bill savings

Payback periods

Not every household has an **upgrade** package that can lower their bills after installing heat pumps. But for households that can achieve savings, their **out-of-pocket expenses** can be evaluated in terms of a **payback period**: how long it'll take for the resulting savings to pay back the household's share of the up-front costs.

For instance, a ccASHP purchased with no **federal tax credits** or **state subsidies** might have a 10-15 year payback period. Using those federal and state incentives would bring down the payback period, so residents can pocket the savings sooner.[12]

[12] Over time, changes in the price of electricity and fossil fuels could change the household's ultimate payback period.

Subsidies

Bucks for Boilers would subsidize each home's upgrades up to whatever level is required to reach the **target payback period** associated with their household's income:

Income level	Definition	Payback period
Low	0-60% AMI	0 years
Moderate	60-120% AMI	0 years
Medium	120-180% AMI	4 years
High	180%+ AMI	7 years

In other words, if a household needing heat pumps, weatherization, and repairs has an annual income under 120% of their area's median income, **state subsidies** would cover 100% of the cost of these **upgrades** *not already paid for* by **federal tax credits**, minus the price of a new boiler.

Example

Let's say a high-income household installs a $17,000 heat pump, instead of buying another $5,000 boiler. Federal tax credits cover $3,000, leaving them with $14,000 to pay out-of-pocket.

They would've paid $5,000 for a new boiler, so the heat pump premium—the cost difference between the heat pump and replacing their existing system—is $9,000, in this case.

Bucks for Boilers only subsidizes the premium, not the heat pump's entire cost. The heat pump would cut their energy bills by $1,000 a year compared with the boiler, leaving them with 9 year payback period *on the premium*. This exceeds the household's **target payback period** of 7 years.

Under Bucks for Boilers, the state would then kick in a $2,000 subsidy, leaving the household to pay $7,000 out-of-pocket for the premium, to be paid back by savings over 7 years.

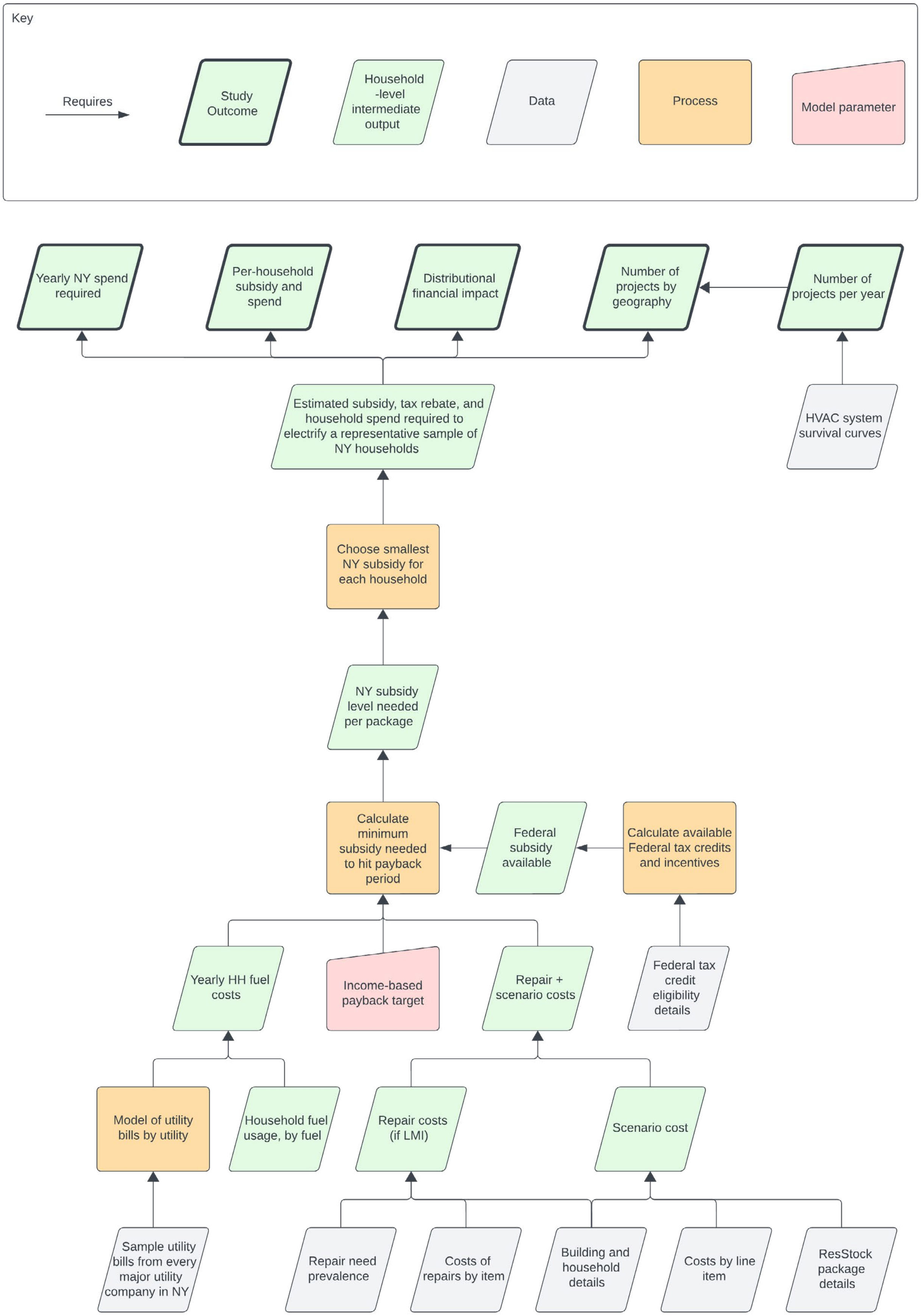
Model & Datasets

The remainder of this technical appendix lays out how we calculate each household's **federal tax credits**, **state subsidies**, and **out-of-pocket expenses** under Bucks for Boilers.

Big Picture

For an overview of how the various components of our model fit together at a high level, see Figure 7. For a technical description of the model, see Section 4.3.3.1, Section 4.3.5.3, and Section 4.3.6.6.

Figure 7: Dependency flowchart



Housing units and load profiles

To estimate energy loads under different heating scenarios, we relied on ResStock, an NREL optimization model that simulates energy consumption for a representative, synthetic sample of US households. Households are simulated at rate of 1 in 242 compared to the actual population. Simulations are run for various electrification scenarios (see Section 4.3.3).

The dataset resulting from these ResStock simulations is the called End-Use Load Profiles for the U.S. Building Stock (EULP, Wilson and Li 2021). We used the 2022 release of EULP, version 1.1 run on weather year 2018.

There are 33,676 New York housing units in EULP. The units could be stand-alone single family homes, or apartments in a multi-family buildings. The dataset contains hundreds of variables describing the physical characteristics of each unit: the number of floors, number of exterior walls, wall materials, type of HVAC system, efficiency of hot water systems, air infiltration levels, solar exposure, basement types, and so on.

To illustrate, here are 10 synthetic housing units for New York, showing just a handful of the hundreds of variables available in the dataset:

bldg_id	type	square_feet	age	heating_fuel	air_conditioning
10	Single-Family Detached	885	<1940	Natural Gas	Room AC
11	Multifamily with 5+ units, 1-3 stories	1138	<1940	Natural Gas	Room AC
27	Multifamily with 5+ units, 1-3 stories	1623	1950s	None	Room AC
64	Multifamily with 2-4 Units	853	<1940	Natural Gas	Room AC
67	Single-Family Detached	2663	1970s	Propane	Room AC
69	Multifamily with 5+ units, 1-3 stories	617	<1940	Electricity	Room AC
72	Single-Family Detached	2176	1960s	Fuel Oil	Central AC
76	Multifamily with 2-4 Units	853	1980s	Natural Gas	None
132	Multifamily with 5+ units, 1-3 stories	2590	2010s	Natural Gas	Room AC
161	Single-Family Detached	1690	1970s	Fuel Oil	Room AC

ResStock uses these variables to build a 3D model of each housing unit. It then uses EnergyPlus to simulate how the units' appliances would behave in response to a sample year of weather in that geographical area.

For each unit, this simulation outputs time series of electrical, gas, and fuel oil consumption at 15 min intervals, the so-called **load profiles**:

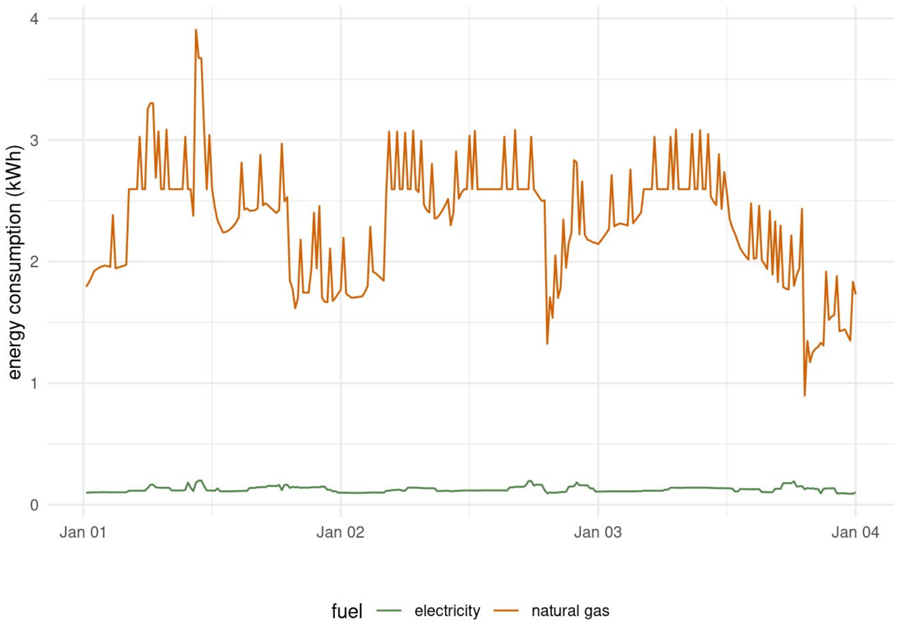


Figure 8: Electrical and gas consumption for a single unit over a 3-day period in the EULP dataset

For our analysis, we added up the amount of fuel consumed by each unit every month:

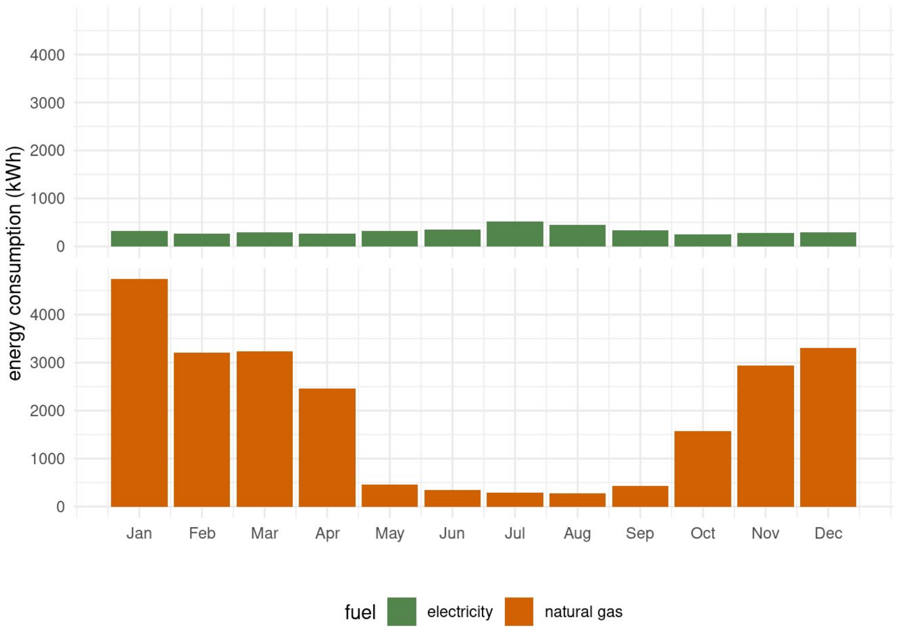


Figure 9: Monthly electrical and gas consumption for the same unit

This particular housing unit's electricity use is steady throughout the year, while natural gas peaks grows peaks in winter and plummets in summer, as expected.

Upgrade scenarios

The idea of ResStock is to simulate load profiles like these under alternative scenarios: what if the housing unit used heat pumps instead of whatever heating system it has now? What if also applied a basic weatherization package? How would electrical and gas consumption change month-by-month as a result?

The 2022 EULP release includes 10 scenarios, each capturing a different combination of building upgrades. Our analysis uses three of these:

1. **Baseline**: simulate the building using whatever building systems are currently installed—furnaces or boilers, gas water heaters, and so on. [13]
2. **Heat pumps**: simulate the building if it used a moderate-efficiency ccASHP, heat pump water heater, and heat pump dryer (if replacing gas) instead.[14]
3. **Heat pumps + weatherization**: the previous scenario, plus a weatherization package including air sealing, insulation of roofs, basements, and wooden walls, and a handful of smaller measures.[15]

Note

Because the 2022 EULP release only includes load profile for low efficiency[16] and very high efficiency[17] heat pumps, we felt it necessary to construct a load profile dataset using a moderate-efficiency unit, to make our results more accurate. To simulate a moderate efficiency heat pump, we averaged the energy savings from high and low heat pumps. [18]

[13] For full details on the baseline scenario, see here.

[14] Homes with ducts receive ducted heat pumps, while homes without receive mini-splits. Full heat pump specs here.

[15] Weatherization measures depend on details of each unit: for instance, only homes with wood studs walls, ducts, and basements received wall, duct, and basement insulation, respectively. For measure eligibility, see Section 4.3.4.4; for technical measure specs, see here.

[16] Ducted: SEER 15 / 9 HSPF
Ductless: SEER 15 / 9 HSPF
Complete technical specs here

[17] Ducted: SEER 24 / 13 HSPF
Ductless: SEER 29.3 / 14 HSPF
Complete technical specs here

[18] An approach suggested and validated by Mohammad Fathollahzadeh, building simulation expert at Rewiring America.

Here’s the monthly energy consumption for the same housing unit we saw earlier under scenario 2, when the gas furnace and water heater have been replaced by heat pumps:

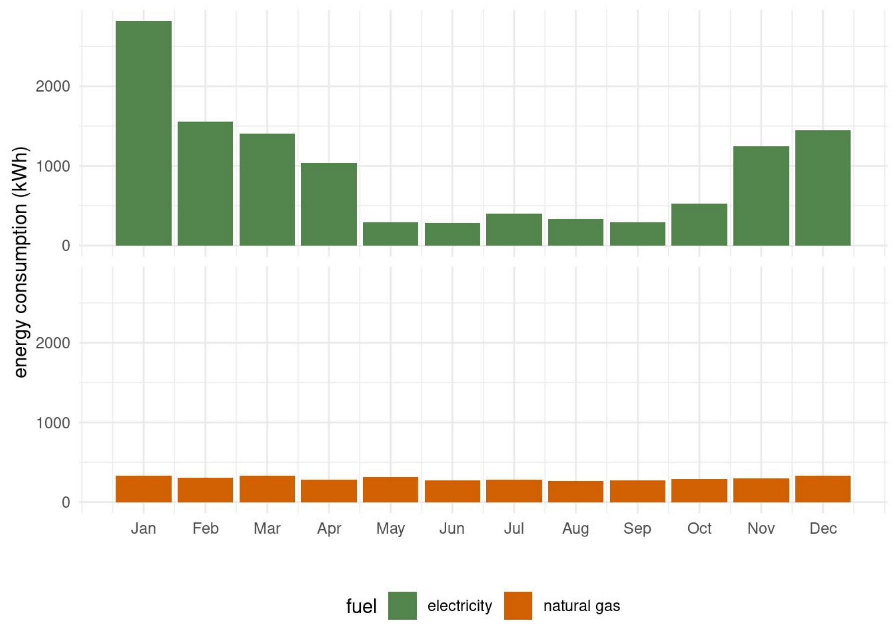


Figure 10: Electrical and gas consumption for over a 3-day period, Scenario 2

Natural gas consumption is nearly eliminated, leaving only what the gas stove uses. Electricity use now has the same winter-peaking shape that gas had in the baseline scenario. Notice that building is now consuming half as much energy, a testament to the efficiency of heat pumps.

Here’s what this same unit looks like under scenario 3, after weatherization (and the stove being electrified):

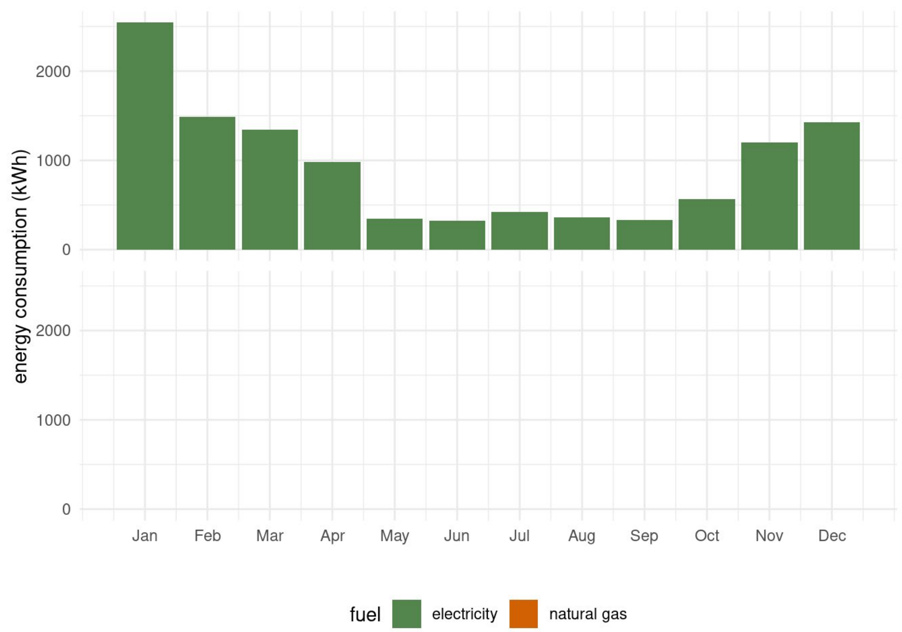


Figure 11: Electrical and gas consumption for over a 3-day period, Scenario 3

Technical description of upgrade scenarios

We now turn to a mathematical formalization of our model's upgrade scenarios.

Variable	Meaning
i	Index of simulated household
j	Upgrade scenario, $j \in \{0, 1, 2\}$ where $j = 0$ (baseline) $j = 1$ (heat pumps) $j = 2$ (heat pumps + weatherization)
$\vec{b}_i$	Vector of physical household characteristics For example: current heating system, square footage, presence of basement, insulation, and so on
k	Individual line items on an invoice For example: heat pump, furnace, insulation, heat pump installation labor, taxes, asbestos removal labor
$K_j(\vec{b})$	Mapping from $\vec{b}$ to the set of required k, under scenario j For example: given a particular brick apartment, what are all of the invoice line items required under scenario $j = 2$ (heat pumps and weatherization)?
$K_{i,j}$	The set of k for household i under scenario j Output from $K_j(\vec{b}_i)$
$R(k \mid j, \vec{b}_i)$	Probability of needing repair k for a household in order to be eligible for scenario j, based on characteristics in $\vec{b}_i$ For example: needing mold remediation, removal of asbestos, etc., based on the home vintage and region
$R_{i,j}$	The realized set of repairs required for household i under scenario j, drawn from $R(k \mid j, \vec{b}_i)$

Up-front costs

The EULP data tells us exactly which upgrades each household got under each scenario: the heat pump's BTU capacity, heat pump water heater's gallon capacity, whether they got a heat pump dryer, whether the roof was insulated with spray foam or cellulose, whether the basement was insulated, and so on.

But it doesn't tell us how much those upgrades actually cost to install. To calculate the up-font cost of each unit's upgrades, we gathered real-world prices for both equipment and labor from a multitude of sources.

Heating Systems: Heat Pumps

The cost of heat pumps varies based on capacity and model type. Using heat pump retrofit data from MA's MassSave Whole Home Electrification Pilot[19],

[19] Massachusetts Clean Energy Center ran a Whole-Home Heat Pump Pilot from May 2019 through June 2021, and produced a detailed dataset of 158 projects.

we modeled total installation costs as a function of BTU capacity using linear regression, for both ducted and ductless systems.[20]

For a given household in scenarios 2 and 3, we used this model to predict the installation cost of the heat pump, based on its BTU capacity and whether it was ducted or ductless.

[20] Specifically, we inflated equipment and labor costs using Q4 2022 inflation indices from FRED, the St. Louis Federal Reserve's economic portal, modeled and predicted each quantity separately, and combined the predictions to arrive at the estimated heat pump install cost for a given household.

Heating Systems: Furnaces, Boilers, Electric Resistance

Calculating the heat pump premium required estimating the costs of re-installing existing heating systems, be they furnaces, boilers, or electric resistance heat.

- **Labor costs**: we assumed a flat $1000 for all heating systems installations, based on conversation with HVAC contractors.
- **Equipment costs**: the housing units in the baseline had a very wide range of heating systems, so our equipment cost estimates needed to take this into account. Using web searches, we collected prices for a few dozen models of furnaces and boilers (both oil and gas), as well as electric furnaces and baseboards. We modeled equipment costs as a function of system efficiency and capacity using linear regression. For a given household in scenarios 2 and 3, we used this model to predict the equipment cost of replacing the existing heating system, based on its efficiency and capacity.

Water Heaters: Heat Pumps, Gas, Oil, Electric Resistance

Water heaters in the baseline scenario varied by fuel type (gas, oil, electricity), gallons, and BTUs. The heat pump water heaters in scenario 2 and 3 also varied by gallons and BTUs. To estimate the total up-front costs for water heaters, we used the same procedure as for (non-heat-pump) heating systems: a flat $1000 for labor costs, and regression models of market prices to predict equipment costs based on fuel type, gallons, and BTUs.

Weatherization

We gathered parts and labor costs for each measure in scenario 3's weatherization package through interviews with numerous weatherization contractors:

measure	unit	cost per unit	measure applies when...
air sealing	unit footprint area (ft^2)	$3.00	ACH50 > 15
attic insulation (blow-in)	attic floor area (ft^2)	$2.50	attic is unfinished
attic insulation (spray foam)	attic floor area (ft^2)	$11.87	attic is finished, roof insulation is R-13 or less

measure	unit	cost per unit	measure applies when...
wall insulation (drill-and-fill)	exterior wall area (ft^2)	$5.00	uninsulated wood stud walls
rim joist insulation (spray foam)	rim joist area (ft^2)	$4.75	foundation is heated basement or crawlspace
basement wall insulation (spray foam)	basement wall area (ft^2)	$4.75	foundation is unheated basement
crawlspace floor sealing (6mil plastic)	crawlspace floor area (ft^2)	$1.50	foundation is vented crawlspace
duct sealing	duct length (linear ft)	$7.00	leaky ducts in unconditioned space
duct insulation	duct length (linear ft)	$12.00	uninsulated ducts in unconditioned space

Repairs

Unlike heating systems and weatherization, the EULP dataset did *not* contain any data about the prevalence of problems like mold and asbestos that must be remediated before weatherization. Because Bucks for Boilers includes subsidies for pre-weatherization repairs, it was critical for our analysis to estimate pre-weatherization repair prevalence and costs.

To collect this data, we interviewed over a dozen weatherization contractors, asking them to estimate how often they encounter each of the following problems when they inspect low-to-moderate (LMI) income homes, and how much these problems cost to repair. We then averaged their responses to arrive at the following prevalence and cost estimates.

We found that single-family LMI buildings, which are often old and made of wood, experience a wide array of problems:

problem	prevalence	unit	cost per unit
mold in attic	12%	attic floor area (ft^2)	$4
mold in basement	7%	basement floor area (ft^2)	$4
water in basement	8%	per remediation	$1,000
vermiculite in attic	5%	per remediation	$10,000
knob & tube electrical	4%	total home area (ft^2)	$13
roof leak	7%	per remediation	$1,000

According to the contractors we interviewed, multifamily LMI buildings, especially those downstate, experience a smaller set of physical problems that directly impede air sealing and insulation, and these buildings tended to have easier access to loans to pay for remediation.

problem	prevalence	unit	cost per unit
mold in basement	7%	basement floor area (ft²)	$4
roof leak	9%	per remediation	$1,000

Electrical upgrades

Due to the higher electrical loads resulting from heat pumps, some older buildings, particularly multi-family ones, may require new service lines, panels, or wiring.

While our analysis estimated the prevalence and cost of pre-weatherization repairs, we did not attempt to do so for these pre-electrification upgrades. This is due to two reasons:

1. **Missing electrical capacity data**: No systematic data exists on the electrical capacity of New York State buildings.[21]
2. **Uncertain electrical capacity requirements**: Heat pump technology is moving so quickly that it is impossible to predict what electrical capacity will be needed to electrify New York's building stock. Today, the typical 1,000 square foot NYC apartment only needs a small heat pump system, which requires about 30 amps of current at full load. While an apartment with only 40 amp service would still need an upgrade to meet the electrical code[22], smart panels may obviate the need for this, and many buildings offer 60 amp service or above. And while induction stoves and window-unit cold-climate heat pumps used to require 240V lines, newer models[23] do not.

[21] See p. 16 of Urban Green Council's "Going Electric: Retrofitting NYC's Multifamily Buildings" (2020) report

[22] *ibid.*, p. 17

[23] See Impulse for 120V induction stoves, and Gradient for 120V cold-climate window-unit heat pumps.

While some level of electrical upgrades will undoubtedly be necessary, the amount is currently impossible to estimate with any accuracy, and may be lower than expected due to rapid technological progress.

Fuel costs

While EULP contained detailed fuel consumption time series for thousands of buildings under each scenario, it did not contain fuel prices. We gathered prices for electricity, natural gas, propane, and fuel oil from a variety of sources.

Electricity & Natural Gas

To make our analysis as accurate as possible, we assembled electricity and natural gas rates for standard residential customers for each utility in New York State. We did so by collecting dozens of customer bills, representing each utility territory.

The resulting utility rate dataset can be viewed here.

Propane & Heating Oil

We gathered average propane and average heating oil cost for October 2023 across New York State from the Energy Information Administration:

fuel	unit	price
oil	gallons	$4.41
propane	gallons	$3.27

Technical description of costs

What follows is a mathematical description of how we applied the **up-front** and **fuel costs** described above to the **upgrade scenarios** formalized in Section 4.3.3.1:

Variable	Meaning
$C_k(\vec{b})$	The up-front cost for line item k in household as a function of household characteristics Note this is a function because most of the costs scale proportionately with e.g. square footage, BTUs, etc.
$C_{i,j}$	The cost to get household i all of the requisite line items for scenario j $C_{i,j} = \sum_{k \in K_{i,j}} C_k(\vec{b}_i)$
s	Fuel type index (electricity, oil, propane or natural gas)
t	Month t (from 1 to 12)
$F_{i,j,s,t}$	Usage by household i of fuel s in month t under scenario j (in kWh, gallons, etc)
l	Fuel rate forecast regime. For this report, we used only one, which is to set rates for all time to those in October 2023.
$P_{s,i,l}(x)$	The total cost of fuel s at quantity x for household i (based on its geographical location and utility company)
$T_{i,j}$	Annual cost of all fuels to household i under scenario j $T_{i,j} = \sum_{s,t} P_{i,s,l}(F_{i,j,s,t})$

Subsidies

Federal subsidies: Inflation Reduction Act grants

Many states are looking to the subsidies within the Inflation Reduction Act to fund building decarbonization investments. In order to understand how big of an impact these subsidies would have, we had to incorporate them into our model.

Under the IRA's HER and HEEHRA programs, New York State will receive a combined total of $317 million in federal funds to spend on LMI building decarbonization. Given that these are one-time grants, and that New York will require several billion dollars *a year* in revenue for building decarbonization, we excluded these subsidies from our analysis.

Federal subsidies: Inflation Reduction Act tax credits & deductions

We did however apply IRA tax credits and deductions that cover envelopes, heat pumps, and heat pump hot water heaters:

- For owner-occupied units, the 25C Residential Energy Efficiency tax credit covers 30% of heat pumps, heat pump water heaters, and weatherization measures, up to $3,200 per year. That data can be viewed here.
- For renter-occupied units[24], the 179D Energy Efficient Commercial Buildings Deduction provides per-square-foot tax deductions for envelopes, heat pumps, and heat pump hot water heaters: $0.50 per square foot for buildings that achieve at least 25% energy savings with these measures, with an additional $0.02 per square foot for each percentage point of savings above 25%, for a maximum of $1 per square foot for 50% energy savings.

[24] In multi-family buildings of four or more stories, including those owned by non-profits or governments.

Federal subsidies: tax liability calculation

Since residential tax credits for homeowners can only be fully claimed by households with sufficient tax liability, we had to estimate each household's federal income tax burdens.

We used the TAXSIM 35 model (Feenberg and Coutts 1993), via the R package usincometaxes; we assume that households with two persons are married, and that those with $n > 2$ people are married, filing jointly, and with $n - 2$ dependents.

State subsidies

As noted in the reports, we purposely did not include any existing state incentives in our analysis. Our goal was to calculate much state funding would be required to realize the Bucks for Boilers subsidy scheme after accounting for the Inflation Reduction Act. During implementation, the state's existing building decarbonization could contribute to achieving Bucks for Boilers, and additional funds could be collected from ratepayers, taxpayers, cap-and-trade program revenues, and so on.

Area Median Income

Since the subsidy a household receives under Bucks for Boilers is based on their income level (see Section 4.2.4), and income levels are defined as percentage of Area Median Income (AMI), we needed to determine how each household's income compared to their area's median income.

Because the EULP data uses 2021-vintage income data from the American Community Survey, we used 2021 AMI statistics from the federal Department of Housing and Urban Development (HUD) to define our income buckets. The LMI income cutoff (80% of AMI) we used for every county and household size can we viewed here.

Technical description of subsidies

We now finish our model's technical description, by formalizing our subsidy calculations given the upgrade scenarios from Section 4.3.3.1 and the costs from Section 4.3.5.3:

Variable	Meaning
$\vec{h}_i$	Vector of information on household members, such as income, number of persons, county and so on
$m(\vec{h}_i))$	The income category of the household, e.g. LMI, middle income, high income
$G(m)$	The goal payback period, in years, as a function of income category
$D(\vec{h}_i)$	Federal income tax, as a function of household income and number of persons
$I(D, \vec{h}_i, C_{i,j})$	Federal tax subsidy from the Inflation Reduction Act (IRA), as a function of federal income tax, household income, and cost of upgrades under scenario j
$S_{i,j}$	The subsidy required to hit the payback period goal. If $T_{i,j} >= T_{i,0}$ for all $j \neq 0$, then household i has no scenario which saves money and so they are exempt from this program, and $S_{i,j}$ is undefined. Otherwise, $T_{i,j} < T_{i,0}$ for some j, and there are scenarios which save money yearly for the household. For these scenarios subsidy required is $S_{i,j} = \min(0, (C_{i,j} - C_{i,0}) - G(m) \cdot (T_{i,j} - T_{i,0}) - I(D, h_i, C^{i,j}))$
S_i	The chosen subsidy for a particular household, selecting the scenario with the lowest subsidy which hits the payback goal and still saves money. $S_i = \min_j \{S_{i,j} \mid T_{i,j} < T_{i,0}, j \neq 0\}$

The formula for $S_{i,j}$ follows the logic laid out in Section 4.2.4; the subsidy is what remains after accounting for the cost to upgrade, the tax benefits, and the yearly savings times the number of required years.

Assumptions

- **Costs remain fixed**: while heat pumps are expected to get cheaper, and fuel prices are notoriously volatile, we did not attempt to forecast up-front and fuel costs, but assume these costs are static through 2070.
- **IRA credits are renewed**: the IRA's 25C tax credit is currently set to expire on December 31, 2032. We assume the tax credit will be renewed due to the program's popularity. We also expect that 179D, covering rental properties, will be maintained.
- **Mandate kicks in fully in 2030**: we assume that an all-electric mandate would apply to all housing units in 2030; the Scoping Plan suggests that mandate should apply to single-family homes in 2030, and multi-family homes 5 years later.
- **Households pay for everything**: we assume that all households pay for upgrades/repairs and electric/natural gas/delivered fuel bills, as opposed to those charges being baked into their rent, or paid for by landlords.
- **Households receive subsidies**: we also assume that households always receive full federal and states incentives, even in the case of renters (see below).
- **Renters vs. owners**: to comply with the two preceding assumptions, we assume that landlords pass upgrade/repair/bill costs to tenants in the form of higher rent, and tenants receive subsidies to cover the costs of upgrades and repairs. In reality:
    - Landlords pay for upgrades and repairs, so they would be the subsidy recipients, for e.g. 179D tax credits.
    - Tenants typically pay for electric bills. Natural gas / delivered fuel are sometimes paid by tenants, and sometimes by landlords. In the latter case, installing heat pumps would shift heating bill payments from landlords to tenants. Our analysis ignores this possibility by assuming that tenants were already paying for heating through higher rent. Since this may not be the case for many low-income tenants, New York State should adopt policies to guard against this **cost-shifting**.
- **Pre and post-2030 scenarios**: our analysis is focused on the period after 2030. We identify which upgrades and repairs would be necessary for households to electrify with savings once they are unable to install furnaces and boilers, and evaluate a proposed subsidy scheme to make these projects affordable for all. In the period

before 2030, we assume that the market share of heat pumps would grow year over year, reaching 100% of heating system installations by 2030, in line with New York State's Climate Scoping Plan. We believe this assumption is justified: because proposed subsidy levels are significantly higher than at present, the cost to households of installing heat pumps would shrink, which would induce increased sales. We did not perform an econometric analysis to rigorously estimate the impact of reduced prices on sales, however.

- **Out-of-pocket costs paid with cash, not loans**: we assume that households pay after-subsidy up-front upgrade costs with cash. In practice, many households would take out loans. In this scenario, the loan's interest rate would affect the household's payback period, and therefore, by definition, the up-front subsidy they would receive.

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