Methodology Document Focus: Buildings

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INTRODUCTION

This supplement outlines the methodology and more detailed analysis results regarding the economic impacts of building electrification in Maryland, as shown in the piece "Heat Pumps Can Lower Energy Bills in Maryland Today." It explains how RMI used its Green Upgrade Calculator to arrive at the published outputs, describes key assumptions, and lays out results for analyzed water and space heating electrification scenarios.

METHODOLOGY

The analysis article uses RMI's Green Upgrade Calculator version 1.3 — a tool for energy professionals to analyze the lifetime cost and environmental benefits of residential decarbonization solutions, including heat pump upgrades. For more information about the model's data sources and calculations, please visit the Calculator's FAQ at the top right-hand corner of the webpage.

1. For this analysis, RMI assessed the up-front and operating cost impact of installing an air-source heat pump or a heat pump water heater relative to installing the same space heating equipment or water heater that is currently being operated using methodology from the US Energy Information Administration's (EIA's) RECS 2020 Microdata for Maryland. This was used to identify the typologies and prevalence of home types, existing HVAC systems, and existing water heating systems. See the *Home Typologies and Prevalence* section for more details.
2. The home typology data was used to identify the Green Upgrade Calculator simulations to run and generate up-front, operating, and lifetime cost results for each scenario. See the *Green Upgrade Calculator Inputs* section for more details.
3. Lastly, the results were weighted by each scenario's corresponding prevalence as noted in the *Home Typologies and Prevalence* section.

The analysis was limited to single-family attached and detached households due to the scope of the Green Upgrade Calculator and does not include mobile homes or multifamily dwellings.

GREEN UPGRADE CALCULATOR INPUTS AND ASSUMPTIONS

Each Green Upgrade Calculator analysis is conducted with inputs to inform the scenario analysis. The inputs include:

- Location (which is used for local climate and state electricity and gas prices)
- Home typology
- Year home was built
- Existing system and fuel used for space heating

- Existing system and fuel used for water heating

RMI analyzed 72 distinct scenarios for Maryland based on EIA RECs 2020 microdata. The data set represents about 1,188,100 detached single-family homes and about 372,700 attached single-family homes (i.e., townhouses). For details on percentages used for Maryland, see Appendix A.

Through this data set, we see the mix of homes by:

Climate Zone
4A (e.g., Baltimore, MD)
5A (e.g., Bloomington, MD)

Year home was built
Pre-1980
1980–2000
2000–present

Home size (sq ft)	Home Type
1,200	Single-Family Detached
2,200	Single-Family Detached
3,300	Single-Family Detached
1,751	Townhouse

The analysis assumes that either a furnace breaks *or* a water heater breaks and the homeowner either installs the same piece of equipment or upgrades to a heat pump or heat pump water heater. The analysis does not assess the cost impact of replacing both pieces of equipment at once. The new equipment lifetime is 15 years.

In all HVAC scenarios, we assume the homes have an air conditioning (AC) system. In the air-source heat pump upgrade scenarios, we assume the heat pump becomes both the primary heating and cooling system. In the business-as-usual scenario where a resident installs the same furnace, we assume either 1) the existing AC unit continues to operate for another 7 years before it needs replacement (default) or 2) the home has an aging AC unit that will need imminent replacement alongside the furnace (when specifically noted).

Consequently, when assessing costs over the 15-year lifetime of the HVAC equipment, the business-as-usual case incurs the cost of a new AC replacement at year 7. The heat pump upgrade case does not incur this cost.

For space heating, RMI used the following HVAC equipment variables:

Existing heating system	Existing cooling system	Upgraded heating/cooling system
Gas Furnace	Ducted Central AC	Ducted Central Air-Source Heat Pump
Fuel oil furnace	Ducted Central AC	Ducted Central Air-Source Heat Pump
Propane furnace	Ducted Central AC	Ducted Central Air-Source Heat Pump
Electric resistance furnace	Ducted Central AC	Ducted Central Air-Source Heat Pump
Gas boiler	Window AC	Ductless Mini-Split Air-Source Heat Pump
Electric resistance baseboard	Window AC	Ductless Mini-Split Air-Source Heat Pump

The type of air source heat pump installed is determined by the climate zone. Residents in Baltimore install a high-efficiency, moderate climate heat pump. Residents in Garrett install a high-efficiency, cold climate heat pump that serves as the primary mode of heating with electric resistance heating serving as a backup.

For water heating, the following water heater equipment variables were used:

Existing water heater	Upgraded water heater
Tank gas water heater	Heat pump water heater
Tank propane water heater	Heat pump water heater
Tank electric resistance water heater	Heat pump water heater

The annual bill impacts isolate the energy costs of the specified end-use: space heating scenarios show the annual cost for heating and cooling, water heating scenarios show the annual cost for water heating.

For all other model inputs, we used the calculated default values, including the following:

- **ENERGY RATES:** The volumetric rate for electricity and natural gas are the 2023 state average residential rate, and the volumetric rate for delivered fuel is the 2023 regional average, sourced from the Energy Information Administration.
- **HVAC SYSTEM SIZE:** The default air-source heat pump is sized to meet more than 95% of the annual heating load, with electric resistance for backup heating, based on its hourly capacity versus outdoor air temperature.

- **WATER HEATER TANK SIZE:** The traditional water heater tank size is estimated based on the home size and number of individuals. The heat pump water heater tank is sized one size up from the traditional unit based on industry standards (e.g., a 50 gallon gas water heater tank translates to a 65 gallon heat pump water heater).
- **UP-FRONT COSTS:** Up-front costs are estimated based on data and feedback from various home energy contractors and local electrification program advisors given the technology size and efficiency. These national estimates are then adjusted by Maryland RS Means material and labor indices to estimate state cost variation. The up-front costs include the full installation cost of the new equipment, including material, labor, and overhead. It does not include potential panel or service upgrade costs or weatherization.
- **HVAC EFFICIENCY:** The listed AFUE of the combustion furnace is 0.90 and listed SEER2 of the central AC system is 16. The listed SEER2 and HSPF2 of the ducted ASHP are 17 and 9 and ductless ASHP 19 and 9.5, respectively. The hourly efficiency of the ASHP is based on the performance curve for its minimum, average, and maximum capacity and efficiency versus outdoor air temperature. This performance curve is based on the manufacturer-reported data for an average subset of 100 common air-source heat pumps listed in the Northeast Energy Efficiency Partnerships' Air Source Heat Pump (ASHP) database, with the subset based on the user-selected ASHP size and ducting type. These performance curves are adjusted linearly based on any user override in capacity or efficiency (e.g., increasing the heating efficiency curve by 10% if a user overrides HSPF2 from 9.5 to 10.5), and derated by 15% to estimate reductions for real-world performance based on conversations with regional energy efficiency organizations. These performance curves are then applied to the hourly TMY3 temperature data in the user's climate zone. The supplemental heating element then covers any unmet heating load.
- **WATER HEATING EFFICIENCY:** The listed Uniform Energy Factor of the combustion tank water heater is 0.70 based on the value needed for the selected equipment to meet Energy Star requirements. The listed Uniform Energy Factor of the heat pump water heater (HPWH) is 3.7 based on common heat pump water heaters in the market today. The hourly efficiency of the HPWH is based on the performance curve for the HPWH's compressor's capacity and efficiency versus ambient air temperature. This performance curve is based on reported data from two common electric heat pump water heater manufacturers as found in HPWHSim; this data is also used in CBECC-Res. These performance curves are then derated by 15% to account for reductions for real-world performance. These performance curves are then applied to the hourly ambient temperature surrounding the water heater based on the selected water heater location (e.g., living space, basement, garage, outside) and the user's climate zone.

For more details, please visit the FAQ at the top right-hand corner of the Calculator's webpage.

RESULTS — WATER HEATING

All results are rounded to the nearest 10.

ENERGY BILLS

RMI's analysis found that residents upgrading to a heat pump for water heating could save $360 per year on average, ranging from $150 for gas customers to $520 for electric resistance customers. Values below are rounded to the nearest 10.

The primary driver of water heating bill savings was prior fuel type. Homes with electric resistance heating customers saved the most, followed by propane and gas water heating. In all cases, the heat pump water heater lowered energy bills.

Exhibit 1: Average first year water heating energy savings by equipment type after upgrading to HPWH

	Before electrification	After HPWH electrification	Savings with HPWH
Tank Natural Gas Water Heater	$ 320	$ 170	$ 150
Tank Propane Water Heater	$ 640	$ 160	$ 480
Tank Electric Resistance Water Heater	$ 690	$ 170	$ 520

For any insight on bill savings, there is likely to be a distribution of outcomes depending on consumer behavior, specific product choice, installation quality, and other variables. Though unable to account for every variable, our analysis simulated a range of bill outcomes for each retrofit by varying home size, equipment size, building envelope, and equipment type.

Exhibit 2: Minimum and maximum scenario results for first year of water heating energy savings after upgrading to HPWH

	Weighted average savings	Lowest observed savings	Highest observed savings
Gas Water Heater	$ 150	$ 100	$ 200
Propane Water Heater	$ 480	$ 340	$ 640
Electric Resistance Water Heater	$ 520	$ 360	$ 670

UP-FRONT COST, SIMPLE PAYBACK, AND LIFETIME SAVINGS

Heat Pump Water Heater: The up-front cost of an HPWH includes installed costs (labor, maintenance, and equipment capital cost) and the federal Inflation Reduction Act 25c tax credit that all US residents can access. We take the annual bill savings from the HPWH divided by the cost premium of an HPWH and compare to a like-for-like water heater replacement to estimate the simple payback. We use EIA's RECS 2020 microdata to assess the number of homes that fall within each payback period.

The simple payback period is 7 years or less for all HPWH scenarios.

Exhibit 3: Distribution of simple payback period, without state incentives

HPWH simple payback period	% of homes analyzed
0 years	0%
1 year	8%
2 years	47%
3 years	1%
4 years	0%
5 years	8%
6 years	28%
7 years	8%

In all cases analyzed, HPWHs save residents money over the 15-year lifetime of the equipment relative to gas, propane, or electric resistance water heaters. On average, residents can save over $5,000 with a heat pump water heater over the equipment lifetime. Lifetime savings include the up-front costs and the annual water heating bills with assumed rate projections.

Exhibit 4: Average 15-year lifetime savings after upgrading to an HPWH

	Weighted average lifetime savings
Tank Natural Gas Water Heater	$ 1,400
Tank Electric Resistance Water Heater	$ 7,930
Tank Propane Water Heater	$ 6,760

IMPACTS OF ILLUSTRATIVE STATE INCENTIVES (EMPOWER PROGRAM)

With HPWH incentives becoming more accessible, RMI's analysis explored the impact of incentives by applying incentives to a sample scenario. We look at a scenario with a mid-sized (2,200 sq ft) single-family home with a tank gas water heater. First, we apply an illustrative $1,600 incentive from the state and the 25c tax credit and find the HPWH cost is $160 cheaper than a gas water heater. When applying the maximum IRA HEAR rebate, which can be accessed by households with less than 150% Area Median Income, we found the HPWH becomes over $1,350 cheaper than a gas water heater.

Exhibit 5: Impact of hypothetical state incentives on up-front costs

	Capital cost	Illustrative utility rebate	IRA rebate	IRA tax credit	Out-of-pocket up-front cost
Tank Gas Water Heater	$2,200	$0	$0	$0	$2,200
Heat Pump Water Heater with Federal Tax Credit & Illustrative Utility Rebate	$4,300	$1,600	$0	$660	$2,040
Heat Pump Water Heater with Federal Tax Credit, Federal Rebate, & Illustrative Utility Rebate	$4,300	$1,600	$1,750	$135	$815

RESULTS – SPACE HEATING

ENERGY BILLS

Maryland residents upgrading to a heat pump for space heating and cooling could save $705 per year on average, ranging from $360 for gas customers to $1,670 for electric resistance customers.

The primary driver of space heating bill savings was prior fuel type. Customers with electric resistance heating saved the most, followed by heating oil and gas water heating. In all cases analyzed, the air source heat pumps lowered energy bills.

Exhibit 6: Average first year heating and cooling energy savings by equipment type after upgrading to ASHP

	Before electrification	After installing ASHP	Weighted average dollar savings
Gas Heat + AC	$ 1,230	$ 870	$ 360
Electric Resistance Heat + AC	$ 2,560	$ 890	$ 1,670
Oil Heat + AC	$ 2,170	$ 850	$ 1,320
Propane Heat + AC	$ 1,610	$ 600	$ 1,010

For any insight on bill savings, there is likely to be a distribution of outcomes depending on consumer behavior, specific product choice, installation quality, and other variables. Though unable to account for every variable, RMI's analysis simulated the range of bill outcomes for each retrofit by varying home size, equipment size, building envelope, equipment type, and climate zone.

Exhibit 7: Minimum and maximum first-year heating and cooling energy savings by equipment type after upgrading to ASHP

	Weighted average savings	Lowest observed savings	Highest observed savings
Gas Heat + AC	$ 360	$ 190	$ 460
Electric Resistance Heat + AC	$ 1,670	$ 950	$ 2,820
Oil Heat + AC	$ 1,320	$ 810	$ 2,030
Propane Heat + AC	$ 1,010	$ 1,010	$ 1,010

UP-FRONT COST, SIMPLE PAYBACK, AND LIFETIME SAVINGS

Air Source Heat Pump: The up-front cost of an air source heat pump includes installed costs (labor, maintenance, and equipment capital cost) and the Inflation Reduction Act 25c tax credit that all US residents can access. We take the annual bill savings from the heat pump divided by the cost premium of a heat pump over a fossil fuel or electric resistance space heater to estimate the simple payback. We use EIA's RECS 2020 microdata to assess the number of homes that fall within each payback period. The median payback period for the homes analyzed is 11 years. Homes using electric resistance see a payback within 2–8 years; homes with oil and propane see payback in 4–8 years; homes with gas see a payback in as soon as 5 years on the lower end or more than 15 years on the upper end. The simple payback of the ASHP does *not* consider the cost of a separate air conditioning system.

Exhibit 8: Simple payback period for homes that upgrade to an air-source heat pump (excluding state incentives)

ASHP simple payback period (years)	% of homes analyzed
0	1%
1	0%
2	2%
3	2%
4	3%
5	15%
6	6%
7	6%
8	1%
9	0%
10	0%
11	21%
12	0%
13	30%
14	4%
15	2%
15+	9%

Notably, the simple payback values above exclude the cost of a new air conditioning system to reflect a scenario where the furnace breaks first and requires immediate replacement. However, a home with an existing air conditioning system that upgrades to a heat pump will no longer need to replace the air conditioning system when it breaks because the heat pump provides both heating and cooling.

This presents a particularly attractive opportunity for homes whose heating and cooling systems are both nearing end of life. When also including the avoided cost of a new air conditioning system in year 1, 65% of homes will save money on an air-source heat pump relative to a new furnace and AC system, and all homes see a payback within 10 years.

Exhibit 9: Simple payback period for homes that upgrade heating to an air-source heat pump and also needed an AC replacement

ASHP simple payback period (years)	% of homes analyzed
0	65%
1	21%
2	8%

3	1%
4	1%
5–10	4%

Heat pumps save residents money over the 15-year lifetime of the equipment relative to alternative fuels and electric resistance in 91% of the homes analyzed.

IMPACTS OF ILLUSTRATIVE STATE INCENTIVES (EMPOWER PROGRAM)

Exploring how incentives impact the simple payback of an air-source heat pump, RMI found that with illustrative state incentives of $3,000 for ducted central heat pumps and $4,500 for ductless mini-split heat pumps, the median payback period shifts to 6 years.

Exhibit 10: Simple payback period for homes that upgrade to an air-source heat pump with illustrative state incentives

ASHP simple payback period (years)	% of homes analyzed
0	7%
1	0%
2	2%
3	13%
4	10%
5	2%
6	21%
7	29%
8	4%
9	3%
10	7%
11	0%
12	0%
13	0%
14	0%
15	0%
15+	1%

We looked at the impact of incentives across different fuel types using one scenario as an example. A mid-sized home built between 1980 and 2000 sees the following ASHP payback shift before and after the illustrative state incentive assuming different existing equipment types:

Exhibit 11: Impact of hypothetical state incentives in simple payback period by prior equipment type – 1980-2000 vintage, Midsized Home

Equipment type	Years to pay back before hypothetical state incentive	Years to pay back after hypothetical state incentive
Gas Heating	13	7
Oil Heating	6	4
Electric Resistance Heating	5	3
Any Heating and Aging AC	1	0

ADDITIONAL CONSIDERATIONS

APPENDIX A

Home Typologies and Prevalence

Single-family detached homes, Climate Zone 4A									
Year home was built	pre-1980			1980–2020			post-2000		
Size of home	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Gas Furnace	8.2%	10.8%	6.7%	0.9%	10.5%	2.2%	0.5%	3.8%	0.5%
Electric Resistance Furnace	1.2%	1.3%	1.5%	0.5%	2.4%	0.0%	0.0%	1.8%	0.5%
Fuel Oil Furnace	3.8%	3.8%	0.9%	1.0%	0.4%	0.5%	0.0%	0.4%	0.0%
Gas Boiler	0.7%	2.5%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Propane Furnace	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric Resistance Baseboard	1.8%	0.9%	1.1%	0.5%	0.0%	0.5%	0.0%	0.0%	0.0%

Single-family detached homes, Climate Zone 5A									
Year home was built	pre-1980			1980–2020			post-2000		
Size of home	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Gas Furnace	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric Resistance Furnace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fuel Oil Furnace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gas Boiler	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Propane Furnace	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electric Resistance Baseboard	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Note: Only one county in Maryland is included in this climate zone, one of the state's least populous.

Single-family attached homes, Climate Zone 4A			
Year home was built	pre-1980	1980–2020	post-2000
Size of home	Medium		
Gas Furnace	33.5%	5.3%	21.3%
Electric Resistance Furnace	1.4%	6.2%	1.1%
Fuel Oil Furnace	0.0%	0.0%	0.0%
Gas Boiler	4.7%	0.0%	0.0%
Propane Furnace	0.0%	0.0%	0.0%
Electric Resistance Baseboard	1.3%	1.1%	0.0%

Single-family attached homes, Climate Zone 5A			
Year home was built	pre-1980	1980–2020	post-2000
Size of home	Medium		
Gas Furnace	0.0%	0.0%	0.0%
Electric Resistance Furnace	0.0%	0.0%	0.0%
Fuel Oil Furnace	0.0%	0.0%	0.0%
Gas Boiler	0.0%	0.0%	0.0%
Propane Furnace	0.0%	0.0%	0.0%
Electric Resistance Baseboard	0.0%	0.0%	0.0%

Note: Only one county in Maryland is included in this climate zone, one of the state's least populous.