HUD Portfolio Energy Performance Baseline and Retrofit Scenario Analysis: Public Summary

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Energy Modernization for the Affordable Housing Stock

Aggressive U.S. building energy modernization – achieved through improved building energy efficiency, the adoption of modern, high-efficiency equipment and appliances, and on-site renewable energy generation – will bolster national energy security and reduce utility bills for American families. Such improvements to the national building stock will provide major health benefits to American families, minimize the prevalence of harmful air pollutants, and increase resilience to extreme weather events. In addition, the technologies required for building energy modernization can be manufactured in the United States and installed by American workers, supporting the continued growth of the U.S. energy economy.

HUD will accelerate residential building energy modernization for all Americans through updated program requirements, guidance, incentives, and technical assistance that promote energy independence, efficiency, and affordability. The Department intends to develop a **Portfolio Energy Modernization Framework** which will establish the current baseline energy performance of the HUD portfolio, identify opportunities to improve the energy performance of HUD-supported housing, and develop a multi-year strategy to implement these changes. This work benefits from a recent Memorandum of Understanding with the Department of Energy to advance U.S. building energy modernization through coordination on the research, development, demonstration, and deployment for innovative energy modernization solutions and technologies.

The Framework will allow the Department to make data-informed, strategic decisions to reduce HUD's $6.9 billion utility bill while maximizing energy independence, increasing resilience to extreme weather and other natural disasters, and improving resident health, comfort, and affordability. These Departmental actions, targeted primarily at HUD's public housing and assisted and insured multifamily housing portfolios, will help enable low-income and underserved communities to take full advantage of the newest building energy technologies and realize the significant, life-changing benefits of living in an energy efficient, low-pollution home.

There is significant need for new capital investment across the HUD-supported portfolio, and net-positive energy modernization projects are a major avenue for addressing this need. Enabling residents of HUD-supported housing and their communities to benefit from Federal energy modernization funding and resources from states, localities, utilities, and philanthropic organizations will be crucial for unlocking the full potential level of investment. HUD's Build for the Future webpage and Funding Navigator tool provide critical information on funding opportunities, offer guidance materials, and foster peer-to-peer knowledge sharing.

Portfolio Energy Modernization Framework – Phase 1: HUD Portfolio Energy Performance Baseline and Retrofit Scenario Analysis

The **HUD Portfolio Energy Performance Baseline and Retrofit Scenario Analysis** (Baseline and Scenario report) provides analysis of the baseline energy performance for the HUD portfolio: its estimated current energy consumption, utility costs, and carbon emissions.[1] Through scenario modeling, the Baseline and Scenario Report also provides potential energy performance improvements for HUD-supported units resulting from different combinations of energy retrofit measures (i.e. retrofit packages) relative to the energy baseline. The measures include additional insulation and air sealing, installation of efficient electric heat pumps and heat pump water heaters, and substitution of outdated appliances with modern, high-efficiency replacements.

HUD worked closely with the Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) to leverage their residential building stock energy model (ResStock) for this first, foundational component of the Framework, helping overcome major gaps in HUD's building-level data to provide HUD decision-makers with the most accurate assessment of the HUD portfolio's energy performance to date. The Baseline and Scenario Report presents:

1. An estimated 2018 energy performance baseline for the Public Housing and HUD-assisted/insured Multifamily Housing portfolios based on the characteristics of HUD's housing;[2] and
2. Modeled energy performance improvements for portfolio-wide energy retrofit adoption scenarios over the short term (2024-2028) and long term (2029-2050) to be used by HUD decision makers.

Key Characteristics of HUD-Supported Housing Portfolio in the Baseline Analysis

Using data maintained by HUD program offices, the Baseline and Scenario Report focuses on two major components of the HUD-supported housing portfolio and their impact on HUD's energy performance:

- **Public Housing (PH)**, consisting of 197,064 buildings, amounting to 992,197 units; and
- **HUD-assisted/insured Multifamily Housing (MFAI)**, consisting of 31,417 properties, totaling 2,673,031 units.[3, 4]

The PH and MFAI portfolios have significantly different compositions in terms of geographical location, building type, and construction date. The PH portfolio is largely concentrated in the Northeast and Great Lakes states, includes single family attached and detached building types, and is dominated by units in buildings constructed in the 1970s. The MFAI portfolio is more distributed across states east of the Mississippi and in Texas and California. It includes only units in 2+ unit multifamily buildings that were largely constructed in two time periods: the first in 1970s and 1980s, and the second in the 2000s and 2010s. The makeup of each portfolio accounts for much of the anticipated differences in their estimated baseline energy performance.

HUD-Supported Housing Baseline Energy Performance

Based on HUD's analysis in partnership with NREL, the PH and MFAI portfolios are together estimated to consume over 49,000 Gigawatt-hours of energy per year as of 2018, representing about 3.3 percent of

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[1] ResStock models housing unit-level energy usage and the resulting carbon emissions. The Baseline and Scenario Report assumes that the harmful air pollution from this energy generation and consumption activity is tightly correlated with modeled carbon emissions.

[2] 2018 was the most recent year of modeling data available from NREL when this analysis was completed; due to the slow pace of change in the U.S. residential housing stock, these estimates provide an accurate snapshot of the performance of the HUD portfolio today.

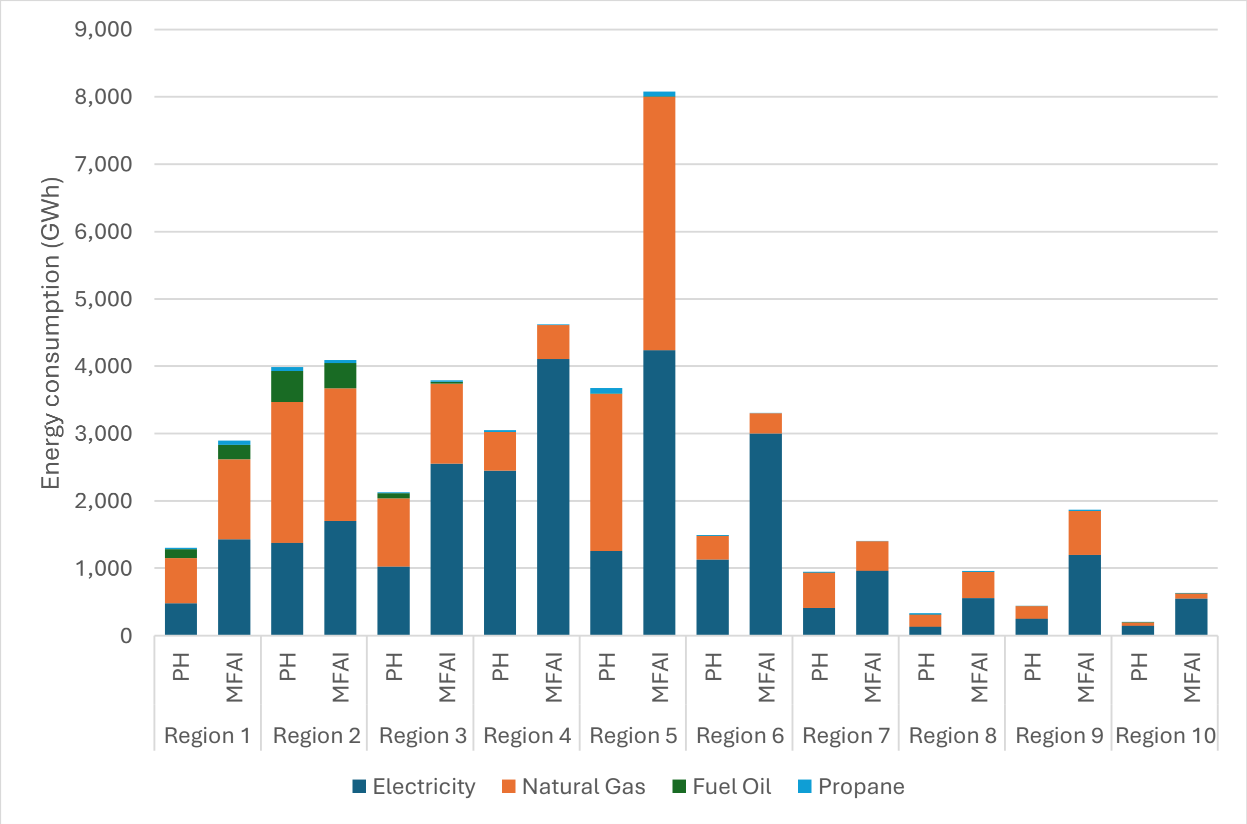
[3] Portfolio characteristics based on data from September 2023.

[4] The Baseline and Scenario Report does not include Section 8 units (either project-based vouchers or Housing Choice Vouchers), units supported under Community Planning and Development programs, or units in residential healthcare facilities. Analysis of the single family insured portfolio is included in Appendix 4.

total U.S. residential energy sales for that year.[5] Electricity made up the majority of the energy consumption type in both portfolios, accounting for 59% of all HUD energy usage compared to 37% for natural gas. While every unit in the HUD portfolio uses electricity for most household appliances, air and water heating, cooking, and clothes drying can be fueled by either electricity or natural gas. Propane and fuel oil make up a small percentage of the heating load for HUD-supported homes.

Total nationwide utility costs for both portfolios amount to approximately $5.45 billion a year using 2018 state energy prices.[6] Electricity accounts for about 78% of that total cost, a greater proportion of total energy consumption due to the comparably high cost of electricity per Kilowatt-hour. Units in the Northeast and Midwest states are heavy consumers of fossil fuels for heating, while units in Southeastern states have lower heating demand which is largely met with electricity. The West Coast has very low overall energy consumption due primarily to large proportions of the population living in temperate climates with limited demand for heating and/or cooling.

Figure 1: HUD portfolio estimated annual energy consumption by region, by fuel



The baseline analysis also indicated that the PH and MFAI portfolios are estimated to produce over 17 million metric tons of CO_2-equivalent emissions annually, the average annual CO_2-equivalent emissions for about 3,700,000 passenger vehicles.[7] Emissions from electricity generation account for roughly 12.5 million metric tons of CO_2-equivalent emissions, with emissions from on-site fuel combustion comprising the remaining 4.5 million metric tons. The MFAI portfolio generally has lower per-unit consumption and

[5] See: https://www.eia.gov/electricity/data/eia861/.
[6] The annual cost savings starting in 2025 would likely be higher due to increased energy prices.
[7] Greenhouse Gas Emissions from a Typical Passenger Vehicle | US EPA

emissions; denser (i.e. multifamily) housing is inherently more energy efficient due to housing units having shared interior walls and smaller average floor areas.

Energy Modernization Scenarios in the HUD-Supported Portfolio

HUD modeled the potential impact of building energy retrofits on the PH and MFAI portfolios in the short- and long-term, based on several retrofit adoption scenarios. These scenarios primarily relied upon the cost-effectiveness of the retrofit packages to simulate unit-level decision-making about retrofit adoption. This illustrative analysis includes consideration of the impact of supporting modernization efforts with rebates funded by the Inflation Reduction Act.[8, 9] The analysis provides HUD leadership with new insights on how to prioritize investments to reduce the overall energy demand and utility costs of the HUD portfolios.

HUD analyzed scenarios for cost-effective energy retrofit adoption according to building location, type, and age. In the short term (2024-2028) and long term (2029-2050), these retrofits would reduce total energy consumption across the combined PH and MFAI portfolios by 13% to 15% and 18% to 19%, respectively. The expected utility cost savings would translate to $490 to $530 million annually, enough to support over 40,000 more HUD-assisted multifamily units.[10] Energy consumption and utility cost savings will vary across the country with differences in energy prices, climate, and building stock characteristics affecting the feasibility and impact of the building retrofits. Notably, the cost effectiveness of installing efficient electric heat pumps and modern, high-efficiency appliances depends significantly on the price of electricity and natural gas and/or fuel oil and regional demand for heating. The analysis shows this effect in some West Coast states, where equipment and appliance modernization would lead to increased utility costs due to the combination of high electricity prices relative to natural gas and low heating demand, which limits the economic benefit of efficiency improvements.

Baseline Analysis Methodology

HUD worked with NREL to use ResStock – their residential building stock energy model – to estimate the current energy performance of the PH and MFAI portfolios. ResStock leverages data from multiple sources (including Federal surveys, peer-reviewed empirical research, and national and international standards and definitions) and uses statistical sampling techniques to represent the U.S. residential building stock through analyzing 550,000 synthetic housing units.[11] Each of these synthetic units is characterized by over 100 different parameters describing every building feature relevant to energy performance, which ResStock uses to model annual energy performance for each one. “Energy performance” refers to a building’s modeled or actual energy demand, which determines its energy consumption and resulting utility costs and emissions.

The following steps outline the approach used to fit the ResStock model to accurately reflect the specific characteristics of the PH and MFAI portfolios, estimate their baseline energy performance, and model the energy savings impacts of potential retrofit adoption:

1. Collect best available data characterizing the PH and MFAI portfolios

[8] After reviewing the Inflation Reduction Act, it was determined that the tax credits were not applicable to the retrofits analyzed in this analysis. As such, only the HER and HEAR rebates are included in the scenario analysis.
[9] The analysis does not consider other sources of funding from other federal, state, or local programs or utility providers. These additional funding sources should be considered for any real-world projects.
[10] Assuming $12,000 subsidy per unit, per year.
[11] ResStock Analysis Tool | Buildings | NREL

2. Work with NREL to apply modeled building performance estimates to HUD portfolios
3. Calculate HUD's estimated energy performance baseline
4. Formulate portfolio retrofit adoption scenarios for HUD portfolios
5. Use scenarios to estimate short- and long-term energy performance improvements

NREL Modeling – Estimated Energy Use in the HUD Portfolio

Figure 2: An example of end-use energy consumption timeseries of a single synthetic housing unit from ResStock

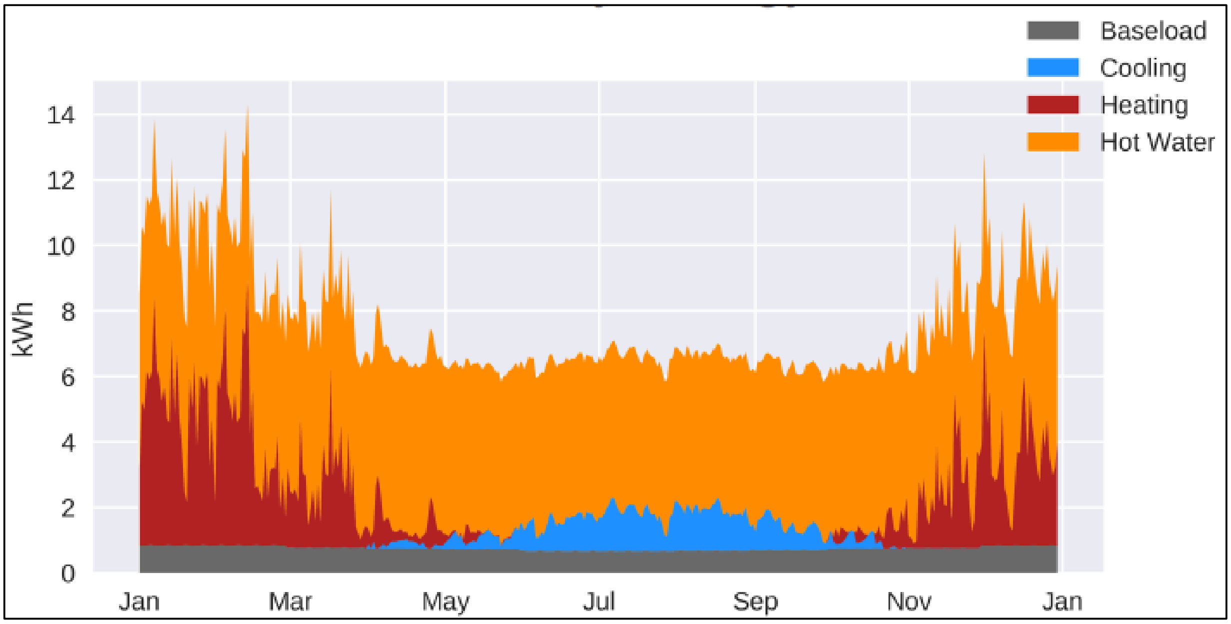


Figure 2 presents an example of a 15-minute-increment load profile, which is the ResStock modeling output for each synthetic housing unit. The load profiles for each synthetic housing unit are generated based on the 100 key parameters (building size and occupancy, building age, structure materials, systems and appliances, location, etc.) that determine energy performance. The energy performance estimates from ResStock were applied to the HUD portfolios by matching key building characteristics between the synthetic housing units and the PH and MFAI units.

The ResStock data set includes load profiles for baseline energy performance as well as the energy performance improvements for each of ten standard energy retrofit packages. The retrofit packages were applied to the synthetic housing units by upgrading the relevant building characteristics and then modeling the resulting energy performance improvements for each package. The retrofit packages include upgrades to the building envelope, HVAC systems, and other appliances as well as estimated implementation costs.[12] The best retrofit package for any building will depend on many factors, including its location, characteristics, and available funding sources; there is no single solution across the PH and MFAI portfolios.

HUD-Supported Housing Portfolio-wide Retrofit Adoption Scenarios

Short- and long-term retrofit adoption scenarios were developed to simulate the potential adoption of specific retrofit packages in the HUD portfolios under real-world decision criteria for building upgrades.

[12] Utility costs and savings use 2018 energy prices; retrofit package implementation costs are in 2022 dollars.

Two economics-based scenarios were developed to model portfolio-wide retrofit adoption in the short term (2024-2028):

- **Scenario 1**, which maximizes energy savings from cost-effective retrofit packages, and
- **Scenario 2**, which maximizes energy savings from cost-effective retrofit packages using maximum eligible Home Efficiency Rebates (HER) and Home Electrification and Appliance Rebates (HEAR) available due to the Inflation Reduction Act.[13]

The economics of different retrofit choices (including the choice not to implement retrofits) were modeled based on retrofit package effectiveness (i.e. annual energy savings), payback period, unit recapitalization status, and applicability of local or state building performance standards. To model long-term retrofit adoption (2029-2050), Scenarios 1 and 2 were extended through 2050. In addition, a third, performance-based long-term scenario was developed:

- **Scenario 3**, which optimizes building energy modernization efforts toward eliminating harmful air pollution by 2050.

These short- and long-term retrofit adoption scenarios enable HUD to assess the impacts of energy performance improvements in the PH and MFAI portfolios over time. This provides key insight into the differences in cost savings and emissions reductions under an economically feasible retrofit adoption pathway versus an adoption scenario that aggressively modernizes the PH and MFAI portfolios.

HUD-Supported Housing Energy Baseline and Scenario Analysis Findings

Energy consumption. Current total annual energy consumption for both the PH and MFAI portfolios is 49,195 GWh. With retrofit packages adopted in Scenario 1 over the short term, combined energy consumption would decline by 13% to 42,900 GWh. Utilizing available IRA rebates, Scenario 2 results in consumption savings of 15% from the current baseline consumption to 41,826 GWh. Long-term (through 2050) energy consumption savings for the PH portfolio are 20% and 24% for Scenarios 1 and 2; for the MFAI portfolio long-term savings for Scenarios 1 and 2 are 17% and 16% respectively. The PH portfolio has greater potential consumption savings than the MFAI portfolio largely due to differences in building types. Long-term energy savings for Scenario 3 greatly exceed those of Scenarios 1 or 2, reducing combined energy consumption by 53% to 23,128 GWh. Figure 3 provides more detail on the energy consumption for the PH and MFAI portfolios.

Figure 3: Energy consumption for the PH and MFAI portfolios

	Short-term (2024-2028)		**Long-term (2029-2050)**	
	Consumption (GWh)	**Consumption savings**	**Consumption (GWh)**	**Consumption savings**
Public Housing				
Baseline	17,547			
Scenario 1	15,438	12%	14,114	20%
Scenario 2	14,564	17%	13,383	24%
Scenario 3			7,273	59%
Multifamily Assisted/Insured				

[13] After reviewing the Inflation Reduction Act, HUD determined that the tax credits were not applicable to the retrofits analyzed in this analysis. As such, only the HER and HEAR rebates are included in Scenario 2.

Baseline	31,648			
Scenario 1	27,462	13%	26,268	17%
Scenario 2	27,262	14%	26,736	16%
Scenario 3			15,855	50%
Combined Portfolios				
Baseline	49,195			
Scenario 1	42,900	13%	40,382	18%
Scenario 2	41,826	15%	40,119	19%
Scenario 3			23,128	53%

Annual utility bills. Current total annual utility costs for both portfolios amount to $5.45 billion a year using 2018 state energy prices, with electricity accounting for about 78% of the total cost. Retrofit adoption under Scenario 1 would result in a 9% utility cost reduction in the short term or a savings of $490 million. Factoring in available Inflation Reduction Act rebates (analyzed in Scenario 2) would result in an additional $40 million of cost savings in the short term or a 10% reduction in annual utility costs.

Over the long term, the continued adoption of additional retrofit packages would further reduce utility costs in both Scenarios 1 and 2 to $4.9 billion, an 11% reduction relative to baseline utility costs by 2050. This would constitute an annual savings of $607 million and $594 million for Scenarios 1 and 2, respectively. In comparison, Scenario 3, which models the rapid energy modernization of the PH and MFAI portfolios, reduces utility costs to $3.94 billion, a 28% reduction compared to current expenditures, or an annual savings of $1.5 billion. Figure 4 provides more detail on the utility cost analysis for each portfolio.

Figure 4: Annual utility costs for the PH and MFAI portfolios

	Short-term (ending 2028)		**Long-term (ending 2050)**	
	Utility costs (2018$)	**Utility cost reduction**	**Utility costs (2018$)**	**Utility cost reduction**
Public Housing				
Baseline	$1,708,857,179			
Scenario 1	$1,550,658,116	9%	$1,511,379,040	12%
Scenario 2	$1,522,191,612	11%	$1,491,752,953	13%
Scenario 3			$1,197,811,854	30%
Multifamily Assisted/Insured				
Baseline	$3,756,124,734			
Scenario 1	$3,424,270,174	9%	$3,346,455,133	11%
Scenario 2	$3,411,342,155	9%	$3,379,237,770	10%
Scenario 3			$2,742,928,364	27%
Combined Portfolios				
Baseline	$5,464,981,913			
Scenario 1	$4,974,928,290	9%	$4,857,834,173	11%
Scenario 2	$4,933,533,767	10%	$4,870,990,723	11%
Scenario 3			$3,940,740,218	28%

Total emissions. The PH and MFAI portfolios are currently estimated to produce over 17 million metric tons of CO_2-equivalent emissions annually. Over the short term, Scenarios 1 and 2 reduce emissions by

12% and 14%, respectively. In the long term, the combined emissions reductions for both scenarios relative to the 2018 baseline are 67%. Though this is still short of the 87% reduction estimated for Scenario 3, the percentage savings for emissions is significantly greater than the savings for utility costs or energy consumption as HUD's portfolio benefits from expected improvements to the electric grid. Figure 5 presents more detail on the emissions of the PH and MFAI portfolios.

Figure 5: Emissions for the PH and MFAI portfolios

	Short-term (ending 2028)		**Long-term (ending 2050)**	
	Emissions (metric tons)	**Emissions reduction**	**Emissions (metric tons)**	**Emissions reduction relative to 2018 baseline***
Public Housing				
2018 Baseline	5,711,155			
Scenario 1	5,060,034	11%	2,207,850	61%
Scenario 2	4,851,736	15%	2,042,782	64%
Scenario 3			717,439	87%
Multifamily Assisted/Insured				
2018 Baseline	11,518,841			
Scenario 1	10,057,428	13%	3,565,376	69%
Scenario 2	10,055,343	13%	3,652,554	68%
Scenario 3			1,530,851	87%
Combined Portfolios				
2018 Baseline	17,229,996			
Scenario 1	15,117,462	12%	5,773,226	67%
Scenario 2	14,907,079	14%	5,695,336	67%
Scenario 3			2,248,290	87%

* Not shown are long-term baselines, which reflect long-term emissions reductions due to predicted reductions in electric grid carbon intensity separate from building energy performance improvements. The reported emissions reductions relative to 2018 baseline include both grid decarbonization and reduced energy consumption due to improved energy performance.

Additional Considerations for Modernizing the HUD-Supported Portfolio

Achieving substantial progress toward energy modernization is possible. Energy modernization funding from the Inflation Reduction Act provides resources to jumpstart investment in the residential building sector nationwide. HUD, DOE, and other Federal agencies are working to ensure multifamily housing, especially affordable multifamily housing, can access as much available funding as possible. Given these efforts, it is likely that the improvement in energy performance of HUD's portfolio will be between the estimates for Scenarios 1 and 2 over the short term, a modest but meaningful step forward with no cost to the Department. Full energy modernization of HUD's portfolio will require additional resources beyond what is currently available.

HUD portfolio energy modernization can be a vehicle for achieving energy affordability and security for all Americans. Energy modernization for the HUD-supported portfolio will help ensure the Department can continue to effectively serve low- and moderate-income families by reducing energy costs and increasing energy security. The HUD portfolio needs to be enhanced to better withstand the extreme heat and other extreme weather events occurring more regularly and for longer durations across the country.[14] Retrofitting the housing stock will improve the resilience of HUD housing and provide health benefits for residents by reducing or eliminating harmful air pollutants. Residents will also see lower energy bills typical of more efficient homes. The Department has the ability to ensure that HUD-supported low-income and underserved communities realize the benefits of a modernized home.

The optimal energy modernization pathway will vary by the location and characteristics of each building. There is not a “one size fits all” solution to retrofitting the HUD-supported housing portfolio. Significant regional variability in building type and age interacts with regional climate and utility configurations in complex ways. In order to maximize the effectiveness of various retrofit measures, HUD actions to advance energy modernization must be sensitive to these nuances.

Conclusion

The Department can accelerate energy modernization for the HUD-supported housing portfolio through improved building energy efficiency, high-efficiency equipment and appliances, and on-site renewable energy generation. The Portfolio Energy Modernization Framework will provide policymakers at HUD with the tools necessary to take effective action—through updated program requirements, guidance, incentives, and technical assistance—to facilitate the adoption of modernization strategies in both new and existing HUD-supported affordable housing. It will also help to ensure equitable access to any new energy modernization resources like the funding made available through Inflation Reduction Act. By adopting effective modernization strategies for affordable housing, HUD will help enable low-income and underserved communities nationwide to fully participate in the clean energy transition and realize the significant, life-changing benefits of living in an energy efficient, healthy home.

The first phase of the Portfolio Energy Modernization Framework, the HUD Portfolio Energy Performance Baseline and Retrofit Scenario Analysis, presents an estimated performance baseline for the Public Housing and HUD-assisted/insured multifamily housing portfolios and models possible energy performance improvements for portfolio-wide energy retrofit adoption scenarios over the short term (2024-2028) and long term (2029-2050). The findings indicate that meaningful reductions in annual energy consumption (15%), utility costs (10% or $530 million), and emissions (14%) are possible in the short term using only rebates available through the IRA, with the opportunity for further reductions in the long term even without additional subsidies. Through the remaining phases in the Portfolio Energy Modernization Framework, HUD will identify the set of effective and feasible policy actions to accelerate the energy modernization of the HUD-supported portfolio, resulting in more affordable, healthy, and resilient homes for residents and significant reductions to HUD’s $6.9 billion utility bill.[15]

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[14] See https://science.nasa.gov/climate-change/extreme-weather/.

[15] Note that this total includes utility costs for Housing Choice Voucher units while the $5.45 billion annual cost modeled for the Baseline and Scenario Report does not model the costs for these units.