Residential Home Repairs, Energy Efficiency, and Electrification in the Hill District of Pittsburgh

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National Renewable Energy Laboratory

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Notice

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About Communities LEAP

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

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

Hill District Communities LEAP Overview

Through Communities LEAP, a community coalition focused on the Hill District neighborhood of Pittsburgh is working with a technical assistance provider network led by the National Renewable Energy Laboratory (NREL). The coalition includes community organizations, nonprofits, the city government, and the utility.

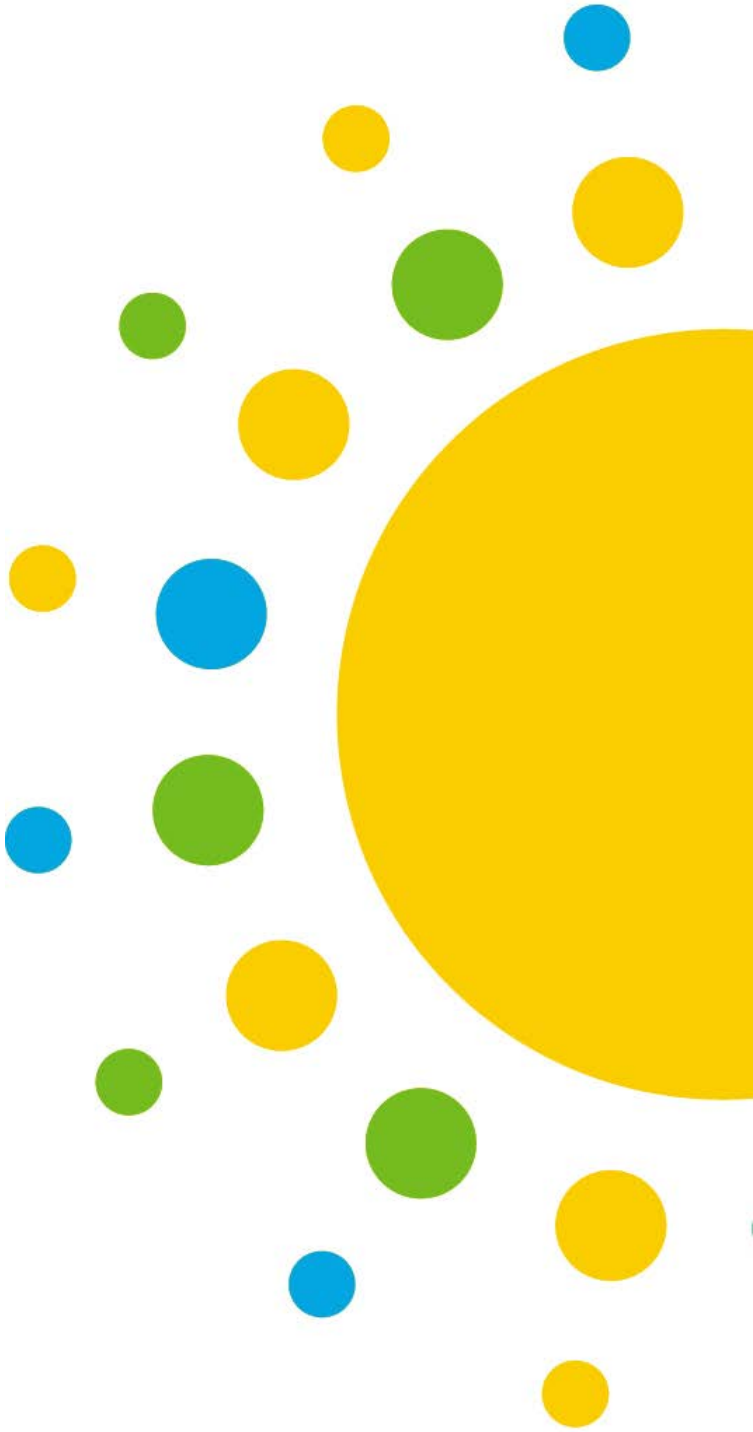
Technical assistance provides analysis and information to support Hill District stakeholders in their goals to create informed residential energy efficiency and renewable energy transition strategies that:

- Improve housing conditions and lower energy bills
- Incorporate energy efficiency and renewable energy strategies into existing, community-driven development efforts
- Generate quality local jobs.

Report Overview

- This report summarizes the insights from two workstreams:
  - **Stakeholder engagement** with organizations that provide home repair services, weatherization, and residential energy efficiency in the Hill District
  - **Building analysis** to characterize Hill District housing stock and the potential costs and benefits of energy efficiency and electrification measures.
- The results of these two workstreams are being presented in a single report to emphasize the importance of considering existing challenges with housing in the Hill District, which was a key concern expressed by the community coalition, alongside discussions regarding the potential for energy efficiency and electrification.

Stakeholder Engagement Summary



Overview

Purpose of Stakeholder Engagement

- NREL staff engaged with four organizations that administer programs that provide home repair services, weatherization, and residential energy efficiency in the Hill District. These organizations are providing critical services, including financial assistance that covers some or all of the cost to residents, to homes across Pittsburgh and Allegheny County.
- NREL staff engaged with representatives from each of the four organizations, and gathered application data for programs administered by two of the organizations, to understand the following:
  - The scope and scale of the current home repair and energy efficiency program offerings in the Hill District
  - The primary needs of applicants to the two programs (e.g., whole-home repair and energy efficiency upgrades)
  - The challenges these programs face and additional resources that are needed to support Hill District residents.
- This analysis is intended to:
  - Provide critical context for the technical results of a building stock analysis NREL staff conducted for the Hill District as part of Communities LEAP
  - Equip the community coalition with information that can be used to support applications for additional funding to address critical needs in the Hill District.

Limitations of This Summary

- This summary of results is not intended to directly represent the perspectives of any single organization engaged as part of the Communities LEAP project in the Hill District.
- The program application data gathered from two of the four organizations represent only a portion of Hill District housing, so the insights presented here may not apply more broadly across the Hill District.
- The data analyzed do not provide any information on how individual applications were evaluated (e.g., why some were deferred and others were accepted).
- Applicants to the programs analyzed were not engaged through this process, so this analysis only considers a single type of perspective (i.e., that of the organizations running these programs).

Key Stakeholder Organizations

Organization Name	Description	Key Programs	Communities LEAP Engagement Methods
ACTION-Housing, Inc.	Allegheny County weatherization agency, housing and workforce services provider	Weatherization Assistance Program; Whole-Home Repairs Program	Meetings; data sharing
Rebuilding Together Pittsburgh	National nonprofit providing homeowners with owner-occupied home rehabilitations and repairs	Affordable Housing Repair; Safe and Healthy Homes	Meetings
Urban Redevelopment Authority (URA)	City of Pittsburgh's economic development enterprise	Homeowner Assistance Program; Homeowner Assistance Program for Independence	Meetings; data sharing
City of Bridges	Regional nonprofit/community land trust developing permanently affordable housing for low-income families	Community Land Trust	Meetings

Stakeholder Engagement Themes

Organizations performing home repair and energy efficiency services in the Hill District identified common themes and challenges.

- **Workforce Availability and Skills**
- **Funding**
- **Hierarchy of Needs for Upgrades**
- **Owner-Occupied vs. Renter-Focused Programs**

Stakeholder Engagement Themes

Workforce Availability and Skills

- Organizations mentioned **limitations in the local workforce**, including overall number of workers (i.e., energy auditors, contractors, etc.), as well as skills and training to perform energy efficiency upgrades.

Funding

- Organizations mentioned **limitations in funding** from federal, state, and local sources; organizations stack funding sources to provide needed services.
- Organizations mentioned that **funding is often allocated to the entire county or city**, creating constraints in **targeting offerings** in a smaller geographic area like the Hill District.

Stakeholder Engagement Themes

Hierarchy of Needs for Repairs and Upgrades

- Organizations mentioned that funding is often devoted to **major home repairs, accessibility modifications,** and **bringing houses up to code**.
- Organizations mentioned that cost-effectively incorporating energy efficiency upgrades into existing home repair work is difficult.
- Organizations noted the prevalence of older homes, which can present issues like occupant health and comfort (Clarke et al. 2023).

Owner-Occupied vs. Renter-Focused Programs

- Many programs focus on owner-occupied housing, including the Whole-Home Repair Program and Homeowner Assistance Programs, and there is **less focus on renter-occupied housing,** which comprises a significant portion of housing in the Hill District.

Hierarchy of Needs for Repairs and Upgrades

Commonly Cited Home Repairs

- Several organizations mentioned needed repairs, with **roofs, windows, and doors** as the most common issues addressed through their services.
  - Window and door replacements are a less common upgrade within the weatherization assistance program on a national scale, as they are not as cost effective as other measures in terms of savings-to-investment ratio (Oak Ridge National Laboratory, 2014).
- Further, **weatherization deferrals are common**, with roof leaks mentioned as the primary reason for deferral. This aligns with the deferral reasons cited in the Pennsylvania WAP agency survey conducted by the Department of Community and Economic Development in 2015-2017.
  - The top three deferral reasons for both years were moisture issues, roof repairs, and knob and tube remediation (Pennsylvania Department of Community and Economic Development 2020).
  - *Weatherization deferrals occur when the condition of the home renders delivering weatherization services either unsafe or ineffective. Deferral does not mean that assistance will never be available, but that work must be postponed indefinitely until the problems can be resolved and the home can be made "weatherization-ready" (NASCSP N.d.).*

Masonry/Brick Homes Consideration

- Several organizations mentioned the challenges in addressing **envelope improvements in brick homes**, which comprises a significant portion of the residential housing stock (i.e., estimated to be approximately 30%).
  - This characteristic in the housing stock may limit the ease and scope of possible energy efficiency improvements.

Modeled Envelope Status for Masonry-Built Homes in the Hill District

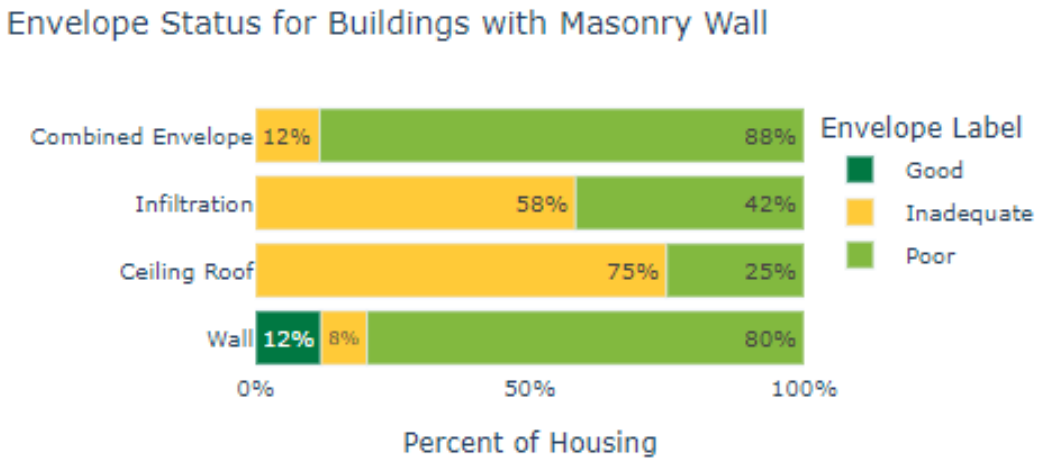


Image from Liu et. al 2023

Challenges in Addressing Energy Efficiency

- Several organizations mentioned the **need to make homes safe and habitable** before they can begin to consider energy efficiency.
- While energy efficiency is addressed through upgrading windows, roofs, and doors, organizations mentioned **limited remaining budget** for other energy efficiency improvements, including adding insulation, air sealing, etc.

Whole-Home Repair Program Data Summary

Whole-Home Repair Program (WHRP) Background

- Pennsylvania's Whole-Home Repair Program (WHRP) provides funding for county agencies to improve the **safety, habitability, accessibility, and energy efficiency of homes** (Pennsylvania Department of Community and Economic Development 2023).
- **Round 1** applications were collected in June 2023, and **Round 2** applications were collected October–November 2023.

Funding and Eligibility

- ✓ Provides **eligible homeowners** with up to **$50,000 per owner-occupied unit**.
- ✓ Household income must not exceed **80% of the total Area Median Income (AMI)** for Allegheny County.
- ✓ **Grant program** administered by ACTION-Housing in Allegheny County; local contractors perform upgrades.

Source: Action Housing Inc. (n.d.)

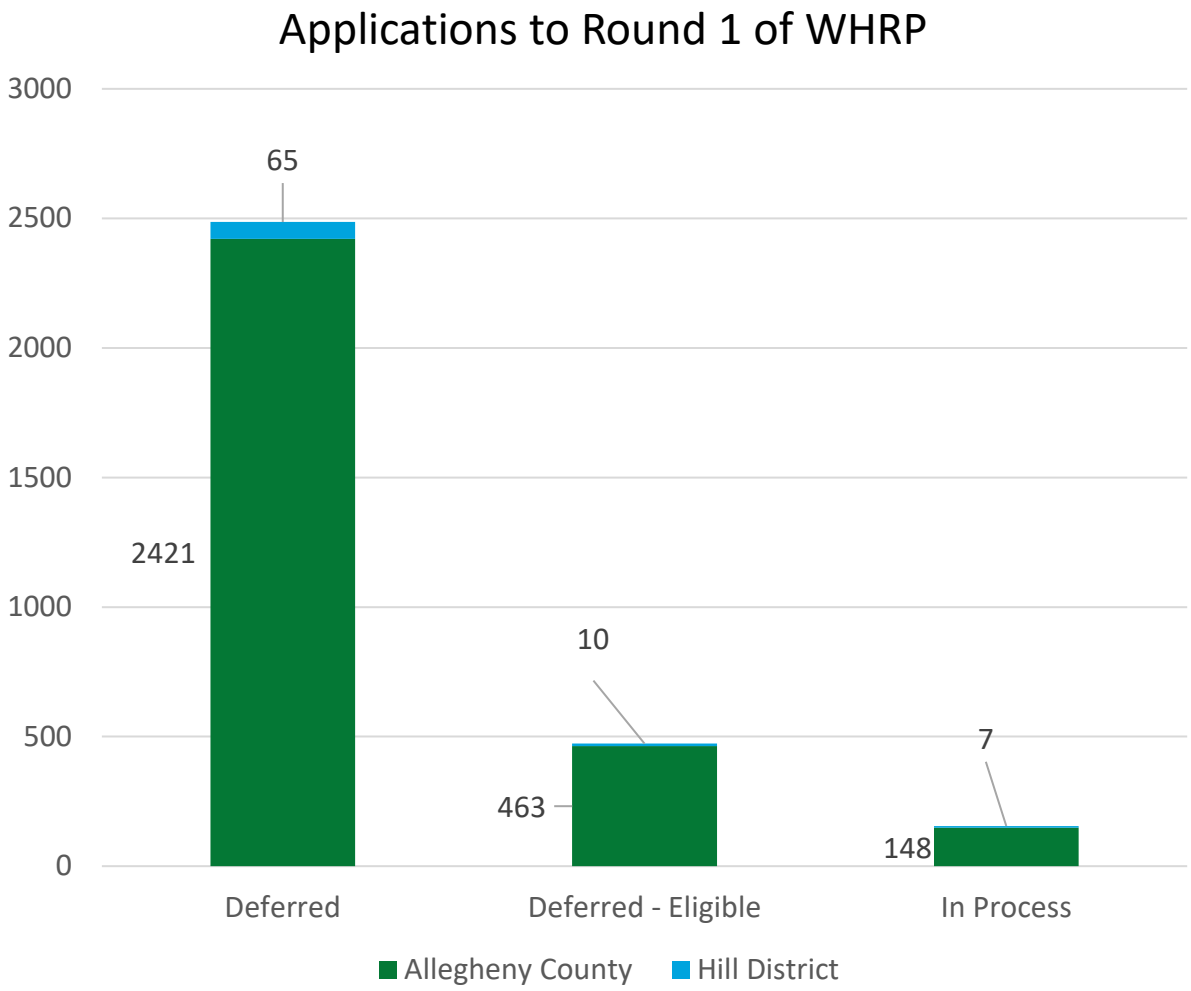
WHRP Application Status Definitions

The status of applications for the WHRP fall into the following categories:

- **Deferred:** The eligibility for these applications has not been confirmed, but funding is not available to confirm eligibility.
- **Deferred-eligible:** The eligibility for these applications has been confirmed, but funding is not available to pursue repairs.
- **In process:** These applications were selected to move forward, and work is underway (includes scoping, bidding, or actual construction).

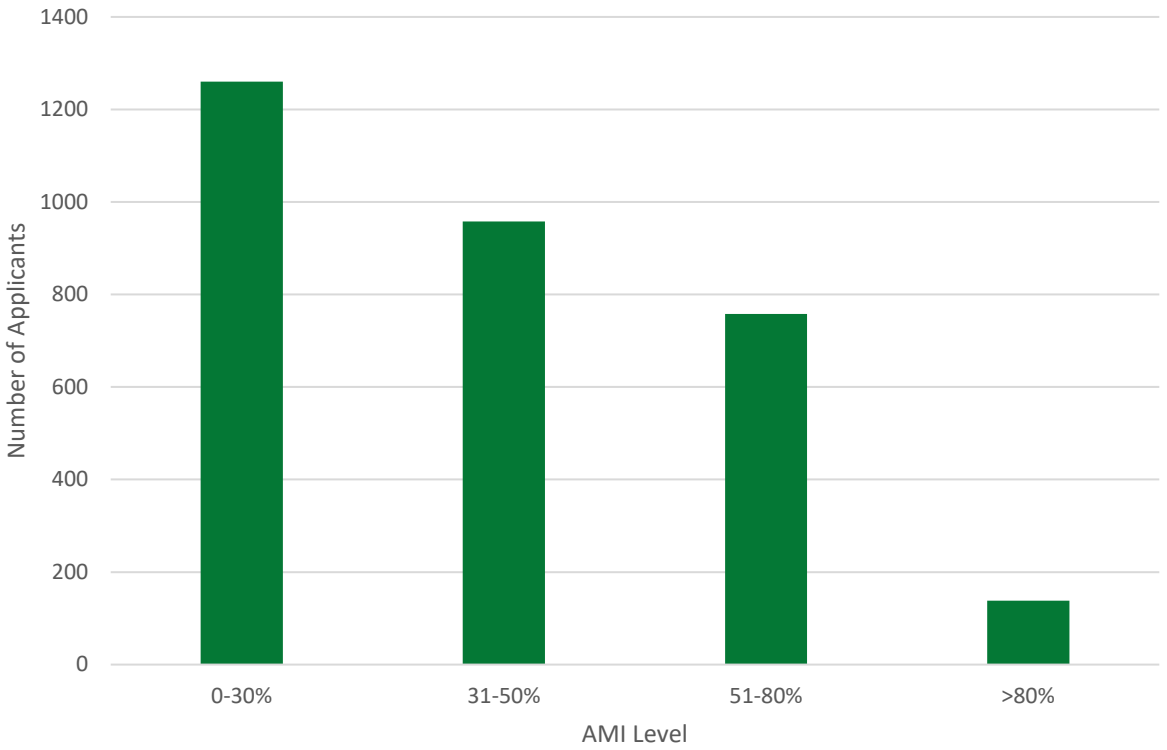
WHRP Round 1 Applicant Totals

- There were **3,114 total applicants in Allegheny County** to Round 1 of program, with 155 applications **(5%)** in process.
- According to the program website, the WHRP is expected to serve **200-250 homes in Allegheny County** (6-8% of total applicants).
- There were **82 total applicants** from 15219 and 15213 zip codes covering the **Hill District**, with 7 applications **(9%)** in process.

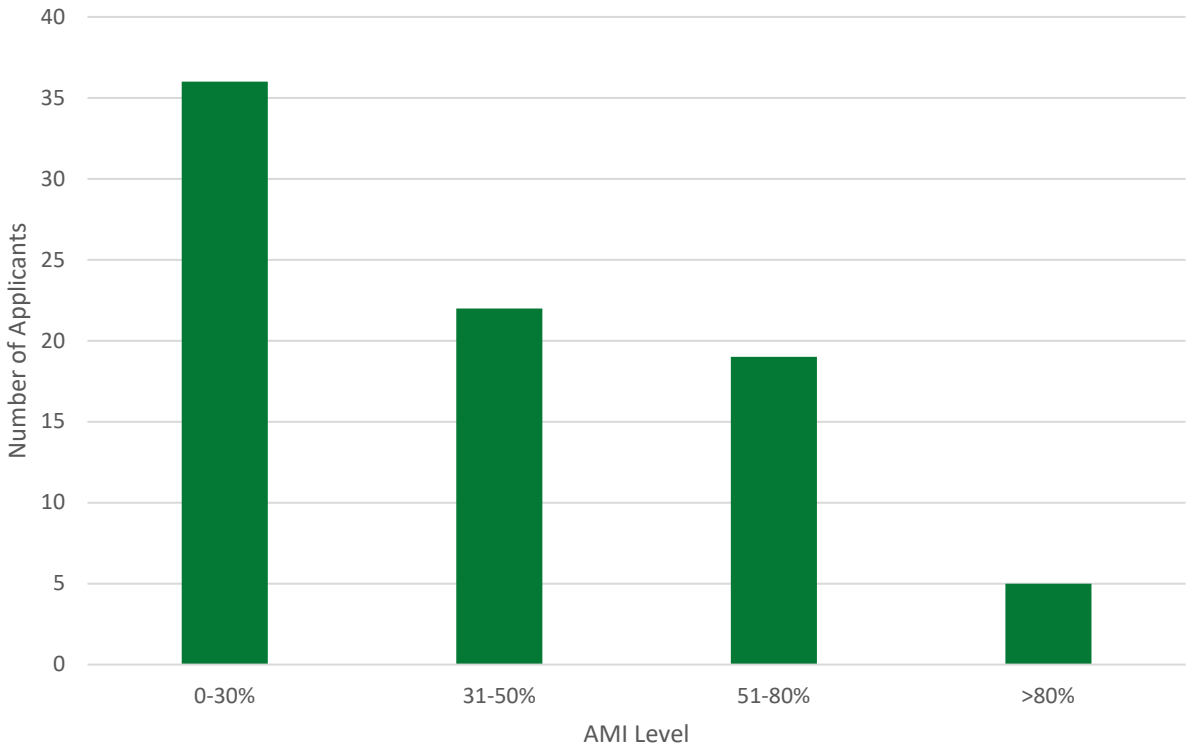


WHRP Round 1 Applicant Income

AMI Level of Allegheny County Applications (Round 1)

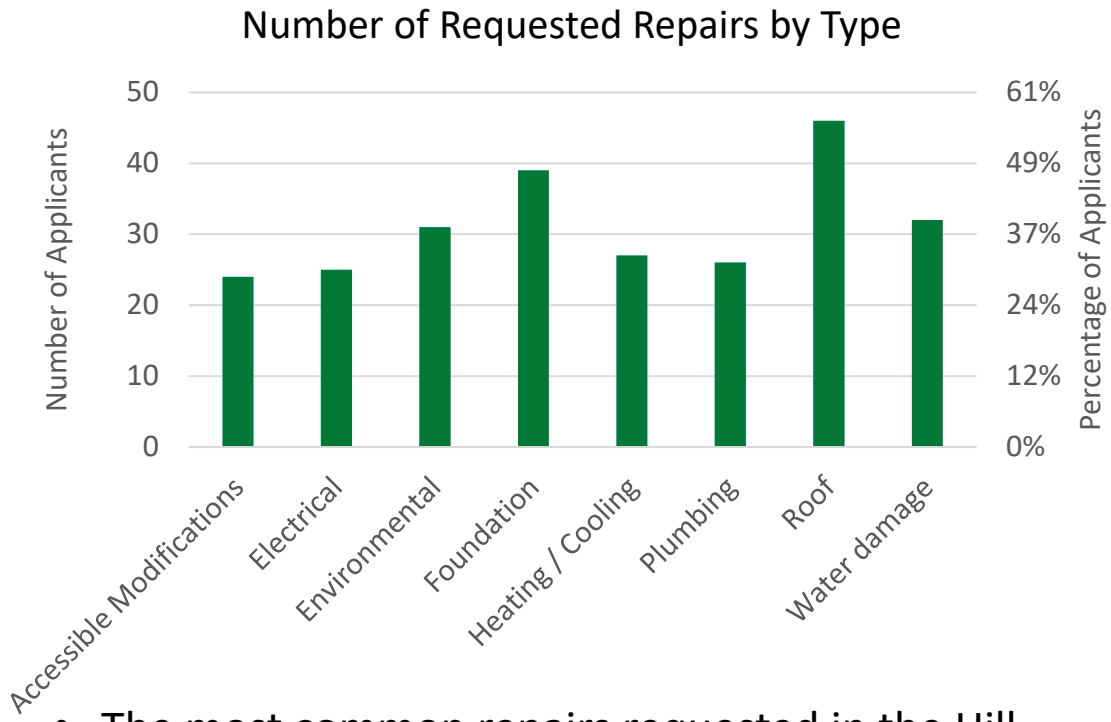


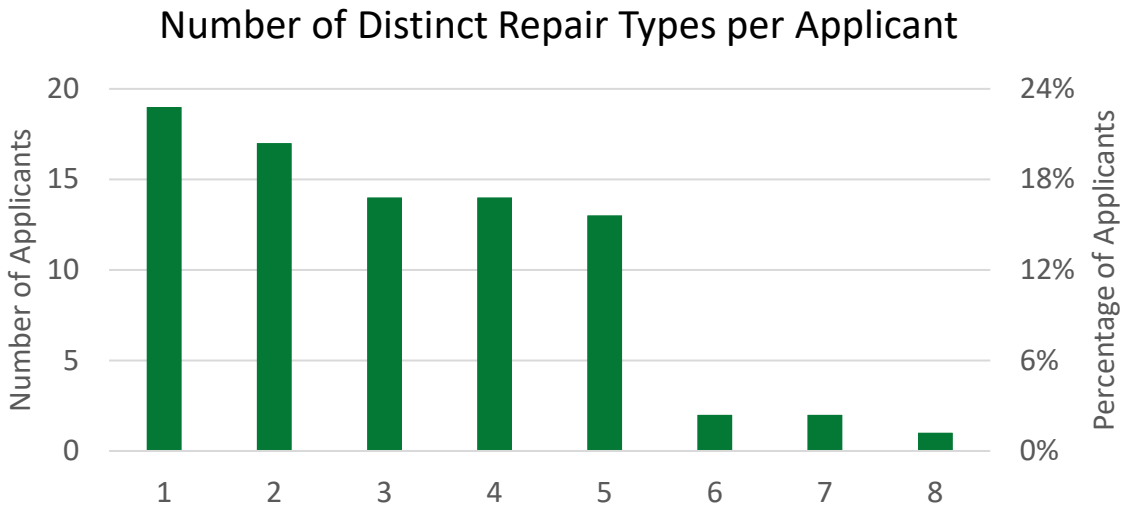
AMI Level of Hill District Applications (Round 1)



A higher percentage of applicants come from the 0-30% AMI income bracket than any other income bracket, both at the county level and from the Hill District.

WHRP Round 1 Repairs Requested



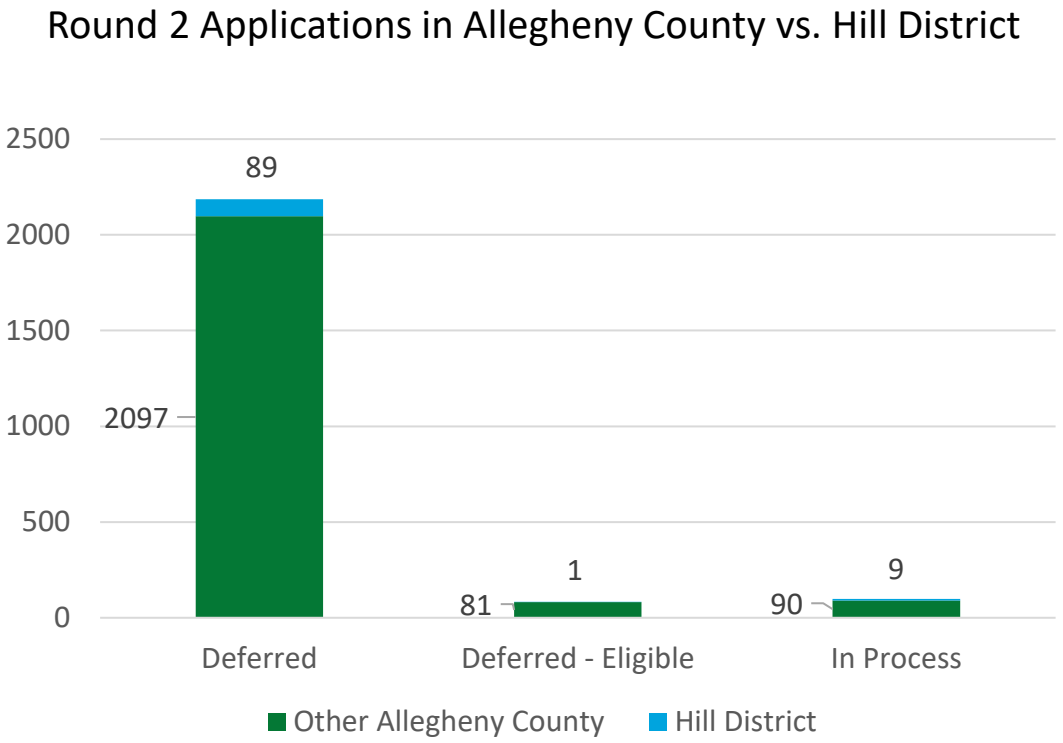


- The most common repairs requested in the Hill District were for roofs (56%), foundations (48%), and water damage (39%).
- 24% requested both foundation and roof repair.

- 56% of Hill District applicants requested 3 or more types of repairs.
- 39% of Hill District applicants requested 4 or more types of repairs.

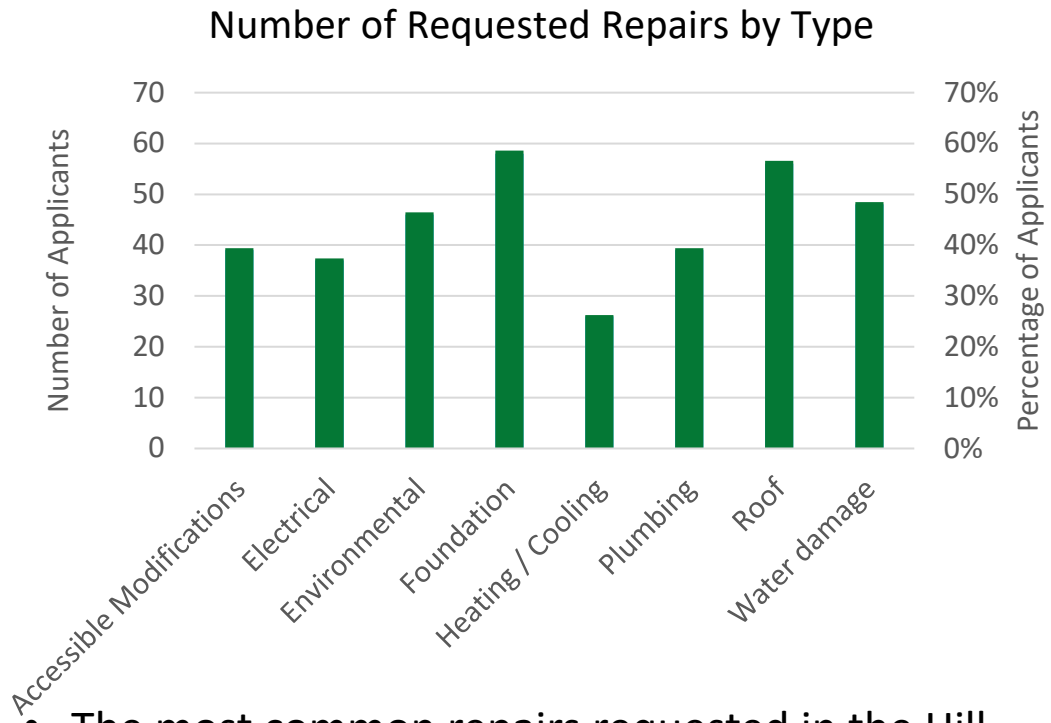
WHRP Round 2 Applicant Totals

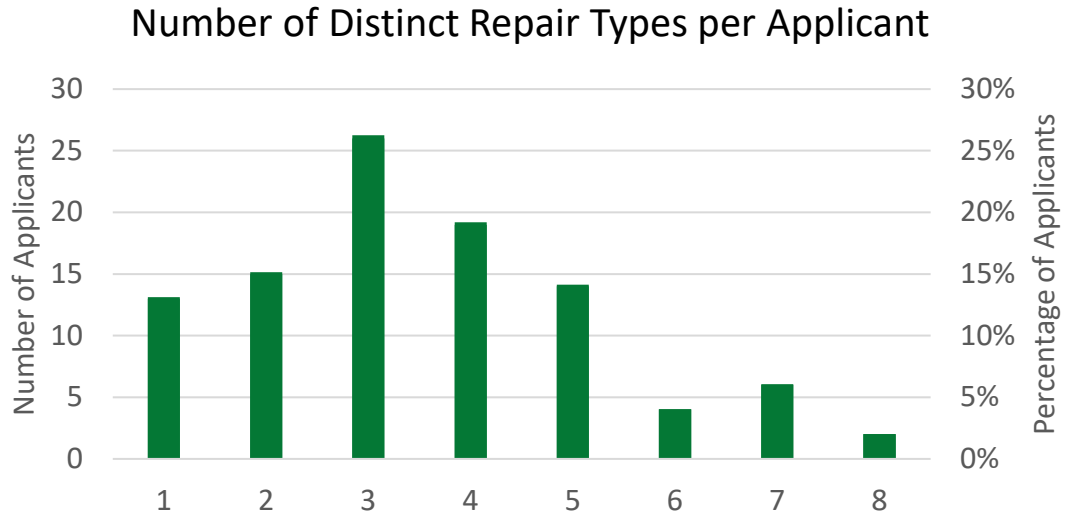
- The WHRP collected applications for Round 2 of the program between October–November 2023.
- There were **2,367 applications from Allegheny County** in Round 2 of the program, with 99 applications **(4%)** in process.
- There were **99 applications from the Hill District** (15219 and 15213 zip codes), with 9 applications **(9%)** in process.



Note: 32% of Round 2 applications were recertified applications, meaning that the homeowner applied in Round 1 and was Deferred or Deferred-eligible, choosing to recertify their application for eligibility in Round 2.

WHRP Round 2 Repairs Requested





- The most common repairs requested in the Hill District were for foundations (59%), roofs (57%), and water damage (48%).
- 34% requested both foundation and roof repair.

- 72% of Hill District applicants requested 3 or more types of repairs.
- 45% of Hill District applicants requested 4 or more types of repairs.

WHRP Summary of Takeaways

- 9% of applicants in the Hill District are receiving repairs, potentially indicating an unmet need for home repairs.
  - A higher percentage of applicants from the Hill District are receiving repairs than applicants to the program overall (5%).
- Most applicants requested substantial repairs (e.g., foundation, roof), and often requested several major repairs.
  - This indicates that there may be a significant need for home repairs that are being prioritized over energy efficiency upgrades (stakeholder engagement with program providers indicated that major home repairs are being prioritized over energy efficiency upgrades).

Urban Redevelopment Authority (URA) Programs Data Summary

URA HAP and HAPI Programs

The **Homeowner Assistance Program (HAP)** and **Homeowner Assistance Program for Independence (HAPI)** are both offered through the City of Pittsburgh's Urban Redevelopment Authority.

HAP

- Provides up to $35,000 in financial assistance to eligible homeowners at or below 80% of AMI.
- Assistance aimed at rehabilitating and improving residential, owner-occupied properties.
- Funds are in the form of a 0% interest, 20-year deferred loan.

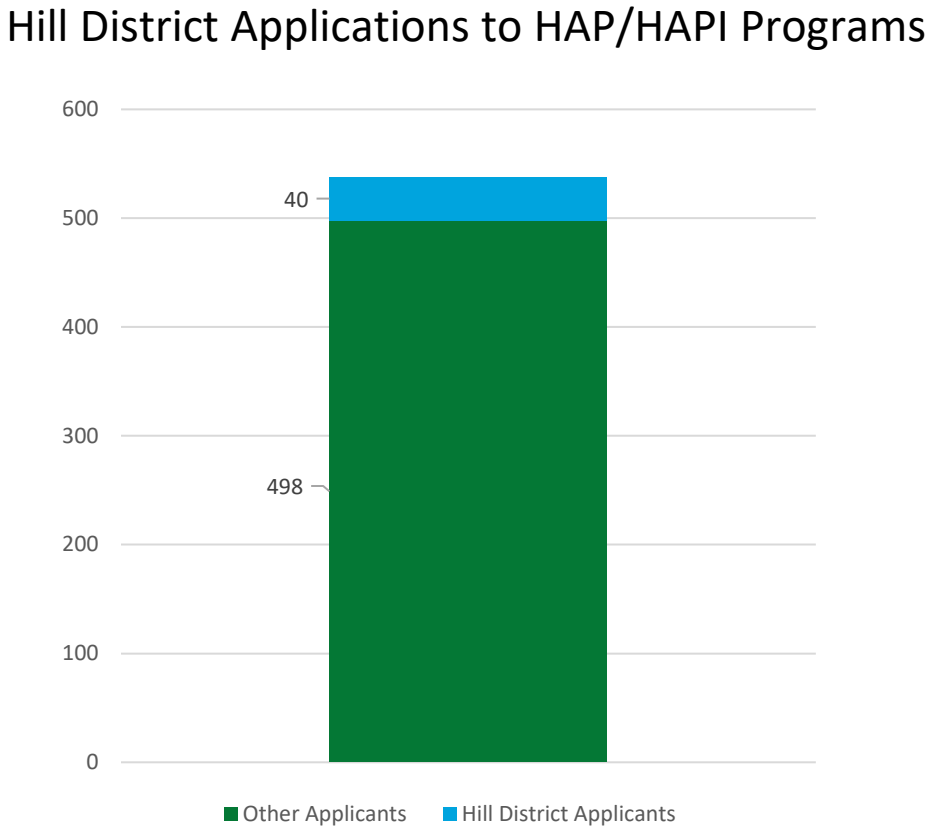
HAPI

- Grants to assist eligible homeowners and landlords to construct accessibility modifications to homes.
- Modifications include exterior ramps, chair lifts, and bathroom modifications.
- Eligible homeowners receive a grant from $1k-$15k for a single-unit home. Landlords receive a grant up to $7,500 per unit.

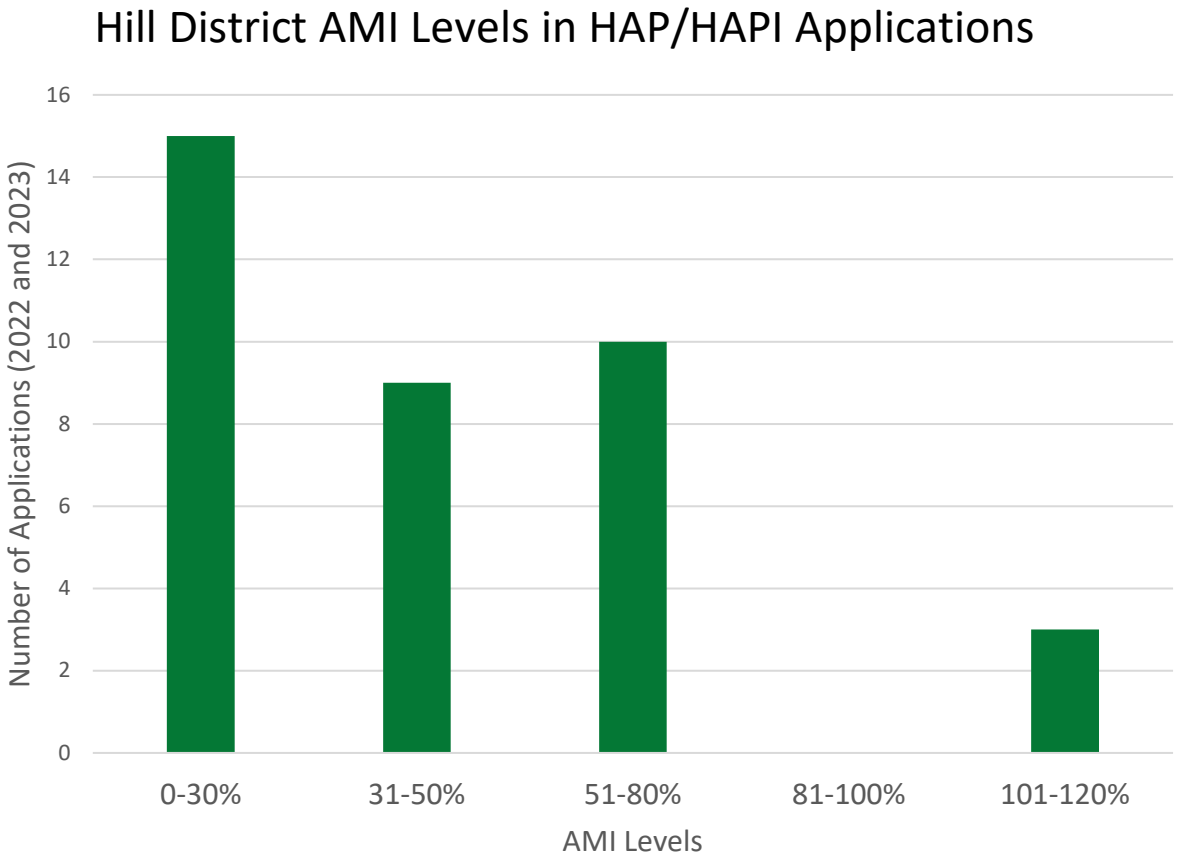
Source: URA (n.d.)

URA HAP and HAPI Program Applicant Totals

- **538 total applicants** overall in the years 2022 and 2023 for the HAP/HAPI programs
- **40 total applicants** from the Hill District in the years 2022 and 2023 for the HAP/HAPI programs
- **20% of applications** from the Hill District **accepted** into HAP/HAPI programs (versus **30% of applications for the program overall**).



URA HAP and HAPI Programs Applicant Income

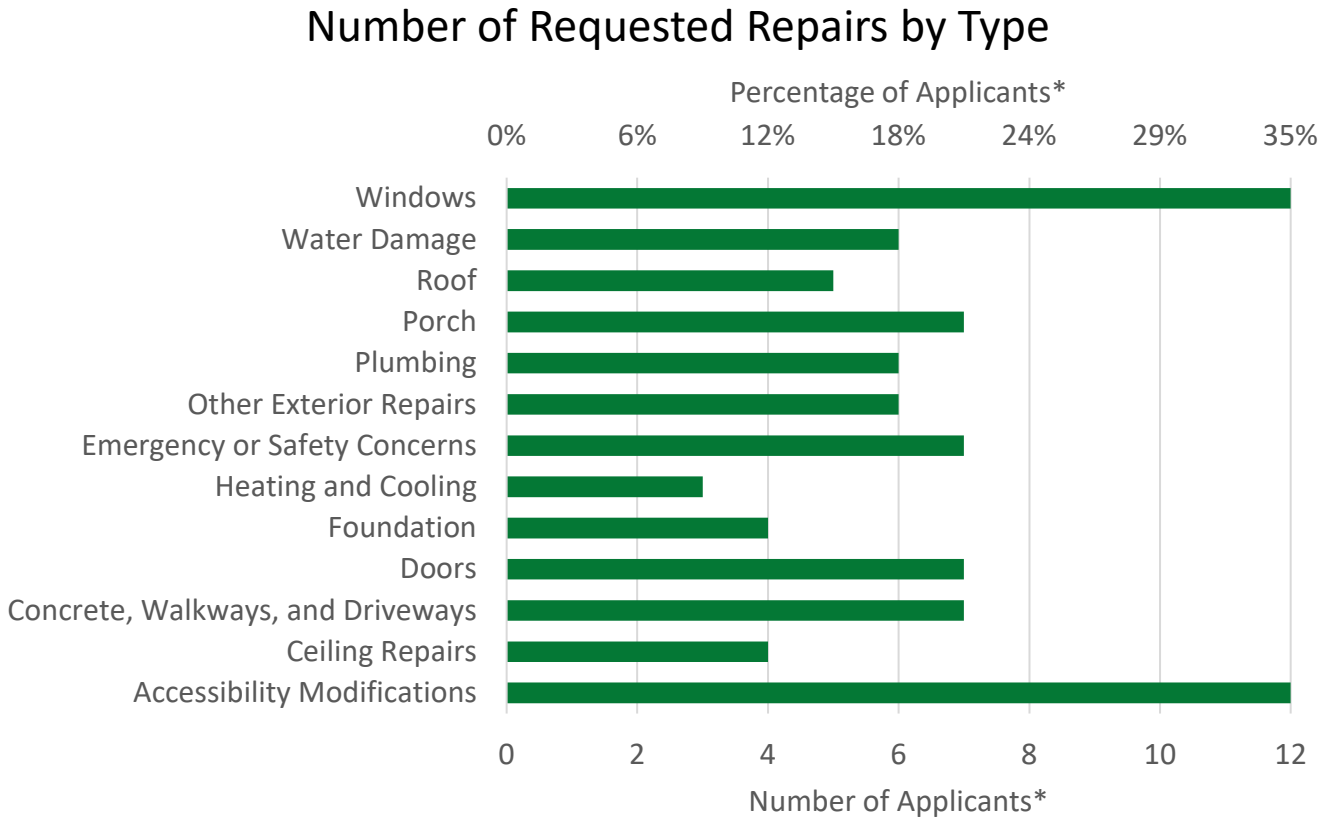


HAP targets homeowners at or below 80% AMI, with **Hill District applicants** mostly falling between **0-30%** or **31-50% AMI.**

Please note that applicants with 101-120% AMI were eligible for HAPI program only.

URA HAP and HAPI Programs Data Summary

- **Accessibility modifications** and **windows** were the most common applicant requests, each accounting for **35% of applications.***
- **Concrete, walkways, and driveways; doors; emergency or safety concerns;** and **porches** were the second most common applicant requests, each accounting for **21% of applications.***

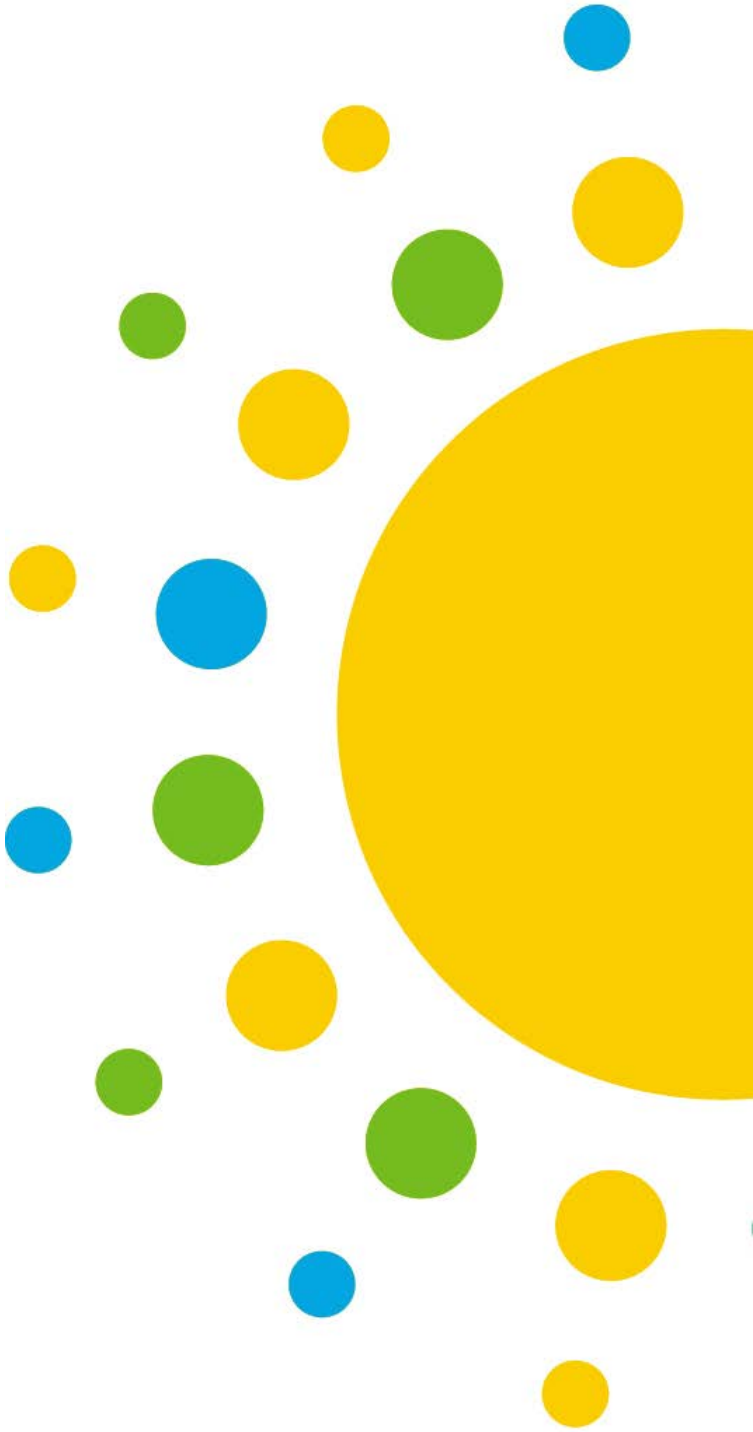


*Excluding 6 applicants who did not indicate specific repairs. Applicants also requested other repairs, but at lower rates, than those shown here. See Appendix I for more information on repair types.

URA HAP and HAPI Summary of Takeaways

- 20% of applications in the Hill District were accepted, potentially indicating an unmet need.
  - A lower percentage of applicants from the Hill District were accepted than among applicants to the program overall (30%).
- Many applicants requested accessibility modifications and cited emergency repairs or safety concerns.
  - This indicates that there may be a significant need among applicants for home repairs and upgrades that are being prioritized over energy efficiency upgrades (stakeholder engagement with program providers indicated that emergency repairs and repairs to resolve accessibility and safety concerns are being prioritized over energy efficiency upgrades).
- Many applicants requested windows, indicating a potential opportunity for energy efficiency upgrades through the program.

Housing Characteristics and Energy Upgrade Analysis



Overview

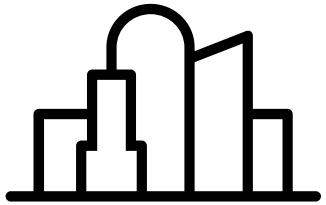
Modeling Background

- A building modeling tool called ResStock™ was used by NREL researchers to generate results.
- Models are a **mathematical/statistical representation of reality.**
- Models use national and regional data on actual buildings combined with statistical assumptions and buildings expertise to generate estimates for modeled buildings.

Please note: NREL's building stock analysis included modeled homes from the Hill District and the nearby surrounding areas; in-person assessments or site visits were not completed on homes in the Hill District.

The ResStock Workflow

ResStock



Building stock characteristics database

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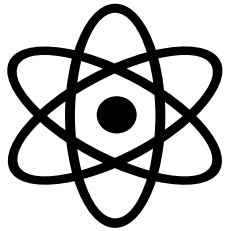

Physics-based computer modeling

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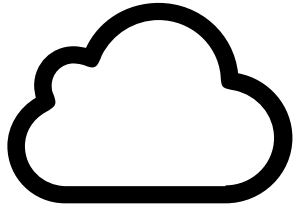


High-performance computing

This is where Communities LEAP comes in.

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

Intended Uses for This Analysis

Inform strategic priorities

Results can be used to inform strategic direction of programming and funding allocation (e.g., prioritizing across upgrades or housing segments).

Reinforce local knowledge

Results can validate and augment knowledge, experiences, and perspectives from community organizations.

Support funding applications

Results can be used to demonstrate alignment between the needs and opportunities in the Hill District and the goals of relevant funding opportunities.

Energy Efficiency and Electrification Approaches

Key Terms:

1. **Building Energy Efficiency:** Improving building enclosure and installing measures like insulation and air sealing can reduce the energy consumption for space heating and cooling, other appliances, and contribute to a more comfortable indoor environment.
2. **Building Electrification:** The adoption of technologies that use electricity in place of natural gas or other fossil fuels. Key examples for electrification include space heating, water heating, appliances, and other equipment.

NREL researchers analyzed how building enclosure and electrification upgrades to existing residential buildings might impact the following areas:

1. Energy consumption (site-level)
2. Greenhouse gas (GHG) emissions
3. Energy burden
4. Utility bills.

Please note: All energy values included in this presentation represent site energy consumption. Site energy consumption can be described as "the amount of heat and electricity consumed by a building as reflected in your utility bills" (ENERGY STAR® N.d.).

Modeling Details: Energy Upgrades

- Energy upgrade packages were analyzed using NREL's ResStock model.
- **Upgrade packages describe a set of energy efficiency measures.**
  - For example, the Basic Enclosure package includes general air sealing and wall insulation.
- Those highlighted in **green** were a focus of this analysis.
- Additional details on upgrades are included in Appendix II.

Modeled Energy Upgrade Packages

1. **Basic Enclosure**
2. **Enhanced Enclosure**
3. Electric Clothes Dryer
4. Heat Pump Clothes Dryer
5. Electric Cooking
6. Induction Cooking
7. **Heat Pump Water Heater**
8. Minimum-Efficiency Heat Pump with Existing Heat Backup
9. Minimum-Efficiency Heat Pump with Electric Heat Backup
10. **High-Efficiency Heat Pump with Electric Heat Backup**
11. Minimum-Efficiency Whole-Home Electrification
12. High-Efficiency Whole-Home Electrification
13. Basic Enclosure + HPWH + High-Efficiency HP/Electric Backup
14. Basic Enclosure + High-Efficiency Whole-Home Electrification
15. Enhanced Enclosure + HPWH + High-Efficiency HP/Electric Backup
16. Enhanced Enclosure + High-Efficiency Whole-Home Electrification.

Modeling Details: Housing Segments

- The community coalition and NREL staff selected housing segments in 2023.
- Housing segments help to **narrow the focus of analysis** on specific types of housing or occupant characteristics.
  - For example, all segments only focus on 0-80% AMI homeowners/renters.
  - 98.9% of housing units included in the analysis for the Hill District were brick masonry.

Housing Segments Analyzed in ResStock Modeling

Segment 1: Single-Family Detached	**Segment 2:** Single-Family Attached	**Segment 3:** Multifamily Housing	**Segment 4:** All 0-80% AMI Housing
• Single-Family Detached • Renter • Pre-1940 • Masonry construction • 0-80% AMI.	• Single-Family Attached • Renter • Pre-1940 • Masonry construction • 0-80% AMI.	• Multifamily • Masonry construction • 0-80% AMI.	• All 0-80% AMI housing stock.

Impact of Housing Type on Modeling Results for the Hill District

- Single-family detached units (Segment 1) do not have any walls shared with other housing units. Single-family attached units (Segment 2) have at least one shared wall. Multifamily housing units (Segment 3) often have multiple shared walls. Multifamily housing units (Segment 3) are generally smaller than single-family units (Segments 1 and 2).

- The size and configuration of housing units has an impact on modeled results. Modeled average energy use, energy reductions, and upfront upgrade package costs for most upgrades were higher for larger housing units with fewer shared walls.
  - Modeled average energy use, energy reductions, and upfront upgrade package costs were generally higher for single-family homes compared to multifamily homes.
  - Single-family detached homes had higher modeled energy use, energy reductions, and upfront upgrade package costs compared to single-family attached homes.

Cost Limitations and Assumptions

- National average costs were scaled based on a local cost and inflation adjustment factor. Costs do not include rebates. Costs for any individual project can vary substantially. More information on methodology can be found in the NREL data catalog (https://data.nrel.gov/submissions/224).
- Cost estimates are intended to inform community-level, strategic planning around residential energy efficiency.
  - Cost estimates do not correspond to any individual home in the Hill District.
  - This analysis does not consider the costs to deploy these measures in the context of a program such as the WHRP or HAP, and these costs may vary across segments.
- Results are *not* recommended to guide individual investment decisions.
  - Costs for any individual project can vary substantially based on factors such as existing home conditions and local contractor rates.
- For all packages, the average modeled costs represent full purchase and installation costs, rather than the incremental cost of replacement at the time of failure of existing equipment (e.g., the additional cost for installing a heat pump minus the cost of replacement with a new version of the existing equipment).

Other Key Modeling Assumptions and Limitations

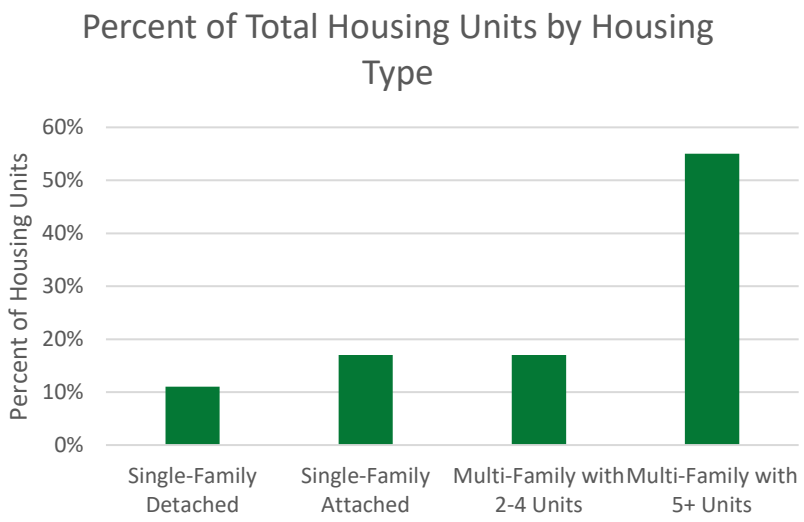
- Analysis is based on ResStock-modeled energy consumption. All models have uncertainties.
- Modeling is aggregated across collections of housing units. Results for individual housing units can vary substantially.
- Utility rates were provided by Duquesne Light.
- Specific measures and upgrade packages were modeled. Not all potential technologies/performance levels and packages available within ResStock were modeled.
- Building upgrades that may be needed before electrification (e.g., remediation, new electric panel) were not considered.
- Heat pumps were modeled with the existing heating system as backup and modeled separately with electric backup. Heat pumps were sized for cooling loads, which can produce more conservative estimates. More information can be found in the End-Use Savings Shapes documentation (https://oedi-data-lake.s3.amazonaws.com/nrel-pds-building-stock/end-use-load-profiles-for-us-building-stock/2022/EUSS_ResRound1_Technical_Documentation.pdf).
- Households without existing cooling systems were assumed to use cooling after a heat pump upgrade, which adds a new service and improved thermal comfort, but can also substantially affect the cost-effectiveness of packages.

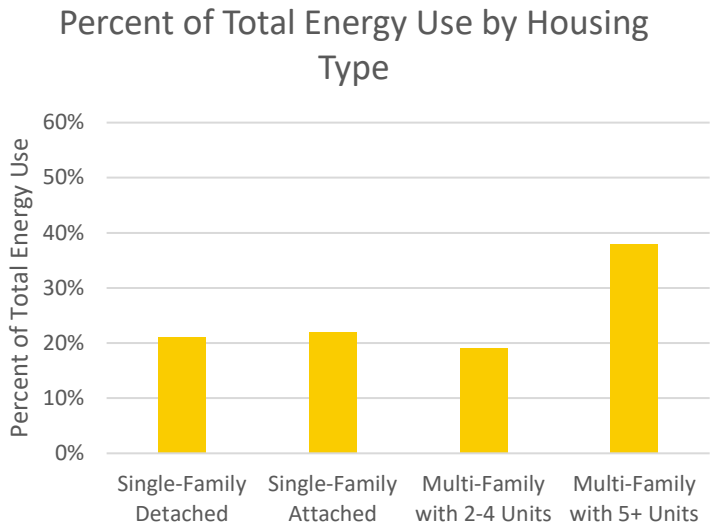
Housing Stock Summary

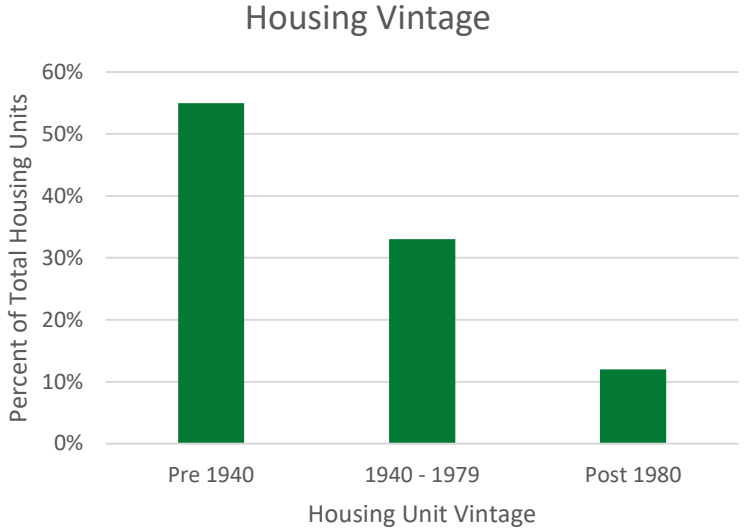
Housing Type, Energy Use, and Vintage

For the modeled housing stock in the Hill District:

- 55% of the Hill District's housing units are Multifamily with more than 5 units. However, these units only consume 38% of the total energy use.
- Single-Family Detached and Single-Family Attached units consume 43% of total energy, despite only accounting for 28% of total households.
- 55% of housing units in the Hill District were built before 1940, 33% of housing units were built between 1940 and 1979, and 12% of housing units were built after 1980.





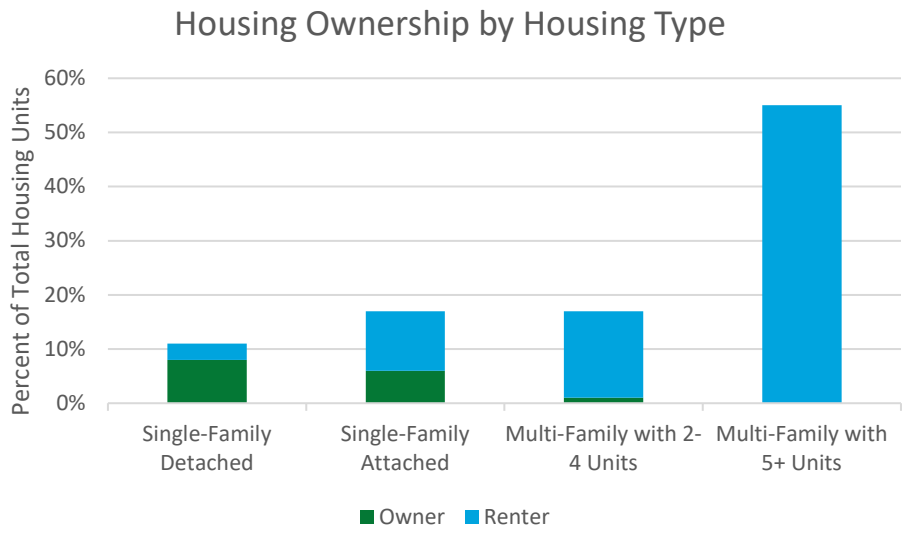


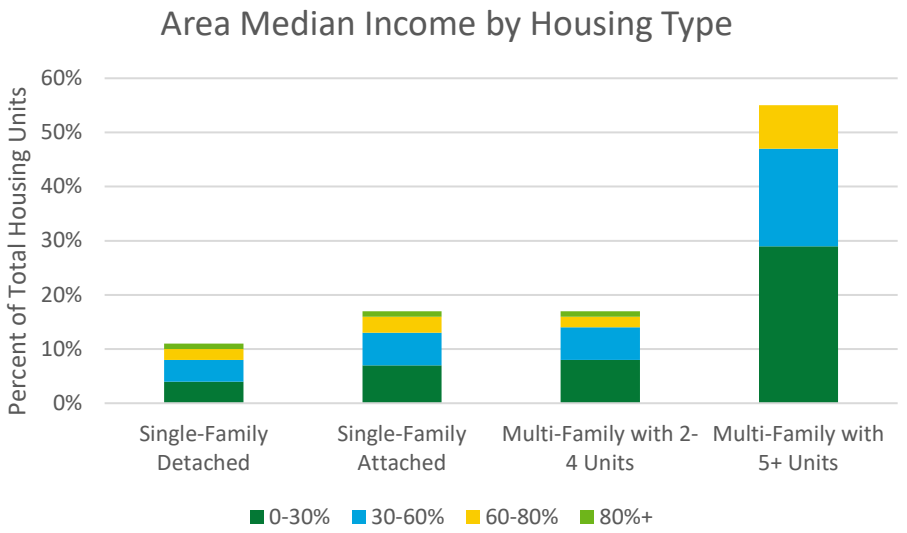
Please note: The results presented in the housing stock summary represent all modeled households in the Hill District, not just specific housing segments.

Housing Tenure and Area Median Income (AMI)

For the modeled housing stock in the Hill District:

- 85% of homes in the Hill District are currently occupied by renters, and 98% of those living in multifamily units are renting.
- Of those that do own their homes, 93% of homeowners live in a single-family home. Single-Family Detached is the only housing type where there are more homeowners than renters.
- Within the modeled data presented here, 48% of housing units make less than 30% of the Pittsburgh Area Median Income (AMI). 29% of the modeled Hill District households are multifamily buildings with more than 5 units and make less than 30% AMI.



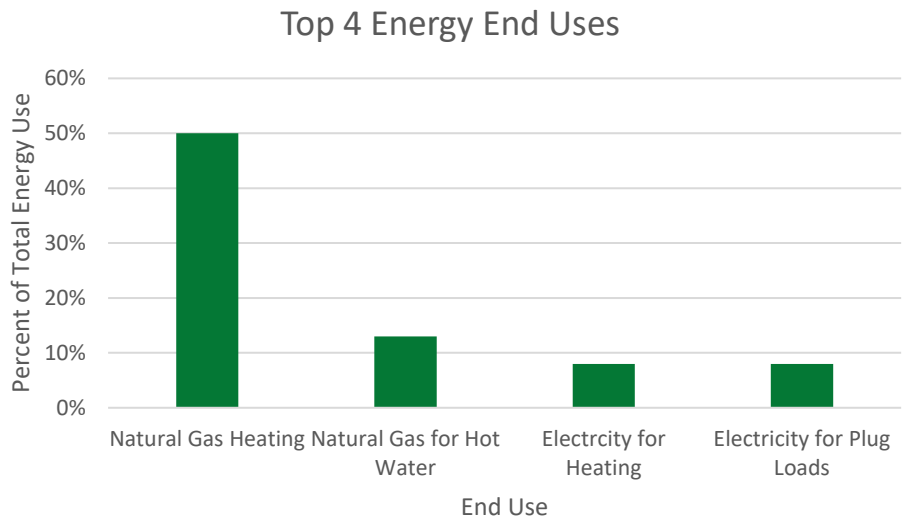


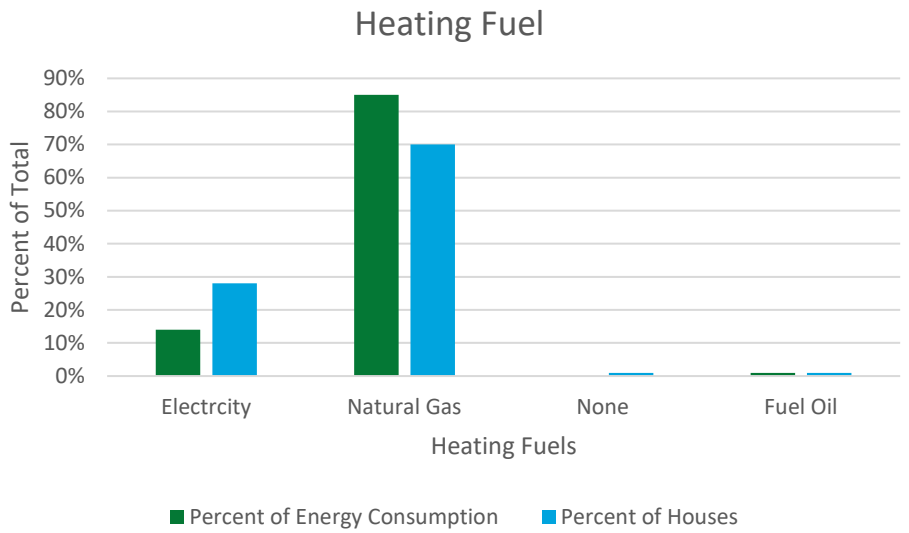
Please note: The results presented in the housing stock summary represent all modeled households in the Hill District, not just specific housing segments.

Energy End Uses and Heating Fuel

For the modeled baseline energy consumption in the Hill District:

- The top four energy end uses are natural gas heating, natural gas for hot water, electricity for heating, and electricity for plug loads. The two heating end uses account for 63% of total energy consumption.
- The share of total heating energy consumption for natural gas is 85%, and 70% of homes have natural gas heating. Electric heating comprises 13% of total energy consumption, and 28% of homes have electric heating.





Please note: The results presented in the housing stock summary represent all modeled households in the Hill District, not just specific housing segments.

Modeling Results: Energy Efficiency Upgrade Packages

Energy Efficiency Upgrade Background

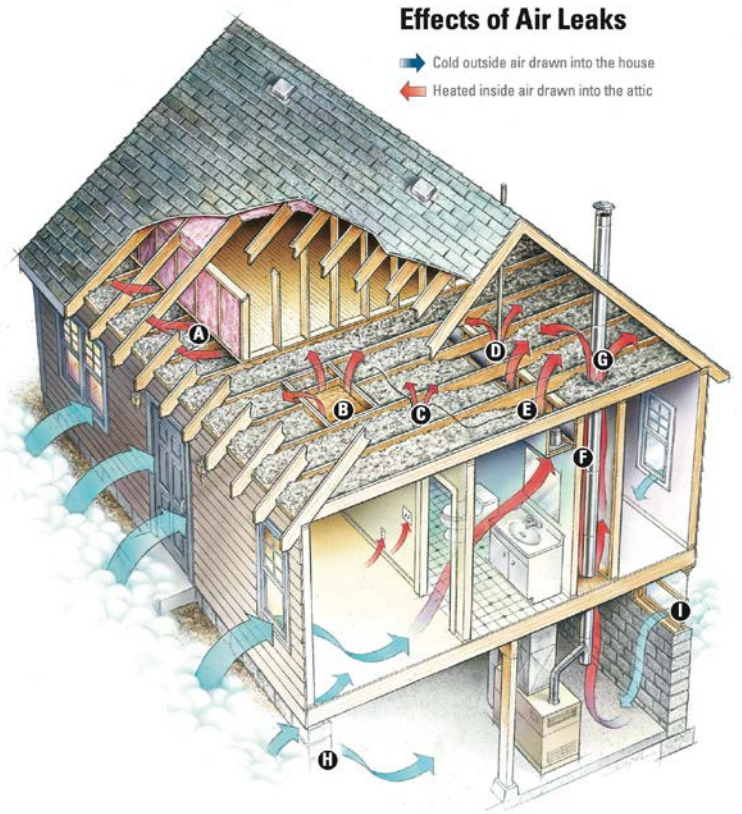
- The analysis in this section focuses on the following enclosure upgrade packages:
  - Basic Enclosure
  - Enhanced Enclosure.
- The section summarizes details of the modeling results corresponding to these packages, as well as narrative to highlight key results.

Energy Efficiency Upgrade Background

- Building Enclosure: Everything that separates a home from the outside.
  - Walls
  - Windows
  - Attic and roof
  - Foundation floors and walls.
- Impacts of building enclosure:
  - Comfort: A well-insulated, well-sealed home stays warmer in the winter and cooler in the summer.
  - Utility Bill Reductions: Heating and cooling equipment does not have to work as hard and uses less energy to maintain indoor comfort.

Energy Efficiency Upgrade Background

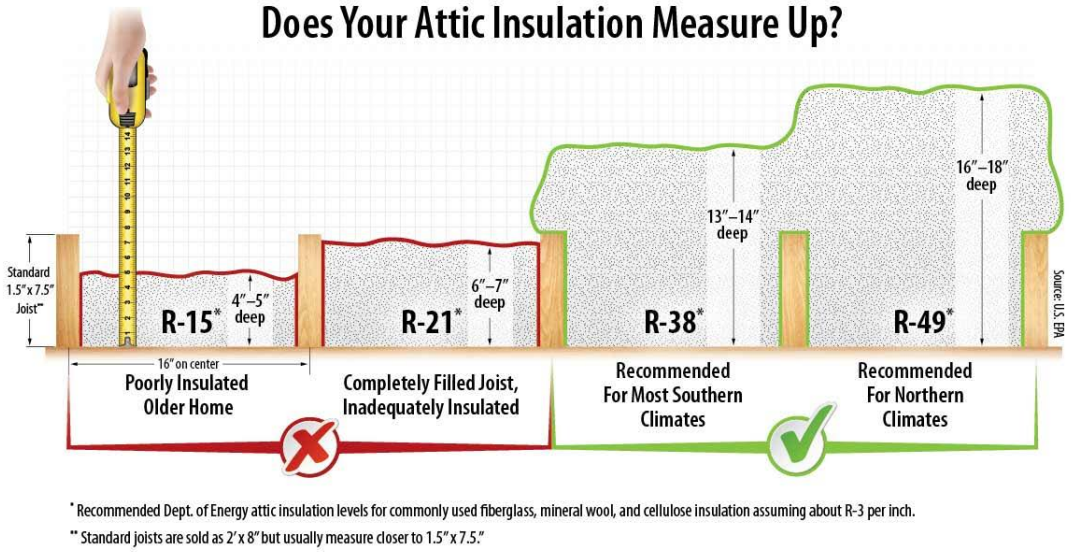
- Infiltration/Exfiltration: Air leakage into and out of a home (DOE Energy Saver n.d.)
- Why does infiltration matter?
  - A leaky house requires more energy and is more expensive to heat and cool; it can also be less comfortable for occupants.
  - Poor infiltration is linked to home health hazards, including asthma triggers such as mold and pests (DOE n.d.).



Source: ENERGY STAR (n.d.)

Energy Efficiency Upgrade Background

- Insulation: Keeps the house cooler in the summer and warmer in the winter.
- R-Value: Measure of insulation's ability to resist heat traveling through it.
- E.g., for new single-family construction, ceiling insulation:
  - IECC 2009: R-38
  - IECC 2018: R-49 (Pittsburgh today)
  - Enterprise Green Communities: R-49
  - IECC 2021 (latest codes): R-60 (EERE 2021).



Ceiling insulation r-values and acceptability for residential homes based on climate. Image from ENERGY STAR n.d.

Basic Enclosure Measure Package Details

Upgrade attic insulation to modern building codes (IECC 2021)

Reduce air leakage (infiltration) by 30%

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

Drill and fill wall insulation to R-13.

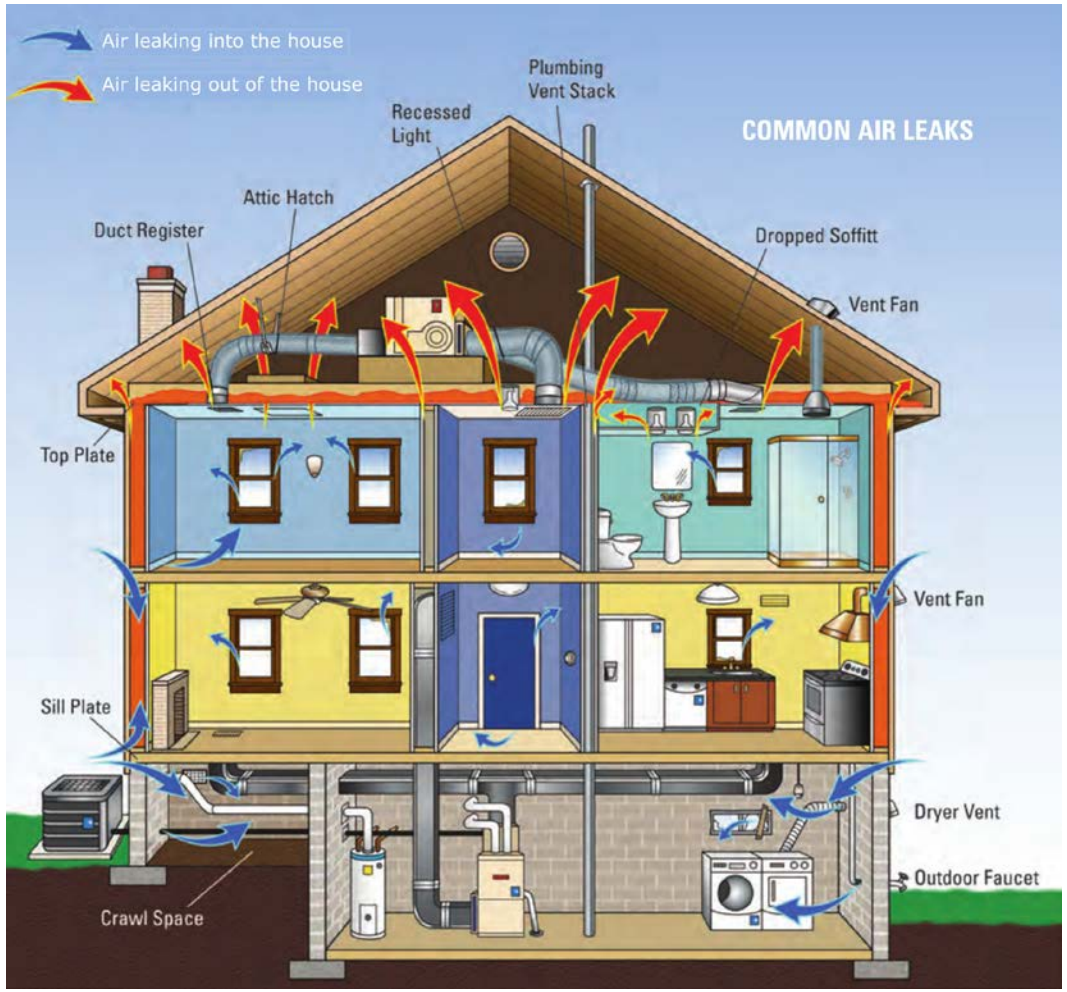
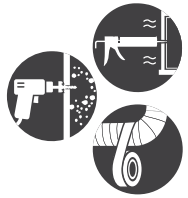


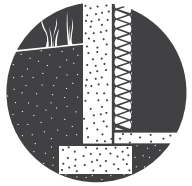
Illustration from EPA 2009

Image: Dennis Schroeder, NREL 171785
Image: Cory Chovanec, NREL
Image: Dennis Schroeder, NREL 28694
Image: Dennis Schroeder, NREL 28725

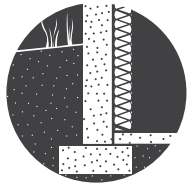
Enhanced Enclosure Measure Package Details



Everything in the basic enclosure package, and…



Add R-10 to foundation walls and rim joists



Seal crawlspace vents

Insulate finished attic and cathedral ceilings to R-30.

Installing attic insulation.

Installing exterior insulation.

Installing crawlspace insulation.

Rim joist installation.

Basic Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

- Results show modeled average energy and emissions reductions per housing unit for every segment.
- Average modeled energy and emissions reductions per housing unit are highest for the single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.

- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

Basic Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

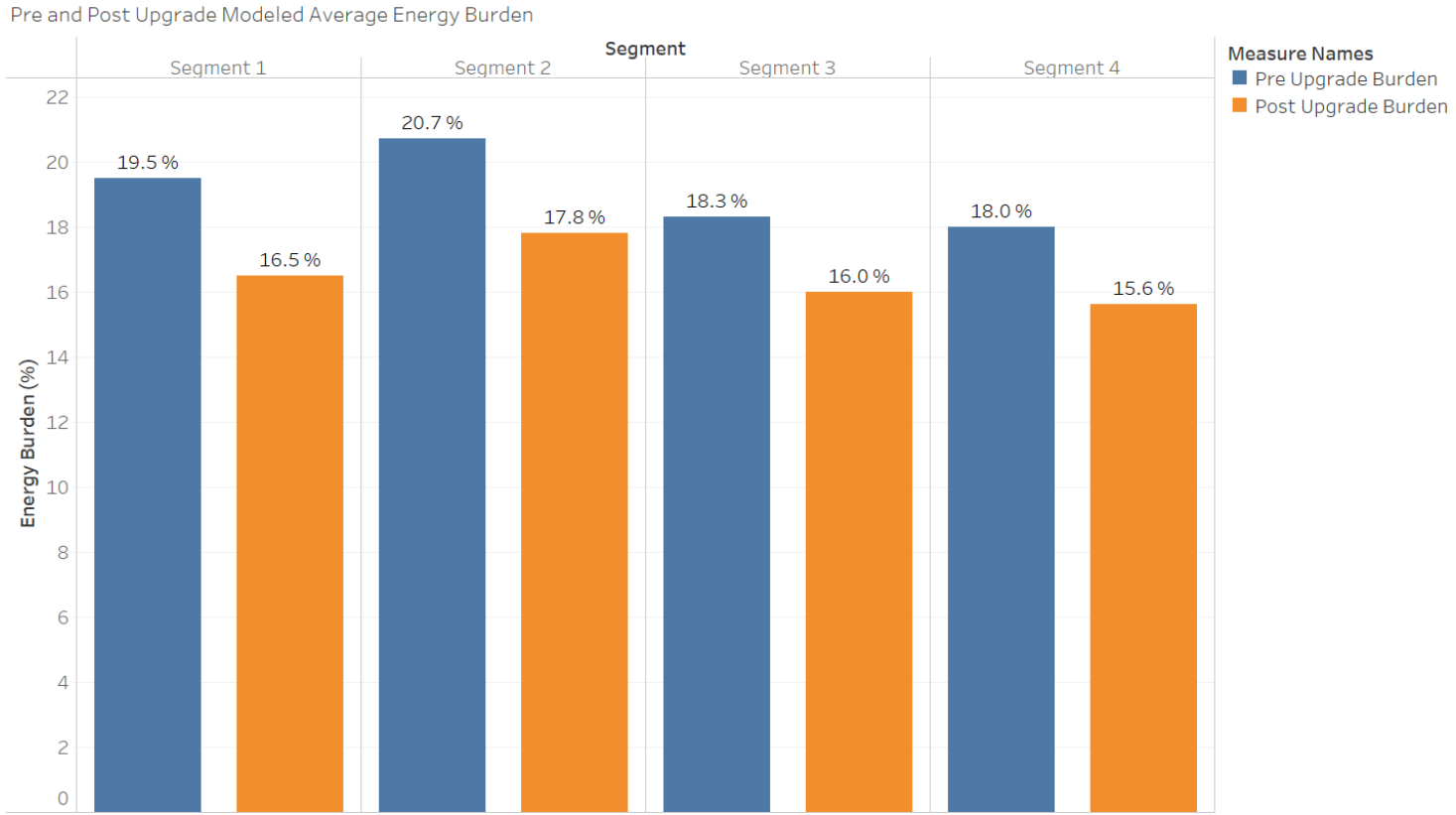
- Average modeled upgrade costs are highest for the single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.
- Results show modeled average bill reductions across all segments.
- Average modeled bill reductions are highest for single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.

- All numbers are modeled average per housing unit by segment.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Assumed performance of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

Basic Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

- Modeled average energy burden is highest for the single-family attached homes in Segment 2.
- Results show average modeled energy burden decreases from bill reductions for all segments.
- Average modeled energy burden reductions from bill reductions are higher for the single-family homes in Segments 1 and 2 than for the multifamily homes in Segment 3.

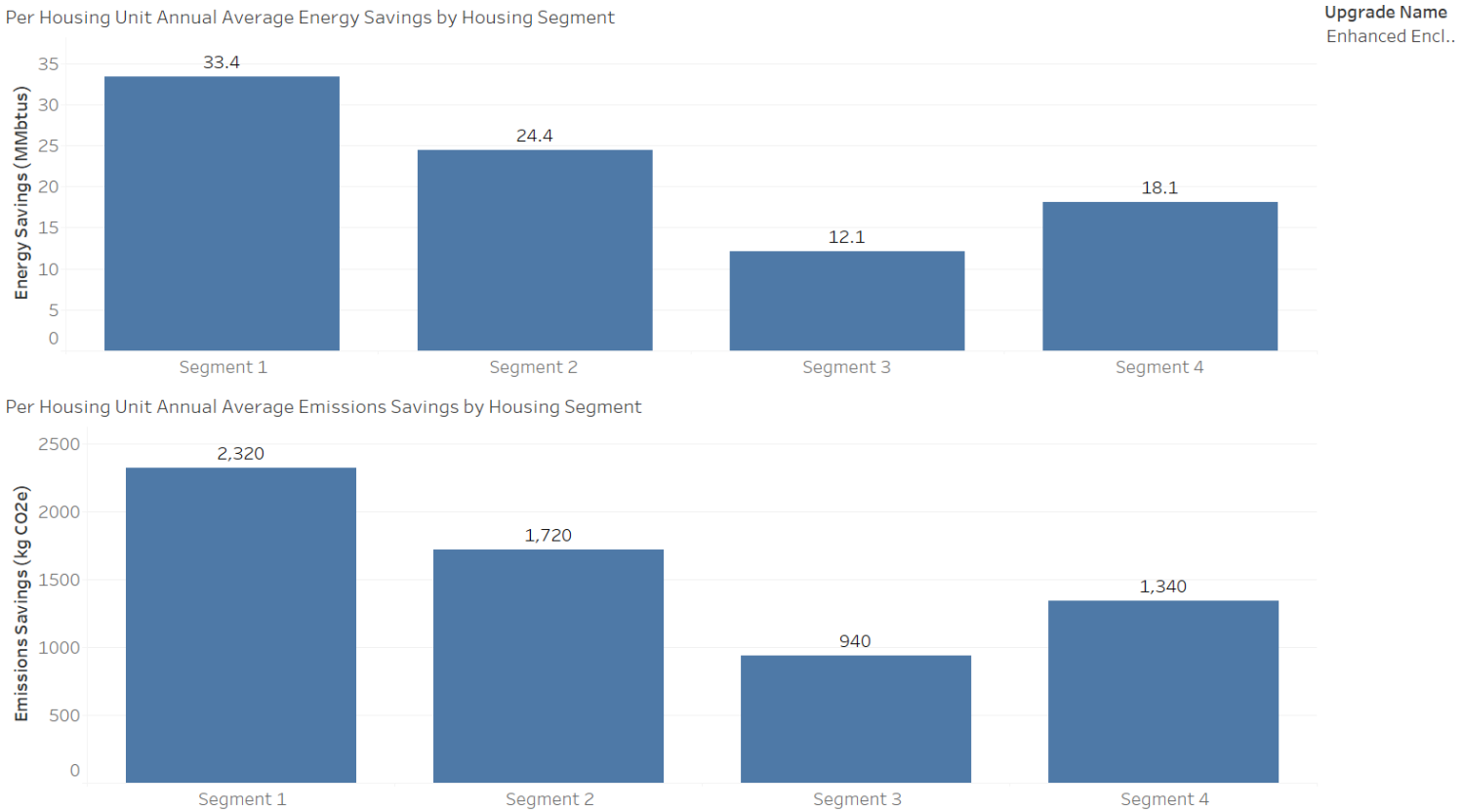


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Enhanced Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

- As expected, results show higher modeled average energy reductions across all segments compared to the Basic Enclosure upgrade.
- Average modeled energy and emissions reductions are highest for the single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

Enhanced Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

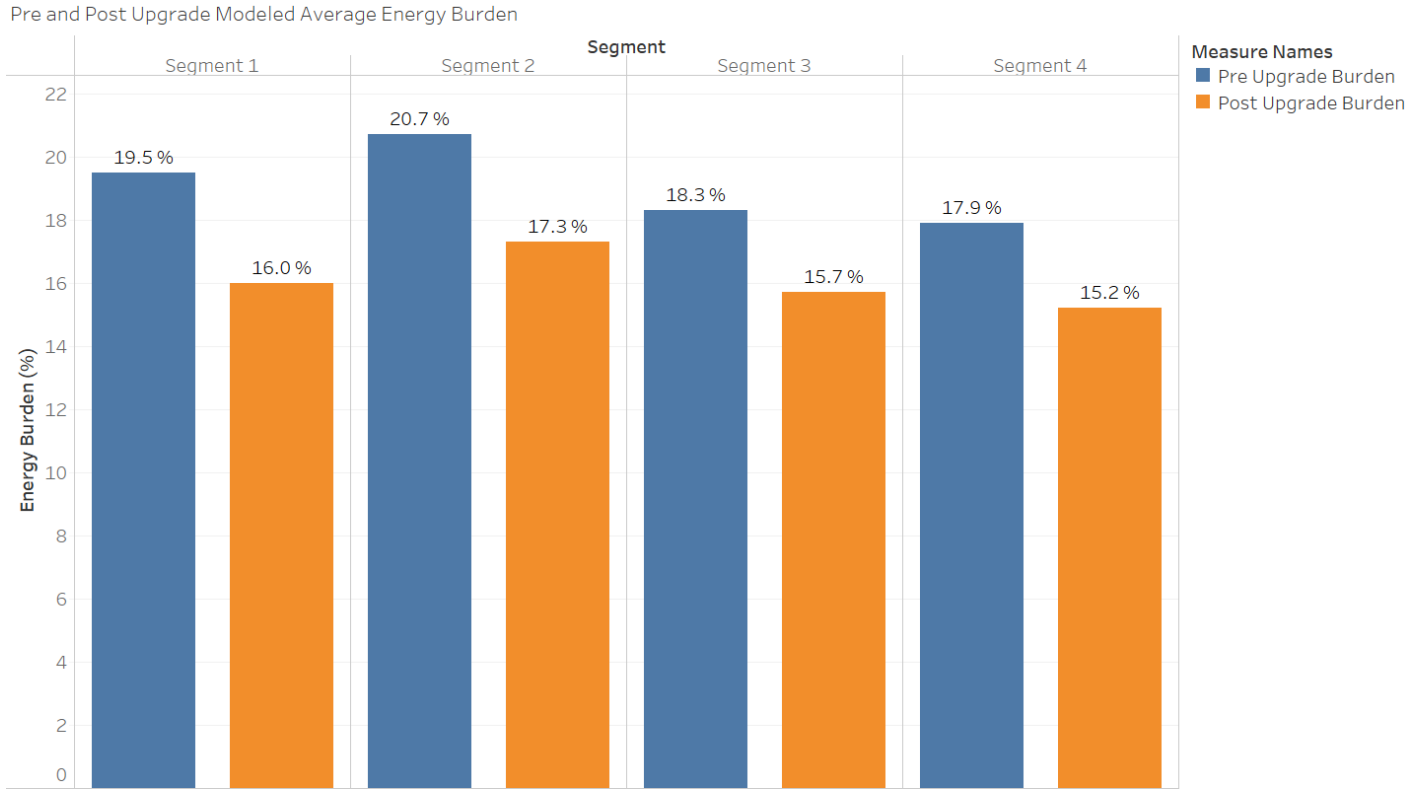
- As expected, results show higher modeled average upgrade costs across all segments compared to the Basic Enclosure upgrade.
- Results show modeled average bill reductions across all segments.
- Average modeled bill reductions are highest for the single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.

- All numbers are modeled average per housing unit by segment.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

Enhanced Enclosure Upgrades

For the modeled upgrade measures in the Hill District:

- As expected, results show higher modeled average energy burden reductions from bill reductions across all segments compared to the Basic Enclosure upgrade.
- Results show average modeled energy burden decreases from bill reductions for all segments.
- Average modeled energy burden reductions from bill reductions are higher for the single-family homes in Segments 1 and 2 than for the multifamily homes in Segment 3.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Modeling Results: Electrification Upgrade Packages

Electrification Upgrade Package Background

- The analysis in this section focuses on the following key electrification upgrade packages:
  - High-Efficiency Heat Pump with Electric Heat Backup
  - Heat Pump Water Heater.
- The section summarizes details of the modeling results corresponding to these packages, as well as narrative to highlight key results.
- Results for additional upgrade packages are included in Appendix III.

Electrification Upgrade Package Background

A heat pump:

- Uses electricity to transfer heat from a cool space to a warm space.
  - During the heating season, heat pumps move heat from the cooler outdoors into your warmer house.
  - During the cooling season, heat pumps move heat from your cooler house into the warmer outdoors.
- Because they transfer heat rather than generate heat, heat pumps can efficiently provide comfortable temperatures for your home.
- Can require additional electrical work (e.g., electrical panel upgrade) if replacing equipment with other fuel sources (e.g., natural gas furnace).
- A heat pump water heater works by moving heat from air into the water.
- For more information on heat pumps, see DOE's Energy Saver site: Heat Pump Systems (https://www.energy.gov/energysaver/heat-pump-systems) and Heat Pump Water Heaters (https://www.energy.gov/energysaver/heat-pump-water-heaters).

(Dennis Schroeder, NREL)

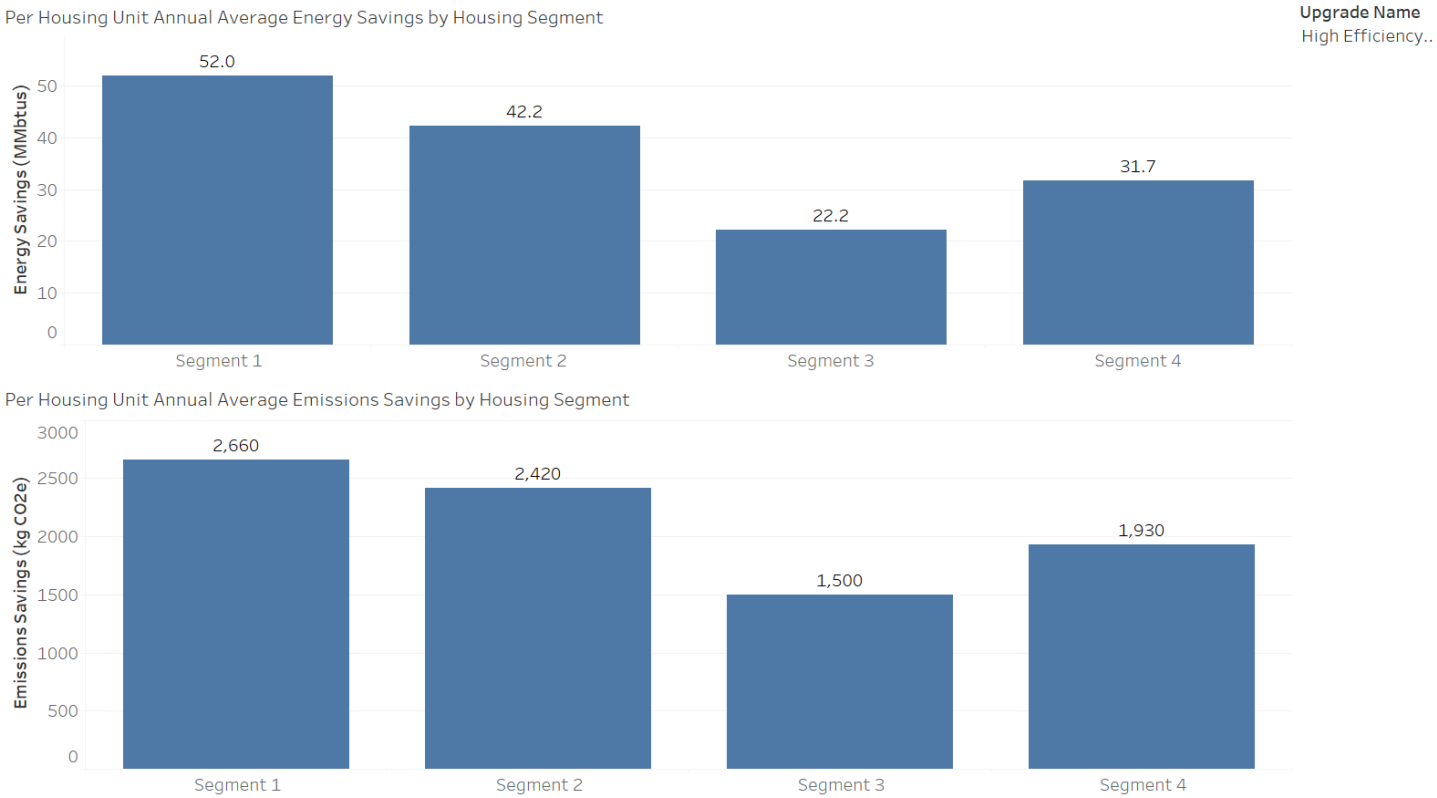
Electrification Upgrade Package Details

- The High-Efficiency Electric Heat Pump w/Electric Backup package includes upgrading natural gas or propane HVAC units to high-efficiency electric units.
  - If the existing system is electric, the existing heating system is retained as backup.
  - If the existing system is not electric, electric resistance backup heating is installed.
  - The backup system is used when the heat pump cannot meet heating loads.
- The Heat Pump Water Heater package includes upgrading natural gas or propane water heating units to electric heat pump water heaters.
- Additional details on upgrades are included in Appendix II.

High-Efficiency Heat Pump w/ Electric Backup Upgrades

For the modeled upgrade measures in Hill District:

- Results show modeled average energy and emissions reductions for every segment.
- Average modeled energy and emissions reductions are highest for the single-family detached homes in Segment 1, and lowest for the multifamily homes in Segment 3.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

High-Efficiency Heat Pump w/ Electric Backup Upgrades

For the modeled upgrade measures in Hill District:

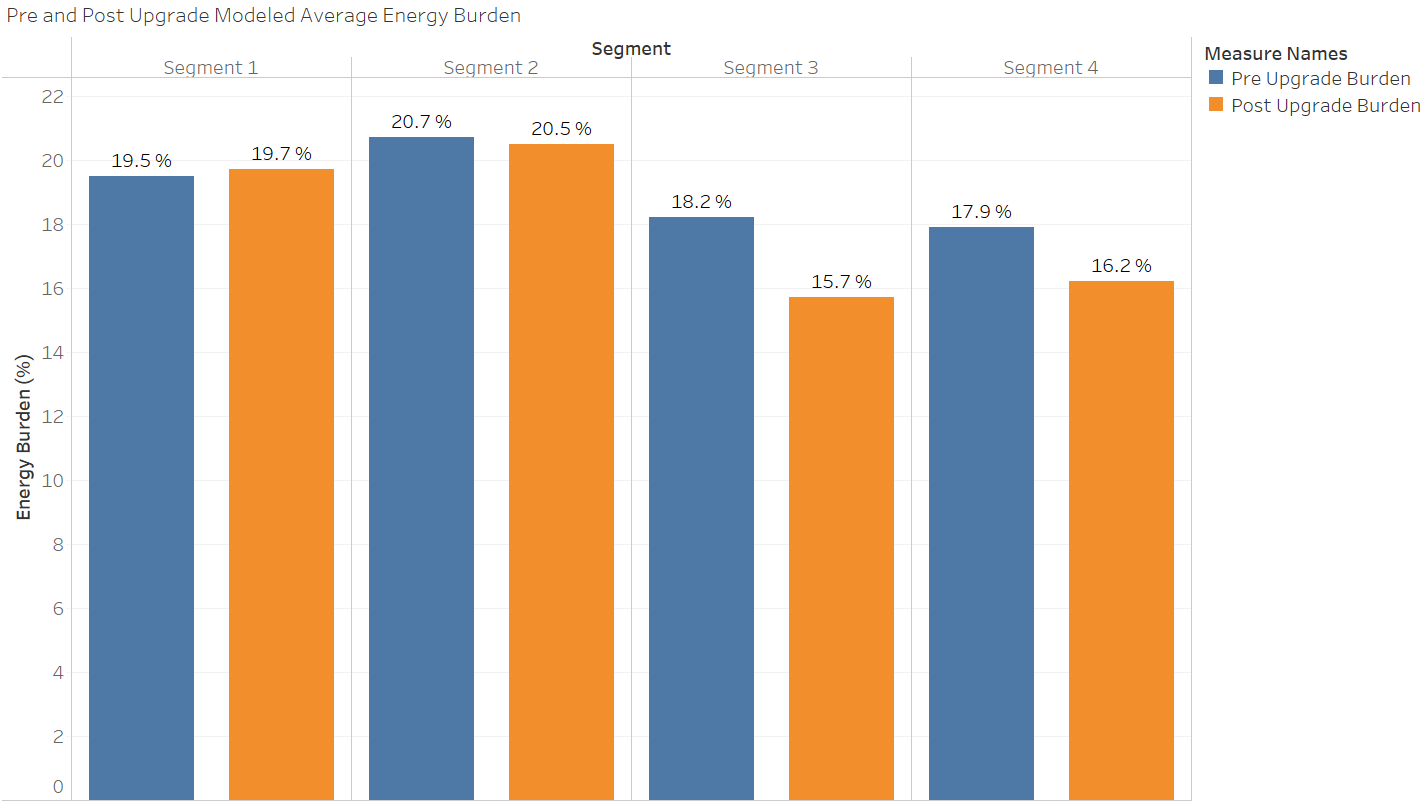
- The modeled average upgrade costs for the heat pump are much higher than for enclosure upgrade packages.
- Average modeled costs do not consider any rebates or programs that may exist to help lower the cost of installing the heat pumps.
- Modeled average energy bills decrease for all segments except Segment 1. This increase in energy bills is due to increased electricity consumption outweighing reduced gas consumption.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

- All numbers are modeled average per housing unit by segment.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.

High-Efficiency Heat Pump w/ Electric Backup Upgrades

For the modeled upgrade measures in Hill District:

- Results show average modeled energy burden reductions from bill reductions for all segments except Segment 1.
- Average modeled energy burden reductions from bill reductions are highest for the multifamily homes in Segment 3.

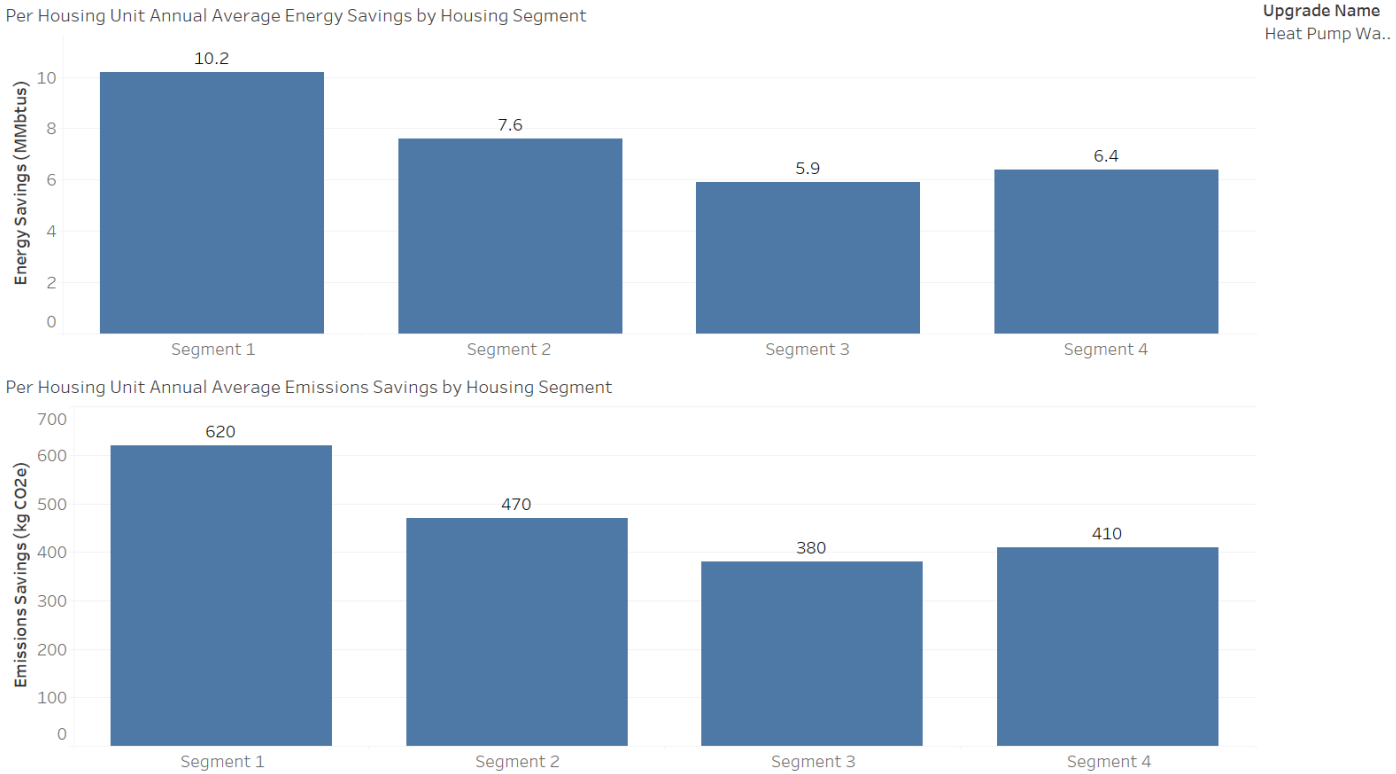


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Heat Pump Water Heater Upgrades

For the modeled upgrade measures in the Hill District:

- Results show modeled average energy and emissions reductions for every segment.
- Average modeled energy and emissions reductions are highest for the single-family detached homes in Segment 1 and lowest for the multifamily homes in Segment 3.

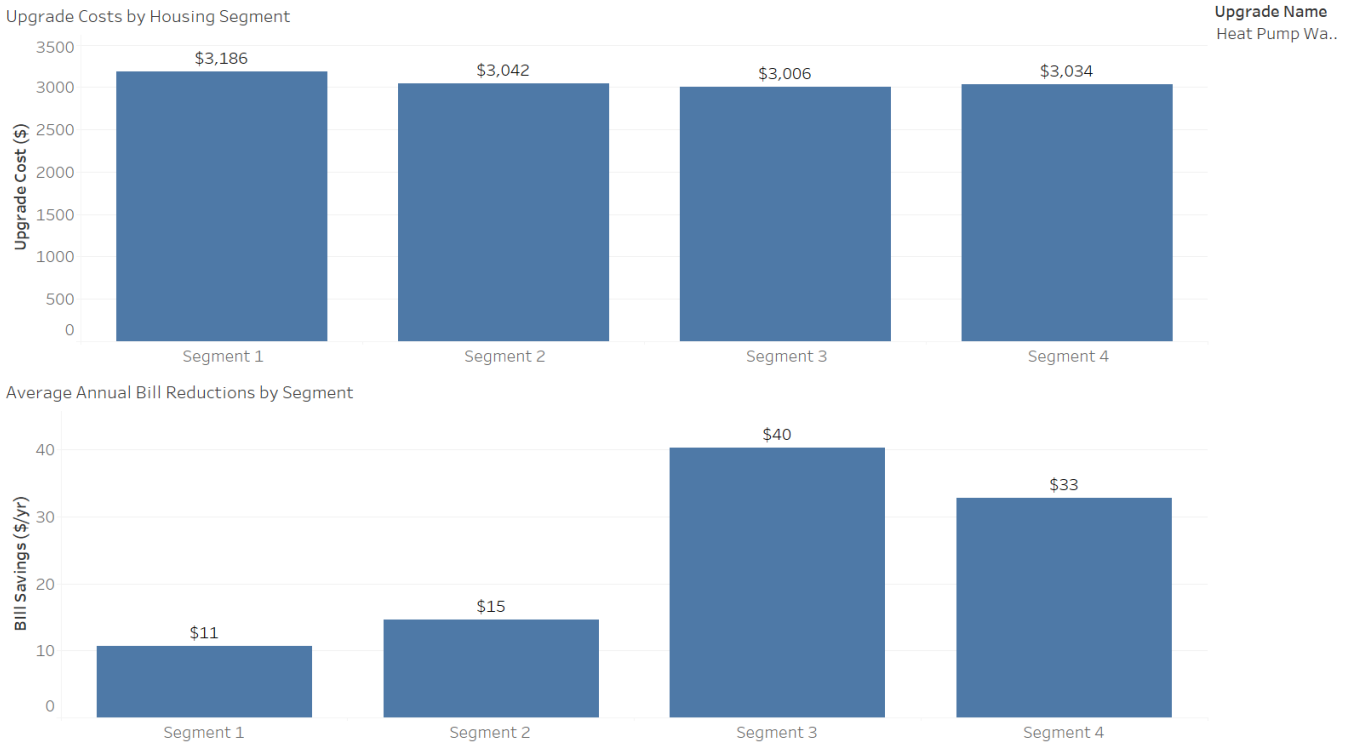


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.

Heat Pump Water Heater Upgrades

For the modeled upgrade measures in the Hill District:

- The modeled average upgrade costs for the heat pump water heaters are very similar across all segments.
- Average modeled bill reductions are highest for the multifamily homes in Segment 3 and lowest for the single-family detached homes in Segment 1.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

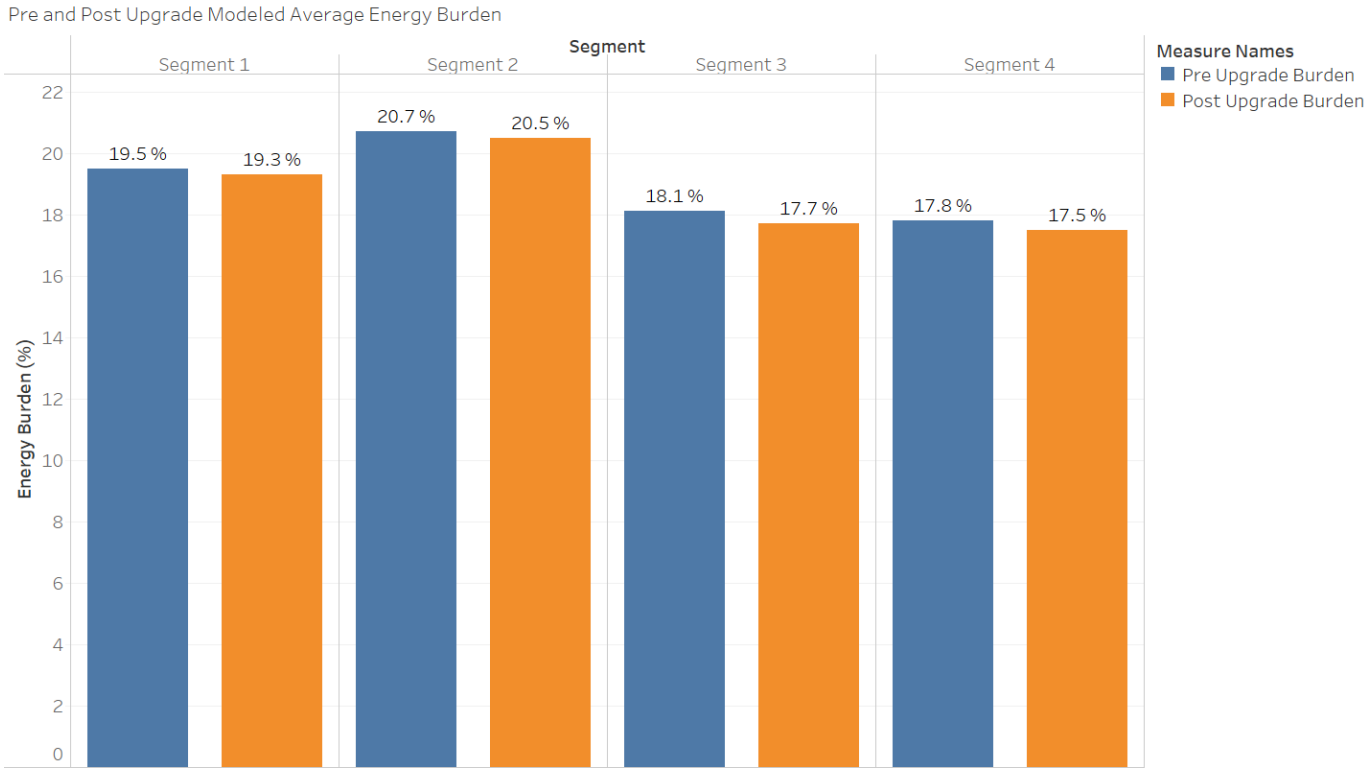


- All numbers are modeled average per housing unit by segment.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.

Heat Pump Water Heater Upgrades

For the modeled upgrade measures in Hill District:

- The post-upgrade modeled average energy burden (not including upgrade costs) is down slightly for every segment.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Community-Wide Reductions

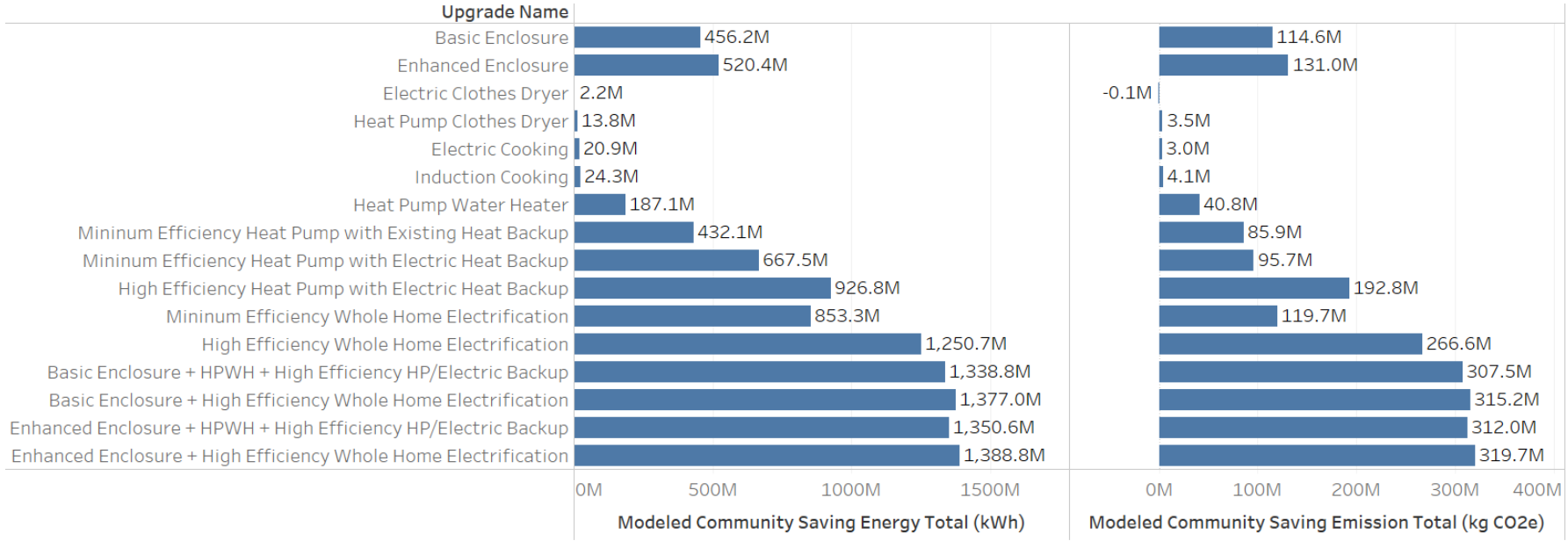
Community-Wide Reductions Background

- The analysis in this section shows modeled community-wide impacts if each measure were deployed across all modeled homes in the Hill District.
- Impacts are shown in terms of energy, emissions, electricity, and fossil fuel reductions.

Community-Wide Energy and Emissions Reductions

Modeled Energy Upgrades in Hill District

- The modeled community-wide energy and emissions reductions for each upgrade package are outlined below.
- Each upgrade package provides some energy reductions; however, not all packages resulted in emissions reductions.
  - For example, the electric clothes dryer measure sees an emissions increase due to the electricity consumption increase, which is higher than any emissions reductions due to natural gas decreases.

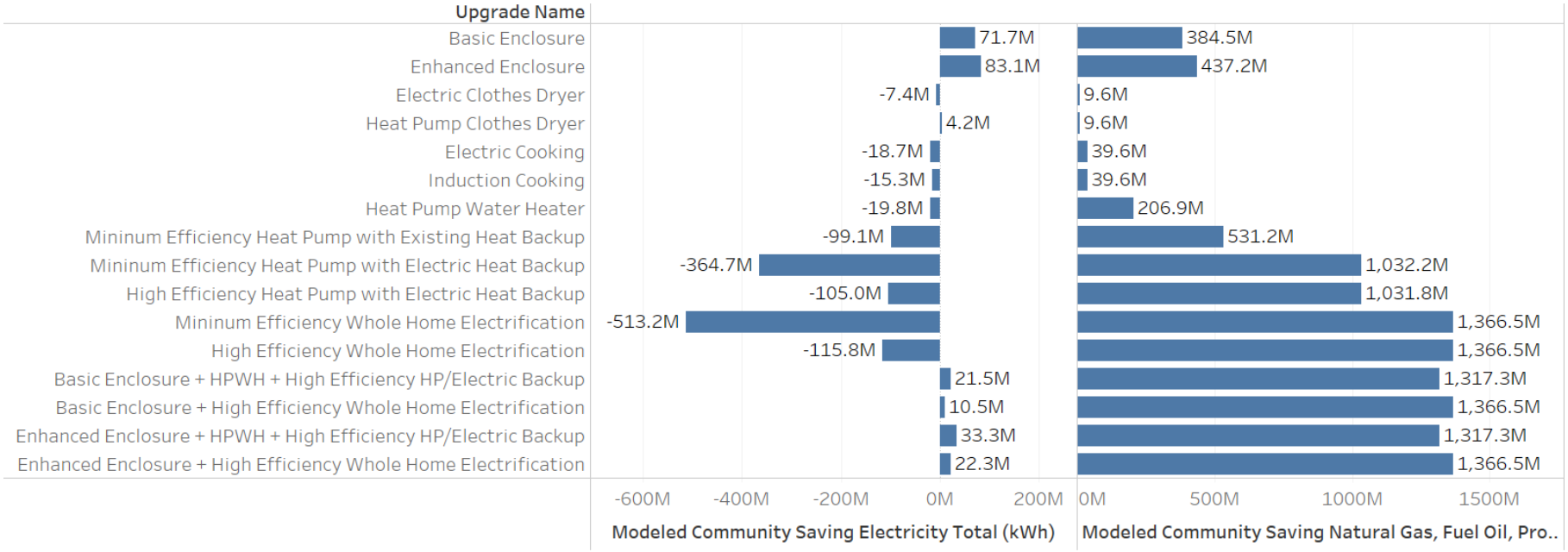


Please note: The results presented in the housing stock summary represent all modeled households in the Hill District, not just specific housing segments.

Community-Wide Electricity and Fossil Fuel Reductions

Modeled Energy Upgrades in Hill District

- The modeled electricity and natural gas reductions for each upgrade package are outlined below.
- Most packages include an electrification upgrade, which generally means there will be a reduction in natural gas consumption, but an increase in electricity consumption. Enclosure upgrades reduce both the natural gas and electricity consumption.



Please note: The results presented in the housing stock summary represent all modeled households in the Hill District, not just specific housing segments.

Key Results and Considerations

Key Results: Enclosure Upgrades

For the **Basic Enclosure** and **Enhanced Enclosure** upgrade packages modeled in Hill District:

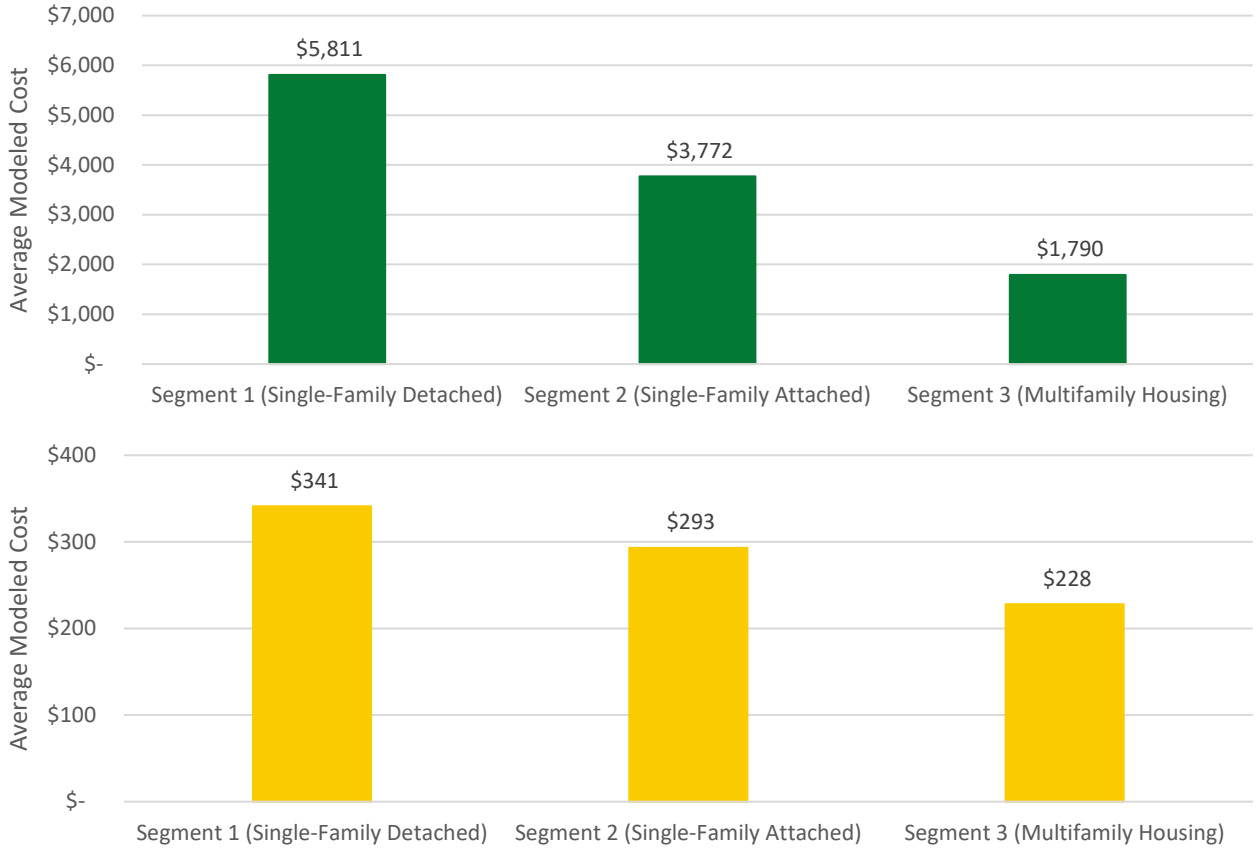
- Segments 1 and 2 (single-family homes) see the largest average modeled energy reductions, emissions reductions, and reduction in energy bills across both packages.
- The Enhanced Enclosure package has higher average modeled energy reductions, emissions reductions, and reduction in energy bills than the Basic Enclosure package across all segments.
- Segment 3 (multifamily homes) has lower average modeled upgrade costs, as well as a higher weighted average cost-effectiveness*, compared to Segments 1 and 2.
  - For the Basic Enclosure package, Segment 3 has 69% lower average modeled costs ($1,790) than Segment 1 ($5,811), but only 33% lower average modeled bill reductions ($228/year vs. $341/year).
- The weighted average cost-effectiveness* is lower across all segments for the Enhanced Enclosure versus the Basic Enclosure package.
  - For Segment 3, the Enhanced Enclosure package has 36% higher average modeled costs ($2,431) than the Basic Enclosure package ($1,790), but only 13% higher average modeled bill reductions ($258/year vs. $228/year).

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

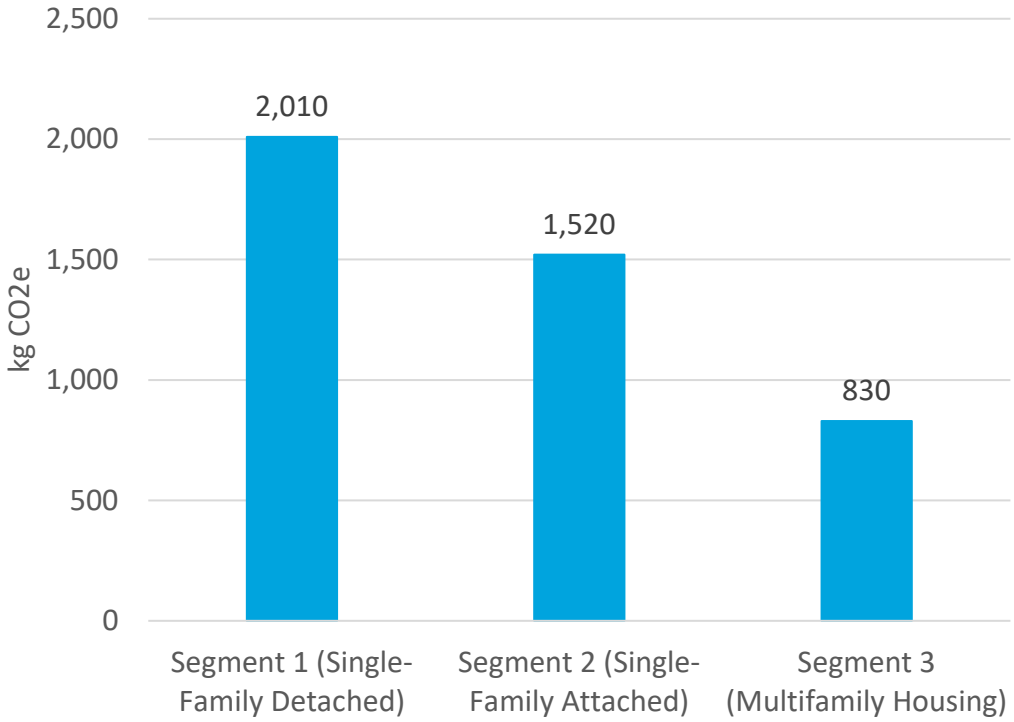
Basic Enclosure Key Results by Segment

For the **Basic Enclosure** upgrade packages modeled in Hill District:

Average Modeled Upgrade Costs and Annual Bill Reductions



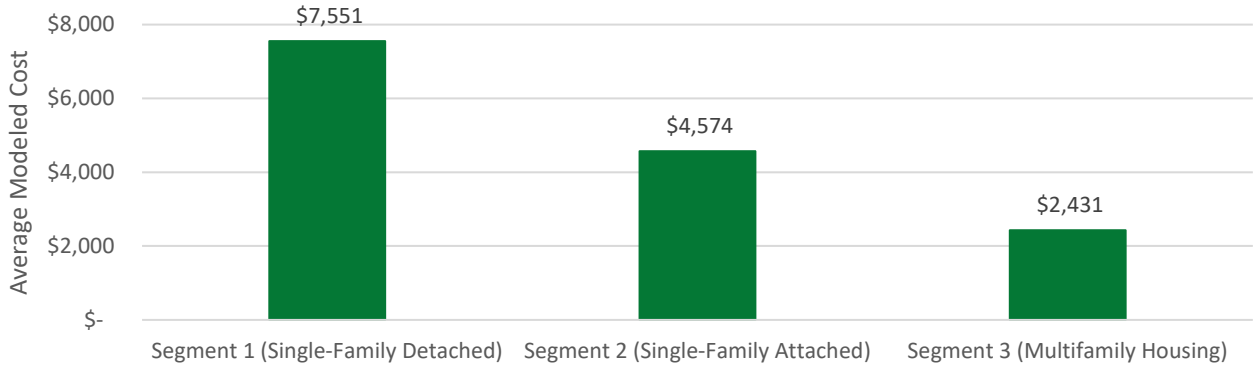
Average Modeled Emissions Reductions

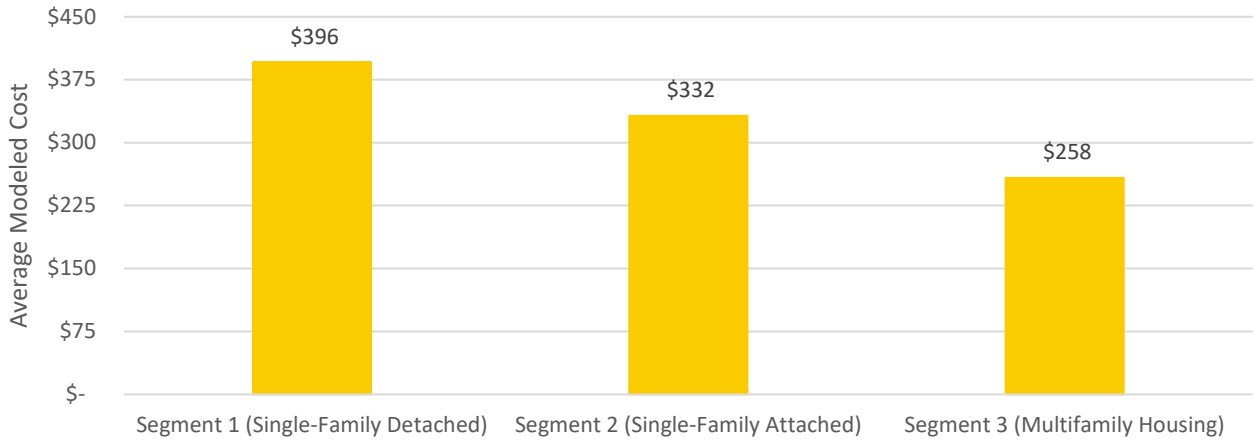


Enhanced Enclosure Key Results by Segment

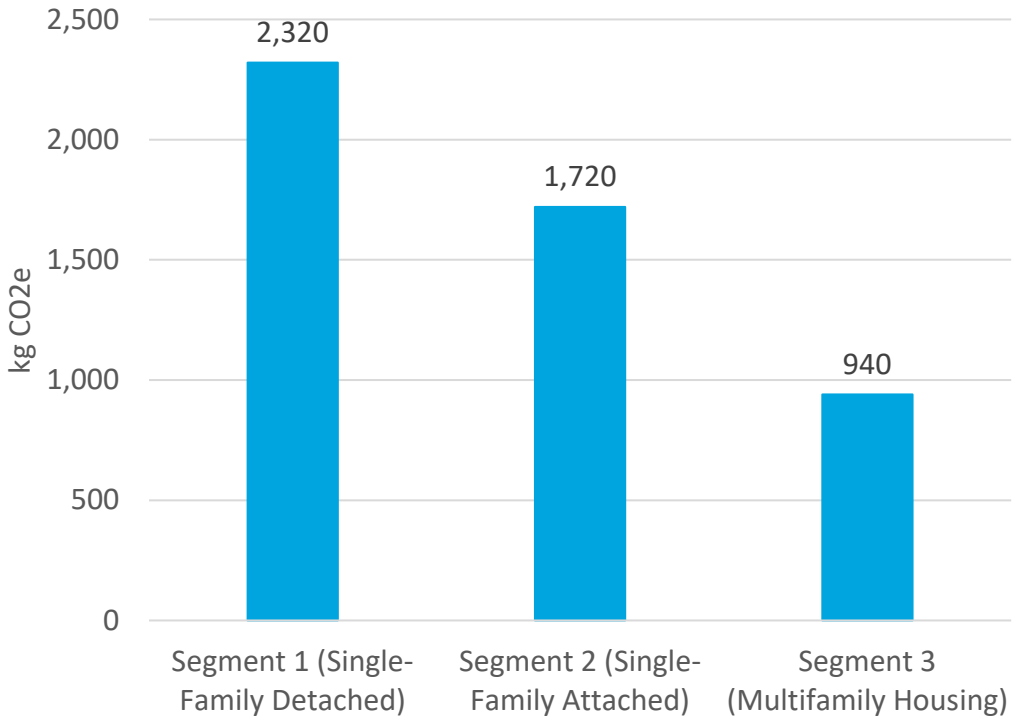
For the **Enhanced Enclosure** upgrade packages modeled in Hill District:

Average Modeled Upgrade Costs and Annual Bill Reductions





Average Modeled Emissions Reductions



Key Results: High-Efficiency Heat Pumps

For the **High-Efficiency Heat Pump with Electric Backup** upgrade package modeled in Hill District:

- Average modeled utility bills increase for Segment 1, and for Segment 2, bill reductions are substantially lower for this package than for the enclosure packages.
- Average modeled costs for this package are significantly higher than for the enclosure packages across all segments.
- The weighted average cost-effectiveness* is significantly lower across all segments for this upgrade package compared to the enclosure packages.
  - For Segment 3, this package has 11 times higher average modeled costs ($19,999) than the Basic Enclosure package ($1,790), but only 10% higher average modeled bill reductions ($251/year vs. $228/year).
- Average modeled emissions reductions are higher for this package than for the enclosure packages across all segments.
  - For Segment 3, average modeled emissions reductions are 81% higher than for the Basic Enclosure package.
- Households without existing cooling systems were assumed to use cooling after a heat pump upgrade, which adds a new service and improved thermal comfort, but can also substantially affect the cost-effectiveness of packages.

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

Key Results: Heat Pump Water Heaters

For the **Heat Pump Water Heater** upgrade package modeled in Hill District:

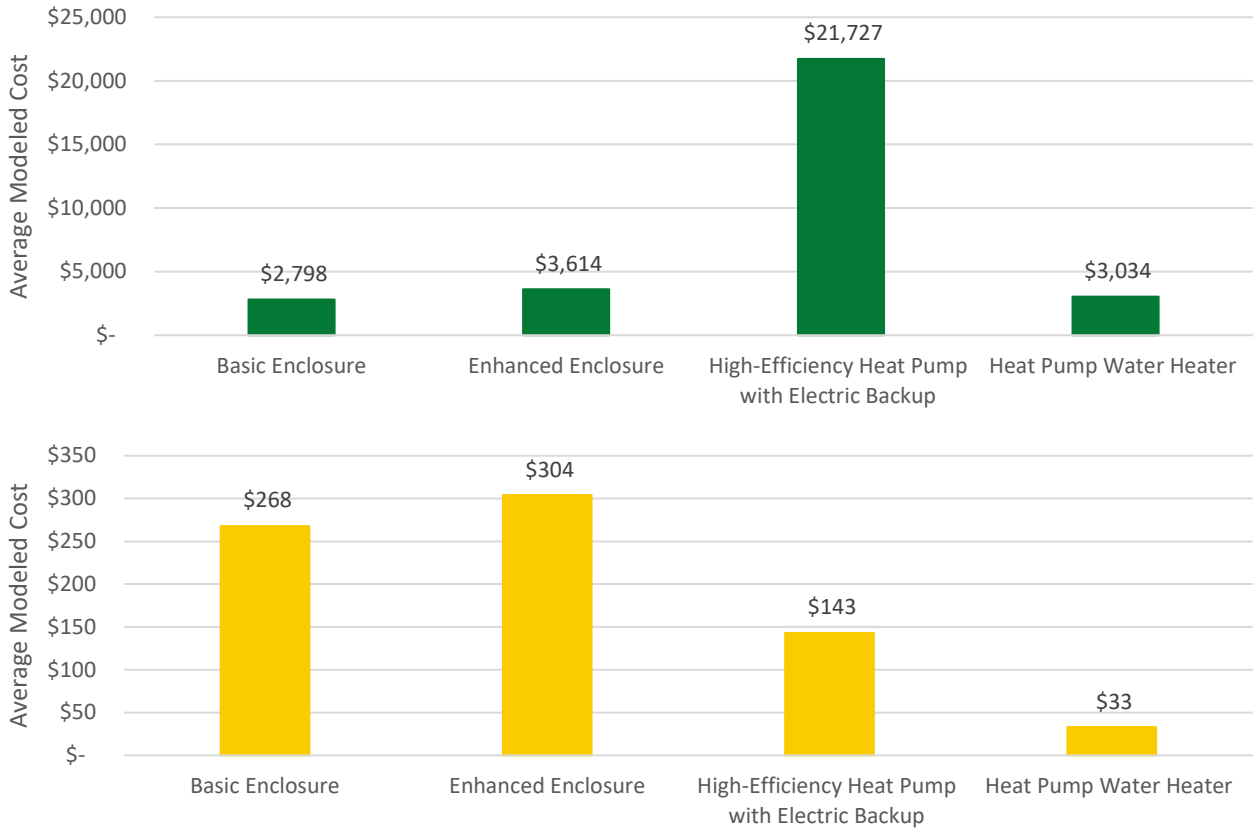
- Average modeled bill reductions are significantly lower for this package than for enclosure and heat pump packages across all segments.
- The weighted average cost-effectiveness* is lower across all segments for this upgrade package compared to the enclosure upgrade packages.
  - For Segment 3, the Heat Pump Water Heater package has 68% higher average modeled costs ($3,006) than the Basic Enclosure package ($1,790), but 82% lower average modeled bill reductions ($40/year vs. $228/year).
  - As previously noted in the limitations, the full cost of the measure was modeled; installing a heat pump water heater at or near the end of life of an existing water heater can be more cost-effective.
- Average modeled emissions reductions are lower for this package than for the enclosure and heat pump packages across all segments.
  - For Segment 3, average modeled emissions reductions are 54% lower than for the Basic Enclosure package.

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

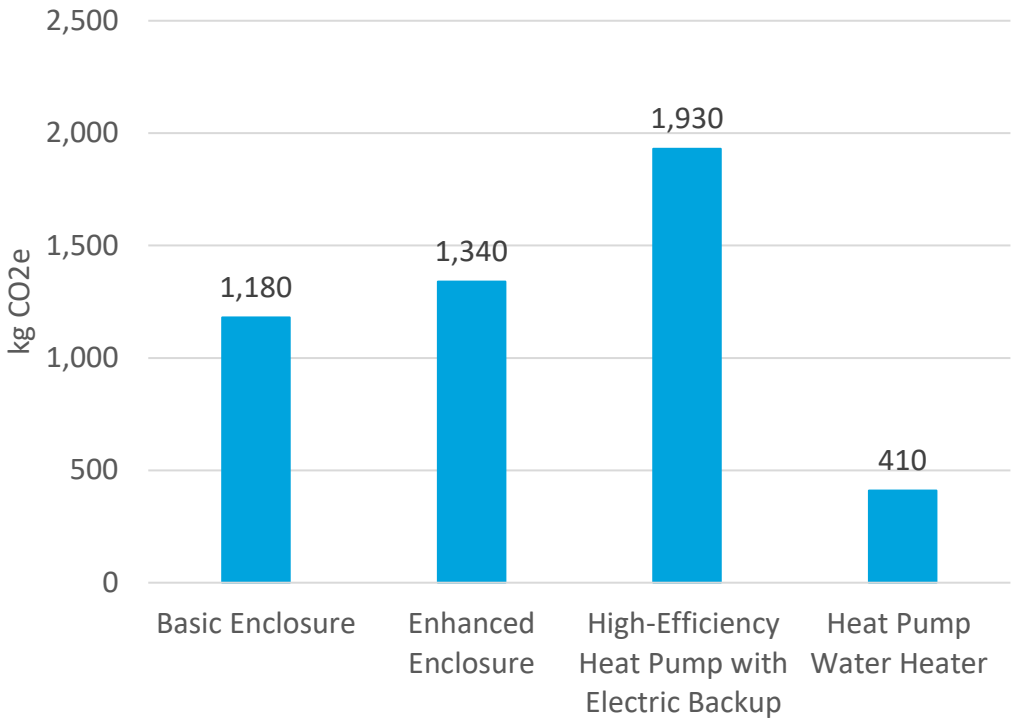
Key Results: All 0-80% AMI Housing (Segment 4)

For upgrade packages modeled in Hill District:

Average Modeled Upgrade Costs and Annual Bill Reductions



Average Modeled Emissions Reductions



Considerations

- Results highlight the potential benefits of increased programming and funding that incorporate measures from the modeled upgrade packages. However, this analysis does not consider the costs to deploy these measures in the context of a program (as opposed to as an individual investment).
- Stakeholder engagement highlighted that funding is often allocated to the entire county or city, creating constraints in targeting offerings to a smaller geographic area. Modeling results could be used to inform a more strategic and targeted approach.
- Potential questions to consider for current or future programs based on this analysis:
  - What upgrade packages best align with programmatic goals, and what are the trade-offs between those goals? (e.g., energy burden reductions, emissions reductions)
  - How do the trade-offs between average modeled impact (e.g., emissions reductions, bill reductions) and modeled upgrade costs for different upgrade measures and housing segments inform potential program design? (e.g., depth of impact in each home versus total number of homes addressed)
  - How can programs be designed to address costs with available incentives or by timing upgrades to align with equipment end of life (for heat pumps and heat pump water heaters)?

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Appendices

Appendix I

URA HAP and HAPI Repair Categories

- Requested repairs were not organized into standard categories in the applicant data that NREL staff received.
- This table provides more detail on how repair requests were categorized.

Repair Category	Applications mentioned the following repairs:
Accessibility Modifications	Accessibility modifications, stairlifts, bathrooms, stairs, railings
Ceiling Repairs	Ceiling repairs
Concrete, Walkways, and Driveways	Concrete, walkways, and driveways
Doors	Doors, screen doors
Foundation	Foundation
Heating and Cooling	Heating and cooling
Emergency or Safety Concerns	Emergency or safety concerns
Other Exterior Repairs	Facade updates, soffit and fascia, retaining wall, gutters, fencing, landscaping
Plumbing	Plumbing, pipes, sewage, faucets, drains
Porch	Porch, patio
Roof	Roof
Water Damage	Water damage, leaks
Windows	Windows
Accessibility Modifications	Accessibility modifications, stairlifts, bathrooms, stairs, railings
Ceiling Repairs	Ceiling repairs

Appendix II

Upgrades

Appendix II

- Basic Enclosure Upgrades
- Enhanced Enclosure Upgrades
- Heat Pump Upgrades
- Electric Water Heater Upgrades
- Whole-Home Electrification Upgrades
- Whole-Home Electrification and Envelope Upgrades

Attic Floor Insulation

- International Energy Conservation Code levels:
  - R-30 for homes in Climate Zone 1A with ≤ R-13
  - R-49 for homes in Climate Zones 21, 2B, 3A, 3B, 3C with ≤ R-30
  - R-60 for homes in other climate zones with ≤ R-38..

General Air Sealing

- 30% total reduction in Air Changes per Hour
- Applied to homes with greater than 10 ACH_{50}.

Duct Sealing

- Ducts improved to 10% leakage, R-8 insulation
- Applied to homes with leakier or less-insulated ducts.

Wall Insulation

- R-13 drill-and-fill insulation
- Applied to homes with wood stud walls and no insulation.

Appendix II

- Basic Enclosure Upgrades
- **Enhanced Enclosure Upgrades**
- Heat Pump Upgrades
- Electric Water Heater Upgrades
- Whole-Home Electrification Upgrades
- Whole-Home Electrification and Envelope Upgrades

Everything in the *Basic Enclosure* package

+

Foundation Wall and Rim Joist Insulation

- Add R-10 interior insulation to foundation walls and rim joists
- Seal crawlspace vents.

Finished Attic and Cathedral Ceiling Insulation

- Insulate finished attics and cathedral ceilings to R-30.

Appendix II

- Basic Enclosure Upgrades
- Enhanced Enclosure Upgrades
- Heat Pump Upgrades
- Electric Water Heater Upgrades
- Whole-Home Electrification Upgrades
- Whole-Home Electrification and Envelope Upgrades

High-Efficiency Heat Pump

Seasonal energy efficiency ratio (SEER) 24, 13 heating seasonal performance factor (HSPF), conventional centrally-ducted for homes with ducts and a ductless mini-split heat pump SEER 29.3, 14 HSPF for dwelling units without ducts.

Min-Efficiency Heat Pump

SEER 15, 9 HSPF, conventional centrally-ducted for homes with ducts and a ductless mini-split heat pump SEER 15, 9 HSPF for dwelling units without ducts.

Backup Heating

For upgrades with electric backup heating:

- If existing system is electric, existing heating system retained as backup.
- If existing is not electric, electric resistance backup installed.
- Backup system used when heat pump cannot meet heating load.

For upgrades with existing backup:

- Existing heating system retained as backup.
- Backup system used when heat pump cannot meet the load.

Appendix II

- Basic Enclosure Upgrades
- Enhanced Enclosure Upgrades
- Heat Pump Upgrades
- **Electric Water Heater Upgrades**
- Whole-Home Electrification Upgrades
- Whole-Home Electrification and Envelope Upgrades

50-Gallon, 3.45 Uniform Energy Factor (UEF) Heat Pump Water Heater

- For one- to three-bedroom homes.

66-Gallon, 3.35 UEF Heat Pump Water Heater

- For four-bedroom homes.

80-Gallon, 3.45 UEF Heat Pump Water Heater

- For greater than four-bedroom homes.

Appendix II

- Basic Enclosure Upgrades
- Enhanced Enclosure Upgrades
- Heat Pump Upgrades
- Electric Water Heater Upgrades
- **Whole-Home Electrification Upgrades**
- Whole-Home Electrification and Envelope Upgrades

Homes With Non-Electric…	Receive
Heating	Minimum-efficiency heat pump and electric resistance backup heat, as listed in Heat Pump Upgrades
Water heating	Heat pump water heater from measure package for heat pump water heaters
Dryer	Electric resistance dryer
Cooking	Electric range and oven

- No enclosure measures
- No change to existing electric loads.

Appendix II

Basic Enclosure Upgrades
Enhanced Enclosure Upgrades
Heat Pump Upgrades
Electric Water Heater Upgrades
Whole-Home Electrification Upgrades
Whole-Home Electrification and Envelope Upgrades

Enhanced Enclosure Upgrades

- Attic floor insulation
- Air sealing
- Duct sealing
- Drill-and-fill wall insulation
- Foundation wall and rim joist insulation
- Finished attic and cathedral ceiling insulation.

Whole-Home Electrification Upgrades

- Heat pump
- Heat pump water heater
- Ventless heat pump dryer
- Induction range and electric oven.

Appendix III

Other Upgrade Packages

Electric Clothes Dryer Upgrades

For the modeled upgrade measures in Hill District:

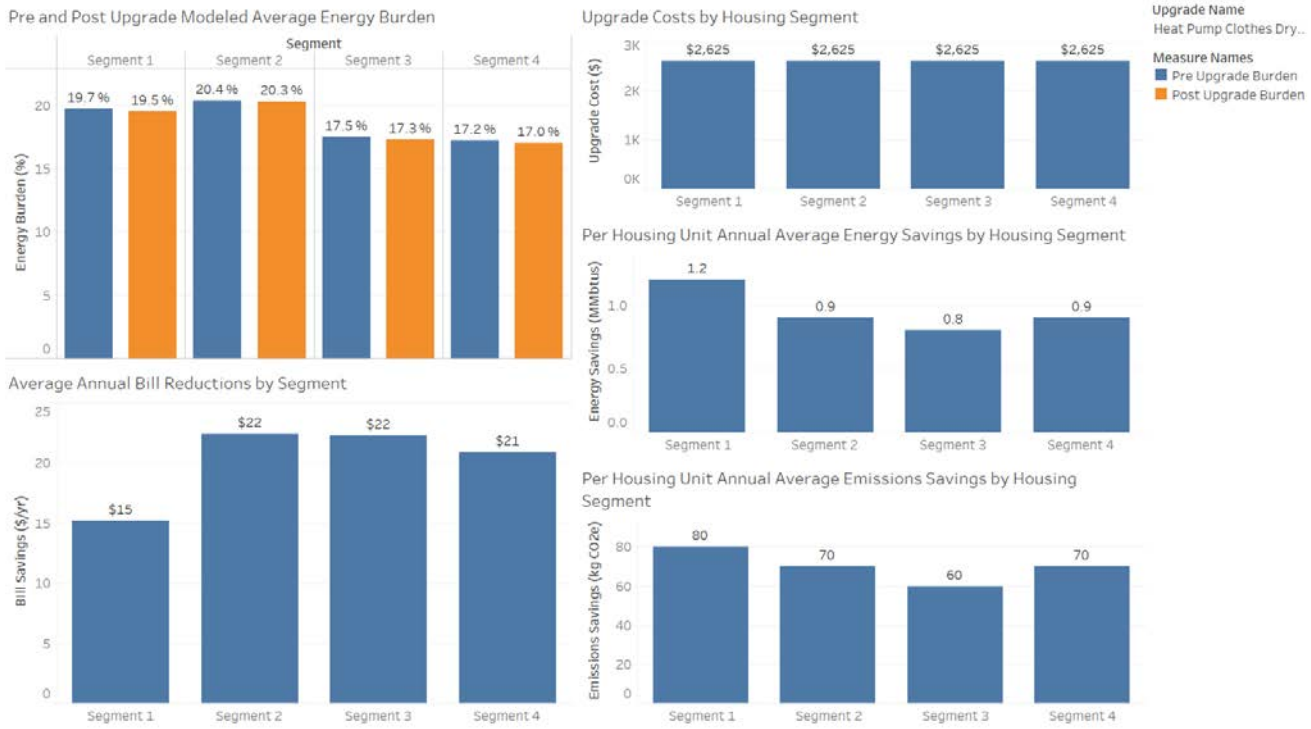
- The package includes upgrading from a gas clothes dryer to an electric clothes dryer.
- Modeled average energy bills, energy burden, and emissions increase for every segment.
- Results show modeled average energy reductions for every segment.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Heat Pump Clothes Dryer Upgrades

For the modeled upgrade measures in Hill District:

- The package includes upgrading from a non-heat pump clothes dryer to an electric heat pump clothes dryer.
- Results show similar modeled average energy burden reductions, bill reductions, energy reductions, and emissions reductions across all segments.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
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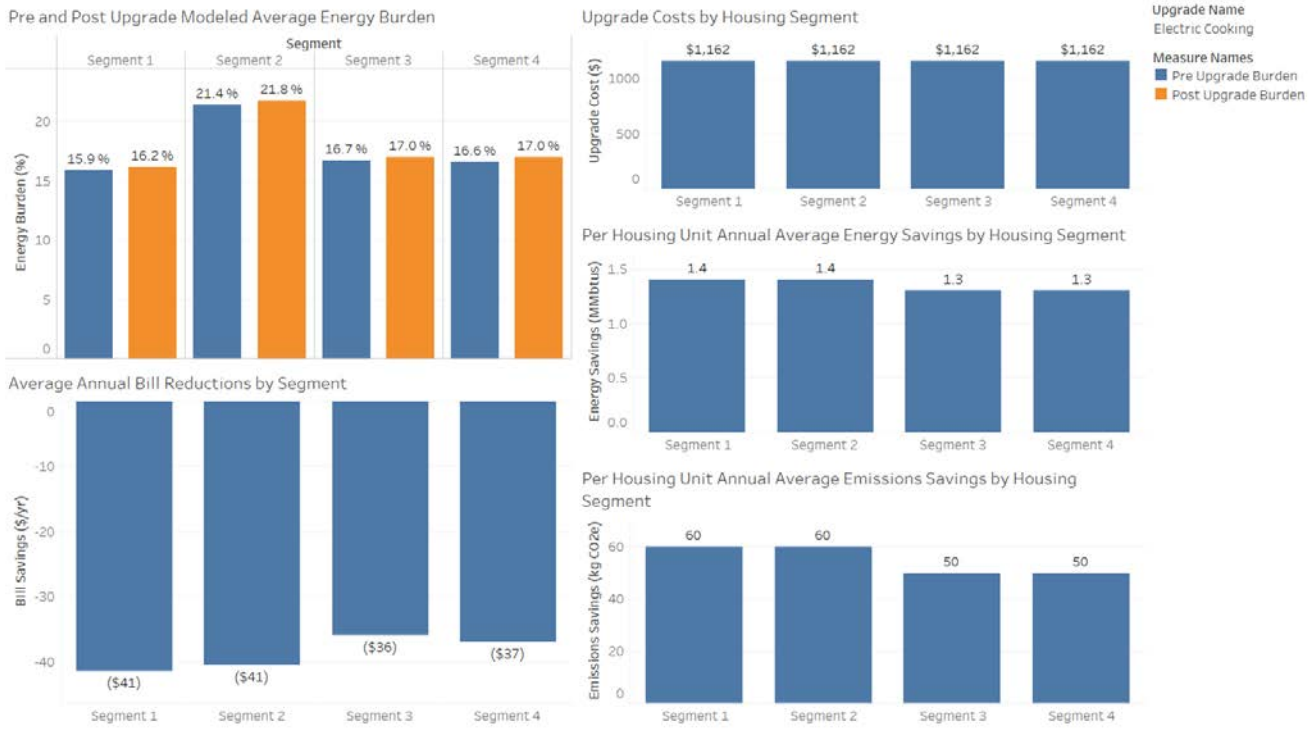
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Electric Cooking Upgrades

For the modeled upgrade measures in Hill District:

- The package includes upgrading from a gas stove to an electric stove.
- Modeled average energy bills and energy burden increase for every segment.
- Results show modeled average energy and emissions reductions for every segment.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

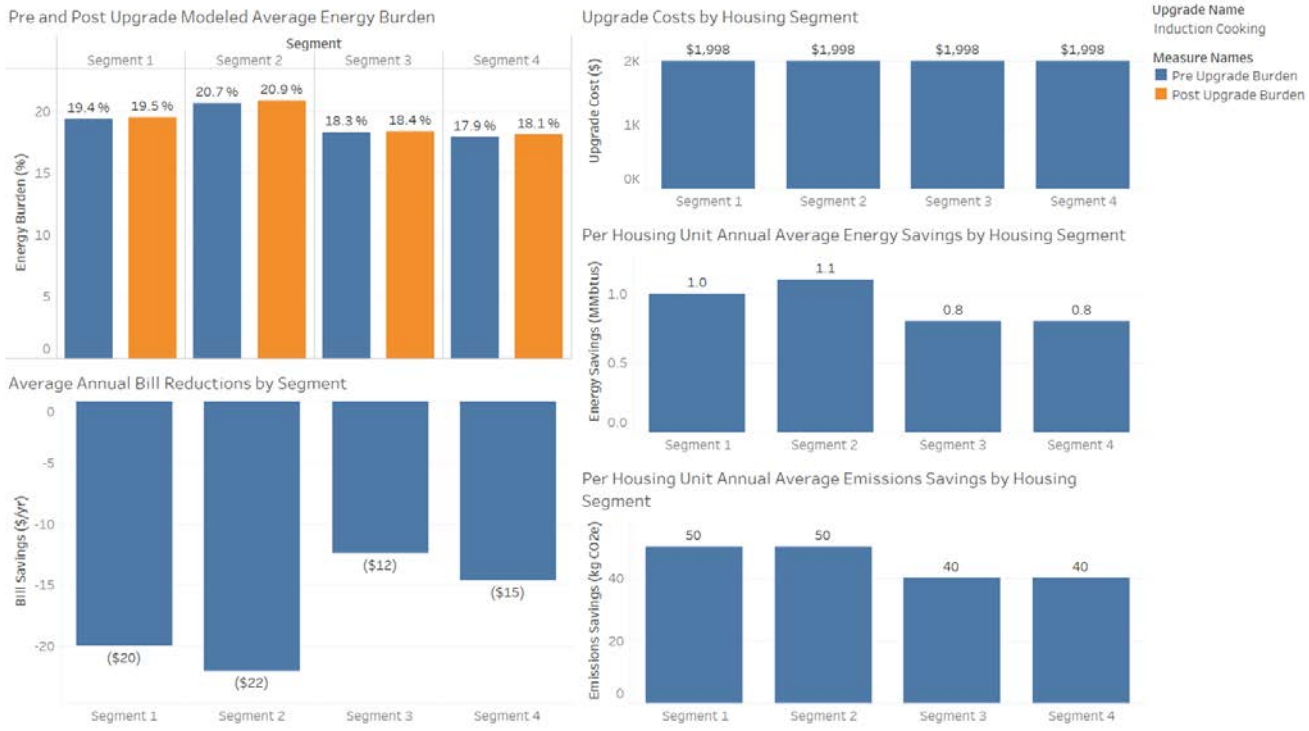


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Induction Cooking Upgrades

For the modeled upgrade measures in Hill District:

- The package includes upgrading from a non-induction stove to an induction stove.
- Modeled average energy bills and energy burden increase for every segment.
- Results show modeled average energy and emissions reductions for every segment.

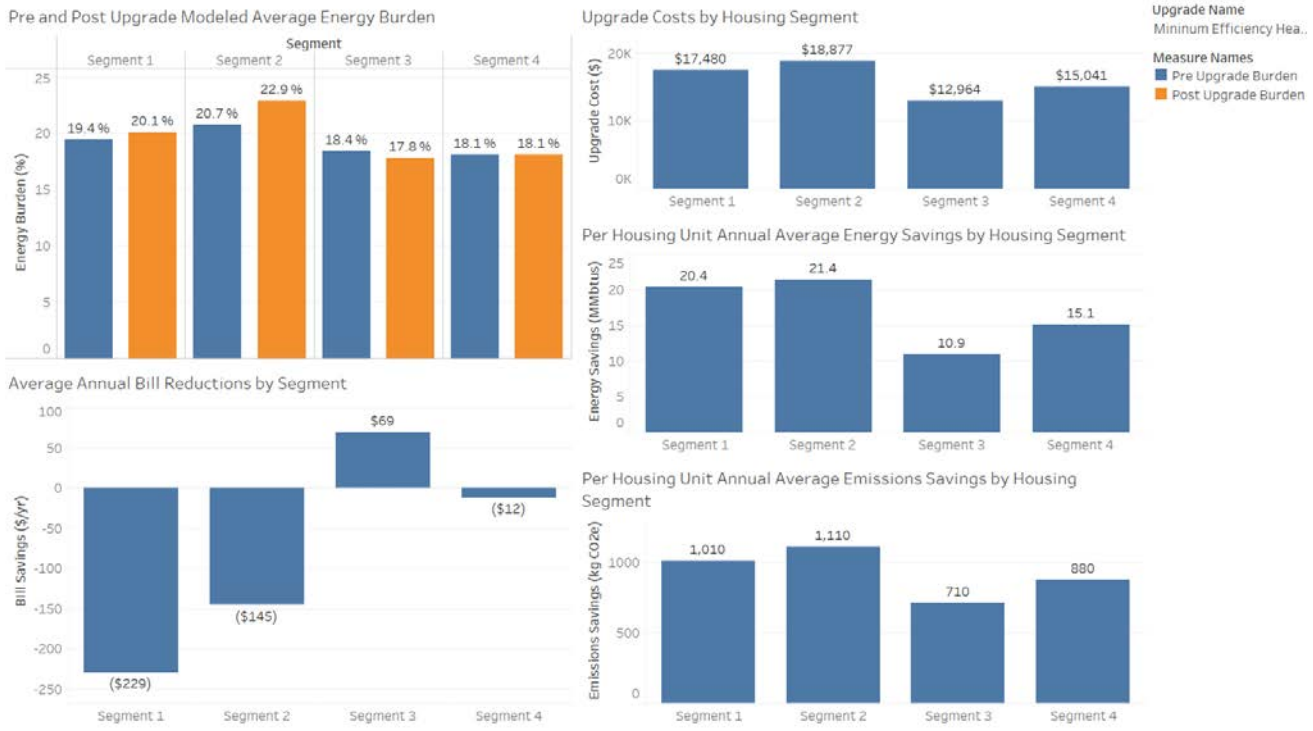


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Minimum-Efficiency Heat Pump w/ Existing Backup Upgrades

For the modeled upgrade measures in Hill District:

- This measure package includes upgrading natural gas or propane HVAC units with minimum-efficiency electric heat pump units, while keeping the existing heating unit as a backup.
- All segments see an increase in modeled average energy bills and energy burden except Segment 3. This increase in energy bills is due to increased electricity consumption outweighing reduced gas consumption.
- Results show modeled average energy and emissions reductions for every segment.
- This package includes an electrification measure, which generally increase spending on electricity while decreasing spending on gas.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Minimum-Efficiency Heat Pump w/ Electric Backup Upgrades

For the modeled upgrade measures in Hill District:

- This measure package includes upgrading natural gas or propane HVAC units with minimum-efficiency electric heat pump units with electric backup (either existing or newly installed).
- Modeled average energy bills and energy burden increase for every segment.
- Results show modeled average energy and emissions reductions for every segment.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Minimum-Efficiency Whole-Home Electrification Upgrades

For the modeled upgrade measures in Hill District:

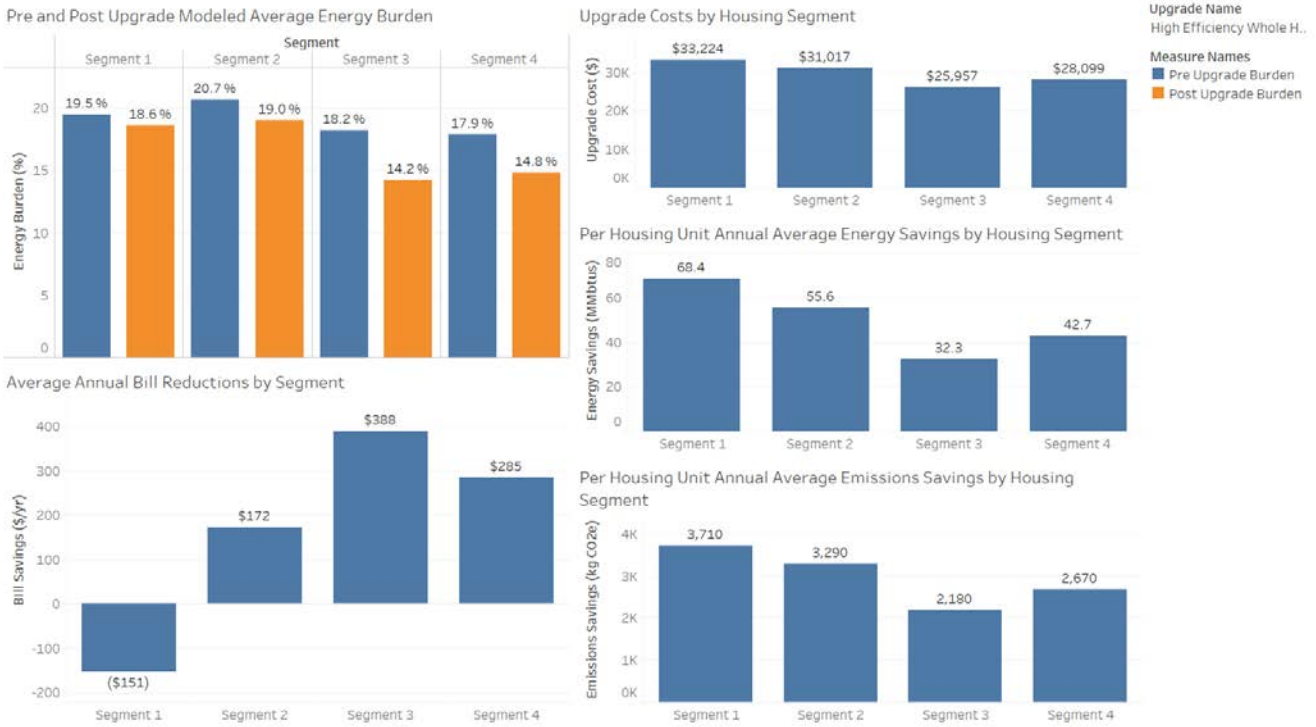
- This package includes a minimum-efficiency heat pump, heat pump water heater, electric dryer, and an electric range. No change in enclosure is modeled for this package.
- Modeled average energy bills and energy burden increase for every segment.
- Results show modeled average energy and emissions reductions for every segment.
- This package includes an electrification measure, which generally increases spending on electricity while decreasing spending on gas.

- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

High-Efficiency Whole-Home Electrification Upgrades

For the modeled upgrade measures in Hill District:

- The Whole-Home Electrification package includes a high-efficiency heat pump, heat pump water heater, heat pump dryer, and an induction stove. No change in enclosure is modeled for this package.
- Modeled average energy bills decrease for all segments except Segment 1. This increase in energy bills is due to increased electricity consumption outweighing reduced gas consumption.
- Results show modeled average energy and emissions reductions for every segment.

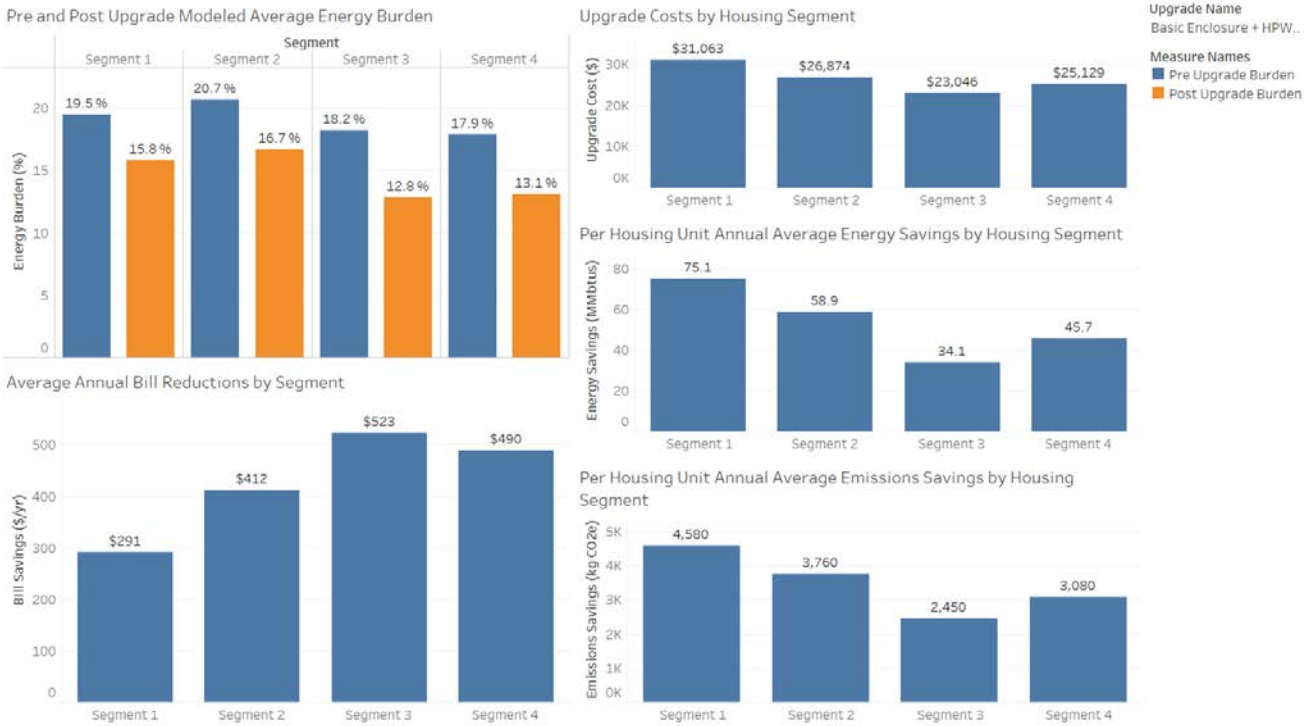


- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
- National average costs were scaled based on a local cost and inflation adjustment factor and used in analysis. Costs do not include rebates or any incentives. Costs for any individual project can vary substantially. More details on modeling methodology can be found here: https://data.nrel.gov/submissions/224.
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Basic Enclosure, Heat Pump Water Heater, and High-Efficiency Heat Pump Upgrades

For the modeled upgrade measures in Hill District:

- This upgrade package includes a high-efficiency heat pump, heat pump water heater, and the Basic Enclosure package.
- Results show modeled average energy burden reductions, bill reductions, energy reductions, and emissions reductions across all segments.



- All numbers are modeled average per housing unit by segment.
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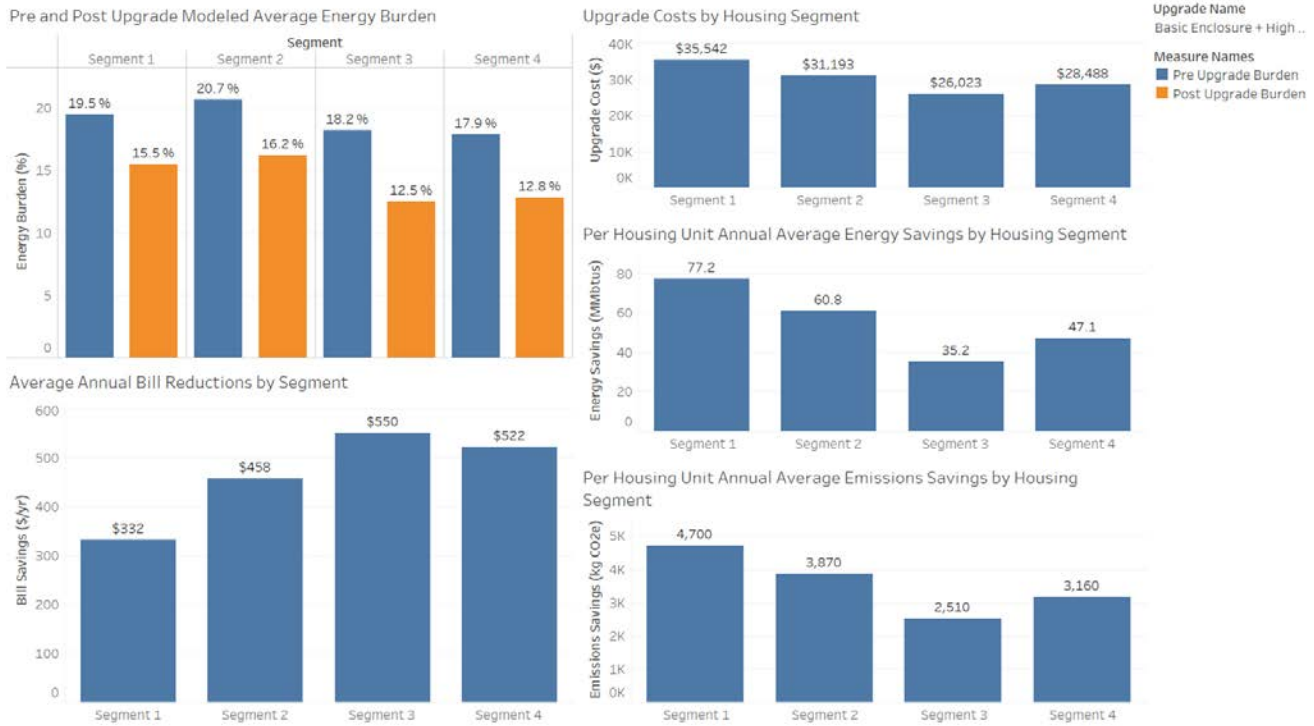
- Bill impacts of electrification see an increased spending on electricity and a decreased gas spending.
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Basic Enclosure and High-Efficiency Whole-Home Electrification Upgrades

For the modeled upgrade measures in Hill District:

- This upgrade package includes the High Efficiency Whole Home electrification package and the Basic Enclosure package.
- Results show modeled average energy burden reductions, bill reductions, energy reductions, and emissions reductions across all segments.



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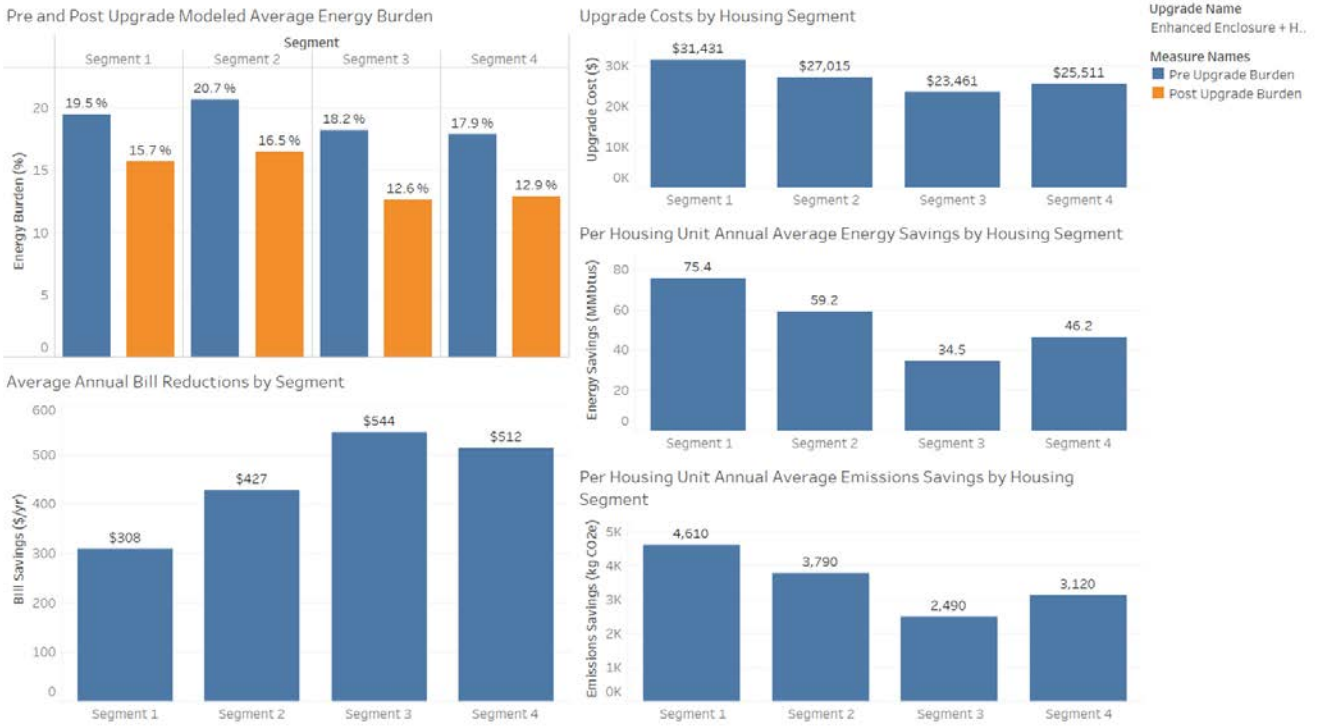
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Enhanced Enclosure, Heat Pump Water Heater, and High-Efficiency Heat Pump Upgrades

For the modeled upgrade measures in Hill District:

- This upgrade package includes a high-efficiency heat pump, heat pump water heater, and the Enhanced Enclosure package.
- Results show modeled average energy burden reductions, bill reductions, energy reductions, and emissions reductions across all segments.



- All numbers are modeled average per housing unit by segment.
- Assumed performances of upgrade measures are summarized in Appendix 1; performance may vary substantially for upgrades to specific individual housing units and may change over time.
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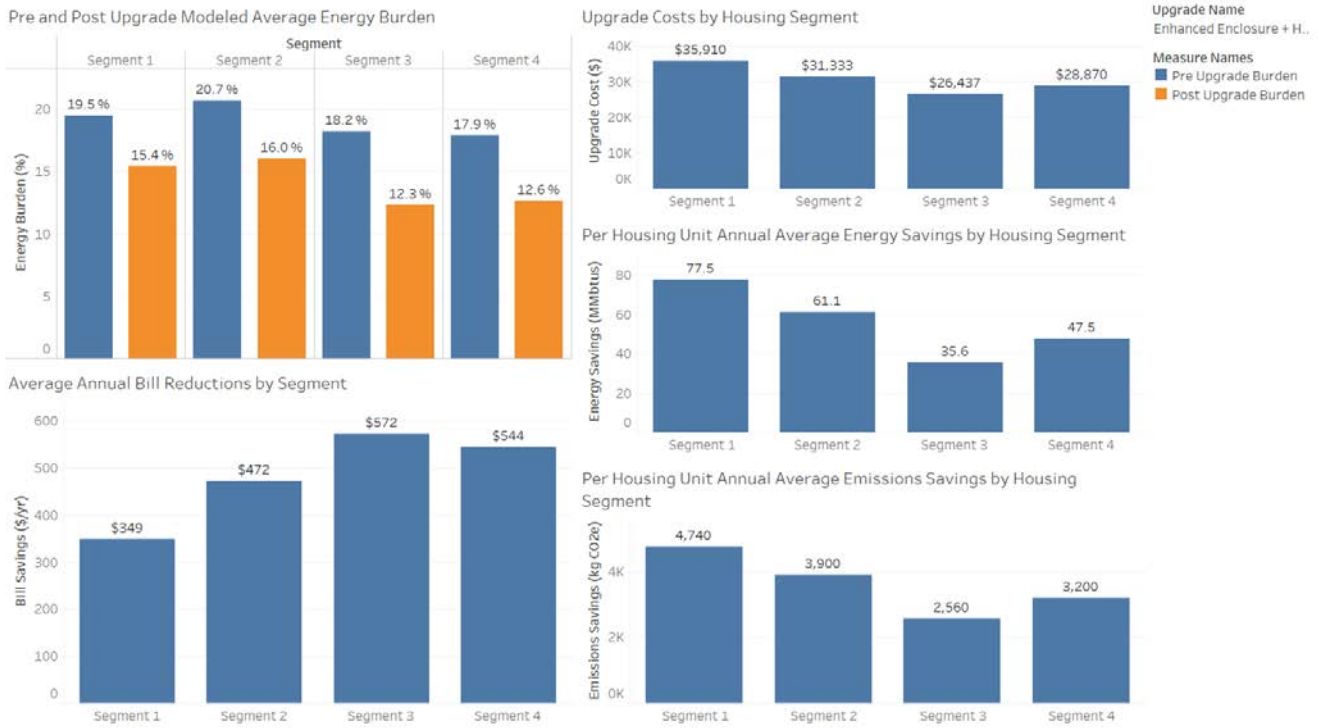
- Energy burden is the percentage of a household's income that goes toward paying energy bills. Energy burden calculations only consider energy burden reductions resulting from bill reductions, and do not consider the costs of upgrade packages.

Enhanced Enclosure and High-Efficiency Whole-Home Electrification Upgrades

For the modeled upgrade measures in Hill District:

- This upgrade package includes the high-efficiency whole-home electrification and the Enhanced Enclosure package.
- Results show modeled average energy burden reductions, bill reductions, energy reductions, and emissions reductions across all segments.



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Thank you

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