STRONG UNIVERSAL ENERGY EFFICIENCY STANDARDS WILL MAKE MANUFACTURED HOMES MORE AFFORDABLE

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White Paper

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Contents

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The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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Executive Summary

KEY TAKEAWAYS

- Strong efficiency standards for new manufactured homes will improve rather than harm home affordability for most residents, including low-income residents.
- Low-income residents of manufactured homes tend to be renters or to live in older homes—only 3% of low-income manufactured home residents own homes less than 10 years old.
- The stronger standard proposed by the Department of Energy would yield $3,383 in net savings over the life of an average home, with residents of older homes receiving most of the savings.
- Including heat pumps and other efficiency options could increase the average net lifetime savings to $5,544 and reduce the number of residents with high energy burdens by one-third.

Efficiency standards for manufactured homes have not been updated in nearly three decades. Yet these homes make up roughly 7% of the new homes built each year and are an essential source of affordable housing. The Department of Energy (DOE) has proposed a new tiered standard that would be weaker for cheaper manufactured homes; as a result, the most vulnerable residents would receive low-quality homes. Our analysis shows that a strong universal standard would benefit manufactured homes in all regions, lessen high energy burdens, and avoid an inequitable two-tiered standard.

We analyze the impacts of the tiered standard and of stronger standards using DOE's methodology with updated cost and financing assumptions. We find that DOE overestimates the costs and does not fully consider the impacts on affordability for all residents. DOE's stronger tier would generate about $900 more in net life-cycle cost savings in the average single-section home than would the weaker standard. Additionally, DOE's proposal excludes efficiency options that would increase residents' energy savings (and further reduce emissions). Including an efficient heat pump water heater could increase the life-cycle savings by approximately $2,000 beyond those of DOE's stronger tier (to $5,544).

To measure the impacts on affordability, the main justification for DOE's tiered standard, we calculate the number of manufactured home residents who face high energy burdens (energy bills exceed 6% of their income) or high housing burdens (total housing costs exceed 30% of their income) under each standard. We find that the strong, universal standard with an efficient heat pump water heater would relieve nearly 1,000,000 households from high energy burdens, roughly 440,000 more than under DOE's tiered standard. The stronger standard would also decrease housing burdens, slightly lowering the share of residents with high housing burdens from 31.8% to 30.9%.

Introduction

Manufactured homes are homes that are made in factories and shipped in one or more sections to home sites, where they are placed on foundations. Such homes are an essential source of affordable housing for millions of Americans. The median household income of manufactured home residents is about $35,000, which is just over half that of site-built home residents. Further, half of households occupying manufactured homes have income less than two times the federal poverty level (which is the threshold we use for "low income" in this paper).[1] Approximately 6.8 million manufactured homes are used as residences in this country; in 2020, 94,390 new manufactured homes were shipped, about 7% of all new homes, with an average price of $87,000.[2]

Energy bills are an important part of the overall affordability of a home. For residents of manufactured homes, the median energy burden (i.e., the energy cost as a percentage of income) is 5.3% compared to 2.9% for all homes, and 44% of manufactured home residents face a high energy burden (more than 6% of their income). Home efficiency features can reduce the energy burden and provide protection from energy price surges.

Thus, manufactured housing energy efficiency standards should be considered in the context of affordability. On August 26, 2021, the Department of Energy (DOE) proposed new efficiency standards for manufactured homes.[3] The energy standards currently in effect were set by the Department of Housing and Urban Development (as part of the "HUD Code") in 1994. In 2007, Congress directed DOE to set an energy standard based on the most recent version of the model code for site-built homes, the International Energy Conservation Code (currently, the 2021 IECC). But DOE has yet to set that standard.[4]

Manufactured housing standards are needed for two key reasons. First, they lower energy bills and improve the health and comfort of the residents and the resilience of their homes, thus improving the quality of affordable housing. Efficiency measures can reduce asthma and mold, and help residents remain safely in their homes during extreme weather.[5] Second, such standards are needed to help meet the goals of federal energy and environmental policy. New standards could have a significant environmental impact: DOE estimates that a strong universal code would result in a reduction of 120 million metric tons of carbon dioxide emissions over 30 years of new home production—which is equivalent to taking 26 million cars off the road for one year.

However, because of "affordability concerns," DOE's primary proposal would set a two-tiered standard for manufactured homes based on the home's price. Tier 1, which would apply to homes with a manufacturer's retail list price of up to $63,000, is limited to an initial added cost of roughly $750. Thus, it would mostly improve air and duct sealing, with small increases in insulation levels. Tier 2, which would apply to more expensive homes and is based on the 2021 IECC, though with weakening changes. Tier 2 would require significant improvements to windows and insulation. One alternative would apply the Tier 1 standard to all single-section homes (also called *single wides*), which is almost half of new homes.

In addition to basing the threshold solely on first cost, DOE's life-cycle cost (LCC) analyses are too narrow and out of date. They focus solely on owners and, in some cases (as in the 10-year analyses), they focus only on a home's first owner, which is a small subset of residents and typically not the lowest income ones. Consequently, this approach fails to account for the benefits that new standards would create for all residents, including renters and second and third owners. But even DOE's limited approach finds that the Tier 2 standard will have net savings over the life of the measures.

In this paper, we first examine data on manufactured home residents, their ownership and financing, and their energy costs in order to better understand affordability of the homes. We then use those data to analyze the impact of DOE's proposals on the LCC and the total housing burden for all residents. In addition, we update two of DOE's cost assumptions and add a key missing element from the 2021 IECC (the option packages) in order to get a better picture of the likely impacts of an effective standard. Our conclusion is that a weak standard for cheap homes does the opposite of protecting low-income residents; rather, it gives them sub-par homes and high energy bills.[6] In contrast, a strong universal energy efficiency standard lowers energy costs, improves the quality of affordable housing, and supports greenhouse gas emissions reduction goals.

Manufactured Housing Affordability

While a majority of manufactured home residents are low or moderate income, it is important to consider for which residents affordability is the greatest concern, and which housing costs contribute to the burden. DOE analyzes the cost effectiveness of the proposed standard for owners over the first 10 years and over 30 years. (DOE notes an average resident tenure of 13 years, and it estimates a typical useful life of 30 years for the new efficiency measures). But, according to U.S. Census 2019 American Housing Survey (AHS) data, only 5% of manufactured home residents own homes that are less than 10 years old, and only 62% of owners of new manufactured homes have home loans. Owners of newer manufactured homes have relatively higher average incomes, and they therefore tend to be more able to afford housing costs than other residents, as figure 1 and table 1 show. Affordability concerns are greatest for low-income households, only 3% of whom own newer homes; these residents tend to rent or to own older homes.[1]

Based on these data, we include renters as well as owners in our analyses. In the 10-year analyses, we look at residents in years 1–10, 11–20, and 21–30 of a home to gain a better understanding of the impact on all residents.

Figure 1. Variations in manufactured home resident ownership and income by the age of the home. The top graph shows the portion of residents who own the home with a mortgage or chattel loan (personal property loan), own the home without a loan, or rent. The bottom part shows the percentage of residents who are low income and own or rent the home. Source: U.S. Census, 2019 American Housing Survey data.

Table 1. Median household income of residents of manufactured homes

Residents		Ownership		Age of home	
All residents	$34,800	Owners	$35,300	0–10 years	$50,100
Low-income	$18,300	With loan	$48,600	11–20 years	$35,000
		Renters	$30,880	21–30 years	$32,000
				31–40 years	$34,000
				41–60 years	$27,540

Source: U.S. Census, 2019 American Housing Survey data

FINANCING COSTS

Manufactured housing costs are significantly affected by the way they are financed, especially the use of *chattel loans*—personal property loans, which are somewhat like car loans. Such loans are almost always used when the borrower does not own the land under the home (e.g., in mobile home parks), and are sometimes used by borrowers who do own the land. Chattel loans typically have higher interest rates than mortgages. DOE assumes that all cheaper manufactured homes are purchased using chattel loans. But there is no evidence to support that. As figure 1 shows, 25% of all residents, 29% of residents in homes less than 10 years old, and 33% of low-income residents of newer homes, rent their homes. Another 56% of all residents, 27% in newer homes, and 57% of low-income residents, are owners without loans. According to a 2021 Consumer Financial Protection Bureau (CFPB) report, among manufactured home buyers who do take a loan, only about half are chattel loans (see table 2).[7] As Appendix A shows, we estimated that only about one-fourth of residents of new manufactured homes take out chattel loans (one-third if one includes renters of homes for which owners take out chattel loans).

Although income data are limited, there is no evidence that taking out chattel loans varies significantly by income level. The median income of borrowers is almost the same for mortgages and chattel loans. As table 3 shows, the percentage of homeowners who also own the land is almost identical for low-income and other owners. Consequently, we assumed that residents of single-section (or Tier 1) homes and lower-income residents had the same mix of financing as other residents and that they did not all pay higher interest rates.

Table 2. Portion of manufactured home loans and household income by loan type

	Mortgages	Chattel
% of all loans	53%	42%
% of purchase loans	44%	51%
Median income	$53,000	$52,000

Source: Based on CFPB data, using data for all loans and percentage that are purchase loans. The rest of the loans are "exempt" and are a mix of chattel and mortgages.

Table 3. Share of residents who own the land by income

	Low-income residents	Other residents	All residents
All homes			
Own land	63%	65%	64%
Not own land	37%	35%	36%
Single-section homes			

	Low-income residents	Other residents	All residents
Own land	54%	56%	55%
Not own land	46%	44%	45%

Source: U.S. Census, 2019 American Housing Survey

ENERGY COSTS

Energy costs are an especially important part of the housing burden for manufactured home residents, as we illustrated in the introduction above. Manufactured homes typically have higher energy costs per square foot than comparable site-built homes. Though AHS data indicate that manufactured home residents' median total housing burden is similar to that of their site-built home counterparts (20% and 22%, respectively), for manufactured homes, energy is a larger part of the burden—the median energy burden of 5.3% is roughly double that of residents of site-built homes and makes up roughly one-quarter of the total housing burden.

While these high energy burdens have multiple causes, they result in part from weak efficiency measures.[8] Setting stronger efficiency standards can improve the affordability of these homes by lowering their occupants' high energy burdens. DOE's threshold between tiers based solely on the initial price does not reflect the importance of energy costs or the impact of energy savings under the standard.

Our analysis here examines the impact of the standard on affordability—including added home costs and energy bill savings—for all residents of manufactured homes.

Analysis Methodology

We looked at the life-cycle cost effectiveness of both the proposed standard and a strengthened proposal using a methodology similar to DOE's analysis but with different assumptions. We also examined the impact on housing burdens for manufactured home residents. Following is a brief description of our methodology and assumptions. Appendix A offers further details.

FINANCING AND OWNERSHIP ASSUMPTIONS

As we described above, we assume one uniform set of financial parameters regardless of the home's list price or size. Based on AHS data for 2016–2019, we assume that 25% of residents of new homes are renters, 22% are owners who purchased with cash, and the remaining 53% are owners who purchased with loans. Based on CFPB estimates, we assume an equal number of chattel and mortgage loans. Appendix A offers additional details. Following DOE, we use discount rates for each group based on the interest rates for chattel and mortgage loans (9% and 5%, respectively), 5% for cash purchases, and a blended rate based on financing for renters.

For renters, we assume that landlords who purchase units pass on their added purchase, financing, and property tax costs to renters (but we do not include multiple countervailing income tax effects). Without publicly available data on purchasers of rental units, we assume that these purchasers had a blend of financing identical to that assumed for other first owners, but that costs are amortized and added to rents over only the first 15 years (with the exception of added property taxes, which are passed on over the measure life).

For second and third owners in the 10-year LCC analyses, we calculate savings in the same fashion as for first owners, with energy savings increasing with inflation and with the measures' residual value in nominal dollars depreciating linearly over 30 years. Thus, second and third owners face decreasing costs.

MODIFIED COSTS AND HEAT PUMP OPTIONS PACKAGES

DOE estimated the incremental costs associated with each of its proposed standards based on industry-reported data from 2015, which were used in a negotiated rulemaking at that time. However, these costs appear out of date and are not based on implementation at scale. For our modified cost scenario, we use more recent cost estimates to adjust the incremental costs for continuous insulation and windows for Tier 2, as estimated by DOE. For one scenario, we also estimate costs and savings from using a heat pump water heater (HPWH). Appendix A provides details on these cost adjustments.

MODIFIED LIFE-CYCLE COST-SAVINGS ANALYSIS

Using DOE's methods, we analyze the 10- and 30-year LCC savings (i.e., the discounted present value of the energy savings minus the added costs—including financing costs—over the analysis period, in 2020 dollars) for three progressive cases[9]:

1) The proposed Tier 1 and Tier 2 standards under updated financing assumptions, including the addition of renters

2) Adding updated estimated costs for two measures under Tier 2

3) Adding the 2021 IECC efficiency package options provision, which we model as shifting to HPWHs (we also include separate results for shifting to heat pumps for air heating and cooling)

As with the DOE results, our results are an aggregate of results from 19 locations in different climates, with DOE's shipment weights. We assume that all energy efficiency measures would last 30 years.

HOUSING BURDEN ANALYSIS

Using AHS microdata, we estimate the impacts on housing and energy burdens from the two-tiered standards compared to our proposed Tier 2 package (with HPWHs). We use a simplified annual incremental cost estimate and first-year energy cost savings to determine the impact of each standard. In contrast to the LCC analyses, we were not able to

incorporate the full spectrum of costs over the 30-year period when estimating a one-year snapshot of energy and cost burdens. Instead, we approximated annual costs by amortizing incremental costs over 30 years using the blend of financing and discount rates that we assumed for first owners. Because AHS data do not include the initial home price, for the tiered standard, we use Tier 1 for single-section homes and Tier 2 for multi-section homes. The total housing costs include loan payments, rent, land rent, home insurance, utilities, property taxes, homeowner association fees, and maintenance, as well as energy costs. Energy costs include electricity, natural gas, oil, and other fuels. We divide the costs by total household income before taxes.

Analysis Results

With more accurate assumptions on ownership, financing, and cost, we can look at the proposed standards' impacts for all types of residents of manufactured homes. In this section, we look at overall cost effectiveness, cost effectiveness for specific owners, and impact on energy and housing burdens.

30-YEAR LIFE-CYCLE COST SAVINGS

An analysis of the 30-year LCC savings under our three scenarios shows substantial savings from a strong standard once the costs and financing are updated, especially with an HPWH. As table 4 and figure 2 show, with updated costs, Tier 2 has more lifetime savings than Tier 1. With the added HPWH 2021 IECC efficiency package option, the stronger standard saves $5,544 per single-section home over the life of the home after subtracting added costs; this is about $3,000 more in savings than Tier 1 (see Appendix B for additional details and multi-section results). Even without the HPWH, the savings are about $900. The savings are significant in each climate zone, but they are especially striking in the South (Climate Zone 1), which has been the center of affordability concerns. As Appendix B shows, a heat pump for space heating and cooling would save about $1,000 on average in addition to these savings, with significant variation by climate and base-case heating type.

Table 4. 30-Year LCC savings for different standard levels (single-section homes only)

	Tier 1 (updated financing)	Tier 2 (+updated costs)	Tier 2 (updated +HPWH)
Climate Zone 1	$1,641	$3,482	$5,626
Climate Zone 2	$1,795	$2,805	$5,005
Climate Zone 3	$3,844	$3,687	$5,840
National average	**$2,486**	**$3,383**	**$5,544**

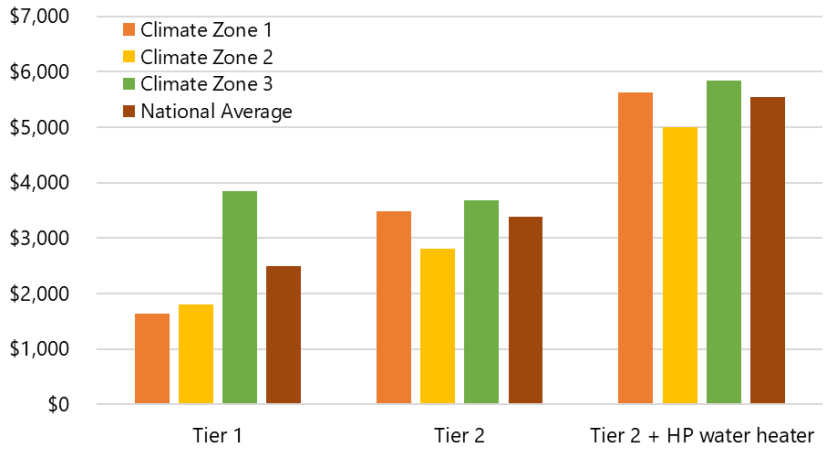

Figure 2. Savings for a single-section home by climate zone at different standard levels compared to a HUD Code home. Climate Zone 1 is in the South, Zone 2 in the middle, and Zone 3 in the North. The estimates are based on DOE's analysis but have updated financing and cost assumptions.

We estimate significantly higher LCC savings than DOE predicted in all cases. As table 5 shows, the difference is due to both updated financing assumptions and updated cost assumptions. With these corrections, savings from the Tier 2 standard increase by approximately $1,900, even before improving the standard.

Table 5. 30-Year LCC savings for Tier 2 with different assumptions (single-section homes)

	Tier 2 (DOE assumptions*)	Tier 2 (+updated financing)	Tier 2 (+updated costs)
Climate Zone 1	$1,942	$2,578	$3,482
Climate Zone 2	$487	$1,277	$2,805
Climate Zone 3	$1,533	$2,452	$3,687
National average	$1,418	$2,197	$3,383

***DOE assumptions are for DOE's "untiered" calculation (but with spreadsheet corrections, as described in Appendix A)**

10-YEAR LIFE-CYCLE COST SAVINGS

We can use the 10-Year LCC analyses to get a sense of the impacts on individual residents. DOE examines the LCC impacts for the first owner, but it is important to consider all residents and—as we described above—residents of older homes in particular, since more of these residents are low-income. Table 6 summarizes the 10-year LCC savings for three 10-year periods of the manufactured home for each of our three scenarios, as well as under the less stringent Tier 1 standard. Consistent with DOE's findings (under different financing assumptions), Tier 1 produces modestly higher LCC savings than Tier 2 in the first 10 years of

the home. However, even for the first decade, the strongest standard (with the HPWH 2021 IECC efficiency package option) offers the largest savings.

The net savings from Tier 2 surpass Tier 1 in the second and especially the third decade, as the energy cost savings continue and the cost (residual value) of the measures decreases. With the cost updates, Tier 2 delivers an average net savings of $773 in the first decade and $4,003 in the third. With HPWHs, these savings rise to $1,514 and $6,069, respectively. The savings are much larger for the less-expensive older homes (and thus for many lower-income residents), but the Tier 2 measures and HPWHs are cost effective even for the first residents.

Appendix B provides additional city-level data. The discounted sum of the savings for the three periods is very close to the 30-year analysis described above.

Table 6. 10-Year LCC savings, by period (single-section homes)

	Tier 1 (+updated financing)	Tier 2 (+updated financing)	Tier 2 (+updated costs)	Tier 2 (+HPWH)
Resident 1 (first 10 years)				
Climate Zone 1	$584	$511	$1,133	$1,905
Climate Zone 2	$646	–$655	$395	$1,171
Climate Zone 3	$1,481	–$183	$667	$1,352
National average	**$928**	**–$43**	**$773**	**$1,514**
Resident 2 (years 11–20)				
Climate Zone 1	$1,021	$1,771	$2,197	$3,515
Climate Zone 2	$1,112	$1,277	$1,997	$3,354
Climate Zone 3	$2,323	$1,964	$2,546	$3,898
National average	**$1,520**	**$1,714**	**$2,273**	**$3,614**
Resident 3 (years 21–30)				
Climate Zone 1	$1,522	$3,216	$3,441	$5,409
Climate Zone 2	$1,654	$3,428	$3,804	$5,852
Climate Zone 3	$3,359	$4,452	$4,756	$6,953
National average	**$2,228**	**$3,712**	**$4,003**	**$6,069**

HOUSING BURDEN ANALYSIS

We estimate that adopting the Tier 2 standard with the efficiency package option would lower the median energy burden for manufactured home residents from 5.3% to 3.5% (for an average savings of $605 a year).

Table 7 summarizes the impacts of new standards on the share of residents with high energy burdens and high housing burdens. A Tier 2 standard with an HPWH would lower the overall share of residents with high energy burdens from 44% to 28% (compared to 35% under a

two-tier standard). This would relieve about one million households of high energy burdens—440,000 more than would see such relief under DOE's proposal. The Tier 2 package would also slightly decrease the overall housing burden, lowering the share of residents with a high total housing burden from 31.8% to 30.9%. These impacts are consistent for the most income-constrained residents: The share of low-income residents with high energy burdens drops from 71% to 47% under the Tier 2 standard, relieving about 800,000 low-income households from high energy burdens. The share of renters with high energy burdens drops from 46% to 30% under the Tier 2 package. Similarly, the share of owners of older homes with a high energy burden decreases significantly under the Tier 2 package. These trends are consistent across single-section and multi-section homes.

Table 7. Impacts of new standards on the share of residents with high energy and housing burdens

	High energy burden*			High housing burden**		
	HUD Code	Tier 1/2*** (Updated)	Tier 2 (+HPWH)	HUD Code	Tier 1/2 (Updated)	Tier 2 (+HPWH)
All residents	43.5%	34.9%	28.0%	31.8%	31.3%	30.9%
Renters	46.1%	37.4%	29.9%	41.7%	41.5%	41.0%
Owners of older homes	44.0%	35.2%	28.2%	29.0%	28.2%	27.9%
Owners of newer homes	26.2%	18.8%	16.5%	24.9%	24.8%	24.3%
Low-income residents	71.4%	58.9%	47.4%	51.6%	50.8%	50.3%

***High energy burden = energy costs greater than 6% of income.**
****High housing burden = total housing costs greater than 30% of income.**
*****In Tier 1/2, the Tier 1 standard applies to single-section homes, and the Tier 2 standard (with updated costs) applies to multi-section homes.**

Conclusion

Manufactured homes provide an essential source of affordable housing. However, the disproportionately low- and moderate-income residents who live in these homes face high energy costs due to the poor efficiency of most of the homes. Updating the efficiency standards for these homes so that they are similar to the IECC for site-built homes will ensure higher energy savings, increased health and comfort, and greater resiliency. All residents should receive these benefits, not just those who can afford a more expensive home. DOE's analysis focuses partly on first-cost and first-owner impacts of new standards, but this is just a small piece of the affordability of manufactured homes, as energy savings and benefits accrue over the lifetime of the home. Adopting a strong standard including

efficient equipment will ensure that low-income and other residents receive the energy bill, health, and resilience benefits and that the nation receives the electric grid and environmental benefits.

Appendix A. Methodology Details

FINANCING ASSUMPTIONS

Table A1 summarizes the financing assumptions that we used in our analysis, as well as DOE's assumptions, which were based on earlier data. Consumer Finance Protection Bureau (CFPB) data show that roughly 42% of all manufactured home loans are chattel loans and 53% are regular mortgages (the other 5% are unspecified). In our analysis, we estimate that loans for new homes are 50/50 for chattel and mortgages based on data for home purchase loans (there are not data specifically on new homes). Although data are limited for secondary (and tertiary) manufactured housing markets, there is evidence that these markets are relatively informal and can rely heavily on cash purchases.[10] In the 10-year life-cycle cost (LCC) analyses, we assume that buyers of second- and third-hand homes buy increasingly with cash and shift from chattel to mortgages. Our 30-year LCC analysis, like DOE's, lets the initial loans run their full term (and then has no financing after chattel loans). Otherwise, our analysis relied on the same terms and rates as DOE:

- Chattel loan: 9% interest and discount rate, 23-year term, and 10% down payment
- Mortgage: 5% interest and discount rate, 30-year term, and 20% down payment
- Cash purchase: 5% discount rate, 100% up-front payment
- Taxes and fees: 0.9% property tax, 3% sales tax, 1% loan fees

Table A1. Financing assumptions

	Chattel	Mortgage	Cash	Renters	Total
DOE:					
Tier 1	100.0%	-	-	-	100.0%
Tier 2	39.5%	20.5%	40.0%	-	100.0%
Untiered	54.6%	15.4%	30.0%	-	100.0%
Our analysis:					
First resident	26.6%	26.6%	21.8%	25.0%	100.0%
Second resident	11.3%	26.3%	37.5%	25.0%	100.0%
Third resident	3.8%	7.5%	63.8%	25.0%	100.0%
Owner of rental home	35.5%	35.5%	29.0%	n/a	100.0%

PRICING AND NEW SAVINGS ASSUMPTIONS

It is difficult to project the cost of measures to meet future standards, i.e., the cost for wide-scale implementation of measures that may not be common in current manufactured homes, and if used at all, may be in expensive premium or pilot homes. However, typically these costs will be for bulk purchases of equipment or components installed under optimized factory conditions, and thus should be cheaper than for typical site-built homes. In addition, prices for advanced technologies have decreased in recent years (while prices for components broadly increased because of pandemic-related shortages, we believe the

market is rebalancing and prices are already coming down). DOE largely relied on prices that the manufactured home industry voluntarily reported in 2015, escalated with inflation. While we believe many of these prices may be too high, we focused on a few high-price components as well as on equipment that was not included in DOE's analysis but that we think the standard should include. We used recent prices for site-built homes, as well as experience in pilot manufactured homes, adjusted for inflation at DOE's 2.28% per year, which should be conservative.

Continuous insulation: For site-built homes, DOE has used an installed cost of $0.98/sf from RS Means.[11] With DOE's assumed opaque wall area of 1,053 square feet (sf) for single-section homes and 1,036 sf for double-section homes, the cost is about $1,100. This is confirmed in a 2016 study of a manufactured home, which found a cost of $936 to add foam sheathing.[12]

Windows: Environmental Protection Agency (EPA) field research on current prices for windows (for a 12-window replacement project) estimated that the price difference for a 15 sf low-e window (U-factor 0.32–0.35) to add argon (0.28–0.31) is $6 and to lower solar heat gain coefficient (SHGC) is $7.50.[13] Taking the price per sf with DOE's assumed window area of 111 sf for single-section homes and 188 sf for double-section homes, this corresponds to a total price difference of roughly $50 and $80, respectively, to add argon (in Climate Zone 3). EPA did not look at prices of less-efficient windows because it did not find any in the market. However, Faithful+Gould's 2012 report to the Pacific Northwest National Laboratory (PNNL)—which was used for DOE's analyses of the IECC—estimated a $4.18/sf difference for U-factor of 0.50 versus 1.2, a $0.89/sf difference for 0.35 versus 0.50, and a $0.18/sf difference for 0.32 versus 0.35.[14] This corresponds to a single-section cost of about $600 in Climate Zone 1 and $150 in Climate Zone 2 in 2011 dollars (not including the cost of improving SHGC in Climate Zone 2, which EPA data indicate should add about $50).

Heat pump water heaters: Although ENERGY STAR® certified HPWHs now achieve 3.3 modified energy factor (MEF), we estimated actual efficiency of 2.5 MEF (assuming an actual efficiency below the rated value) compared to 0.95 for electric resistance water heaters that just meet the standard (DOE's assumption), for 62% savings of hot-water energy use. PNNL estimates in its 2021 IECC cost-effectiveness analysis an added cost of $975 for upgrading to a 2.0 EF HPWH from a 0.92 EF electric resistance water heater in site-built homes.[11] This is based on recent big-box retailer prices for a single unit, and thus likely overstates the costs for manufacturers purchasing in bulk. It also is compared to the cheapest baseline water heater. Previous work estimated costs of $1,781 for a HPWH versus $1,325 for a propane water heater in 2017 dollars in site-built homes,[15] suggesting approximately $450 in added costs. We used an average of the two incremental costs after adjusting to 2023 dollars.

Heat pump space conditioning: We also looked at shifting to heat pumps using the energy usage for homes with heat pumps from DOE's analysis and an added cost from the pilot study (mentioned above) of $518 (we assume in 2014 dollars).[12] Again, for simplicity we used one cost compared to all baseline space heating types (except heat pumps, for which we assumed no cost or savings).

Table A2 shows the prices we used in 2023 dollars (using DOE's updated price escalator) compared to DOE's assumptions for Tier 2.

Table A2. Adjusted prices used in the analysis (2023 dollars)

		DOE assumptions		This analysis	
Component	Climate zones	Single section	Multi-section	Single section	Multi-section
Continuous insulation	2 + 3	1,678	1,666	1,104	1,086
Windows	1	1,646	2,788	764	1,294
	2	1,144	1,938	228	386
	3	679	1,149	48	80
Heat pump water heater	All			771	771
Heat pump space conditioning	All			633	633

MODIFICATIONS TO DOE'S LCC ANALYSIS CALCULATIONS

To conduct our analysis, we relied on DOE's Manufactured Housing Life-Cycle Cost (LCC) Analysis Spreadsheet posted on August 13, 2021. We made the following three modifications to formulas in it. First, the "property cash flow" tab presents property payments in real dollars, but they are subsequently discounted using a nominal rate in the "LCC Calc" tab. We adjusted all property cash flow payments to be in nominal dollars, such that the discounting used for the LCC calculation is consistent. Second, DOE assumes that the residual value of the energy efficiency measures depreciates linearly in nominal dollars over their 30-year life cycle. However, the incremental property tax payments included in the total costs assume that the assessed value of these measures is constant over time. We adjusted the property tax payments to decline annually consistent with the residual value assumptions. Third, DOE's October 26, 2021 Notice of Data Availability extends the assumed chattel loan term to 23 years. However, the "property cash flow" tab calculates chattel payments only to year 15. We adjusted this formula accordingly.

Appendix B. Detailed Results

Heat pump options packages: We analyzed 2021 IECC option packages with heat pump water heaters (HPWHs), heat pumps for space conditioning in place of furnaces and air conditioners, and both combined. Table B1 summarizes the LCC savings associated with Tier 2 homes with each package. Installing HPWHs yields a large increase in LCC savings for most homes—adding an average of $2,161. Heat pump HVAC for space conditioning typically yields somewhat lower savings, and sometimes increases costs compared to natural gas heat. But compared to other heaters in some cities, heat pump HVACs can have greater savings than HPWHs, as the city-level data below show.

Table B1. 30-Year LCC savings for Tier 2 with equipment (single-section homes)

	No shift to heat pumps (HPs)	HP water heater	HP space conditioning	Both heat pumps
Climate Zone 1	$3,482	$5,626	$5,007	$7,150
Climate Zone 2	$2,805	$5,005	$3,987	$6,186
Climate Zone 3	$3,687	$5,840	$3,980	$6,133
National average	**$3,383**	**$5,544**	**$4,369**	**$6,530**

City-level data: The following tables show some of the city-level results from which the other tables were aggregated.

Table B2. City-level 30-year LCC savings, single-section homes

	Tier 1 (updated financing)				Tier 2 (updated costs)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
Miami	$825	7.3	$86	$627	$2,363	7.2	$239	$1,718
Houston	$1,503	5.0	$124	$627	$3,305	5.9	$293	$1,718
Atlanta	$2,364	3.6	$173	$627	$4,396	4.8	$355	$1,718
Charleston	$1,736	4.6	$137	$627	$3,586	5.6	$309	$1,718
Jackson	$2,050	4.0	$155	$627	$4,110	5.1	$338	$1,718
Birmingham	$2,057	4.0	$156	$627	$4,011	5.2	$333	$1,718
Phoenix	$1,047	6.5	$96	$627	$2,285	10.2	$331	$3,371
Memphis	$2,306	3.7	$169	$627	$3,169	8.8	$383	$3,371
El Paso	$1,584	4.9	$128	$627	$2,756	9.3	$361	$3,371

	Tier 1 (updated financing)				Tier 2 (updated costs)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
San Francisco	$957	7.1	$88	$627	$1,180	12.9	$261	$3,371
Albuquerque	$1,740	4.8	$131	$627	$2,723	9.7	$347	$3,371
Baltimore	$3,662	2.8	$253	$719	$3,428	8.6	$406	$3,485
Salem	$2,322	4.3	$167	$719	$1,731	11.8	$295	$3,485
Chicago	$3,717	3.0	$241	$719	$3,429	9.1	$384	$3,485
Boise	$2,620	3.9	$183	$719	$2,238	10.8	$322	$3,485
Burlington	$3,828	3.0	$238	$719	$3,612	9.2	$380	$3,485
Helena	$3,714	3.0	$242	$719	$3,867	8.5	$409	$3,485
Duluth	$5,841	2.0	$355	$719	$6,596	6.3	$554	$3,485
Fairbanks	$8,571	1.4	$509	$719	$11,081	4.3	$806	$3,485
National	**$2,486**	**3.7**	**$177**	**$661**	**$3,383**	**7.9**	**$354**	**$2,790**

Climate zones	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
1	$1,641	4.7	$132	$627	$3,482	5.7	$303	$1,718
2	$1,795	4.5	$139	$627	$2,805	9.3	$362	$3,371
3	$3,844	2.9	$250	$719	$3,687	8.7	$401	$3,485
National	**$2,486**	**3.7**	**$177**	**$661**	**$3,383**	**7.9**	**$354**	**$2,790**

	Tier 2 (+HP water heater)				Tier 2 (+ HP space conditioning)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
Miami	$3,871	6.7	$369	$2,460	$2,227	8.8	$265	$2,327
Houston	$5,364	5.4	$454	$2,460	$4,587	5.8	$399	$2,327
Atlanta	$6,944	4.5	$544	$2,460	$7,233	4.2	$549	$2,327
Charleston	$5,892	5.1	$484	$2,460	$5,425	5.2	$446	$2,327
Jackson	$6,514	4.7	$520	$2,460	$6,349	4.7	$499	$2,327
Birmingham	$6,513	4.7	$519	$2,460	$6,424	4.6	$503	$2,327

	Tier 2 (+HP water heater)				Tier 2 (+ HP space conditioning)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
Phoenix	$3,363	9.7	$424	$4,113	$2,566	10.5	$380	$3,981
Memphis	$5,507	7.4	$558	$4,113	$5,056	7.6	$522	$3,981
El Paso	$5,050	7.7	$535	$4,113	$3,740	8.9	$450	$3,981
San Francisco	$2,889	10.7	$385	$4,113	$1,350	13.3	$300	$3,981
Albuquerque	$4,436	8.7	$472	$4,113	$3,165	10.1	$393	$3,981
Baltimore	$6,430	6.8	$621	$4,227	$6,886	6.4	$636	$4,094
Salem	$3,575	9.9	$426	$4,227	$2,156	12.2	$336	$4,094
Chicago	$5,316	8.2	$517	$4,227	$3,539	10.5	$391	$4,094
Boise	$4,111	9.3	$455	$4,227	$2,618	11.4	$358	$4,094
Burlington	$5,308	8.6	$491	$4,227	$2,008	15.5	$264	$4,094
Helena	$5,993	7.6	$554	$4,227	$3,495	10.5	$390	$4,094
Duluth	$8,840	6.0	$704	$4,227	$3,528	11.5	$358	$4,094
Fairbanks	$14,001	4.2	$996	$4,227	$3,813	11.5	$356	$4,094
National	**$5,544**	**6.9**	**$514**	**$3,532**	**$4,369**	**7.9**	**$431**	**$3,399**
Climate zones	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
1	$5,626	5.2	$469	$2,460	$5,007	5.5	$423	$2,327
2	$5,005	7.8	$527	$4,113	$3,987	8.7	$460	$3,981
3	$5,840	7.7	$551	$4,227	$3,980	9.7	$420	$4,094
National	**$5,544**	**6.9**	**$514**	**$3,532**	**$4,369**	**7.9**	**$431**	**$3,399**

Table B3. City level 30-year LCC savings, multi-section homes

	Tier 1 (updated financing)				Tier 2 (updated costs)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
Miami	$1,453	6.5	$138	$897	$4,056	6.8	$395	$2,693
Houston	$2,445	4.6	$195	$897	$5,555	5.6	$480	$2,693

Atlanta	$3,794	3.3	$271	$897	$7,381	4.6	$584	$2,693
Charleston	$2,781	4.2	$214	$897	$6,012	5.3	$506	$2,693
Jackson	$3,254	3.7	$241	$897	$6,850	4.9	$554	$2,693
Birmingham	$3,251	3.7	$240	$897	$6,681	4.9	$544	$2,693
Phoenix	$1,704	6.0	$150	$897	$4,117	8.6	$478	$4,097
Memphis	$3,622	3.4	$260	$897	$5,167	7.6	$541	$4,097
El Paso	$2,450	4.6	$194	$897	$4,569	8.1	$508	$4,097
San Francisco	$1,419	7.0	$128	$897	$2,191	11.4	$359	$4,097
Albuquerque	$2,718	4.5	$200	$897	$4,477	8.4	$487	$4,097
Baltimore	$5,457	2.0	$354	$700	$5,132	7.7	$549	$4,235
Salem	$3,350	3.2	$221	$700	$2,635	11.0	$387	$4,235
Chicago	$5,578	2.1	$340	$700	$5,189	8.1	$522	$4,235
Boise	$3,885	2.8	$250	$700	$3,413	9.9	$429	$4,235
Burlington	$5,701	2.1	$333	$700	$5,400	8.2	$514	$4,235
Helena	$5,425	2.1	$333	$700	$5,606	7.8	$546	$4,235
Duluth	$8,541	1.4	$499	$700	$9,437	5.7	$750	$4,235
Fairbanks	$12,383	1.0	$716	$700	$15,503	3.9	$1,091	$4,235
National	**$3,372**	**3.5**	**$237**	**$836**	**$4,974**	**7.3**	**$492**	**$3,601**

Climate zones	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
1	$2,474	4.6	$196	$897	$5,574	5.6	$481	$2,693
2	$2,563	4.5	$198	$897	$4,203	8.5	$482	$4,097
3	$5,295	2.1	$328	$700	$4,995	8.2	$516	$4,235
National	**$3,372**	**3.5**	**$237**	**$836**	**$4,974**	**7.3**	**$492**	**$3,601**

	Tier 2 (+HP water heater)				Tier 2 (+HP space conditioning)			
	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
Miami	$6,111	6.2	$556	$3,435	$4,025	7.7	$427	$3,302
Houston	$8,305	5.0	$681	$3,435	$7,198	5.4	$607	$3,302
Atlanta	$10,748	4.2	$820	$3,435	$10,987	4.0	$822	$3,302

Charleston	$9,074	4.7	$725	$3,435	$8,336	4.9	$671	$3,302
Jackson	$10,035	4.4	$779	$3,435	$9,678	4.4	$748	$3,302
Birmingham	$9,989	4.4	$777	$3,435	$9,726	4.4	$750	$3,302
Phoenix	$5,462	8.3	$585	$4,840	$4,669	8.7	$542	$4,707
Memphis	$8,243	6.4	$757	$4,840	$7,891	6.5	$726	$4,707
El Paso	$7,601	6.7	$724	$4,840	$6,078	7.5	$627	$4,707
San Francisco	$4,329	9.6	$505	$4,840	$2,671	11.4	$414	$4,707
Albuquerque	$6,622	7.6	$633	$4,840	$5,431	8.4	$558	$4,707
Baltimore	$9,071	6.1	$817	$4,978	$9,984	5.7	$857	$4,845
Salem	$4,940	9.2	$541	$4,978	$3,701	10.6	$459	$4,845
Chicago	$7,544	7.3	$677	$4,978	$5,828	8.9	$547	$4,845
Boise	$5,758	8.5	$585	$4,978	$4,399	9.8	$492	$4,845
Burlington	$7,459	7.8	$640	$4,978	$3,979	12.5	$387	$4,845
Helena	$8,269	6.9	$718	$4,978	$5,731	8.9	$543	$4,845
Duluth	$12,241	5.4	$927	$4,978	$5,726	9.8	$495	$4,845
Fairbanks	$19,193	3.8	$1,320	$4,978	$6,379	9.5	$509	$4,845
National	**$7,687**	**6.4**	**$682**	**$4,343**	**$6,417**	**7.1**	**$595**	**$4,210**

Climate zones	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost	LCC savings	Simple payback (years)	Annual energy savings	Initial measure cost
1	$8,314	5.0	$681	$3,435	$7,241	5.4	$609	$3,302
2	$6,867	7.2	$669	$4,840	$5,740	7.9	$599	$4,707
3	$7,724	7.2	$696	$4,978	$6,066	8.5	$573	$4,845
National	**$7,687**	**6.4**	**$682**	**$4,343**	**$6,417**	**7.1**	**$595**	**$4,210**

Endnotes

[1] Census Bureau, *2019 American Housing Survey* (Washington, DC: Census Bureau, 2020). www.census.gov/programs-surveys/ahs. All information on residents in this white paper is from this survey unless otherwise specified. The data are taken from multiple downloaded charts and from analysis of the microdata.

[2] Census Bureau, *Manufactured Housing Survey for 2020* (Washington, DC: Census Bureau, 2020). www.census.gov/programs-surveys/mhs.html; Census Bureau, "New Residential Construction: New Privately Owned Housing Units Completed, 2020 Data" (2021). www.census.gov/construction/nrc/index.html.

[3] DOE (Department of Energy), *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing; Notice of Supplemental Notice of Proposed Rulemaking and Request for Comment*, 86 FR 47744 (Washington, DC: DOE, 2021), www.regulations.gov/docket/EERE-2009-BT-BC-0021. DOE slightly modified the proposal and revised its analysis in *Energy Conservation Program: Standards for Manufactured Housing: Availability of Provisional Analysis; Supplemental notice of proposed rulemaking; reopening of public comment period and notification of data availability (NODA)*, 86 FR 59042 (Washington, DC: DOE, 2021).

[4] For more on the history, see L. Ungar, *Manufactured Housing Standards*, (Washington, DC: ACEEE, 2020). www.aceee.org/topic-brief/2020/11/buildings-efficiency-agenda-2021.

[5] N. Hayden and J. Ramakrishnan, "Oregon Data Shows Disturbing Number of Heat Wave Deaths at Mobile Home Parks," *The Oregonian*, August 6 (2021). www.oregonlive.com/weather/2021/08/oregon-data-shows-disturbing-number-of-heat-wave-deaths-at-mobile-home-parks.html.

[6] We also believe the proposed Tier 1 does not meet the statutory requirement that the standard be based on the most recent IECC (see ACEEE comments at https://www.regulations.gov/comment/EERE-2009-BT-BC-0021-1631), but this white paper will focus on cost effectiveness and affordability.

[7] CFPB (Consumer Financial Protection Bureau), *Manufactured Housing Finance: New Insights from the Home Mortgage Disclosure Act Data* (Washington, DC: CFPB, 2021). www.consumerfinance.gov/data-research/research-reports/manufactured-housing-finance-new-insights-hmda.

[8] J. Talbot, *Mobilizing Energy Efficiency in the Manufactured Housing Sector* (Washington, DC: ACEEE, 2012). www.aceee.org/sites/default/files/publications/researchreports/a124.pdf.

[9] Our analysis was conducted using the data and spreadsheets provided by DOE associated with the SNOPR, including the Technical Support Document, and includes updates in the subsequent NODA. They are available in the same docket, EERE-2009-BT-BC-0021. DOE, *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing; Notice of Supplemental Notice of Proposed Rulemaking and Request for Comment*, 86 FR 47744 (Washington, DC: DOE, 2021). www.regulations.gov/docket/EERE-2009-BT-BC-0021.

[10] Freddie Mac, *The Loan Shopping Experiences of Manufactured Homeowners: Survey Report* (Washington, DC: Freddie Mac, 2020), sf.freddiemac.com/resources/manufactured-homeowners-survey-and-report-on-loan-shopping-experiences.

[11] V. Salcido, Y. Chen, Y. Xie, and Z. Taylor, *National Cost Effectiveness of the Residential Provisions of the 2021 IECC* (Richland, WA: Pacific Northwest National Laboratory, 2021). www.energycodes.gov/sites/default/files/2021-07/2021IECC_CostEffectiveness_Final_Residential.pdf. Section 3.2.2 and Table 10.

[12] E. Levy, J. Dentz, E. Ansanelli, G. Barker, P. Rath, and D. Dadia, *Field Evaluation of Advances in Energy Efficiency Practices for Manufactured Homes* (Washington, DC: DOE, 2016). www.nrel.gov/docs/fy16osti/65436.pdf.

[13] EPA (Environmental Protection Agency), *ENERGY STAR® Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report* (Washington, DC: EPA, 2021). www.energystar.gov/sites/default/files/asset/document/ES_Residential_WDS_Draft%201_Criteria%20Analysis%20Report.pdf.

[14] Faithful+Gould, *Residential Energy Efficiency Measures: Prototype Estimate and Cost Data, Revision 6.0* (Richland, WA: Pacific Northwest National Laboratory, 2012). www.energycodes.gov/sites/default/files/2021-11/Residential_Report.pdf. Tables 5.2.1 and 2.5.

[15] S. Nadel, *Energy Savings, Consumer Economics, and Greenhouse Gas Emissions Reductions from Replacing Oil and Propane Furnaces, Boilers, and Water Heaters with Air-Source Heat Pumps* (Washington, DC: ACEEE, 2018). www.aceee.org/research-report/a1803.