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# Draft Environmental Impact Statement for Proposed Energy Conservation Standards for Manufactured Housing

U.S. Department of Energy (DOE)

Office of Energy Efficiency and Renewable Energy (EERE)

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# Environmental Impact Statement for Proposed Energy Conservation Standards for Manufactured Housing

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**Abstract:**

This draft environmental impact statement (EIS) analyzes the impacts related to DOE's proposed energy conservation standards for manufactured homes. DOE's proposed energy conservation standards are based on the 2021 International Energy Conservation Code (IECC) and relate to the building thermal envelope; air sealing; installation of insulation; duct sealing; heating, ventilation and air conditioning (HVAC); service hot water systems; mechanical ventilation fan efficacy; and heating and cooling equipment sizing. The draft EIS evaluates DOE's proposed action (energy conservation standards tiered based the manufacturers retail list price), alternatives to the proposed action (including energy conservation standards tiered based on size of the manufactured home and untiered standards), and a no action alternative. The draft EIS presents analysis of impacts related to (1) energy resources; (2) air resources (including greenhouse gases, climate change, ambient air quality and indoor air quality); (3) health and safety; (4) socioeconomics; and (5) environmental justice.

# DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR MANUFACTURED HOUSING

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# NOTATION

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACEEE | American Council for Energy Efficient Economy |
| ACS | American Community Survey |
| AEO | Annual Energy Outlook |
| AER | air exchange rate |
| AM | arithmetic mean |
| ANOPR | advance notice of proposed rulemaking |
| APOR | average prime offer rate |
| APR | annual percentage rate |
| ARI | Air Conditioning and Refrigeration Institute |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. |
| AT | averaging time |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| | |
| BW | body weight |
| | |
| CAA | Clean Air Act |
| CAIR | Clean Air Interstate Rule |
| CalEPA | California EPA |
| CARES | Coronavirus Aid, Relief, Economic Security Act |
| CDD | cooling degree days |
| CEQ | Council on Environmental Quality |
| CFIS | central fan integrated supply |
| CFPD | Consumer Financial Protection Bureau |
| CFR | Code of Federal Regulations |
| $CH_4$ | methane |
| CLTV | combined loan-to-value |
| $CO_2$ | carbon dioxide |
| CSAPR | Cross-State Air Pollution Rule |
| | |
| DOE | U.S. Department of Energy |
| DTI | debt-to-income |
| | |
| EA | environmental assessment |
| ED | exposure duration |
| EERE | Office of Energy Efficiency and Renewable Energy (DOE) |
| EF | exposure frequency |
| EGU | electricity generation unit |
| EIA | Energy Information Agency |
| EIS | environmental impact statement |
| EISA | Energy Independence and Security Act |
| EJSCREEN | Environmental Justice Mapping and Screening Tool |
| EPA | U.S. Environmental Protection Agency |

## NOTATION *(Cont'd)*

## ACRONYMS AND ABBREVIATIONS *(Cont'd)*

| | |
|---|---|
| ET | exposure time |
| EUI | energy use intensity |
| | |
| FR | Federal Register |
| | |
| GHG | greenhouse gas(es) |
| GM | geometric mean |
| GRIM | Government Regulatory Impact Model |
| GSD | geometric standard deviation |
| | |
| HDD | heating degree days |
| HERS | Home Energy Rating System |
| HFC | hydrofluorocarbon |
| Hg | mercury |
| HHS | U.S. Department of Health and Human Services |
| HI | hazard index |
| HMDA | Home Mortgage Disclosure Act |
| HOEPA | Home Ownership and Equity Protection Act |
| HPML | higher-priced mortgage loans |
| HQ | hazard quotient |
| HUD | U.S. Department of Housing and Urban Development |
| HVAC | heating, ventilation, and air conditioning |
| | |
| IAQ | indoor air quality |
| ICC | International Code Council |
| IECC | International Energy Conservation Code |
| INPV | industry net present value |
| IPCC | Intergovernmental Panel on Climate Change |
| IR | intake rate |
| IRIS | Integrated Risk Information System (EPA) |
| IUR | inhalation unit risk (EPA IRIS) |
| IWG | interagency working group |
| | |
| LCC | life-cycle cost(s) |
| LIHEAP | Low Income Home Energy Assistance Program |
| LOAEL | lowest observed adverse effect level |
| | |
| MATS | Mercury and Air Toxics Standards |
| MH | manufactured housing |
| MHCC | MH Consensus Committee |
| MHI | Manufactured Housing Institute |
| MHS | Manufactured Housing Survey |

## NOTATION *(Cont'd)*

## ACRONYMS AND ABBREVIATIONS *(Cont'd)*

| | |
|---|---|
| MRL | minimal risk level |
| MV | mechanical ventilation |
| NAAQS | National Ambient Air Quality Standard |
| NAS | National Academy of Sciences |
| NATA | National Air Toxics Assessment |
| NCEI | National Centers for Environmental Information |
| NEEM | Northwest Energy-Efficient Housing Program |
| NEMS | National Energy Modeling System |
| NEPA | National Environmental Policy Act |
| NES | national energy savings |
| NESHAP | national emissions standards for hazardous air pollutants |
| NHPA | National Historic Preservation Act of 1966 |
| $N_2O$ | nitrous oxide |
| $NO_2$ | nitrogen dioxide |
| $NO_X$ | nitrogen oxide(s) |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAEL | no observed adverse effect level |
| NODA | notice of data availability |
| NOI | notice of intent |
| NOPR | notice of proposed rulemaking |
| NPV | national net present value |
| NRC | National Research Council |
| $O_3$ | ozone |
| OEID | Office of Economic Impact and Diversity |
| ORNL | Oak Ridge National Laboratory |
| PBP | payback period |
| PFC | perfluorocarbon |
| PM | particulate matter |
| $PM_{2.5}$ | PM with an aerodynamic diameter of a nominal 2.5 microns or less |
| $PM_{10}$ | PM with an aerodynamic diameter of a nominal 10 microns or less |
| PPI | product price index |
| PUF | Public Use File |
| RBSA | Residential Building Stock Assessment |
| RCP | representative concentration pathway |
| REL | reference exposure level (CalEPA) |
| RESPA | Real Estate Settlement Procedures Act |
| RfC | reference concentration (EPA IRIS) |
| RFI | request for information |

## NOTATION *(Cont'd)*

## ACRONYMS AND ABBREVIATIONS *(Cont'd)*

| | |
|---|---|
| SC-C02 | social cost of carbon dioxide |
| SC-GHG | social cost of greenhouse gases |
| SD | standard deviation |
| SF | slope factor |
| $SF_6$ | sulfur hexafluoride |
| SHGC | solar heat gain coefficient |
| SHS | secondhand smoke |
| SNOPR | supplemental notice of proposed rulemaking |
| $SO_2$ | sulfur dioxide |
| $SO_X$ | sulfur oxide(s) |
| TSD | Technical Support Document |
| USCB | United States Census Bureau |
| USGCRP | United States Global Change Research Program |
| UNEP | United Nations Environment Programme |
| $U_o$ | overall thermal transmittance (factor) |
| U.S.C. | U.S. Code |
| UTL | upper tolerance limit |
| VOC | volatile organic compound(s) |
| WMO | World Meteorological Organization |

## UNITS OF MEASURE

| | |
|---|---|
| Btu | British thermal unit(s) |
| cfm | cubic feet per minute |
| d | day(s) |
| ft | foot (feet) |
| g | gram(s) |
| hr | hour(s) |
| kBtu | one thousand British thermal units |
| kg | kilogram(s) |
| km | kilometer(s) |
| L | liter(s) |
| m | meter(s) |
| m$^3$ | cubic meter(s) |
| µg | microgram(s) |
| µg/m$^3$ | microgram(s) per cubic meter |
| mg | milligram(s) |
| mg/kg-d | milligram(s) per kilogram (body weight) per day |
| mg/L | milligram(s) per liter |
| mg/m$^3$ | milligram(s) per cubic meter |
| mi | mile(s) |
| min | minute(s) |
| mph | mile(s) per hour |
| ppb | part(s) per billion |
| ppm | part(s) per million |
| sec | second(s) |
| sf | square foot (feet) |
| yr | year(s) |

## CONVERSION TABLE

| Multiply | By | To Obtain |
|---|---|---|
| ***English/Metric Equivalents*** | | |
| cubic foot ($ft^3$) | 0.02832 | cubic meter ($m^3$) |
| cubic yard ($yd^3$) | 0.7646 | cubic meter ($m^3$) *(= $10^6$ $cm^3$)* |
| foot (ft) | 0.3048 | meter (m) |
| inch (in.) | 2.540 | centimeter (cm) |
| inch (in.) | 25,400 | micron (µm, or micrometer) |
| knot (kt) | 0.5144 | meter per second (m/s) *(= 1.852 km/hr)* |
| mile (mi) | 1.609 | kilometer (km) |
| mile per hour (mph) | 0.4470 | meter per second (m/s) |
| ounce (oz.) | 28.35 | gram (g) |
| pound (lb) | 0.4536 | kilogram (kg) |
| short ton (tons) | 907.2 | kilogram (kg) |
| short ton (tons) | 0.9072 | metric ton (t) |
| square foot ($ft^2$) | 0.09290 | square meter ($m^2$) |
| square yard ($yd^2$) | 0.8361 | square meter ($m^2$) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| yard (yd) | 0.9144 | meter (m) |
| ***Metric/English Equivalents*** | | |
| centimeter (cm) | 0.3937 | inch (in.) |
| cubic centimeter ($cm^3$, or cc) | 0.0002642 | gallon (gal) |
| cubic meter ($m^3$) | 35.31 | cubic foot ($ft^3$) |
| cubic meter ($m^3$) | 1.308 | cubic yard ($yd^3$) |
| cubic meter ($m^3$) | 264.2 | gallon (gal) |
| gram (g) | 0.03527 | ounce (oz.) |
| kilogram (kg) | 2.205 | pound (lb) |
| kilogram (kg) | 0.001102 | short ton (tons) |
| kilometer (km) | 0.6214 | mile (mi) |
| liter (L) | 0.2642 | gallon (gal) |
| meter (m) | 3.281 | foot (ft) |
| meter (m) | 1.094 | yard (yd) |
| meter per second | 1.944 | knot (kt) *(1 kt = 1.151 mph)* |
| meter per second | 2.237 | mile per hour (mph) |
| metric ton (t) | 1.102 | short ton (tons) |
| micron (µm, or micrometer) | 0.00003937 | inches (in.) |
| milliliter (mL) | 0.0002642 | gallon (gal) |
| square kilometer ($km^2$) | 0.3861 | square mile ($mi^2$) |
| square meter ($m^2$) | 0.0002471 | acre (ac) *(1 ac = 43,560 $ft^2$)* |
| square meter ($m^2$) | 10.76 | square foot ($ft^2$) |
| square meter ($m^2$) | 1.196 | square yard ($yd^2$) |

# SUMMARY

The U.S. Department of Energy (DOE or Department) is obligated to establish standards for energy conservation in manufactured housing, as directed by Section 413 of the Energy Independence and Security Act of 2007 (EISA). EISA directs DOE to base these standards on the most recent version of the International Energy Conservation Code (IECC) and any supplements to that document, except where DOE finds that the IECC is not cost effective or where a more stringent standard would be more cost effective based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs. In accordance with Section 413, DOE is proposing to establish energy conservation standards for manufactured housing. To inform the proposed rulemaking, DOE has prepared a draft environmental impact statement (EIS) pursuant to the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ) NEPA implementing regulations, and DOE's procedures for implementing NEPA.

## S.1 PROCESS TO DEVELOP THE STANDARDS

Since EISA became law in 2007, DOE has undertaken multiple steps to fulfill the directive of Section 413 to promulgate energy conservation standards for manufactured housing. DOE has consulted with the U.S. Department of Housing and Urban Development (HUD) and sought input from the manufactured housing community and the public throughout this process. Most recently, DOE published a notice of proposed rulemaking, initiated an environmental assessment, canceled the environmental assessment, initiated the EIS review process, published a supplemental notice of proposed rulemaking, and a notice of data availability.

On June 17, 2016, DOE published a notice of proposed rulemaking (NOPR) that proposed to establish energy conservation standards for manufactured housing based on the consensus recommendations of the Manufactured Housing Working Group. In tandem, DOE issued a technical support document that presented the analyses underlying the proposed standards.

On June 30, 2016, DOE issued for public review a draft environmental assessment (EA) pursuant to NEPA to evaluate the potential environmental impacts of the proposed standards. In addition to seeking public comments on the environmental issues addressed in the draft EA, DOE requested information that would help it analyze potential impacts of the proposed standards on the indoor air quality of manufactured homes.

On July 7, 2021, DOE published the Notice of Intent to prepare the draft EIS and hold two virtual public scoping meetings in the Federal Register. Additionally, DOE provided notice and a request for scoping comments to tribes, states, and approximately 25,000 stakeholders who have expressed interest in standards and rulemakings processes, individuals and organizations who commented on the draft EA and previous rulemaking processes, members of the Manufactured Housing Working Group, and identified NEPA stakeholders. DOE also reached out to the Department of Housing and Urban Development (HUD) and invited HUD to become a cooperating agency on the preparation of the EIS. HUD responded with a preference to engage with DOE more informally.

On August 26, 2021, DOE published a supplemental notice of proposed rulemaking (SNOPR) to establish energy conservation standards for manufactured housing. In the SNOPR, DOE proposed to include several IECC provisions with modification, incorporating some of the Manufactured Housing Working Group's recommendations that were based on cost-effectiveness. This updated proposal was based on the 2021 version of the IECC and comments received during interagency consultation with HUD as well as from stakeholders. In the SNOPR, DOE requested comments related to recent updates of several data sources used as inputs to the analyses that had not been incorporated in the SNOPR.

On October 26, 2021, DOE published a notification of data availability (NODA) regarding updated inputs and results of corresponding analyses and invited interested parties to comment on these analyses. In addition, DOE reopened the public comment period on the SNOPR through November 26, 2021. DOE explained that it would consider the updated inputs and corresponding analyses, as well as comments on the inputs and analyses, as part of the rulemaking. In addition, DOE stated it may further revise the analysis presented in this rulemaking based on any new or updated information or data it obtains and encouraged stakeholders to provide any additional data or information that may inform the analysis.

DOE received oral scoping comments at the two virtual public meetings and written scoping comments through numerous means. All scoping comments and comments relevant to the scope of the EIS received by DOE during the public comment periods for the draft EA, NOPR, SNOPR and NODA were considered in the preparation of the draft EIS.

## S.2 ALTERNATIVES

DOE is considering three approaches in establishing the energy conservation standards for manufactured housing. The draft EIS refers to each approach as an action alternative. The alternatives were informed by public comments on the EIS scope and by comments on the NOPR, SNOPR, and NODA, as well as coordination and consultation with HUD. In accordance with NEPA, DOE is also considering the alternative of taking no action, which serves as a baseline against which potential consequences of the action alternatives can be compared. Thus, four alternatives (referred to as A, B, C, and D) are evaluated in detail in the EIS. DOE does not have a preferred alternative at the time of the publication of the draft EIS.

Under Alternative A, the proposed standards for energy conservation would be tiered based on a manufacturer's retail list price of $63,000. Within Alternative A, two detailed alternatives (A1 and A2) were analyzed. Alternative A1 represents DOE's proposed action. Under the proposed action, Tier 1 standards would apply to homes with a retail list price of $63,000 or less, and the building thermal envelope requirements would correspond to an incremental increase in purchase price of $750 (on average). Tier 2 standards would apply to homes with a manufacturer's retail list price above $63,000 and would be based on the 2021 IECC. Alternative A2, is the same as Alternative A1 except it would include relaxed insulation requirements for Tier 2 manufactured houses in certain climate zones.

Under Alternative B, the proposed standards for energy conservation would be tiered based on the size of the manufactured home. Like Alternative A, two detailed alternatives were analyzed within

Alternative B (B1 and B2). For Alternative B1, the Tier 1 standards would apply to single-section manufactured homes, and, as with Alternative A, the building thermal envelope requirements would correspond to an incremental purchase price increase of $750. Tier 2 standards would apply to multi-section manufactured homes and would be based on the 2021 IECC. The building thermal envelope requirements for Alternative B1 are the same as those identified for Alternative A1. Alternative B2, is the same as Alternative B1 except it would include relaxed insulation requirements for Tier 2 manufactured homes in certain climate zones.

Alternative C represents an untiered approach to establishing energy conservation standards. Under this alternative, the proposed standards based on the 2021 IECC would apply to all manufactured homes, without considering the manufacturer's retail list price or size. As with Alternatives A and B, two detailed alternatives were analyzed within Alternative C (C1 and C2). Under Alternative C1, the building thermal envelope requirements would be the same as those identified for Tier 2 in Alternative A. Alternative C2 is the same as C1 except it would include relaxed insulation requirements for all manufactured houses in certain climate zones.

Alternative D represents the no action alternative. Under this alternative, DOE would not establish energy conservation standards for manufactured housing, and energy efficiency requirements, and manufacturers would continue to follow the requirements in the existing HUD Code.

DOE considered, but did not analyze in detail, several potential alternatives, including alternatives suggested in comments received during the scoping process for this EIS and in response to the NOPR, SNOPR, and NODA. These alternatives fall within four themes: (1) the mechanism for implementing standards; (2) the basis for the standards, (3) the structure of the standards, and (4) other efficiency requirements. The draft EIS describes why these alternatives were not analyzed in detail.

## S.3 RESOURCES AREAS POTENTIALLY AFFECTED

The proposed energy conservation standards could potentially impact five resource areas: energy resources, air resources, health and safety, socioeconomic resources, and environmental justice. The existing conditions and potential impacts of the proposed action and alternatives are summarized as follows.

### S.3.1 Energy Resources

Total energy consumption consists of: (1) primary energy consumption, (2) purchased electricity, and (3) electrical system energy losses. The first two accounted for 11.6 quads of the total 20.9 quads for the residential sector in 2020. These losses during the conversion of primary energy to electricity and the subsequent transmission and distribution of purchased electricity total 9.3 quads. These energy losses from the electrical system for the residential sector are higher than for any other sector, and they account for a full 10 percent of the nation's entire energy consumption. Two factors make overall energy efficiency a challenge when considering manufactured homes and equipment commonly used today: (1) relatively high reliance on electricity, and (2) the relatively low energy efficiency of electricity compared with primary energy sources because of energy losses inherent to the electrical system. One way to help reduce the losses is to reduce household energy consumption, including through more energy-efficient homes.

Although energy is used to power a wide variety of devices and equipment in homes, on average, more than half the site energy used by U.S. households is for space heating and air conditioning. In every region of the country, manufactured homes are most likely to use electricity alone to meet all their household energy needs, with natural gas addressing just 25 percent of those needs, on average.

The national energy savings estimated for the proposed energy conservation standards for manufactured homes would be about 2 quads over the 30-year period (relative to the no-action alternative D). The national energy savings estimated for the six action alternatives are within 0.5 quad of each other, differing by about 25 percent between least and most savings. For context, EIA (2018) reports a site energy consumption for manufactured homes of 406 trillion Btu, or slightly more than 0.4 quad per year (EIA 2018). Total energy consumption by the residential sector has been fairly stable from year to year, at 20 to 22 quads, which helps frame the energy savings that would be realized by the proposed standards. The national energy savings within each of the three climate zones are similar (within about 10%).

## S.3.2 Air Resources

Associated with energy conservation standards for manufacture homes, DOE estimates reductions in emissions of six pollutants associated with energy savings over the 30-year (2023-2052) period relative to the baseline: carbon dioxide ($CO_2$), mercury (Hg), nitric oxide and nitrogen dioxide ($NO_X$), sulfur dioxide ($SO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Emissions reductions are presented in two sections: (1) greenhouse gases (GHGs), such as $CO_2$, $CH_4$, and $N_2O$; and mercury and criteria pollutants, such as $NO_X$, and $SO_2$.

### S.3.1.1 Greenhouse Gas Emissions and Climate Change

GHGs, emissions reductions relative to the baseline (no-action alternative D) would have positive impacts on climate change under the proposed action (Alternative A2) and other action alternatives. Over the 30-year (2023-2052) period, cumulative emissions reductions under the proposed action (Alternative A2) would be about 83 million metric tons (MT) of $CO_2$, 502 thousand MT of $CH_4$, and 0.84 thousand MT of $N_2O$, totaling about 96 million MT on a $CO_2$ equivalent basis (million MT $CO_2e$). Alternative C1 would achieve the most emissions reductions, about 21 percent more than the proposed action (Alternative A2). In contrast, Alternative B2 has the lowest emissions reductions, about 3 percent lower than Alternative A2. Overall, Alternative C would achieve the most emissions reductions, followed by Alternative A, and Alternative B would have the fewest. As expected, Alternatives A1, B1, and C1 would reduce emissions more than their counterparts, Alternatives A2, B2, and C2.

The projected annual $CO_2$ emissions from the residential sector average about 793 million MT over the 2020-2050 period for the Energy Information Administration (EIA) reference case. With respect to this residential sector annual emission, reductions in $CO_2$ emissions would range from

0.34 percent (Alternative B2) to 0.42 percent (Alternative C1) with 0.35 percent under the proposed action (Alternative A2).

### S.3.1.2 Criteria Pollutants, Mercury, and Ambient Air Quality

The cumulative emissions reductions over the 30-year period (2023-2052) under the proposed action (Alternative A2) would be about 0.13 MT of mercury, 132 thousand MT of $NO_X$, and 29 thousand MT of $SO_2$. Like for the GHG emissions just above, Alternative C1 would achieve about 21 percent more emissions reductions than the proposed action (Alternative A2), while Alternative B2 would achieve about 3 percent fewer reductions. Overall, Alternative C (untiered) would achieve the greatest emissions reductions, followed by Alternative A (price-based tiered standards). Alternative B (size-based tiered standards) would achieve the fewest emissions reductions. Meanwhile, the three alternatives with the more stringent insulation requirement, R-20+5 (Alternatives A1, B1, and C1), would achieve more emissions reductions than their counterparts with R-21 insulation, Alternatives A2, B2, and C2, respectively.

On an annual basis, the estimated reductions in mercury emissions that would be achieved under the proposed action (Alternative A2) would be equivalent to a reduction of about 0.11 percent of the total U.S. mercury emissions from electricity generation units (EGUs) in 2017. The contributions to the further mercury reductions estimated for the other alternatives would be similar, ranging from 0.10 percent (Alternative B2) to 0.13 percent (Alternative C1).

Estimated $NO_X$ emissions reductions under the proposed action (Alternative A2) would be a further reduction of about 0.66 percent of the total U.S. $NO_X$ emissions from power plants in 2020. Emission reductions of $NO_X$ that would be achieved by the other action alternatives would contribute to reductions ranging from 0.63 percent (Alternative B2) to 0.79 percent (Alternative C1) of the 2020 total from U.S. power plants.

$SO_2$ emissions reductions under the proposed action (Alternative A2) would equate to a reduction of about 0.14 percent of the total U.S. $SO_2$ emissions from power plants in 2020. Contributions of these emissions reductions from other action alternatives would be similar, ranging from 0.13 percent (Alternative B2) to 0.17 percent (Alternative C1).

Related to energy conservation standards for manufactured homes, emissions reductions of $NO_X$ and $SO_2$, which are precursors of criteria pollutants, such as ozone and $PM_{2.5}$, along with acid depositions, would improve ambient air quality in the near future years with all things being equal. However, increases in both anthropogenic and natural emissions associated with climate change could offset these benefits to some extent or significantly depending on the future GHG emissions and associated weather conditions.

### S.3.1.3 Indoor Air Quality

Several aspects of indoor air quality are impacted under existing conditions in manufactured housing and would continue to be impacted under the no-action alternative. The available data suggest that concentrations of formaldehyde and acrolein exceed reference levels in the majority and likely the vast majority of manufactured homes. $PM_{2.5}$ concentrations inside manufactured homes may exceed the annual average target level for the National Ambient Air Quality Standards (NAAQS). In homes with smokers, secondhand tobacco smoke (SHS) results in substantially degraded indoor air quality (IAQ). Poorly controlled air leakage from the duct system that distributes heated or cooled air from the central, forced-air, thermal conditioning equipment into the belly or attic can transfer water vapor from humidified air inside the house to connected spaces with cold surfaces that are vulnerable to condensation and subsequent dampness and mold issues.

The proposed action alternatives will impact IAQ through changes to the air sealing requirements of the envelope and the duct system. Since all action alternatives have the same requirements for air sealing, the same IAQ impacts are expected for all, and these impacts are expected to include both positive and negative aspects. If other factors — such as how manufactured home occupants use or do not use ventilation — remain constant, reducing air leakage through improved air sealing is expected to result in lower indoor concentrations of some outdoor air pollutants, higher concentrations of pollutants emitted from indoor sources, and lower risk of moisture problems in the belly and attic. Lower air exchange rates should lead to lower indoor concentrations of ozone, $NO_2$, and $PM_{2.5}$ from outdoor sources. Reducing outdoor air exchange will slow the dilution and removal of pollutants emitted indoors, leading to higher indoor air concentrations and related exposures.

The impacts for indoor-generated air pollutants would be greatest in homes that do not utilize any mechanical or natural ventilation, and these homes are expected to have the highest concentrations of indoor generated pollutants under existing conditions. The levels of indoor-generated pollutants are thought today to be lowest in homes that utilize whole-house mechanical ventilation and also use kitchen and bath exhaust fans, and impacts of the proposed action alternatives would be smallest in homes that utilize these mechanical ventilation options.

Reducing uncontrolled airflow is considered by building science experts to be helpful in reducing the risk of condensation and consequent dampness and mold issues. Condensation risk reduction benefits cannot be quantified as readily as the increase in indoor-emitted chemical air pollutants or the decrease in outdoor pollutants; but they could be large given the potential substantial disease burden caused by dampness and mold.

Air sealing is also an element of integrated pest management, as it reduces openings for pest entry, reducing the allergens that are brought inside by pests and reducing the likelihood that chemical pesticides will be used.

#### S.3.1.1 Wildfire Impacts on Air Quality

The proposed action alternatives would provide increased protection from wildfire smoke; when occupants close all windows and temporarily turn off whole-house ventilation as recommended during wildfire smoke events, their exposure to $PM_{2.5}$ from wildfire smoke will be lowered by an estimated 25 to 30 percent.

### S.3.3 Health and Safety

The health and safety analysis for the proposed energy conservation standards includes potential health risks associated with exposures to indoor air pollutants whose concentrations might change as a result of the proposed energy conservation standards for manufactured homes.

The existing condition is that formaldehyde and acrolein exceed safe exposure targets in most homes, especially when no ventilation is used. The improved air sealing requirements of all proposed action alternatives would not change the hazard status of these pollutants. Even in homes with frequent gas cooking, the chronic $NO_2$ exposure would remain well below the NAAQS annual average concentration benchmark. Across all of the ventilation scenarios and the three locations evaluated, $PM_{2.5}$ from frequent cooking and from occupant activities (excluding smoking) would also remain below the benchmark of the NAAQS annual average. The airflow and pollutant simulations produced a range of hazard quotients that extends to just over 1.0 for total $PM_{2.5}$ in non-smoking homes meeting the HUD Code. The high value is for homes that use no mechanical ventilation and do not routinely open windows. The range of hazard quotients for total $PM_{2.5}$ would extend a bit higher in a home that meets the proposed standards for airtightness with the same indoor sources and outdoor concentrations; but the difference is very small relative to the variability seen in the hazard quotients based on measurements in homes.

Along with SHS, acrolein and formaldehyde also have hazard quotients substantially above 1 in the HUD Code home (no action alternative). Those hazard quotients likely would increase with air sealing, if there were no changes to occupant ventilation practices. As noted in Section 4.2.3, any potential increases in concentrations for these pollutants could be mitigated with increased use of ventilation. The estimated incremental changes to formaldehyde concentrations would not result in a significant incremental cancer risk from formaldehyde exposure. The estimated incremental changes to formaldehyde concentrations would not result in a significant incremental cancer risk from formaldehyde exposure.

### S.3.4 Socioeconomic Resources

The socioeconomics analysis for the proposed energy conservation standards includes impacts to consumers, impacts to manufacturers, and nationwide impacts.

The estimated impacts on consumers under each of the alternatives include lifecycle cost (LCC) and payback period (PBP). The LCC analysis is the total customer cost over the life of the manufactured home over the life of the home (10- and 30-year lifetimes are analyzed in this EIS) which include operating costs and purchase costs discounted to the time of the purchase. Payback periods measures the amount of time it takes for the purchaser of the manufactured home to recover the increase in purchase price of the energy efficiency standards through reduced operating costs. The DOE calculates the payback period as the increase in purchase price divided by the annual (first year) energy savings. For impacts on consumers, the highest life-cycle cost savings for a 10-year home lifetime occurs under Alternative A1 at $726 and $1,015 for single and multi-section homes, respectively. The highest life-cycle cost savings for a 30-year lifetime of the manufactured home occurs under Alternative C2 with $2,432 and $3,291 for single and multi-section homes, respectively. Life-cycle cost savings are positive compared to Alternative D for all of the action alternatives except for the 10-year under Alternative C1 for single-section manufactured homes, indicating consumers will save money under almost every alternative. The highest increase in purchase price was for Alternatives A1 and C1 at $3,902 and $5,267 for single and multi-section manufactured homes, respectively. Similarly, the longest simple payback period occurs under Alternatives A1 and C1, at 11.0 and 10.6 years for single and multi-section homes, respectively. The lowest increase in purchase price occur under Alternatives A2, B2, and C2 at $2,830 and $4,222 for single and multi-section homes, respectively. The lowest payback periods are for these same alternatives at 8.5 for single section homes and 8.9 for multi-section homes.

The manufacturers impact analysis (industry net present value [INPV]) was performed in the SNOPR and is only included in this draft EIS under Alternatives A1 and C1. The MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model using industry financial metrics, manufacturer production costs, shipments, conversion expenditures, and manufacturer markups to estimate changes in industry value as a result of energy conservation standards. Alternative C1 has positive impacts compared to Alternative D under the preservation of gross margin markup scenario and has higher positive impacts on manufacturers than Alternative A1. Under Alternative C1, the change in INPV would be, in 2020 dollars, 0.15 billion and 0.25 billion greater than the no-action alternative for single-section and multi-section homes, respectively. However, under the preservation of operating profit markup scenario, Alternative C1 has negative impacts of a -0.13 billion and -0.21 billion decrease in INPV for single and multi-section homes, respectively compared to the no-action alternative. Alternative A1 does not have as great of a decrease in the preservation of operating profit markup scenario compared to Alternative C1, with an expected decrease of -0.07 and -0.2 billion 2020 dollars change in INPV for single-section and multi-section homes, respectively.

Nationwide impacts were estimated based on national energy savings and net present value of consumer benefits, which were calculated based on projected annual shipments, projected annual energy consumption, and total incremental cost data from the LCC analyses. For single-section homes, the highest net present value total consumer savings assuming a 3% discount rate occurs under Alternative A2 at $1.9 billion in 2020 dollars. The highest net present value for single-section homes assuming a 7% discount rate occurs under Alternatives B 1 and B2 at $0.68 billion in 2020 dollars. For multi-section homes, the highest net present value assuming a 3% discount rate occurs under Alternative B2 at $3.22 billion in 2020 dollars. For multi-section homes assuming a 7% discount rate the highest NPV was Alternative A2 at $0.85 billion in 2020 dollars. Of the action alternatives, the lowest number of shipment reductions occur under Alternative B2 at a projected 31,956 reduced shipments in manufactured housing. The highest reduction occurs in Alternative C1 at 70,203 reduced shipments. There would be no shipment reductions under Alternative D.

### S.3.5 Environmental Justice

The environmental justice impact analysis considers whether the potential impacts from the proposed energy conservation standards disproportionately impact minority and/or low-income populations. This draft EIS evaluated environmental justice in terms of the socioeconomics impacts (access to affordable homeownership and energy insecurity) and indoor air quality and health.

For the tiered alternatives (Alternatives A1, A2, B1, and B2), it is expected that low-income populations would purchase Tier 1 homes. The increase in purchase price of Tier 1 homes under these alternatives would not likely disproportionately impact low-income and minority populations' ability to purchase new homes. However, Tier 1 homes would not receive the same energy conservation standards, decreasing the potential benefits of energy savings for low-income and minority communities who already experience higher energy burdens compared to the national average.

The impacts on indoor air quality and human health are the same across all alternatives. The proposed energy conservation standards are expected to lead to lower indoor concentrations of some outdoor air pollutants and improve the ability to control exposure to wildfire smoke. Conversely, it is expected that the proposed energy conservation standards would lead to higher concentrations of indoor air pollutants air emitted from indoor sources, in particular when ventilation is inadequate.

The degree of adverse impact on low-income and minority populations from the proposed energy conservation standards for manufactured homes would depend on existing conditions because concentrations of pollutants in indoor air will vary with house-specific emission rates and location-specific outdoor pollutant levels.

## S.4 MITIGATION MEASURES

In this draft EIS, DOE identifies the potential for adverse impacts to indoor air quality, health and safety, socioeconomics and environmental justice. In response, DOE identifies six categories of measures that could be implemented to mitigate potential adverse impacts:

1. Promote installation of energy efficient fans for ventilation, to mitigate potential impacts to indoor air quality, health, socioeconomics, and environmental justice;
2. Advance research and stakeholder engagement, to increase implementation of efficient ventilation in manufactured housing to mitigate potential impacts to indoor air quality, health, socioeconomics, and environmental justice;
3. Provide training and technical assistance to manufacturers, to mitigate potential impacts to indoor air quality, health, socioeconomics, and environmental justice;
4. Promote improved indoor air quality and environmental justice through informational resources and labeling, to mitigate potential impacts to indoor air quality, health, socioeconomics, and environmental justice;
5. Promote financial mechanisms to offset first costs through incentives, assistance, and informational resources, to mitigate potential impacts to socioeconomics, and environmental justice; and
6. Promote awareness of DOE's Energy Justice Initiative, to mitigate potential impacts to environmental justice.

# 1 PROGRAM BACKGROUND AND THE PURPOSE AND NEED FOR PROPOSED ACTION

The U.S. Department of Energy (DOE or Department) is obligated to establish standards for energy conservation in manufactured housing,[1] as directed by Section 413 of the Energy Independence and Security Act of 2007 (EISA).[2] EISA directs DOE to base these standards on the most recent version of the International Energy Conservation Code (IECC) and any supplements to that document, except where DOE finds that the IECC is not cost effective or where a more stringent standard would be more cost effective based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs. In accordance with Section 413, DOE is proposing to establish energy conservation standards for manufactured housing.[3] To inform the proposed rulemaking, DOE has prepared this draft environmental impact statement (EIS) pursuant to the National Environmental Policy Act (NEPA),[4] the Council on Environmental Quality (CEQ) NEPA implementing regulations,[5] and DOE's procedures for implementing NEPA.[6] This draft EIS presents information about:

- Potential impacts on the human environment of DOE's proposed action to establish energy conservation standards for manufactured housing;
- Potential impacts of alternatives to this proposed action, including no action; and
- Any adverse environmental effects that cannot be avoided.

This NEPA review is conducted prior to a final agency decision to ensure that DOE decision-makers are informed of potential environmental impacts prior to establishing energy conservation standards for manufactured housing. The statutory context for DOE's proposed energy conservation standards is provided in Section 1.1, and the purpose of and need for this proposed

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[1] Manufactured housing is a category consisting of structures that are constructed in a factory, built on a permanent chassis, and transported in one or more sections to be erected onsite. The National Manufactured Housing Construction and Safety Standards Act of 1974, as amended, defines "manufactured home" as "*a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet or more in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities, and includes the plumbing, heating, air-conditioning, and electrical systems contained therein; except that such term shall include any structure that meets all the requirements of this paragraph except the size requirements and with respect to which the manufacturer voluntarily files a certification required by the Secretary [of Housing and Urban Development] and complies with the standards established under this chapter [at 24 CFR Part 3280]; and except that such term shall not include any self-propelled recreational vehicle*." 42 U.S.C. 5402(6). Manufactured homes may be built in one or more sections attached side-by-side at the home site (HUD 2019).

[2] Public Law (PL) 110-140. "Subtitle A–Residential Building Efficiency, Section 413, Energy code improvements applicable to manufactured housing," 42 U.S.C. 17071.

[3] For more information, see the DOE Manufactured Housing Rulemaking webpage: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=64.

[4] PL 91-190; 42 U.S.C. 4321 et seq.

[5] 40 CFR Parts 1500–1508. Available at: https://www.ecfr.gov/current/title-40/chapter-V. Accessed Dec. 5, 2021.

[6] 10 CFR Part 1021. "National Environmental Policy Act Implementing Procedures." Available at: https://www.ecfr.gov/current/title-10/chapter-X/part-1021. Accessed Dec. 5, 2021.

action are described in Section 1.2. Highlights of DOE's development process for the proposed energy conservation standards are given in Section 1.3, and an overview of public participation is presented in Section 1.4. The organization of this draft EIS is outlined in Section 1.5.

## 1.1 STATUTORY CONTEXT

In addition to directing DOE to establish energy conservation standards for manufactured housing based on the most recent version of the IECC, Section 413 of EISA directs DOE to:

- Provide notice of, and an opportunity for comment on, the proposed standards by manufacturers of manufactured housing and other interested parties;
- Consult with the Secretary of the U.S. Department of Housing and Urban Development (HUD), who may seek further counsel from the Manufactured Housing Consensus Committee (MHCC); and
- Update the standards not later than one year after any revision to the IECC.

In providing DOE with the authority to regulate energy conservation in manufactured housing, Section 413 also identifies that DOE's energy conservation standards may:

- Take into consideration the design and factory construction techniques of manufactured homes,
- Be based on the climate zones established by HUD[7] rather than the climate zones under the IECC, and
- Provide for alternative practices that result in net estimated energy consumption equal to or less than the specified standards.

Section 413 of EISA also states that a manufacturer of manufactured housing that violates a provision of DOE's manufactured housing regulations "is liable to the United States for a civil penalty not exceeding 1 percent of the manufacturer's retail list price of the manufactured housing" (42 U.S.C 10701).

HUD has regulated the manufactured housing industry since 1976 when the HUD Code[8] was first promulgated. The purpose of that Code includes protecting the quality, durability, safety, and affordability of manufactured homes; facilitating the availability of affordable manufactured homes and increasing home ownership for all Americans; protecting residents of manufactured homes with respect to personal injuries and the amount of insurance costs and property damages;

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[7] The statute uses the term "climate zones" in reference to the HUD requirements (42 U.S.C. 17071(b)(2)(B)); HUD has not established climate zones, but has established insulation zones (see 24 CFR 3280.506). DOE understands the statutory reference to climate zones in this context to mean the insulation zones.

[8] "Manufactured Home Construction and Safety Standards," 24 CFR Part 3280. Structures such as site-built and modular homes constructed to state, local, or regional building codes are excluded from coverage by the HUD Code.

and ensuring that the public interest in, and need for, affordable manufactured housing is duly considered in all determinations relating to the Federal standards and their enforcement.

Although certain portions of the HUD Code also relate to energy efficiency,[9] those requirements differ from the IECC standards developed by the International Code Council (ICC) and have not been updated since 1994.[10] The IECC is a nationally recognized model code that has been adopted by many state and local governments in establishing minimum design and construction requirements for the energy efficiency of commercial and residential buildings, including site-built and modular homes.[11] The IECC is developed through a consensus process that seeks input from a number of relevant stakeholders, and it has been updated on a rolling basis since its first publication in 1998, with new editions published about every three years. The most recent version was published in January 2021.[12]

The 2021 IECC contains two sets of provisions, one for commercial buildings and the other for residential buildings. The residential provisions for energy efficiency include specifications for building thermal envelope energy conservation, thermostats, duct insulation and sealing, mechanical system piping insulation, heated water circulation systems, and mechanical ventilation. These residential building requirements are not specific to manufactured housing, and the IECC is not currently applied to manufactured housing (pending the establishment of energy conservation standards in accordance with EISA). The 2021 IECC is generally considered more stringent than the corresponding energy efficiency requirements in the HUD Code, to the extent that the HUD Code regulates similar aspects of energy conservation as the 2021 IECC.

The IECC is designed for building structures that have a permanent foundation, while manufactured housing structures are built on a steel chassis to enable moving or towing when needed. Because manufactured housing presents its own set of unique considerations that the IECC was not intended to address, some aspects of the IECC are unable, or highly impracticable, to be applied to this type of housing. In accordance with Section 413 of EISA, DOE is utilizing aspects of the IECC for residential buildings that are appropriate for manufactured housing as the basis for developing the proposed energy conservation standards, thereby accounting for unique physical characteristics of this housing. Consultations with HUD have informed DOE's development of the proposed standards and the alternatives presented in this draft EIS, and DOE remains cognizant of the HUD Code as well as HUD's Congressional authority to protect the quality, durability, safety, affordability, and availability of manufactured homes.

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[9] See 24 CFR 3280.507(a), specifying thermal insulation requirements; and 24 CFR 3280.508(d), detailing requirements related to the installation of high-efficiency heating and cooling equipment in manufactured homes.

[10] The most recent update of the HUD Code offers an option (but not a requirement) to use a ventilation system that complies with the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE) Standard 62.2.

[11] Modular, or prefabricated, homes are manufactured in sections offsite but finished and assembled on a foundation on site.

[12] The IECC is a copyright-protected document, published and owned by ICC (see more in footnote 28, Chapter 2).

## 1.2 PURPOSE AND NEED

In accordance with EISA, DOE proposes to establish energy conservation standards for manufactured housing that are based on the 2021 IECC. In fulfilling its statutory mandate to establish energy conservation standards, the standards will also:

- Reduce national energy consumption;
- Reduce energy costs for owners of manufactured homes;
- Reduce emissions of outdoor pollutants associated with electricity production;
- Reduce emissions of greenhouse gases associated with electricity production that may lead to climate change; and
- Protect public health and safety related to energy efficiency.

### National Energy Consumption

In 2020, residential buildings accounted for more than 22 percent of the energy consumed by the entire country and nearly 39 percent of all the electricity generated in the United States (EIA 2021a). Residential buildings consumed more electricity than any other end-use sector — spanning industrial, commercial, and transportation uses. Manufactured housing makes up about 6 percent of residential buildings (Census 2021a), and more than 90,000 new homes are manufactured each year (Census 2021b).

### Energy Costs of Manufactured Homeowners

Manufactured homes are typically smaller than site-built homes, and although annual average energy consumption is lower on a household basis, utility costs are typically higher. On average, the energy cost per square foot for a manufactured home is 70 percent higher than for a single-family home (EIA 2018a). The average cost of monthly utilities is often the same as the mortgage amount for manufactured homeowners across the country, and it is twice that amount across the Midwest and South (Census 2019). These challenges highlight the importance of energy-efficient manufactured homes, particularly in light of the population served by manufactured housing.

### Outdoor Pollutant Emissions

Criteria air pollutants and hazardous air pollutants are emitted to outdoor air during electricity production, including nitrogen oxides, sulfur dioxide, and mercury. Chronic exposures to elevated concentrations of these pollutants can adversely impact public health. Increasing the energy efficiency of homes would reduce the demand for electricity and decrease the corresponding emissions of these pollutants to ambient air.

### Greenhouse Gas (GHG) Emissions and Climate Change

The generation of electricity from fossil fuels is the largest source of GHG emissions in the United States. In 2020, the residential sector emitted 900 million metric tons of carbon dioxide ($CO_2$), of which nearly two-thirds were attributed to electric power generation; direct consumption of natural gas accounted for most of the rest (EA 2021a). About 92 percent of total $CO_2$ emissions in the United States comes from fossil fuel combustion, and these emissions accounted for about

80 percent of the country's total GHG emissions in 2019 (EPA 2021a). Meanwhile, the level of $CO_2$ in the atmosphere is the highest in human history, with an increasing frequency and intensity of storms, wildfires and droughts, sea level rise, and other ongoing impacts.

### Public Health and Safety

Manufactured homes are a major source of unsubsidized, low-cost housing for many owners and renters with few housing alternatives. The median household income of those who own manufactured homes is less than half that of U.S. homeowners overall (Census 2021b), and more than one-fourth of those who own manufactured homes live at the poverty level, a fraction 2.5 higher than for U.S. homes overall (HHS 2021; Census 2020, 2021b). Prior to the COVID-19 pandemic,[13] one in three U.S. households reported facing some form of energy insecurity, leading them to reduce or forgo basic necessities; 11 percent (nearly 13 million households) reported keeping their homes at an unhealthy or unsafe temperature in order to pay energy bills, with an even higher number facing a continued threat of utility disconnections (EIA 2018b). The energy burden[14] is a primary metric used to measure energy insecurity, which is a growing public health threat among low-income populations in the United States (Reames et al. 2021).[15] Nearly half of households living in manufactured homes have a high energy burden, and the burden is severe for a quarter of households in manufactured homes (ACEEE 2020). The COVID-19 pandemic has exacerbated energy insecurity challenges for many households, including those living in manufactured homes.

Manufactured housing provides an opportunity for significant energy savings through improved design, construction, and operation. Improving the energy efficiency of manufactured homes would reduce electricity demand, thereby reducing emissions of pollutants associated with electricity production. These emissions include GHGs linked to climate change, and further pollutants linked to respiratory diseases and other health effects.

The proposed action to establish energy conservation standards for manufactured housing would meet the requirements mandated by EISA and would also help meet the national goals of reducing energy consumption, reducing energy costs for those who own manufactured homes, reducing emissions of GHGs and other pollutants to ambient air, and reducing energy insecurity of households in manufactured homes toward improving public health and safety.

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[13] On March 11, 2020, the World Health Organization characterized the coronavirus disease 2019 (COVID-19), an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus, as a pandemic. At the time of publication of this draft EIS, the COVID-19 pandemic is ongoing.

[14] The energy burden is the percentage of household income spent on home energy bills, a burden above 6 percent is considered high, and above 12 percent is considered severe.

[15] On average, households with lower incomes live in homes that are nearly 30 percent less energy efficient than higher-income households, and the median energy burden of low-income households is three times higher than that of non-low-income households (Reames 2016; ACEEE 2020). Living in underheated homes is reported to double the risk of respiratory problems and increase the risk of mental health problems five-fold for adolescents (ACEEE 2016), and living in inadequately heated or cooled homes has been linked with increased asthma symptoms, respiratory problems, heart disease, arthritis, and rheumatism (Reames et al. 2021).

## 1.3 OVERVIEW OF THE STANDARDS DEVELOPMENT PROCESS

Since EISA became law in 2007, DOE has undertaken multiple steps to fulfill the directive of Section 413 to promulgate energy conservation standards for manufactured housing. DOE has consulted with HUD and sought input from the manufactured housing community and the public throughout this process. On February 22, 2010, DOE published an advance notice of proposed rulemaking (ANOPR) to develop and publish energy standards for manufactured housing, together with a request for comment.[16] The ANOPR was published to facilitate the rulemaking process and enhance the quality of the standards and supporting documentation, and to allow interested parties to provide suggestions, comments, and information to DOE.

With this same general purpose, DOE published a request for information (RFI) on June 25, 2013, which highlighted three areas of particular interest.[17] First, DOE sought information related to data, studies, and other materials that address the relationship between potential reductions in levels of natural air infiltration and both indoor air quality and occupant health for a manufactured home, including the potential interplay between air exchange rates comparable to those specified under the IECC edition of that time (2012) and emission control requirements under the HUD Code, as well as typical baseline levels of air infiltration through recently built manufactured homes and information on the role of total air flow through a manufactured home in the protection of occupant health and safety. Second, DOE sought information regarding financing measures that may be available for manufactured homes with higher energy efficiencies. Third, DOE sought information on characteristics of a possible model system of enforcement for its energy efficiency standards.

After reviewing the comments received in response to the 2010 ANOPR, the 2013 RFI, and other stakeholder input, DOE ultimately determined that the development of proposed manufactured housing energy conservation standards would benefit from a negotiated rulemaking process. On June 13, 2014, DOE published a notice of intent (NOI) to establish a negotiated rulemaking Manufactured Housing Working Group.[18] Consisting of 22 members representing interested stakeholders, the Working Group met for a total of 12 days over three months.

On October 31, 2014, the Working Group reached consensus on energy efficiency standards in manufactured housing and provided its recommendations to DOE to develop the proposed rule.[19] These recommendations were based on the most recent IECC provisions for residential site-built buildings (i.e., the 2015 IECC), which were published by the ICC on June 3, 2014.

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[16] "Energy Efficiency Standards for Manufactured Housing." 75 *Federal Register* (FR) 7556 (February 22, 2010).

[17] "Energy Efficiency Standards for Manufactured Housing." 78 FR 37995 (June 25, 2013).

[18] "Appliance Standards and Rulemaking Federal Advisory Committee: Notice of Intent To Establish the Manufactured Housing Working Group To Negotiate a Notice of Proposed Rulemaking (NOPR) for Energy Efficiency Standards for Manufactured Housing." 79 FR 33873 (June 13, 2014).

[19] *Appliance Standards and Rulemaking Federal Advisory Committee, Manufactured Housing Working Group, Term Sheet, October 31, 2014.* Document ID EERE-2009-BT-BC-0021-0107. Available at: https://www.regulations.gov/document?D=EERE-2009-BT-BC-0021-0107.

The Manufactured Housing Working Group recommendations also considered the impact of the 2015 IECC on the purchase price of manufactured housing, total lifecycle construction and operating costs, factory design and construction techniques unique to manufactured housing, and the current construction and safety standards set forth by HUD. The Working Group recommended that DOE adopt some provisions of the 2015 IECC directly into its proposed rule and establish other standards that were modifications of the 2015 IECC.

The Working Group also recommended that DOE conduct an additional analysis to inform the selection of solar heat gain coefficient requirements in certain climate zones. On February 11, 2015, DOE issued an RFI to address that recommendation.[20] DOE also sought public comment and held further meetings with HUD.

On June 17, 2016, DOE published a notice of proposed rulemaking (NOPR)[21] that proposed to establish energy conservation standards for manufactured housing based on the consensus recommendations of the Manufactured Housing Working Group. In tandem, DOE issued a technical support document[22] that presented the analyses underlying the proposed standards. On June 30, 2016, DOE issued for public review a draft environmental assessment (EA)[23] pursuant to NEPA to evaluate the potential environmental impacts of the proposed standards. In addition to seeking public comments on the environmental issues addressed in the draft EA, DOE requested information that would help it analyze potential impacts of the proposed standards on the indoor air quality of manufactured homes, in particular, from sealing the homes more tightly. DOE received nearly 50 comments on the proposed rule during its comment period and more than 700 substantively similar form letters from individuals. DOE also received 7 comments on the draft EA-RFI.

During DOE's interagency consultation with HUD, HUD expressed concerns about the adverse impacts on manufactured housing affordability that would likely follow if DOE were to adopt the approach laid out in the June 2016 NOPR. Various commenters also expressed concerns about potential negative impacts on the affordability of manufactured housing flowing from increased consumer costs resulting from DOE's approach presented in the NOPR.

The NOPR was ultimately withdrawn, and DOE published a notice of data availability (NODA) and RFI on August 3, 2018,[24] with the intent to further inform certain aspects of the proposed energy conservation standards. In the NODA and RFI, DOE stated it was examining a number of

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[20] *Energy Conservation Program: Energy Efficiency Standards for Manufactured Housing.* Request for information. 80 FR 7550 (February 11, 2015).

[21] *Energy Conservation Standards for Manufactured Housing.* 81 FR 39756 (June 17, 2016).

[22] *Technical Support Document for the U.S. Department of Energy's Notice of Proposed Rulemaking Establishing Energy Conservation Standards for Manufactured Housing,* Document ID EERE-2009-BT-BC-0021-01361, Available at: https://www.regulations.gov/document?D=EERE-2009-BT-BC-0021-0136.

[23] *Draft Environmental Assessment for Notice of Proposed Rulemaking, "Energy Conservation Standards for Manufactured Housing" With Request for Information on Impacts to Indoor Air Quality.* Notice of availability request for public comment, and request for information. 81 FR 42576 (June 30, 2016).

[24] *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing.* Notice of data availability; request for information. 83 FR 38073 (August 3, 2018).

possible alternatives to those proposed in the 2016 NOPR, about which it sought further input from the public, including information regarding first-time costs related to the purchase of these homes. In addition, DOE sought input on the analytical assumptions underlying the proposed energy conservation standards, ownership-related costs, prescriptive and performance-based standards, and compliance lead times.

On July 7, 2021, DOE published a NOI to prepare an EIS for energy conservation standards for manufactured housing, to invite public comments on the EIS scope, and to conduct public scoping meetings.[25] DOE conducted online meetings July 21 and July 22, 2021 and invited oral comments on the scope of the EIS, with written comments invited through August 6, 2021.

On August 26, 2021, DOE published a supplemental notice of proposed rulemaking (SNOPR) to establish energy conservation standards for manufactured housing (10 CFR 460). In the SNOPR, DOE proposed to include several IECC provisions with modification, incorporating some of the Manufactured Housing Working Group's recommendations that were based on cost-effectiveness. This updated proposal was based on the 2021 version of the IECC and comments received during interagency consultation with HUD as well as from stakeholders. Public comments on the scope of the EIS were also considered. In the SNOPR, DOE requested comments related to recent updates of several data sources used as inputs to the analyses that had not been incorporated in the SNOPR.

The SNOPR presented a tiered proposal with two potential approaches to the rulemaking, with applicability of the tiers based on the manufacturer's retail list price in light of the cost-effectiveness consideration required by EISA. DOE's primary proposal represents the tiered approach wherein a subset of the energy conservation standards (related to the building thermal envelope) would be less stringent for certain manufactured homes based on a threshold retail list price. Under the alternative approach, there would be no tiers, and the standards would be based solely on the 2021 IECC. That is, the standards would apply to all manufactured homes with no consideration of retail list price. DOE tentatively determined that the energy conservation standards under either the tiered or untiered approach could be considered cost effective when evaluating the impact of the standards on the purchase price of a manufactured home and on the total lifecycle construction and operating costs, and the Department requested comments regarding the cost effectiveness of these two options to inform its decision. The public comment period for the SNOPR extended from August 26 through October 25, 2021.

On October 26, 2021, DOE published a notification of data availability (NODA) regarding updated inputs and results of corresponding analyses and invited interested parties to comment on these analyses (DOE 2021c). In addition, DOE reopened the public comment period on the SNOPR through November 26, 2021.[26] DOE explained that it would consider the updated inputs and corresponding analyses, as well as comments on the inputs and analyses, as part of the rulemaking.

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[25] *Notice of Intent To Prepare an Environmental Impact Statement for Energy Conservation Standards for Manufactured Housing.* NOI to prepare an EIS, to request public comments on its scope, and to conduct public scoping meetings. 86 FR 35773 (July 7, 2021).

[26] *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing*. 86 FR 59042 (October 26, 2021).

In addition, DOE stated it may further revise the analysis presented in this rulemaking based on any new or updated information or data it obtains and encouraged stakeholders to provide any additional data or information that may inform the analysis.

The further analyses presented in the NODA included an update to the manufacturer's retail list price threshold for the tiered standard based on more recent data, in addition to a sensitivity analysis based on comments and consultations with HUD, and consideration of public comments on the scope of the EIS. This sensitivity analysis used an alternate tier threshold for the tiered proposal based on size (single-section versus multi-section homes) rather than retail list price. In the sensitivity analysis, DOE also applied alternate wall insulation requirements for climate zones 2 and 3 for both the tiered and untiered standards.

In both the August SNOPR and the October NODA, DOE presented analyses of (1) lifecycle cost (LCC) and payback period (PBP); (2) national impacts related to national energy savings and national net present value from a national perspective of total consumer costs and savings that would be expected to result from new or amended standards; and (3) environmental benefits in the form of reduced emissions of ambient air pollutants and GHGs associated with electricity production. The energy conservation standards for manufactured housing proposed in the SNOPR and the further analyses in the NODA would not conflict with the standards established by HUD, and complying with DOE's proposed standards would not prevent a manufacturer from complying with the requirements set forth in the HUD Code.

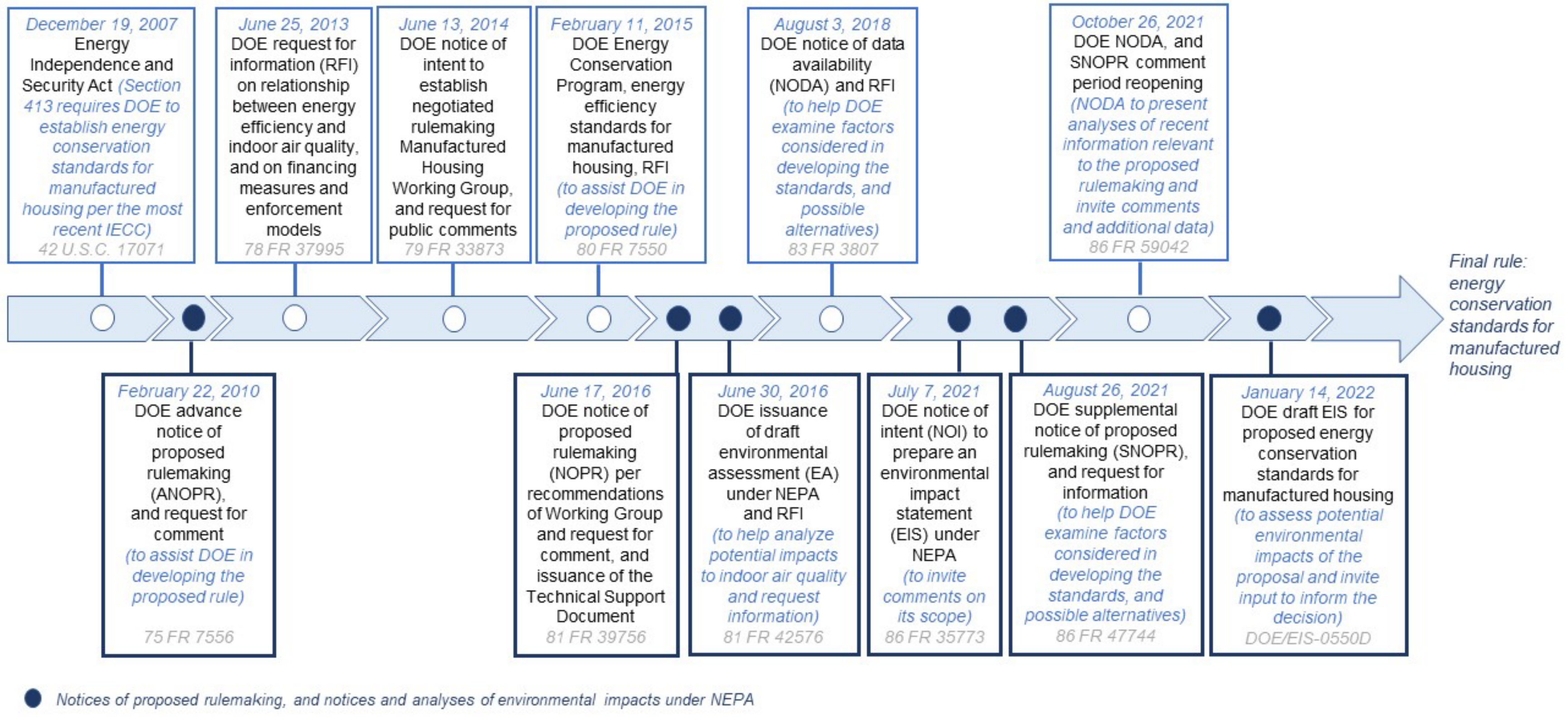
DOE's proposed action and alternatives presented in the SNOPR and NODA are described in Chapter 2 of this draft EIS. The no-action alternative is represented by the HUD Code; that is, if DOE did not establish the standards in accordance with EISA, manufacturers would continue to follow existing standards in the HUD Code. Highlights of the timeline for DOE's development of the energy conservation standards for manufactured housing are presented in Figure 1-1. The standards would take effect one year after the final rule is published in the *Federal Register*.

## 1.4 PUBLIC PARTICIPATION

This section summarizes public participation in the EIS process and comments received to date. Consultations and coordination with tribal, federal, and state agencies are described in Chapter 5.

### Notice of Intent (NOI) and Public Scoping Meetings

DOE prepared this draft EIS to evaluate the potential environmental impacts of the proposed action and alternatives for establishing energy conservation standards for manufactured housing, including the no-action alternative. In addition to publishing in the *Federal Register* the NOI to prepare the EIS, DOE mailed and emailed the notice and a request for comments to the 574 federally recognized tribes and also emailed the notice to approximately 25,000 stakeholders who have expressed interest in standards and rulemakings processes; individuals and organizations who commented on the draft EA and previous rulemaking processes; members of the Manufactured Housing Working Group; and identified NEPA stakeholders.



*December 19, 2007*
Energy Independence and Security Act *(Section 413 requires DOE to establish energy conservation standards for manufactured housing per the most recent IECC)*
42 U.S.C. 17071

*February 22, 2010*
DOE advance notice of proposed rulemaking (ANOPR), and request for comment *(to assist DOE in developing the proposed rule)*
75 FR 7556

*June 25, 2013*
DOE request for information (RFI) on relationship between energy efficiency and indoor air quality, and on financing measures and enforcement models
78 FR 37995

*June 13, 2014*
DOE notice of intent to establish negotiated rulemaking Manufactured Housing Working Group, and request for public comments
79 FR 33873

*February 11, 2015*
DOE Energy Conservation Program, energy efficiency standards for manufactured housing, RFI *(to assist DOE in developing the proposed rule)*
80 FR 7550

*June 17, 2016*
DOE notice of proposed rulemaking (NOPR) per recommendations of Working Group and request for comment, and issuance of the Technical Support Document
81 FR 39756

*June 30, 2016*
DOE issuance of draft environmental assessment (EA) under NEPA and RFI *(to help analyze potential impacts to indoor air quality and request information)*
81 FR 42576

*August 3, 2018*
DOE notice of data availability (NODA) and RFI *(to help DOE examine factors considered in developing the standards, and possible alternatives)*
83 FR 3807

*July 7, 2021*
DOE notice of intent (NOI) to prepare an environmental impact statement (EIS) under NEPA *(to invite comments on its scope)*
86 FR 35773

*August 26, 2021*
DOE supplemental notice of proposed rulemaking (SNOPR), and request for information *(to help DOE examine factors considered in developing the standards, and possible alternatives)*
86 FR 47744

*October 26, 2021*
DOE NODA, and SNOPR comment period reopening *(NODA to present analyses of recent information relevant to the proposed rulemaking and invite comments and additional data)*
86 FR 59042

*January 14, 2022*
DOE draft EIS for proposed energy conservation standards for manufactured housing *(to assess potential environmental impacts of the proposal and invite input to inform the decision)*
DOE/EIS-0550D

*Final rule: energy conservation standards for manufactured housing*

● *Notices of proposed rulemaking, and notices and analyses of environmental impacts under NEPA*

**FIGURE 1-1 Process for Developing the Energy Conservation Standards for Manufactured Housing**

## Release of the Draft EIS and Public Participation

This draft EIS is being released for public review and comment, and DOE encourages public participation through the NEPA process. The comment period extends 45 days from the date the notice of availability of the draft EIS is published in the *Federal Register*, and the public is invited to provide written comments throughout the comment period. Consultations and coordination conducted as part of the EIS process with Native American tribes, as well as with federal and state agencies, are described in Chapter 5.

DOE is providing notification of this draft EIS to everyone who received notice of the July 2021 NOI. DOE is also notifying individuals who attended the online EIS scoping meetings and those who provided comments on the EIS scope during the comment period.

In addition, DOE is notifying individuals who provided comments on the August 2021 SNOPR during the online meeting on September 24, 2021, and in writing throughout the comment periods spanning August 26 through November 26, 2021.

Likewise, DOE is notifying individuals who provided written comments on the NODA during its comment period through November 26, 2021. DOE will also notify any individual or group who requests to receive notice via any of the mechanisms shown below (the EIS website at https://ecs-mh.evs.anl.gov, designated email, or mail to the NEPA Document Manager) within the EIS public comment period.

DOE will hold two online public meetings to invite comments on the draft EIS. At these meetings, DOE will present information on the draft EIS and invite oral comments; written comments are invited throughout the comment period. Information on the dates and times of the public meetings on the draft EIS can be found at the EIS website (https://ecs-mh.evs.anl.gov/). In preparing the final EIS, DOE will consider all oral comments received at the public meetings and all written comments received during the comment period. Written comments can be submitted in any of the following ways:

- *Preferred method*: Directly on the EIS website at https://ecs-mh.evs.anl.gov/
- By email to DOE_EIS_MANUFACTURED_HOUSING@ee.doe.gov
- Or by mail to Dr. Roak Parker, NEPA Document Manager, DOE Golden Field Office, 15013 Denver West Parkway, Golden, CO 80401

DOE will evaluate comments received on the draft EIS for application to the proposed rulemaking for energy conservation standards for manufactured housing.

## 1.5 ORGANIZATION OF THE DRAFT EIS

This draft EIS for DOE's proposed energy conservation standards for manufactured housing is organized as follows:

- Chapter 2 Identifies the proposed action and alternatives, including no action.
- Chapter 3 Describes the affected environment to frame baseline conditions for resource areas that could potentially be affected by the proposed action and action alternatives.
- Chapter 4 Presents potential environmental consequences of the proposed action and alternatives.
- Chapter 5 Provides an overview of consultations and coordination conducted as part of the EIS process.
- Chapter 6 Lists the preparers of the draft EIS.
- Chapter 7 Provides the references cited in the draft EIS.
- Appendix A Summarizes public comments received on the scope of the EIS, in addition to public comments submitted on the SNOPR and NODA relevant to the scope of the EIS.
- Appendix B Describes the methods used to assess the affected environment and potential consequences of the proposed action and alternatives and provides supporting details for the information presented in Chapters 3 and 4.

# 2 PROPOSED ACTION AND ALTERNATIVES

DOE proposes to establish, for the first time, energy conservation standards for new manufactured housing. To establish these standards, DOE is considering three approaches, referred to as action alternatives in this EIS. These alternatives have been informed by public comments on the EIS scope and by comments on the NOPR, SNOPR, and NODA, as well as coordination and consultation with HUD. In accordance with NEPA, DOE is also evaluating the alternative of taking no action, which serves as a baseline against which potential consequences of the action alternatives can be compared. Thus, four alternatives are evaluated in detail in this EIS:

- Alternative A: Tiered standards based on price.

  Tier 1 standards would apply to homes at or below a manufacturer's retail list price threshold; Tier 2 standards would apply to homes priced above the threshold.

- Alternative B: Tiered standards based on size.

  Tier 1 standards would apply to single-section homes; Tier 2 standards would apply to multi-section homes.

- Alternative C: Untiered standards.

  These standards would apply to all homes regardless of price or size.

- Alternative D: No action.

  No change from the existing HUD Code.

A brief synopsis of each alternative is presented in Sections 2.1 through 2.4. The alternatives that DOE considered and eliminated from detailed analysis are discussed in Section 2.5. The potential consequences of implementing each alternative are compared in Section 2.6.

Under all three action alternatives (A, B, and C), DOE would establish energy conservation standards that relate to: (1) climate zones, building thermal envelope, air sealing, and insulation installation; and (2) duct sealing; heating, ventilation, and air conditioning (HVAC); service hot water systems, mechanical ventilation fan efficacy; and sizing of heating and cooling equipment.

HUD defined three U.S. climate zones for the purpose of setting its building thermal envelope requirements in the existing HUD Code more than two decades ago. DOE is using these same climate zones for the current proposed energy conservation standards. The climate zones are shown in Figure 2-1.

The three action alternatives for establishing the energy conservation standards for manufactured housing and the bases of their associated energy efficiency levels are summarized in Table 2-1. This table also includes the no-action alternative (i.e., no change from the existing HUD Code). As shown in the table, Tier 1 standards (those that have a corresponding $750 price increase) are Alternatives A1.1, A2.1, B1.1, and B2.1. Tier 2 standards (those that include more provisions of the 2021 IECC) are A1.2, A2.2, B1.2, B2.2, as well as C1 and C2.

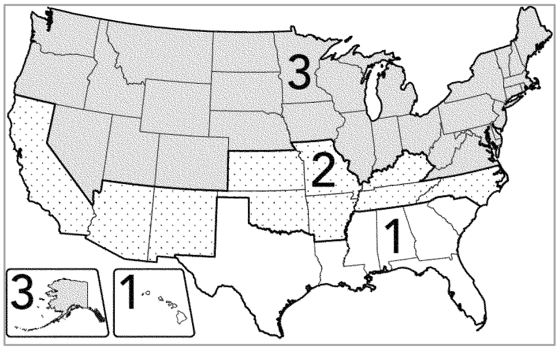


**FIGURE 2-1 Three Climate Zones**

**TABLE 2-1 DOE's Proposed Action and Alternatives for Establishing Energy Conservation Standards for Manufactured Housing[a]**

| General Alternative | Detailed Alternative | Tier and Basis | | Level of Energy Efficiency |
|---|---|---|---|---|
| A<br>Tiered standards based on price (proposed action) | A1 | 1 | $63,000 or less | Corresponding to a $750 increase in purchase price |
| | | 2 | > $63,000 | Based on 2021 IECC with R-20+5 insulation on exterior walls in zones 2-3 |
| | A2 | 1 | $63,000 or less | Corresponding to a $750 increase in purchase price |
| | | 2 | > $63,000 | Based on 2021 IECC except R-21 insulation on exterior walls in zones 2-3 |
| B<br>Tiered standards based on size (action alternative) | B1 | 1 | Single section | Corresponding to a $750 increase in purchase price |
| | | 2 | Multi section | Based on 2021 IECC with R-20+5 insulation on exterior walls in zones 2-3 |
| | B2 | 1 | Single section | Corresponding to a $750 increase in purchase price |
| | | 2 | Multi section | Based on 2021 IECC except R-21 insulation on exterior walls in zones 2–3 |
| C<br>Untiered standards (action alternative) | C1 | None | | Based on 2021 IECC with R-20+5 insulation on exterior walls in zones 2-3 |
| | C2 | | | Based on 2021 IECC except R-21 insulation on exterior walls in zones 2-3 |
| D<br>No action | D | None | | No change from existing HUD Code |

[a] The $750 increase in incremental purchase price is an average; DOE assumes that the change in retail list price due to the efficiency improvements prescribed in the proposed standards is equivalent to the change in purchase price. This implies that incremental manufacturer costs of the efficiency improvements are passed through to the consumer in the form of an equal incremental purchase price. For the exterior wall insulation; R-21 is less expensive than R-20+5. All prices/costs are in real 2020 U.S. dollars. Two untiered standards (Alternative C) were included in response to comments during interagency review.

## 2.1 ALTERNATIVE A: TIERED STANDARDS BASED ON PRICE

For the general Alternative A, proposed standards would be tiered based on a manufacturer's retail list price of $63,000. This threshold is an update from the list price of $55,000 that DOE identified in the SNOPR. The analyses in the SNOPR reflected the 2019 Manufactured Housing Survey (MHS) Public Use File (PUF) and the 2014 Consumer Financial Protection Bureau (CFPB) report. In the October NODA, DOE updated these analyses using the 2020 MHS PUF data and the 2021 CFPB report. Using these newer data, the price threshold was updated to $63,000, in 2020 dollars. DOE proposes that the dollar amount be indexed to the Annual Energy Outlook (AEO) Gross Domestic Product (GDP) price deflator (see section 4.4.1).[1] This proposal in the SNOPR and NODA is otherwise the same. This tiered approach considers the consumer's first cost (home purchase) as part of the cost-effectiveness consideration of EISA.

Within Alternative A, Detailed Alternative A1 represents DOE's proposed action (10 CFR 460). Under this primary proposal, Tier 1 standards would apply to homes with a retail list price of $63,000 or less, and the building thermal envelope requirements would correspond to an incremental increase in purchase price of $750,[2] on average. The Tier 2 standards would apply to homes with a manufacturer's retail list price above $63,000 and would be based on the 2021 IECC (including R-20+5 insulation on exterior walls of manufactured homes in climate zones 2 and 3).

For Alternative A2, Tier 1 standards would apply to homes with a retail list price of $63,000 or less, as in Alternative A1. But in Tier 2 (homes priced higher than $63,000), the standards would be based on the 2021 IECC except for relaxed (R-21) insulation on the exterior walls of homes in climate zones 2 and 3.[3]

Consistent with the MH Working Group recommendation and the 2016 NOPR, DOE proposes that under all three action alternatives being considered, manufacturers could choose between two paths for compliance to ensure that the building thermal envelope would meet the new energy conservation levels (which would be more stringent than those in the HUD Code). One path is prescriptive, the other is based on performance. DOE has tentatively determined that this approach would result in cost-effective energy savings for owners of manufactured homes while providing for flexibility within the manufactured housing industry (10 CFR 460). Key terms are defined in Box 2-1 (next page).

The prescriptive approach for the building thermal envelope identifies specific requirements for component minimum R-value, maximum U-factor, and solar heat gain coefficient (SHGC). This approach would provide a straightforward option for construction planning. The performance approach would allow a manufacturer to use a variety of materials with varying thermal properties so long as the building thermal envelope achieved a required level of overall thermal performance.

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[1] DOE would announce the adjusted price threshold on an annual basis through a published notice in the *Federal Register*.

[2] See https://www.regulations.gov/document/EERE-2009-BT-BC-0021-0592.

[3] The R-20+5 insulation requirement includes an R-20 cavity insulation plus an R-5 continuous insulation, which runs over structural members and is free of significant thermal bridging. The R-21 insulation requirement only includes cavity insulation and does not include continuous insulation.

The proposed performance-based requirements would be functionally equivalent to the prescriptive-based requirements in that both options would result in manufactured homes with about the same amount of energy use.

Beyond a general requirement for manufacturers to install insulation in accordance with the insulation manufacturer's installation instructions, the action alternatives involve specific requirements for insulation in certain locations. These locations are: near access hatches, panels, doors between conditioned space and unconditioned space, adjacent top baffles, ceilings, attics, floors, wall cavities, narrow cavities, rim joists, and exterior walls adjacent to showers and tubs.

Similarly, Alternative A1 involves both general and specific requirements for sealing the manufactured home to prevent air leakage. The general requirements call for manufacturers to properly seal all joints, seams, and penetrations in the building thermal envelope to establish a continuous air barrier, and to use appropriate sealing materials to allow for differential expansion and contraction of dissimilar materials. The specific sealing requirements are identified for ceilings, attics, duct system register boots, electrical or phone boxes on exterior walls, floors, mating line surfaces, recessed lighting, rim joists, showers or tubs adjacent to exterior walls, walls and windows, skylights, and doors.

In addition, Alternative A1 involves requirements related to duct leakage (sealing of the ducted distribution system for the central forced air heating and cooling system), HVAC thermostats and controls, service hot water heating systems, mechanical ventilation fan efficacy, and sizing of heating and cooling equipment. Manufacturers would be required to equip each manufactured home with a duct system designed to limit total air leakage to four cubic feet per minute per 100 square feet of conditioned floor area (4 cfm/100 sf). Specific requirements are also defined for the number and types of thermostats.

### *Box 2-1*

### Building Energy Efficiency Terms

*Building thermal envelope:* Exterior walls, exterior floors, exterior ceiling, or roofs, and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and unconditioned space.

*Solar heat gain coefficient (SHGC):* The ratio of the solar heat gain entering a space through a fenestration assembly to the incident solar radiation (solar heat gain / incident solar radiation). (Fenestration refers to the openings in a building's facade, e.g., windows, skylights, doors.) Solar heat gain includes directly transmitted solar heat and absorbed solar radiation that is then reradiated, conducted, or convected into the space. The SHGC measures how much of the sun's heat comes through, and the value can range from 0 to 1. The lower the SHGC, the less solar heat is let into the building.

*R-value (thermal resistance):* The inverse of the time rate of heat flow through a body (here, a manufactured home) from one of its bounding surfaces to the other surface for a unit temperature difference (between outdoors and indoors, degrees Fahrenheit) between the two surfaces, under steady state conditions, per unit area: $h \times ft^2 \times °F$/British thermal unit (Btu). An insulating material's resistance to conductive heat flow is measured or rated in terms of its thermal resistance or R-value. The R-value depends on the type of insulation, its thickness, and its density. A higher R-value indicates greater insulating effectiveness. Installing more insulation increases the R-value and resistance to heat flow.

*U-factor (thermal transmittance):* The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films: $Btu/h \times ft^2 \times °F$. The U-factor measures how well the feature insulates. For windows, this factor generally ranges from 0.20 to 1.20. A lower value indicates better insulating.

Furthermore, under Alternative A1, manufacturers would be required to install service water heating systems according to the service water heating system manufacturer's installation instructions. Additional requirements include that: (1) automatic controls, temperature sensors, and pumps related to service water heating must be accessible and manual controls must be readily accessible; (2) homeowners must have adequate control over service water heating equipment; and (3) all pipes outside conditioned space and all hot water pipes from a water heater to a distribution manifold must be insulated to at least an R-3 level.

Finally, Alternative A1 specifies requirements for mechanical ventilation system fan efficacy and for the appropriate sizing of heating and cooling equipment in a manufactured home. These requirements are presented in Table 2-2, with a crosswalk between the proposed action (Alternative A) and the action alternatives (Alternatives B and C) compared with the no-action alternative (Alternative D).

The prescriptive requirements for the building thermal envelope proposed for Tiers 1 and 2 of Alternative A1 are illustrated in Figures 2-2 and 2-3. The performance requirements for the building thermal envelope proposed for Tiers 1 and 2 of Alternative A1 are illustrated in Figures 2-4 and 2-5. (The tables corresponding to these figures are provided in Appendix B.)

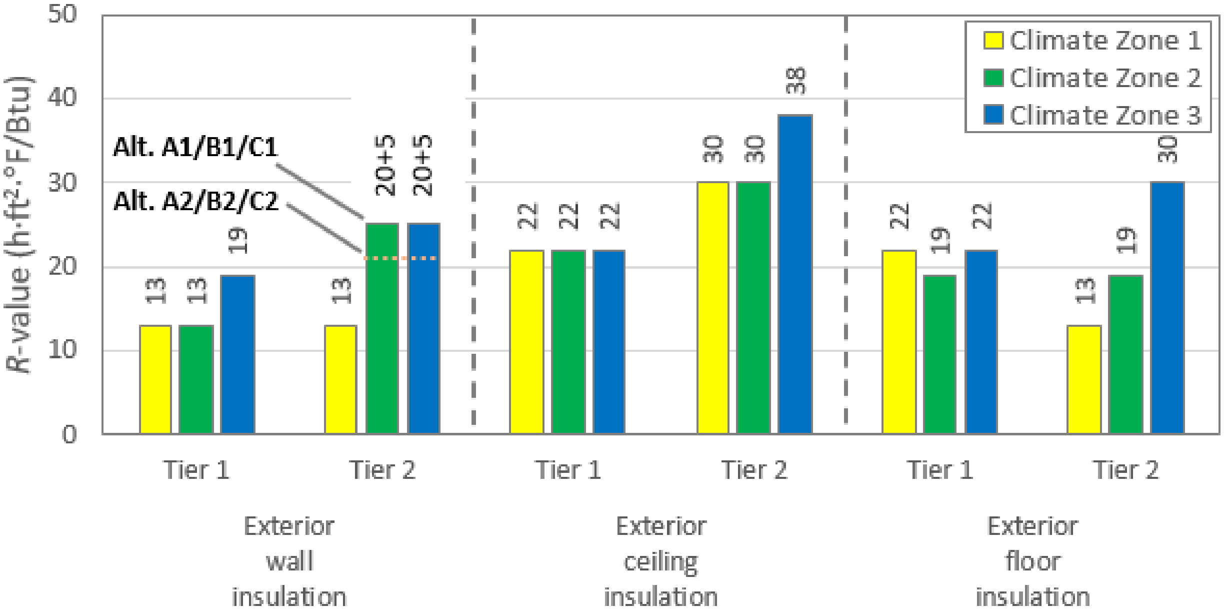

**FIGURE 2-2 Prescriptive Requirements for the Building Thermal Envelope: R-Values by Climate Zone for Tier 1 and Tier 2 Homes under the Action Alternatives**

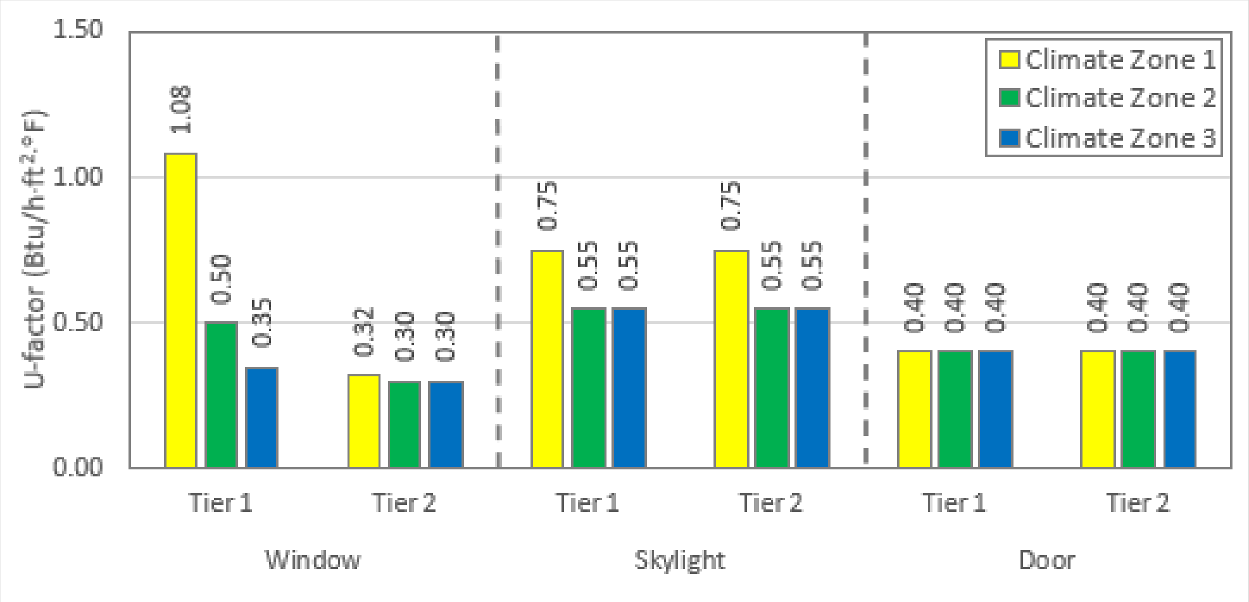

**FIGURE 2-3 Prescriptive Requirements for the Building Thermal Envelope: UFactor- by Climate Zone for Tier 1 and Tier 2 Homes under Alternative A1**

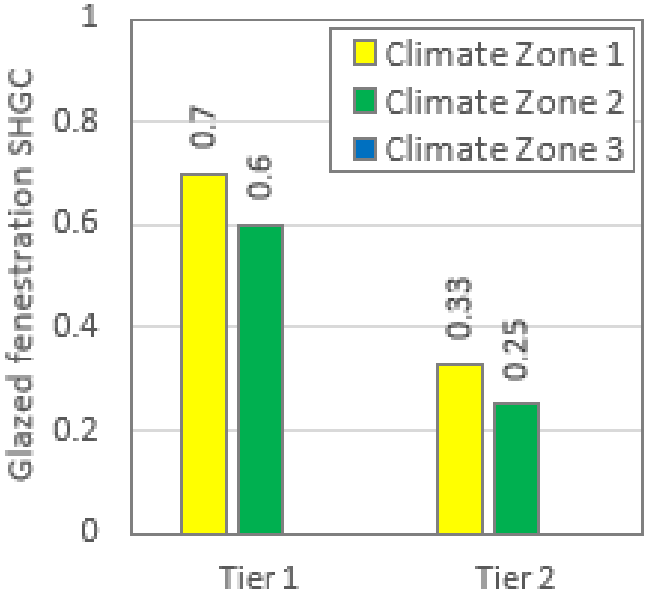

**FIGURE 2-4 Performance-Based Requirements for the Building Thermal Envelope: Glazed Fenestration Solar Heat Gain Coefficient by Climate Zone for Tier 1 and Tier 2 Homes under Alternative A1 (Note: SHGC is not applicable to climate zone 3.)**

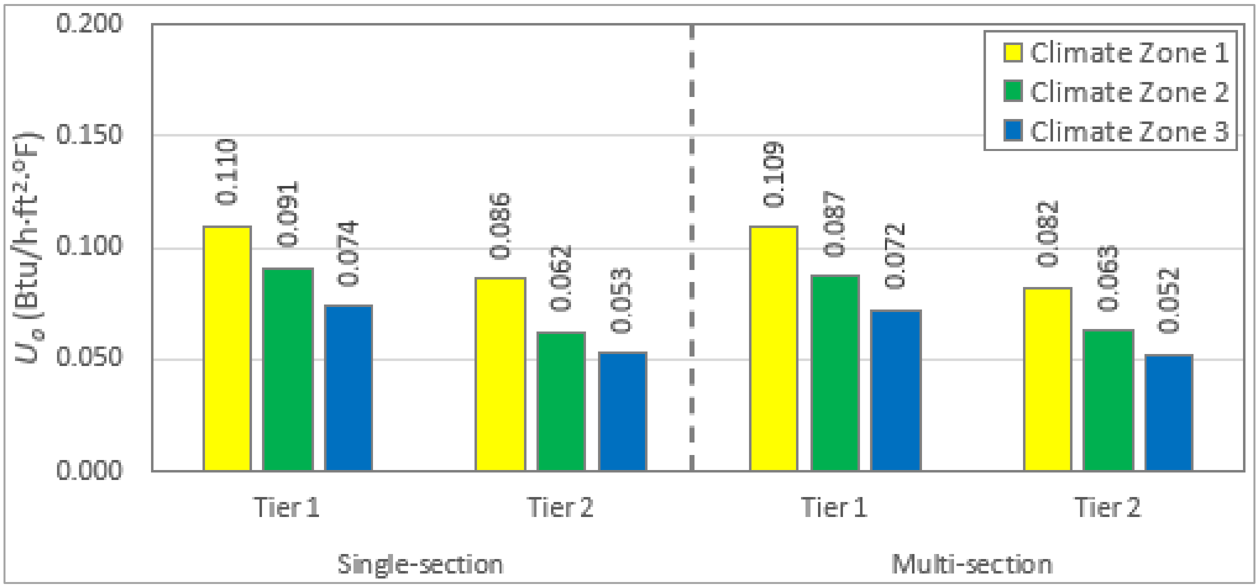

**FIGURE 2-5 Performance-Based Requirements for the Building Thermal Envelope by Climate Zone for Tier 1 and Tier 2 Homes under Alternative A1: $U_0$**

## 2.2 ALTERNATIVE B: TIERED STANDARDS BASED ON SIZE

Under Alternative B, the proposed standards for energy conservation would be tiered based on size.[4] For Alternative B1, the Tier 1 standards would apply to single-section homes, and the building thermal envelope requirements would be less stringent than those in the 2021 IECC, corresponding to an incremental purchase price increase of $750. The Tier 2 standards that would apply to multi-section homes would be based on the 2021 IECC, including R-20+5 insulation requirements. The building thermal envelope requirements for this tiered approach are the same as those identified for Tier 1 and Tier 2 in Section 2.1. For Alternative B2, the standards would be the same as for B1, except that relaxed (R-21) insulation would be specified for the exterior walls on homes in climate zones 2 and 3. This tiered approach considers the consumer's first cost (home purchase) as part of the cost-effectiveness consideration of EISA.

## 2.3 ALTERNATIVE C: UNTIERED STANDARDS

Alternative C is the untiered approach for the energy conservation standards. Under this alternative, the DOE standards based on the 2021 IECC would apply to all manufactured homes, without considering the manufacturer's retail list price or size. Alternative C also includes the two thermal envelope options, with C1 including R-20+5 and C2 utilizing R-21.

## 2.4 ALTERNATIVE D: NO ACTION

The NEPA process requires that a no-action alternative be considered as a baseline against which potential environmental impacts of the proposed action and alternative can be compared. Under the no-action alternative, DOE would not establish energy conservation standards for

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[4] This proposal was presented and analyzed in the October 2021 NODA in response to comments from HUD and the public provided during EIS scoping and on the SNOPR.

manufactured housing, and manufacturers would continue to follow the requirements in the existing HUD Code.

**TABLE 2-2 Crosswalk of Proposed Action and Action Alternatives with No Action**

| Proposed Action and Action Alternatives (DOE 2021 Proposed Rule, 10 CFR 460) | No-Action Alternative (Current HUD Code, 24 CFR 3280) |
|---|---|
| Section 460.101 would establish three climate zones, in line with HUD, that are delineated by state boundaries. DOE proposes different $U_o$ performance requirements for single- and multi-section homes. | Section 3280.506 establishes three zones delineated by state boundaries. The HUD Code establishes one standard for homes of all sizes within a zone. |
| Section 460.102(a) would establish building thermal envelope prescriptive and performance compliance requirements.[a] | Section 3280.506 establishes a performance approach.[a] |
| Section 460.102(b) would set forth the prescriptive option for compliance with the building thermal envelope requirements.[b] | Section 3280.506 establishes a performance approach only.[b] |
| Section 460.102(b)(2) would establish a minimum truss heel height. | No corresponding requirement. |
| Section 460.102(b)(3) would establish an acceptable batt and blanket insulation combination for compliance with the floor insulation requirement in climate zone 3. | No corresponding requirement. |
| Section 460.102(b)(4) would identify certain skylights not subject to SHGC requirements. | No corresponding requirement. |
| Section 460.102(b)(5) would establish U-factor alternatives for the R-value requirements under Section 460.102(b)(1). | No corresponding requirement. |
| Section 460.102(c)(1) would establish maximum building thermal envelope $U_o$ requirements.[c] | Section 3280.506(a) establishes maximum building thermal envelope $U_o$ requirements by zone.[c] |
| Section 460.102(c)(2) would establish maximum area-weighted vertical fenestration U-factor requirements in climate zones 2 and 3. | No corresponding requirement. |
| Section 460.102(c)(3) would establish maximum area-weighted average skylight U-factor requirements in climate zones 2 and 3. | No corresponding requirement. |
| Section 460.102(c)(4) would authorize windows, skylights, and doors containing more than 50 percent glazing by area to satisfy the SHGC requirements of Section 460.102(a) on the basis of an area-weighted average. | No corresponding requirement. |
| Section 460.102(e)(1) would establish a method of determining $U_o$ using the "Overall U-values and Heating/Cooling Loads—Manufactured Homes," or the Battelle method. | Section 3280.508(a) and (b) reference the same. |
| Section 460.103 would require insulating materials to be installed according to the manufacturer's installation instructions and the prescriptive requirements of Table 460.103. | No corresponding requirement. |
| Section 460.103 would establish requirements for the installation of batt, blanket, loose fill, and sprayed insulation materials. | No corresponding requirement. |

**TABLE 2-2 Crosswalk of Proposed Action and Action Alternatives with No Action (Cont.)**

| Proposed Action and Action Alternatives (DOE 2021 Proposed Rule, 10 CFR 460) | No-Action Alternative (Current HUD Code, 24 CFR 3280) |
|---|---|
| Section 460.104 would require manufactured homes to be sealed against air leakage at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the manufacturer's installation instructions and requirements in Table 460.104. | Section 3280.505 establishes air sealing requirements of building thermal envelope penetrations and joints. |
| Section 460.201(a) would require each manufactured home to be equipped with a duct system that must be sealed to limit total air leakage to less than or equal to 4 cfm per 100 square feet of floor area and specify that building framing cavities are not to be used as ducts or plenums when directly connected to mechanical systems. | No corresponding requirement. |
| Section 460.202(a) would require at least one thermostat to be provided for each separate heating and cooling system installed by the manufacturer.[d] | Section 3280.707(e) requires that each space heating, cooling, or combination heating and cooling system be provided with at least one adjustable automatic control for regulation of living space temperature.[d] |
| Section 460.202(b) would require that installed thermostats controlling the primary heating or cooling system be capable of maintaining different set temperatures at different times of day and different days of the week. | No corresponding requirement. |
| Section 460.202(c) would require heat pumps with supplementary electric resistance heat to be provided with controls that, except during defrost, prevent supplemental heat operation when the pump compressor can meet the heating load.[e] | Section 3280.714(a)(1)(ii) requires heat pumps to be certified to comply with ARI Standard 210/240–89,[f] heat pumps with supplemental electrical resistance heat to be sized to provide by compression that is at least 60 percent of the calculated annual heating requirements of the manufactured home, and that a control be provided and set to prevent operation of supplemental electrical resistance heat at outdoor temperatures above 40°F.[e] |
| Section 460.203(a) would establish requirements for installing service hot water systems. | No corresponding requirement. |
| Section 460.203(b) would require any automatic and manual controls, temperature sensors, and pumps associated with service hot water systems to be accessible. | No corresponding requirement. |
| Section 460.203(c) would establish requirements for heated water circulation systems. | No corresponding requirement. |
| Section 460.203(d) would establish a requirement for the insulation of hot water pipes. | No corresponding requirement. |
| Section 460.204 would establish requirements for mechanical ventilation system fan efficacy.[g] | Section 3280.103(b) establishes whole-house ventilation requirements.[g] |
| Section 460.205 would establish requirements for heating and cooling equipment sizing. | No corresponding requirement. |

[a] Both DOE and HUD performance requirements are based on maximum $U_o$ requirements per zone for the building thermal envelope. DOE, however, would establish separate $U_o$ requirements per climate zone for single- and multi-section homes, whereas HUD only establishes one $U_o$ requirement per zone, regardless of home size.

[b] The Battelle method (see the SNOPR) is used to determine performance standards (in terms of $U_o$) from prescriptive standards. DOE's proposed performance standards would be prescribed in Section 460.102(c)(1). The Battelle method is an industry standard for calculating the overall thermal transmittance ($U_o$) of a manufactured home and is also currently referenced in the HUD Code for calculation of overall thermal transmittance. DOE proposes to use the Battelle method to determine the same ($U_o$).

[c] DOE's proposed maximum building thermal envelope $U_o$ requirements are lower (a lower value indicates better insulating) than the corresponding maximum $U_o$ requirements under the existing HUD Code (24 CFR 3280.506(a). Compliance with DOE's proposed $U_o$ requirements would achieve compliance with the $U_o$ requirements under the HUD Code.

[d] DOE's proposed action and action alternatives, and the no-action alternative (HUD Code), require the installation of at least one thermostat that is capable of maintaining zone temperatures.

[e] DOE's proposed action and action alternatives, and the no-action alternative (HUD Code), require heat pumps with supplemental electric resistance heat to prevent supplemental heat operation when the heat pump com- pressor can meet the heating load of the manufactured home.

[f] ARI is the Air Conditioning and Refrigeration Institute.

[g] HUD requirements at 24 CFR 3280.103(b) do not overlap with DOE's proposed action and action alternative; DOE's proposed requirement is for fan electrical efficiency, whereas HUD requirements specify minimum and maximum air flow rates.

## 2.5 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM DETAILED ANALYSIS

DOE considered but did not analyze in detail several potential alternatives, including alternatives suggested in comments received during the scoping process for this EIS and in response to the SNOPR and NODA. These alternatives fall within four themes: (1) the mechanism for implementing standards; (2) the basis for the standards, (3) the structure of the standards, and (4) other efficiency requirements.

### 2.5.1 Mechanism for Implementing the Standards

Several commenters suggested that the standards should be implemented by HUD and not DOE. Further, some recommended that the avenue to update standards is by amending the HUD Code to include new energy efficiency standards for manufactured homes. Finally, other commenters suggested that the standards process is more appropriate to modify through submissions to the Manufactured Housing Consensus Committee, which could recommend possible revisions to HUD.

These alternatives were not evaluated in the EIS, as EISA directs DOE to establish energy conservation standards for manufactured housing.[5] DOE coordinated and consulted with HUD in developing the alternatives that are currently under consideration and analyzed in this EIS.

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[5] 42 U.S.C. 17071.

### 2.5.2 Basis of the Standards

DOE considered, but eliminated from detailed analysis, potential alternatives which would adjust the basis for the standards. Some commenters suggested that DOE base the standards on something other than the 2021 IECC including: the 2015 IECC (upon which the 2016 NOPR was based); previous iterations of the IECC; the existing HUD Code; ASHRAE 90.2-2018; or some other standard besides the 2021 IECC, because the 2021 IECC was not developed or intended for manufactured housing.

EISA requires DOE to base the energy conservation standards on the most recent version of the IECC and any supplements to that document, except in cases where DOE finds that the IECC is not cost-effective or where a more stringent standard would be more cost-effective, based on the impact of the IECC on the purchase price of manufactured housing and on total lifecycle construction and operating costs.[6] DOE tentatively found that proposed standards based on the most recent IECC were cost effective based on the impact on the purchase price of manufactured housing and on total lifecycle construction and operating costs.[7] As such, as required by EISA, DOE is not proposing standards for manufactured homes based on previous versions of the IECC, the existing HUD Code, ASHRAE 90.2-2018, or other standards, and DOE did not evaluate the suggested alternatives in the EIS.

The energy conservation standards proposed in the SNOPR are generally based on certain specifications included in the 2021 IECC, as required by EISA, while also accounting for the unique aspects of manufactured housing. DOE considered the following aspects of manufactured housing design and construction in developing the standards: (1) manufactured housing structural requirements contained in the HUD Code; (2) external dimensional limitations associated with transportation restrictions; (3) the need to optimize interior space within manufactured homes; and (4) factory construction techniques that facilitate sealing the building thermal envelope to limit air leakage. Upon consideration of these aspects of manufactured housing design and construction, DOE did not propose a complete adoption of the 2021 IECC requirements. Rather, DOE proposed to include several IECC provisions with modification, incorporating some of the MH Working Group's recommendations that were based on cost effectiveness and to make the DOE standards better tailored to the manufactured housing industry.

In addition to adjusting the basis for the standards, some commenters suggested that DOE propose a standard based on the Tier 1 proposal only, that is, that all proposed standards should contain the $750 price cap. As stated above, EISA requires DOE to base the standards on the most recent version of the IECC unless they are not cost effective. DOE has tentatively found that the Tier 2 standards, those based on the full 2021 IECC, are cost effective.

DOE developed the tiered proposal in response to concerns related to potential adverse impacts on price-sensitive, low-income purchasers of manufactured homes from the inclusion of energy conservation standards on manufactured housing. To the extent that manufactured home purchasers are cost-driven, in conjunction with the lower median income and net worth of these purchasers, consumers at the lower end of the manufactured home purchase price range generally

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[6] 42 U.S.C. 17071(b)(1).

[7] See 86 FR 47744.

would be more sensitive to increases in purchase price. As such, DOE is considering a tiered approach to the standards to include Tier 1 standards in an effort to mitigate first-cost impacts for purchasers at the lower end of the price range. However, DOE has also tentatively determined that Tier 2 standards remain cost effective and affordable for most purchasers. As such, DOE did not limit the standards to those in the Tier 1 proposal.

### 2.5.3 Structure of the Standards

Regarding the structure of the standards, multiple commenters suggested that basing the tiers on manufacturer's retail list price is not appropriate and the retail price threshold may be discriminatory for low-income purchasers. Therefore, commenters suggested that if DOE wants to finalize a tiered approach based on price, DOE should evaluate alternatives that base the tiers on: (1) actual sales price of the home to the ultimate customer, or (2) a significantly increased retail list price threshold (closer to $110,000).

Alternative A is tiered based on the manufacturer's retail list price. DOE understands the manufacturer's retail list price to be the price that the manufacturer provides in the sales contract to a distributor or retailer – that is, the price that the manufactured home is originally listed at by the manufacturer. The sales price (or purchase price), on the other hand, is the price of the home to the consumer. The retail list price is more appropriate than basing the tiers on the sales or purchase price because that price may not be known until after a manufactured home leaves the manufacturer, and manufacturers may have limited control of the final purchase price of manufactured homes sold by third-party retailers. Therefore, DOE did not analyze an alternative in which the tier would be based on sales price because the manufacturers implementing the standards may not know the ultimate sales price of the manufactured home to a given consumer. DOE also notes that the manufacturer's retail list price is specified in EISA for the purpose of determining penalties for non-compliance.[8]

The number used for the price threshold in the SNOPR was based on sales and purchase price data from the 2019 Manufactured Housing Survey Public Use File (MHS PUF) and loan data from the 2014 CFPB report, which stated that high-priced loans accounted for about 68 percent of manufactured housing loans. DOE assumed that low-income purchasers would purchase single-section homes because they are less expensive, on average, than multi-section homes. DOE also assumed that price-sensitive, low-income purchasers would need to rely on high-priced loans. In applying these two assumptions, DOE found the 68th percentile for the retail price of single-section manufactured homes. Based on 2019 dollars, that amount was $55,000. Since the SNOPR was issued, the inputs that were used to calculate the retail list price have both been updated from the 2019 MHS PUF and the 2014 CFPB report (to 2020 and 2021 versions, respectively). As presented in the NODA, these updates were used to estimate that high-priced loans account for about 70 percent of manufactured housing loans, resulting in an updated retail list price threshold of $63,000 (in real 2020$). DOE proposes that the dollar amount be indexed to the gross domestic product (GDP) price deflator used in the Energy Information Administration (EIA) Annual Energy Outlook (AEO). Therefore, the retail list price would be adjusted over time. While a different threshold amount could be evaluated, DOE has determined that the 70th percentile is a reasonable price upon which to base the tier.

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[8] 42 U.S.C. 17071(d).

Some commenters also suggested that the threshold be location based instead of price based. In the SNOPR, DOE also presented the 2019 MHS PUF data set, which provides data that relates Census region (the U.S. Census Bureau divides the country into four census regions) with purchase price. The data indicated that average price (specifically for single-section homes) does not differ significantly based on Census region, and therefore DOE proposed one retail list price threshold regardless of Census region. DOE also made the same conclusion in the updated analysis as part of the NODA. Accordingly, DOE did not consider an alternative of a location-based approach because the 2019 MHS PUF data suggest price does not differ significantly by Census region.[9]

Accordingly, the above proposed alternatives were not evaluated in the EIS.

### 2.5.4 Other Efficiency Requirements

In response to the SNOPR and NODA, several commenters suggested relaxed efficiency requirements (that is making efficiency requirements less stringent than those proposed or removing some requirements altogether), while other commenters suggested more stringent efficiency requirements (that is making the requirements more stringent than those proposed or adding additional requirements not in the proposed standards). These recommendations included, but are not limited to, lowering $U_o$ requirements, eliminating air and duct sealing requirements, adding the 2021 IECC optional packages provided in section R408 of the 2021 IECC, increasing floor insulation requirements, and lowering the maximum allowed window SHGC.

As discussed previously, EISA requires DOE to base the energy conservation standards on the most recent version of the IECC, and in the SNOPR, DOE had tentatively concluded that standards based on the 2021 IECC could be cost effective. In developing the standards, DOE considered the range of efficiency options originally analyzed by the MH Working Group, which took into consideration the design and factory construction techniques of manufactured homes, as required by EISA.[10]

DOE's objective in defining the Tier 1 incremental purchase price threshold was based on which threshold a low-income buyer purchasing a single-section home (using typical loan terms available to these homebuyers, primarily chattel loans with higher interest rates) would, on average, realize a positive cash flow within the first year of the standard based on the down payment, incremental loan payment, and energy cost savings. As such, DOE preliminarily determined that an incremental purchase price of no more than $750 provided a beneficial financial outcome for these consumers given lifecycle cost savings and energy cost savings, while minimizing first cost impacts. Any requirements for increased efficiency for Tier 1 could push the positive cash flow threshold beyond the first year, specifically countering the objective of the creation of Tier 1.

In developing the Tier 2 standard level, DOE's objective was for it to be based on the most recent version of the IECC, with consideration of cost effectiveness and design and factory construction

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[9] In this draft EIS, DOE evaluated variability by location across different scales, including by Census region and state. As with Census regions, the differences in average prices at the state level are not significant. DOE also recognizes that it would be impractical to establish standards by location, thus requiring manufacturers to comply with up to 50 different standards.

[10] 42 U.S.C. 17071(b)(2).

techniques of manufactured homes.[11] As such, DOE proposed building thermal envelope measures based on those proposed in the June 2016 NOPR, including air and duct sealing requirements, updated to reflect the HUD zones and the 2021 IECC requirements. The June 2016 NOPR included sensitivity analyses around several different SHGCs, which ultimately resulted in the most cost-effective SHGCs proposed as part of the June 2016 NOPR and therefore the SNOPR. Further, in developing the proposed standards for the SNOPR, DOE considered a range of proposals (see alternatives in Table 2-1) to capture a range of performance and cost characteristics in manufactured housing. However, DOE did not consider certain additional efficiency package options either because of recommendations provided by the MH Working Group when they evaluated the 2015 IECC, the potential constraints due to the design and factory construction techniques of manufactured housing, or cost effectiveness. Further, DOE is not proposing energy conservation standards for HVAC, water heaters, lighting, and appliances because the energy efficiency of those products is specifically governed by the comprehensive Appliance Standards program established under the Energy Policy and Conservation Act of 1975.[12]

Accordingly, DOE did consider multiple options in developing both the Tier 1 and Tier 2 standards, and DOE based those standards on the requirements of EISA. DOE determined that the standards for each tier were most appropriate based on the analyses completed for the proposed rulemaking and the requirements of EISA, and thus DOE is not analyzing standards that are less stringent or standards that are more stringent than the proposal.

## 2.6 COMPARISON OF ALTERNATIVES

Table 2-3 provides a summary-level comparison of the alternatives with respect to the potential impacts from DOE's proposed standards for energy conservation in manufactured housing, as directed by Section 413 of the EISA. Potential impacts were evaluated for energy resources, air resources, health and safety, socioeconomics, and environmental justice.

### 2.6.1 Energy Resources

The energy impact analysis for the proposed energy conservation standards includes national energy savings, the difference in national energy consumption between the no-action alternative (Alternative D) and the proposed action and action alternatives (Alternatives A–C). The estimated savings combine projections of annual shipments and energy consumption with total incremental cost data from the lifecycle cost analysis.

The tiered standards based on price (Alternative A) would achieve only slightly more savings than the tiered standards based on size (Alternative B) over the 30-year period. As expected, the three alternatives with relaxed R-21 insulation on the exterior walls (Alternatives A2, B2, and C2) would produce less energy savings over the 30-year period than their counterparts with the more stringent R-20+5 insulation (Alternatives A1, B1, and C1). The national energy savings would be the highest under Alternative C1, but this alternative would also be the most expensive to implement.

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[11] 42 U.S.C. 17071(b)(1) and 42 U.S.C. 17071(b)(2)(A).

[12] 42 U.S.C. 6291–6317.

### 2.6.2 Air Resources

The air resources analysis for the proposed energy conservation standards includes potential impacts to GHG emissions and climate change; criteria pollutants, mercury, and ambient air quality; indoor air quality; and the potential impacts of wildfires on air quality, with an emphasis on indoor air quality.

#### 2.6.2.1 Impacts on Indoor Air Quality

The proposed action alternatives are expected to impact aspects of indoor air quality (IAQ) in both positive and negative directions. Because all action alternatives have roughly the same requirements for air sealing of the building envelope and ducting of the forced air heating and cooling system, very similar impacts are expected for all. With other factors remaining constant, reducing air leakage through required improvements in air sealing is expected to result in lower indoor concentrations of some outdoor air pollutants, higher concentrations of pollutants emitted from indoor sources, and lower risk of moisture problems in the belly and attic. Lower air exchange rates should lead to lower indoor concentrations of ozone, $NO_2$, and $PM_{2.5}$ from outdoors. Air sealing also substantially improves the ability to control exposures to wildfire smoke. This result occurs because these pollutants are removed from indoor air through deposition processes that occur naturally, and $PM_{2.5}$ also is reduced to some extent by even base model filters as air is recirculated through the heating and cooling system. These filters also may be upgraded to substantially increase $PM_{2.5}$ removal. Reducing outdoor air exchange will slow the dilution and removal of pollutants emitted indoors, leading to higher indoor air concentrations and related exposures.

Quantitative estimates of the effect of the processes noted above were determined by simulating airflows and air pollutant emission rates using a physics-based model and parameter values obtained from the literature for four air pollutants that carry a substantial fraction of the total disease burden of indoor air pollutants in U.S. homes and that will be impacted by the proposed action alternatives. The impacts for indoor-generated air pollutants would be greatest in homes that do not utilize any mechanical or natural ventilation, and these homes are expected to have the highest concentrations of indoor generated pollutants under existing conditions. The levels of indoor-generated pollutants are thought today to be lowest in homes that utilize whole-house mechanical ventilation and also use kitchen and bath exhaust fans, and impacts of the proposed action alternatives would be smallest in homes that utilize these mechanical ventilation options.

The proposed action alternative would provide increased protection from wildfire smoke; when occupants close all windows and temporarily turn off whole-house ventilation as recommended during wildfire smoke events, their exposure to $PM_{2.5}$ from wildfire smoke will be lowered by an estimated 25 to 30 percent.

Reducing uncontrolled airflow is widely considered among building science experts to be helpful in reducing the risk of condensation and consequent dampness and mold issues. Under hot, humid outdoor conditions, envelope air sealing reduces the likelihood that humid outdoor air will reach cooled materials in the walls, under floors, and above the ceiling. In the winter, air sealing reduces the outflow of humidified air from the occupied space and into building cavities, where water vapor can condense on cold surfaces in contact with the exterior. Condensation risk reduction benefits cannot be quantified as readily as the increase in indoor-emitted chemical air pollutants or the decrease in outdoor pollutants; but they could be large given the potential substantial disease burden caused by dampness and mold.

Air sealing is also an element of integrated pest management (IPM), as it reduces openings for pest entry, reducing the allergens that are brought inside by pests and reducing the likelihood that chemical pesticides will be used.

None of the proposed alternatives should have any substantial impact on the ability of occupants to utilize equipment-based or administrative controls (e.g., ventilation, filtration, separation of occupant, as feasible), to mitigate potential transmission or airborne infectious diseases, including COVID-19.

#### 2.6.2.2 Comparisons of Reduced Pollutant Emissions among the Alternatives

Associated with energy conservation standards for manufactured homes, DOE estimates reductions in emissions of six pollutants associated with energy savings over the 30-year (2023–2052) period relative to the baseline: carbon dioxide ($CO_2$), mercury (Hg), nitric oxide and nitrogen dioxide ($NO_X$), sulfur dioxide ($SO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Emissions reductions are presented in two sections: (1) GHGs, such as $CO_2$, $CH_4$, and $N_2O$ in Section 4.2.1; and mercury and criteria pollutants, such as $NO_X$, and $SO_2$ in Section 4.2.2.

***Greenhouse Gases***

As shown in Figure 2-6 for GHGs, emissions reductions relative to the baseline (no-action alternative D) would have positive impacts on climate change under the proposed action (Alternative A2; price-based tiers with R-21 insulation) and other action alternatives. Over the 30-year (2023–2052) period, cumulative emissions reductions under the proposed action (Alternative A2) would be about 83 million MT of $CO_2$, 502 thousand MT of $CH_4$, and 0.84 thousand MT of $N_2O$, totaling about 96 million MT on a $CO_2$ equivalent basis (million MT $CO_2e$). Alternative C1 (untiered standards with R-20+5 insulation) would achieve the highest emissions reductions, about 21 percent more than the proposed action (Alternative A2). In contrast, Alternative B2 (size-based tiers with R-21 insulation) has the lowest emissions reductions, about 3 percent lower than Alternative A2. Overall, Alternative C (untiered standards) would achieve the highest emissions reductions, followed by Alternative A (price-based tiers), and Alternative B (size-based tiers) would have the fewest. As expected, Alternatives A1, B1, and C1 would reduce more emissions than their counterparts, Alternatives A2, B2, and C2.

The projected annual $CO_2$ emissions from the residential sector average about 793 million MT over the 2020–2050 period for the EIA reference case. With respect to this residential sector annual emission, reductions in $CO_2$ emissions would range from 0.34 percent (Alternative B2) to 0.42 percent (Alternative C1) with 0.35 percent under the proposed action (Alternative A2).

***Mercury, $NO_X$, and $SO_2$***

The cumulative emissions reductions over the 30-year period (2023-2052) shown in Figure 2-7 under the proposed action (Alternative A2) would be about 0.13 MT of mercury, 132 thousand MT of $NO_X$, and 29 thousand MT of $SO_2$. As with the GHG emissions noted above, Alternative C1 would achieve emissions reductions that are about 21 percent higher than the proposed action (Alternative A2), while Alternative B2 would achieve about 3 percent fewer reductions. Overall, Alternative C (untiered) would achieve the highest emissions reductions, followed by Alternative A (price-based tiered standards). Alternative B (size-based tiered standards) would achieve the fewest emissions reductions. Meanwhile, the three alternatives with the more stringent insulation requirement, use of R-20+5 (Alternatives A1, B1, and C1), would achieve higher emissions reductions than their counterparts, Alternatives A2, B2, and C2, respectively, using R-21 installation.

On an annual basis, the estimated reductions in mercury emissions that would be achieved under the proposed action (Alternative A2) would be equivalent to a reduction of about 0.11 percent of the total U.S. mercury emissions from electricity generation units (EGUs) in 2017. The contributions to the further mercury reductions estimated for the other alternatives would be similar, ranging from 0.10 percent (Alternative B2) to 0.13 percent (Alternative C1).

Estimated $NO_X$ emissions reductions under the proposed action (Alternative A2) would be a further reduction of about 0.66 percent of the total U.S. $NO_X$ emissions from power plants in 2020. Emission reductions of $NO_X$ that would be achieved by the other action alternatives would contribute to reductions ranging from 0.63 percent (Alternative B2) to 0.79 percent (Alternative C1) of the 2020 total from U.S. power plants.

$SO_2$ emissions reductions under the proposed action (Alternative A2) would equate to a reduction of about 0.14 percent of the total U.S. $SO_2$ emissions from power plants in 2020. Contributions of these emissions reductions from other action alternatives would be similar, ranging from 0.13 percent (Alternative B2) to 0.17 percent (Alternative C1).

Related to energy conservation standards for manufactured homes, emissions reductions of $NO_X$ and $SO_2$, which are precursors of criteria pollutants, such as ozone and $PM_{2.5}$, along with acid depositions, would improve ambient air quality in the near future years with all things being equal. However, increases in both anthropogenic and natural emissions associated with climate change could offset these benefits to some extent or significantly, depending on future GHG emissions and associated weather conditions.

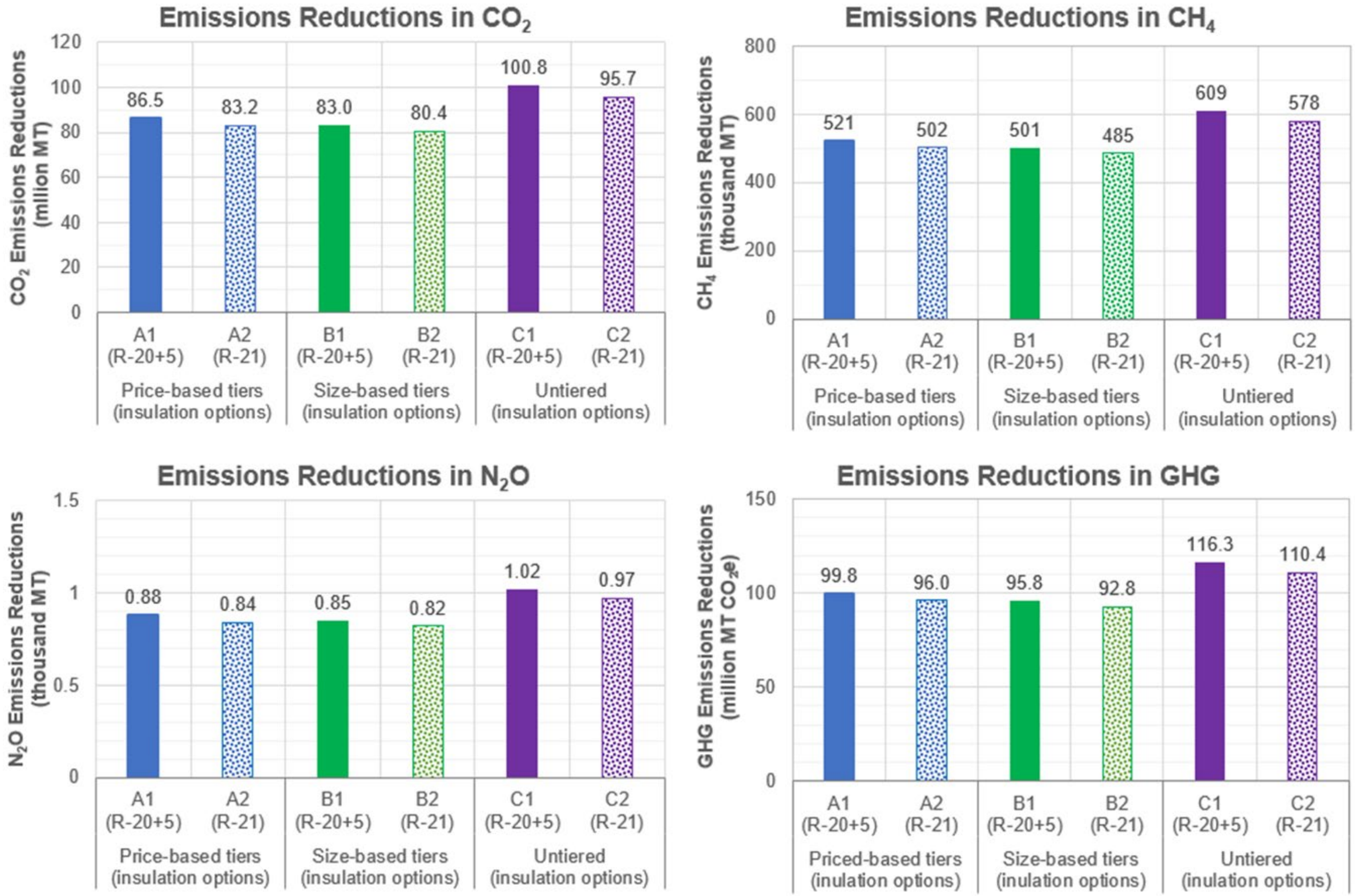
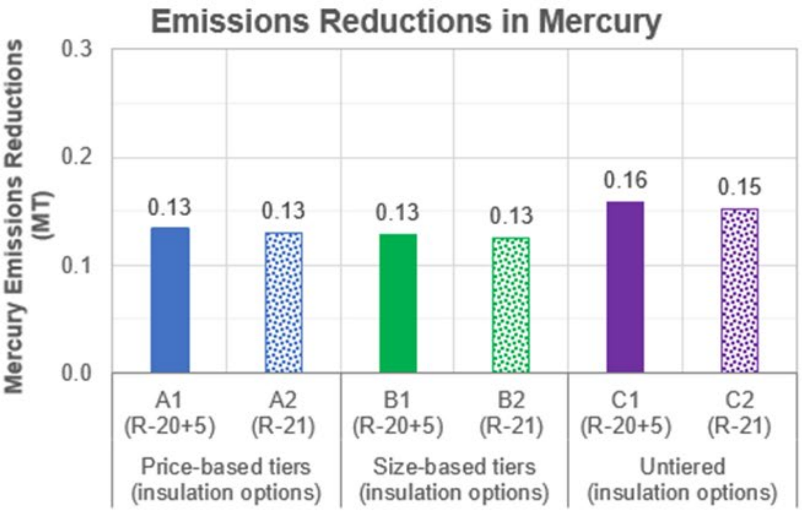
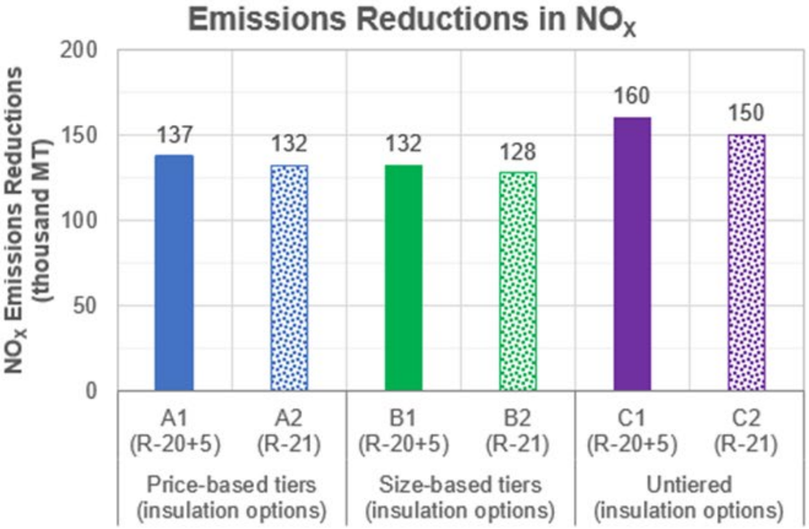
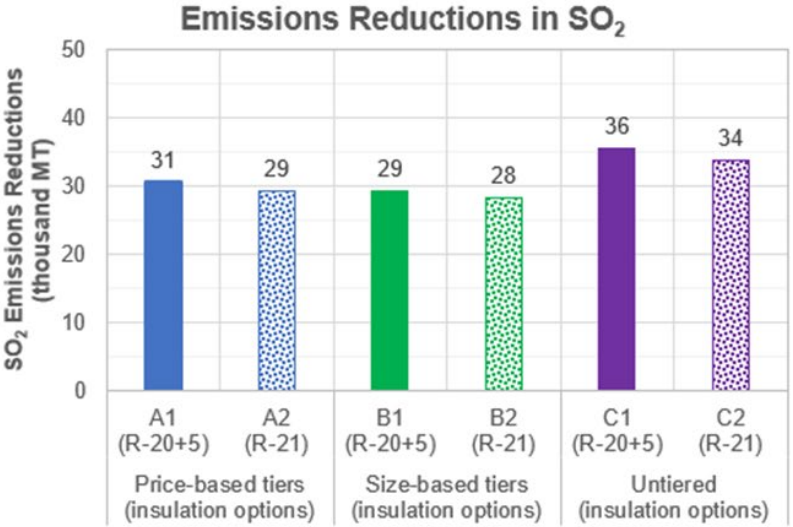


**FIGURE 2-6 Emissions Reductions of $CO_2$, $CH_4$, and $N_2O$ and Combined Total GHG Emissions Reductions on a $CO_2$ Equivalent Basis** ***(Data source: DOE 2021c.)***







(Data source: DOE 2021c.)

### 2.6.3 Health and Safety

The health and safety analysis for the proposed energy conservation standards includes potential health risks associated with exposures to indoor air pollutants whose concentrations might change as a result of the proposed energy conservation standards for manufactured homes.

An analysis that utilized a physics-based simulation model found that the improved air sealing requirements of the proposed action alternatives would not change the hazard status of indoor air pollutant exposures. Even in homes with frequent gas cooking, the chronic $NO_2$ exposure would remain well below the National Ambient Air Quality Standards (NAAQS) annual average concentration benchmark. Across all of the ventilation scenarios and the three locations, $PM_{2.5}$ from frequent cooking and from occupant activities (excluding smoking) would also remain below the benchmark of the NAAQS annual average. The airflow and pollutant simulations produced a range of hazard quotients that extends to just over 1.0 for total $PM_{2.5}$ in non-smoking homes meeting the HUD Code. The high value is for homes that use no mechanical ventilation and do not routinely open windows. The range of hazard quotients for total $PM_{2.5}$ would extend a bit higher in a home that meets the proposed standards for airtightness with the same indoor sources and outdoor concentrations; but the difference is very small relative to the variability seen in the hazard quotients based on measurements in homes.

While the analysis did not explicitly consider secondhand smoke (SHS), the results for $PM_{2.5}$ from occupant activities can be used to infer impacts of the rule in homes with SHS. Across the various ventilation scenarios and the three illustrative cities evaluated, the increase in air tightness is predicted to result in an increase in $PM_{2.5}$ from occupant activities ranging from -4 to 28 percent, and the increase is roughly 20 percent for the worst conditions with no ventilation. A 20 percent increase in $PM_{2.5}$ in homes that already have high concentrations of SHS would represent a substantial increase in the hazard level. However, in the no-action alternative, occupants of homes with SHS that are not effectively controlled would continue to be exposed to very high levels of $PM_{2.5}$.

Along with SHS, acrolein and formaldehyde also have hazard quotients substantially above 1 in the HUD Code home (no action alternative). Those hazard quotients likely would increase with air sealing, if there were no changes to occupant ventilation practices. As noted in Section 4.2.3, any potential increases in concentrations for these pollutants could be mitigated with increased use of ventilation. The estimated incremental changes to formaldehyde concentrations would not result in a significant incremental cancer risk from formaldehyde exposure. The estimated incremental changes to formaldehyde concentrations would not result in a significant incremental cancer risk from formaldehyde exposure.

### 2.6.4 Socioeconomics

The socioeconomics analysis for the proposed energy conservation standards includes impacts on consumers, impacts to manufacturers, and nationwide impacts.

The estimated impacts on consumers under each of the alternatives include lifecycle cost (LCC) and simple payback period (PBP) and are compared in Table 2-3. For impacts on consumers, the highest life-cycle cost savings (10 year) occurs under Alternative A1, and the highest life-cycle cost savings (30 year) occurs under Alternative C2. Life-cycle cost savings are positive compared to Alternative D for all of the action alternatives except for the 10-year savings under Alternative C1. The highest increase in purchase price and longest simple payback period occur under Alternative C1, while the lowest increase in purchase price and shortest simple payback period occur under Alternatives A2 and B2.

The manufacturers impact analysis (industry net present value [INPV]) was performed in the SNOPR and is included in this draft EIS only under Alternatives A1 and C1; the estimated impacts are compared in Table 2-3. Alternative C1 has positive impacts compared to Alternative D under the preservation of gross margin markup scenario and has higher positive impacts on manufacturers than Alternative A1. However, under the preservation of operating profit markup scenario, Alternative C1 has negative impacts compared to the no-action alternative and higher negative impacts than Alternative A1.

Nationwide impacts were estimated based on national energy savings and net present value of consumer benefits, which were calculated based on projected annual shipments, projected annual energy consumption, and total incremental cost data from the LCC analyses. The net present value of total consumer costs and savings under each alternative is compared in Figure 2-8, and the reduction in shipments under each alternative is compared in Figure 2-9. The highest net present value total consumer savings (3 percent discount rate) occurs under Alternative A2, and the highest net present value total consumer savings (7 percent discount rate) occurs under Alternative B2. Of the action alternatives, the lowest number of shipment reductions occurs under Alternative B2. There would be no shipment reductions under Alternative D.

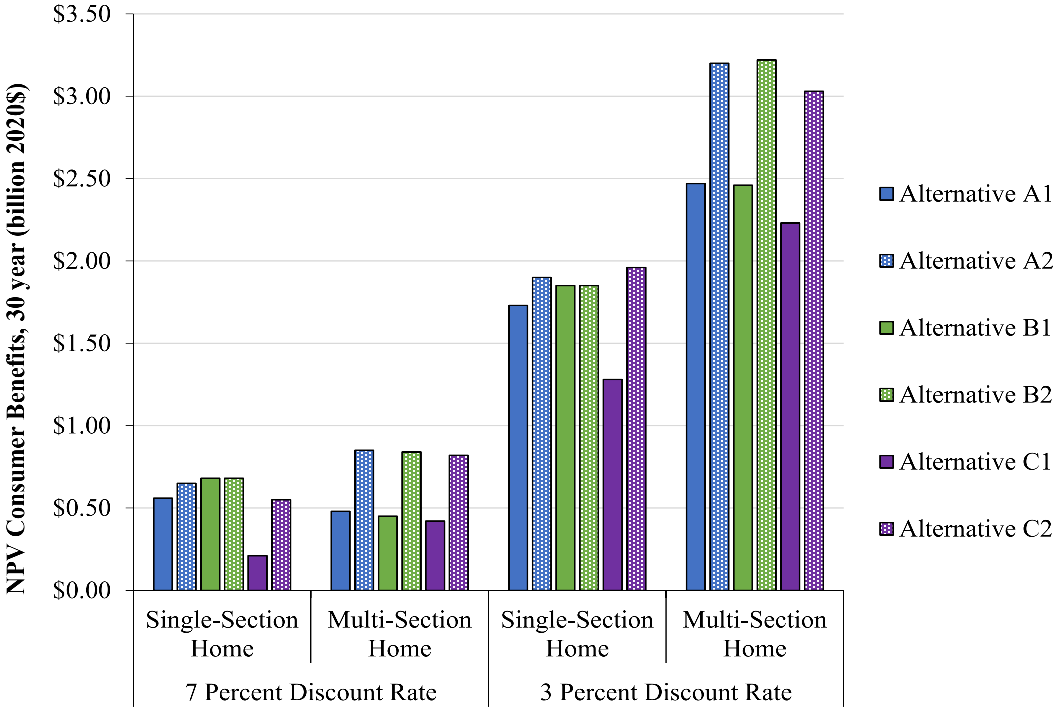


**FIGURE 2-8 Comparison of Alternatives: Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime *(Source: NODA)***

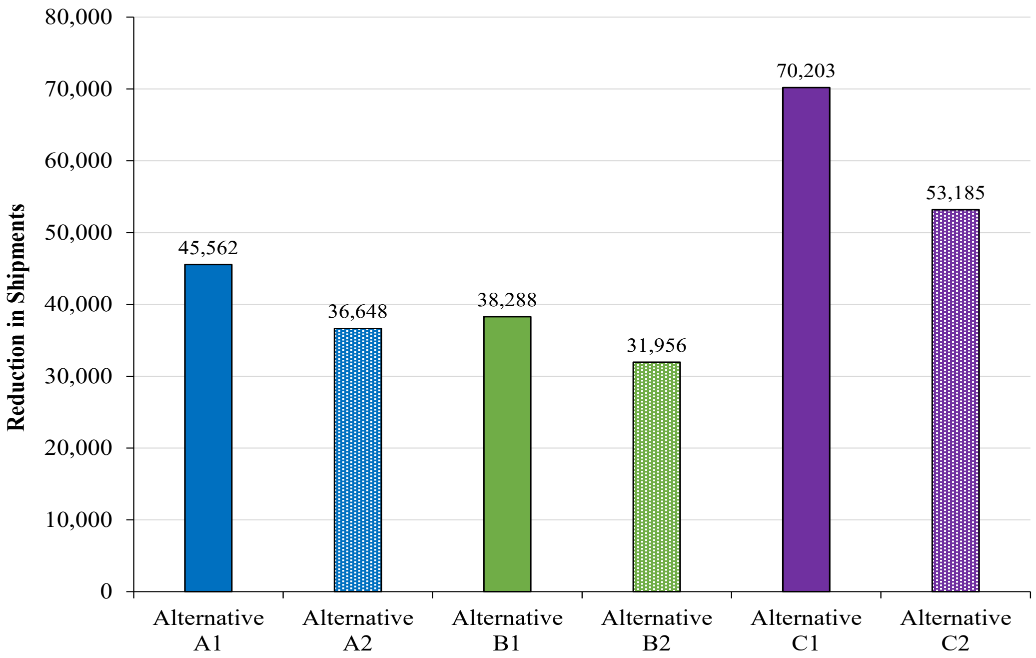


**FIGURE 2-9 Comparison of Alternatives: Reduction of Shipments over the 30-Year Analysis Period *(Source: NODA)***

**TABLE 2-3 Comparison of Alternatives: Consumer Impacts**

| Alternative | Lifecycle Savings, 10 years | | Lifecycle Savings, 30 years | | Increased Purchase Price | | Annual Energy Cost Savings | | National Average Simple Payback *(years)* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Single-Section | Multi-Section | Single-Section | Multi-Section | Single-Section | Multi--Section | Single-Section | Multi-Section | Single-Section | Multi-Section |
| Alternative A1: Tiered standards based on price, R-20+5 insulation | | | | | | | | | | |
| Tier 1 | $726 | $1,015 | $1,606 | $2,205 | $660 | $839 | $176 | $238 | 3.7 | 3.5 |
| Tier 2 | $78 | $235 | $2,045 | $3,023 | $3,902 | $5,267 | $354 | $496 | 11.0 | 10.6 |
| Alternative A2: Tiered standards based on price, R-21 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | $632 | $788 | $2,740 | $3,727 | $2,830 | $4,222 | $331 | $475 | 8.5 | 8.9 |
| Alternative B1: Tiered standards based on size, R-20+5 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | Same as Alternative A1, Tier 2 | | | | | | | | | |

**TABLE 2-3 Comparison of Alternatives: Consumer Impacts (Cont.)**

| Alternative | Lifecycle Savings, 10 years | | Lifecycle Savings, 30 years | | Increased Purchase Price | | Annual Energy Cost Savings | | National Average Simple Payback *(years)* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Single-Section | Multi-Section | Single-Section | Multi-Section | Single-Section | Multi--Section | Single-Section | Multi-Section | Single-Section | Multi-Section |
| Alternative B2: Tiered standards based on size, R-21 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | Same as Alternative A2 with R-21 insulation, Tier 2 | | | | | | | | | |
| Alternative C1: Untiered standards, R-20+5 insulation | | | | | | | | | | |
| Untiered | $-57 | $50 | $1,733 | $2,585 | $3,902 | $5,267 | $354 | $496 | 11.0 | 10.6 |
| Alternative C2: Untiered standards, R-21 insulation | | | | | | | | | | |
| Untiered | $518 | $622 | $2,432 | $3,291 | $2,830 | $4,222 | $331 | $475 | 8.5 | 8.9 |
| Alternative D: No action | | | | | | | | | | |
| No action | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | 0 | 0 |

### 2.6.5 Environmental Justice

The environmental justice analysis for the proposed energy conservation standards considers the potential impacts from the proposed energy conservation standards and whether they disproportionately impact minority and/or low-income populations. This draft EIS evaluated environmental justice in terms of the socioeconomics impacts (access to affordable homeownership and energy insecurity) and indoor air quality and health.

For the tiered alternatives (Alternatives A1, A2, B1, and B2), it is expected that low-income populations would purchase Tier 1 homes. The increase in purchase price under these alternatives would not likely disproportionately impact low-income and minority populations' ability to purchase new homes. However, Tier 1 homes would not receive the same energy conservation standards, decreasing the potential benefits of energy savings for low-income communities that already experience much higher energy burdens compared to the national average. The impacts to indoor air quality and human health are the same across all alternatives. The proposed energy conservation standards are expected to lead to lower indoor concentrations of some outdoor air pollutants and improve the ability to control exposure to wildfire smoke. Conversely, it is expected that the proposed energy conservation standards would lead to higher concentrations of indoor air pollutants air emitted from indoor sources, in particular when ventilation is inadequate. The extent of impact to low-income and minority populations would depend on existing conditions because concentrations of pollutants in indoor air will vary with house-specific emission rates and location-specific outdoor pollutant levels. Table 2-4 presents the overall comparison of all alternatives.

**TABLE 2-4 Comparison of Alternatives**

| Resource Area and Potential Impact | Alternative A1 | Alternative A2 | Alternative B1 | Alternative B2 | Alternative C1 | Alternative C2 | Alternative D |
|---|---|---|---|---|---|---|---|
| **Energy Resources** | | | | | | | |
| Total energy savings (in quads) | 2.01 | 1.94 | 1.93 | 1.88 | 2.36 | 2.26 | 0.0 |
| **Air Resources: Emissions Reductions** | | | | | | | |
| $CO_2$ (million metric tons) | 86.5 | 83.2 | 83.0 | 80.4 | 100.8 | 95.7 | 0.0 |
| $CH_4$ (thousand metric tons) | 521 | 502 | 501 | 485 | 609 | 578 | 0 |
| $N_2O$ (thousand metric tons) | 0.88 | 0.84 | 0.85 | 0.82 | 1.02 | 0.97 | 0.00 |
| GHG total (million metric tons $CO_2e$) | 99.8 | 96.0 | 95.8 | 92.8 | 116.3 | 110.4 | 0.0 |
| Mercury (metric tons) | 0.134 | 0.130 | 0.129 | 0.125 | 0.159 | 0.152 | 0.000 |
| $NO_X$ (thousand metric tons) | 137.1 | 132.0 | 132.3 | 127.7 | 160.0 | 150.0 | 0.0 |
| $SO_2$ (thousand metric tons) | 30.5 | 29.3 | 29.2 | 28.3 | 35.5 | 33.8 | 0.0 |
| **Health and Safety** | | | | | | | |
| Change in hazard quotient category | Acrolein and formaldehyde are commonly at and above the hazard or risk threshold, especially when ventilation is inadequate. | | | | | | No change to existing conditions. |

**Table 2-4 Comparison of Alternatives (Cont.)**

| Resource Area and Potential Impact | Alternative A1 | Alternative A2 | Alternative B1 | Alternative B2 | Alternative C1 | Alternative C2 | Alternative D |
|---|---|---|---|---|---|---|---|
| **Socioeconomics** | | | | | | | |
| ***Consumer Impacts*** | | | | | | | |
| Life-cycle cost savings (10-year period), in billion 2020$ | Tier 1: $726–$1,015<br>Tier 2: $78–$235 | Tier 1: Same as A1, Tier 1<br>Tier 2: $632–$788 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A1, Tier 2 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A2, Tier 2 | $-57–$50 | $518–$622 | $0 |
| Life-cycle cost savings (30-year period) | Tier 1: $1,606–$2,205<br>Tier 2: $2,045–$3,023 | Tier 1: Same as A1, Tier 1<br>Tier 2: $2,740–$3,727 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A1, Tier 2 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A2, Tier 2 | $1,733–$2,585 | $2,432–$3,291 | $0 |
| Increased purchase price | Tier 1: $660–$839<br>Tier 2: $3,902–$5,267 | Tier 1: Same as A1, Tier 1<br>Tier 2: $2,830–$4,222 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A1, Tier 2 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A2, Tier 2 | $3,902–$5,267 | $2,830–$4,222 | $0 |
| Simple payback period | Tier 1: 3.5–3.7<br>Tier 2: 10.6–11.0 | Tier 1: Same as A1, Tier 1<br>Tier 2: 8.5–8.9 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A1, Tier 2 | Tier 1: Same as A1, Tier 1<br>Tier 2: Same as A2, Tier 2 | 10.6–11.0 | 8.5–8.9 | $0 |
| ***Manufacturers Impacts*** | | | | | | | |
| Change in INPV preservation of gross margin percent scenario | $0.10–0.22B (1.9 to 2.1 percent) | Not evaluated | Not evaluated | Not evaluated | $0.15–0.25B (2.2 to 3.0 percent) | Not evaluated | $0 |

**Table 2-4 Comparison of Alternatives** (*Cont.)*

| Resource Area and Potential Impact | Alternative A1 | Alternative A2 | Alternative B1 | Alternative B2 | Alternative C1 | Alternative C2 | Alternative D |
|---|---|---|---|---|---|---|---|
| Industry net present value, preservation of operating profit markup scenario | $-0.07 $0.20B<br>(-1.8 to 1.5 percent) | Not evaluated | Not evaluated | Not evaluated | $-0.21–$-0.13B<br>(-2.7 to -1.8 percent) | Not evaluated | $0 |
| ***National Impacts*** | | | | | | | |
| Net present value total consumer savings (3 percent discount rate) | $4.2B | $5.1B | $4.31B | $5.07B | $3.51B | $4.99B | $0 |
| Net present value total consumer savings (7 percent discount rate) | $1.04B | $1.5B | $1.13B | $1.52B | $0.63B | $1.37B | $0 |
| Reduction of shipments | 45,562 | 36,648 | 38,288 | 31,956 | 70,203 | 53,185 | 0 |
| **Environmental Justice** | | | | | | | |
| Socioeconomics | 1.2 percent increase in purchase price; fewer energy conservation benefits. | 1.2 percent increase in purchase price; fewer energy conservation benefits. | 1.2 percent increase in purchase price; fewer energy conservation benefits. | 1.2 percent increase in purchase price; fewer energy conservation benefits. | 1.2 percent increase in purchase price; equal energy conservation benefits. | 1.2 percent increase in purchase price; equal energy conservation benefits. | No increase in price; no energy conservation benefits. |

**Table 2-4 Comparison of Alternatives** *(Cont.)*

<table>
<tr><th>Resource Area and Potential Impact</th><th>Alternative A1</th><th>Alternative A2</th><th>Alternative B1</th><th>Alternative B2</th><th>Alternative C1</th><th>Alternative C2</th><th>Alternative D</th></tr>
<tr><td>Indoor air quality and health</td><td colspan="6">Lower indoor concentrations of outdoor air pollutants including ozone, $NO_2$, and $PM_{2.5}$; and improves the ability to control exposure to wildfire smoke.<br>Higher concentrations of indoor air pollutants emitted from indoor sources, in particular when ventilation is inadequate.<br>Extent of impact to low-income and minority populations would depend on existing conditions because concentrations of pollutants in indoor air will vary with house-specific emission rates and location-specific outdoor pollutant levels.</td><td>No change to existing conditions.</td></tr>
</table>

# 3 AFFECTED ENVIRONMENT

This chapter describes existing environmental resources potentially affected by DOE's proposal to establish energy conservation standards for manufactured housing. This description provides baseline context for the assessment of potential environmental consequences of the proposed action and alternatives presented in Chapter 4.

In focusing on those aspects of the environment that the proposal potentially affects, this section describes the following: energy resources; air resources, including climate, GHGs and other emissions, and air quality; health and safety; socioeconomic resources; and environmental justice. DOE has determined that the resource areas identified in Table 3-1 would not be substantively affected by the proposed action or action alternatives. Therefore, they are not carried forward for detailed analysis.

**TABLE 3-1 Resource Areas Not Carried Forward for Detailed Analysis**

| Environmental Resource Areas | Considerations |
|---|---|
| Ecological resources, including fisheries, wildlife, aquatic and terrestrial vegetation, threatened and endangered species, designated critical habitat | DOE's proposed action and action alternatives would be expected to result in a reduction in transportation associated use of energy resources, pollutant emissions, and accidents; these reductions would be insignificant relative to current transportation conditions nationwide. |
| Water resources, including surface waters and groundwater | |
| Coastal resources, wetlands, and floodplains | |
| Geology and soils | |
| Land use and infrastructure | |
| Cultural resources, Native American resources, archaeological resources, and historic properties | |
| Visual resources | |
| Noise and vibration | |
| Transportation and accidents | DOE's proposed action and action alternatives would be expected to result in a reduction in transportation- associated use of energy resources, pollutant emissions, and accidents; these reductions would be insignificant relative to current transportation conditions nationwide |
| Intentional destructive acts | DOE's proposed action and action alternatives are not site-specific.<br>Implementing any of the proposed alternatives would not create targets for intentional destructive acts. |

A range of environmental settings that could be impacted by the national rulemaking is provided by describing characteristics of the resource areas across six locations that illustrate different climate, ambient air quality, socioeconomic, and environmental justice conditions. These six locations also represent various conditions regarding the presence of manufactured housing. The six locations[1] are Chicago, Illinois (IL); Fresno, California (CA); Houston, Texas (TX); Memphis, Tennessee (TN); Miami, Florida (FL); and Phoenix, Arizona (AZ). Additional details for their respective environmental settings are provided in Appendix B.

Energy resources are characterized in Section 3.1. Air resources are described in Section 3.2, and health and safety are discussed in Section 3.3. Socioeconomic resources are described in Section 3.4, and environmental justice is discussed in Section 3.5.

## 3.1 ENERGY RESOURCES

Energy resources can be grouped into several types: primary and secondary, renewable and nonrenewable, and nuclear. This section highlights data from the Energy Information Administration (EIA 2018, 2019, 2021a, 2021b). Common terms are explained in the text box on this page.

**Primary energy**

Raw fuel (including fossil fuels: petroleum, natural gas, and coal)

*Measure*: British thermal units (Btu)

**Secondary energy**

Energy product (e.g., electricity, heat, steam) as converted from a primary source

*Electricity measure*: kilowatt, kilowatt-hour

**End-use sectors**

Sectors that consume primary energy plus electricity from the electric power sector:

- transportation
- commercial
- industrial
- residential

**Total energy consumption**

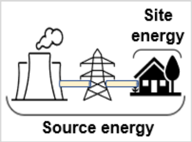
Combined: primary energy use, purchased electricity, electrical system energy losses, and other losses (e.g., during generation, transmission, delivery of electricity to site)

**Site energy**

Amount of heat and electricity consumed at the building (as reflected in its utility bill)

**Source energy**

Total amount of raw fuel needed to operate the building, taking all energy use into account and including energy losses during production, transmission, and delivery



In 2020, energy consumption in the United States totaled about 93 quadrillion ($10^{15}$) Btu, or 93 quads. This was 7 percent lower than in 2019, which is the largest annual decrease on record and reflects impacts resulting from the SARS-CoV-2 pandemic. The main factor was lower consumption of fossil fuels, notably of petroleum used for transportation and coal used to generate electricity.

Fossil fuel consumption still dominated the total U.S. energy consumption, accounting for about 78 percent in 2020. This was 9 percent lower than in 2019 and the lowest level since 1991. The rest of the nation's energy consumption came from non-fossil sources, with renewables at 13 percent and nuclear at 9 percent (EIA 2021a).

Total energy consumption by the residential sector in 2020 accounted for more than 22 percent of the

---

[1] This assessment considered the presence of manufactured homes indicated by the fractions of national shipments allocated to the 19 cities as listed in the Technical Support Document (DOE 2021); in order, these were highest: Houston at 11.7 percent, El Paso (a climate surrogate for Fresno) at 11.4 percent, Chicago at 10.7 percent, Miami at 9.3 percent, and Memphis at 8.9 percent; Phoenix is lower and is included (like Fresno) per consideration of wildfire events.

U.S. total, at 20.9 quads. The consumption of primary energy (from burning raw fuel) accounted for nearly a third of this, at 6.6 quads. The total consumption (which includes energy losses from the electrical system) is about 3 percent lower than in 2019, even though more people stayed home in 2020 because of the pandemic. This total energy consumption by the residential sector previously fluctuated between about 20 and 22 quads since 2000. Proportions among the four end-use sectors — transportation, industrial, commercial, and residential — have been generally similar over this time, particularly for the residential and commercial sectors, although there were some variations from year to year (Figure 3.1-1) (EIA 2021a).

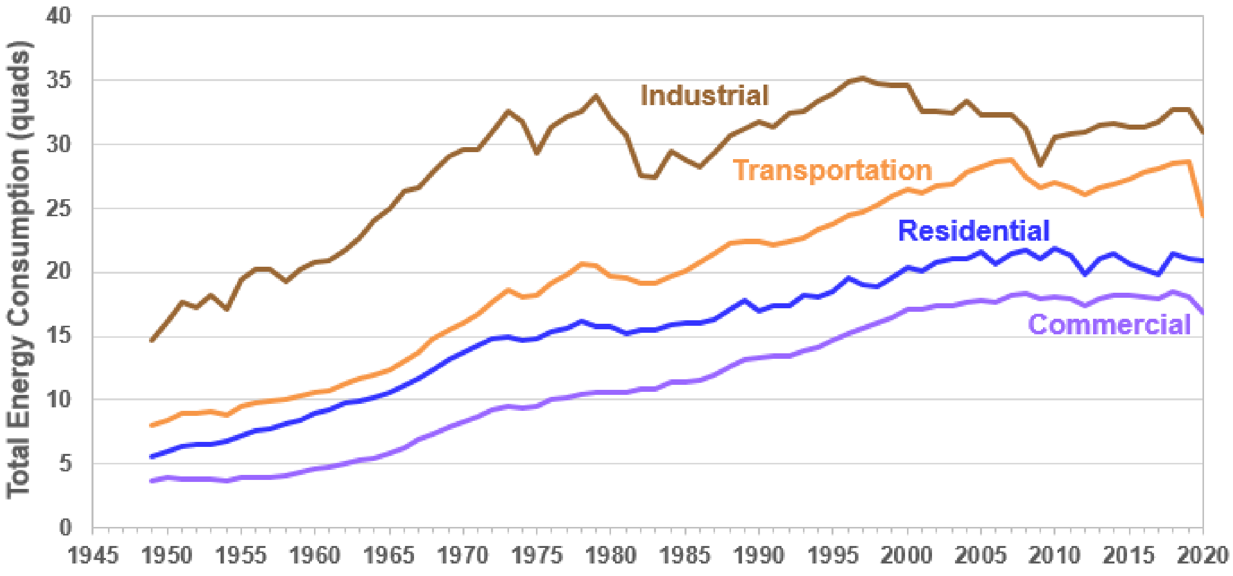


**FIGURE 3.1-1 Total Energy Consumption by End-Use Sector, 1949–2020**

Nearly all homes in the United States use electricity (secondary energy). The 2020 data indicate that retail electricity purchases account for 24 percent of all energy consumed by the residential sector, at 5.0 quads. Natural gas (primary energy) accounts for about the same amount: 23 percent, or 4.8 quads (EIA 2021a). Petroleum and renewable sources (both primary energy) account for about 5 and 4 percent, at 1.0 and 0.8 quads, respectively. These source energy contributions are shown in Figure 3.1-2 (EIA 2021a). This figure also illustrates the seasonality of residential energy consumption.

The residential sector accounted for about 8 percent of all primary fossil fuel consumption in the United States, at 5.8 quads (EIA 2021a). Of the fossil fuels directly consumed by residential buildings, natural gas dominates (83 percent), and is commonly used to heat building space and water; petroleum accounts for most of the remainder.

Figure 3.1-3 shows the major sources that have supplied energy for residential consumption over the years (EIA 2021a). Natural gas and petroleum dominated until the 1970s energy crisis, when petroleum fell below electricity while natural gas generally leveled off. The role of electricity has continued to increase; as of 2020, it accounted for a slightly larger percentage of consumption than natural gas.

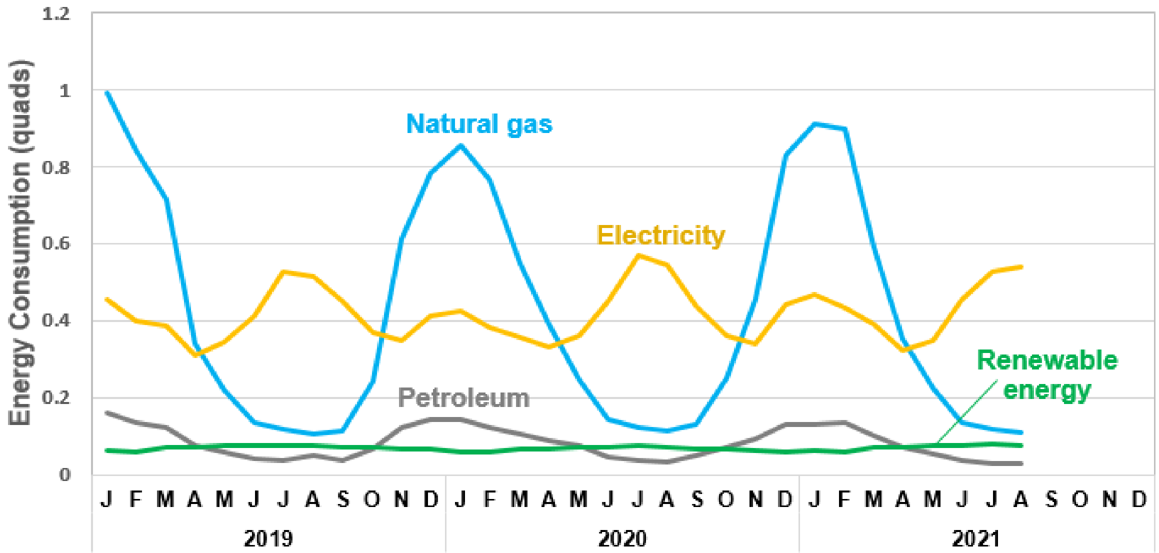


FIGURE 3.1-2 Residential Energy Consumption by Major Source, Monthly (2019–2021)

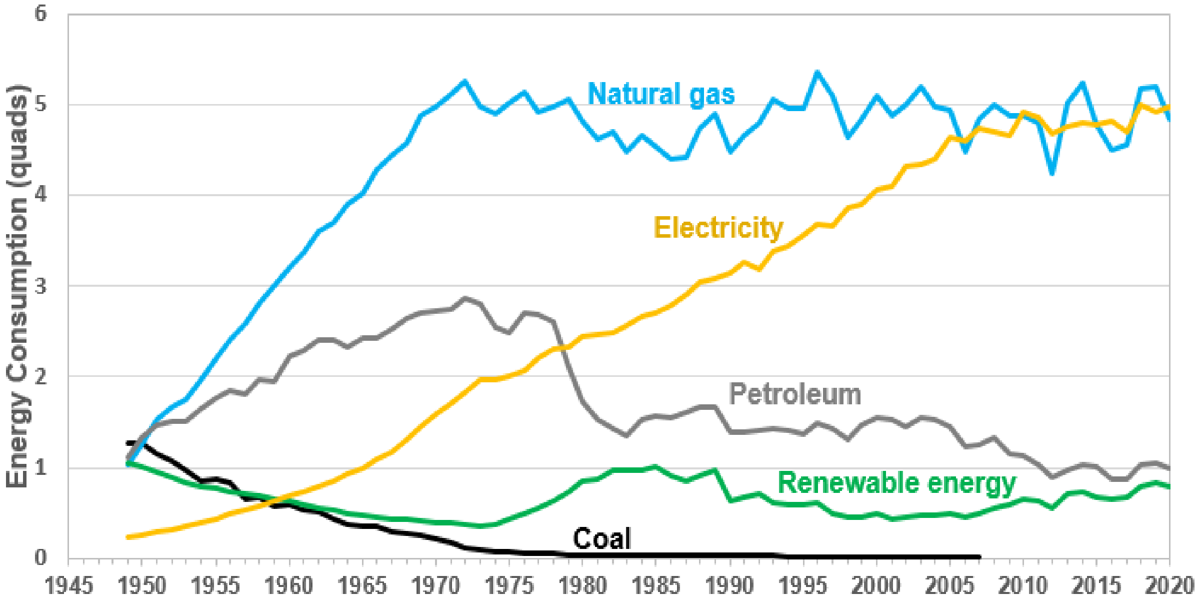


FIGURE 3.1-3 Annual Residential Energy Consumption by Major Source

Total energy consumption consists of: (1) primary energy consumption, (2) electricity retail sales (purchased electricity), and (3) electrical system energy losses. Together, primary consumption and retail sales for the residential sector accounted for 11.6 quads in 2020 (EIA 2021a). Losses during the conversion of primary energy to electricity and the subsequent transmission and distribution of purchased electricity total 9.3 quads, as shown in Figure 3.1-4 (EIA 2021a). These energy losses from the electrical system for the residential sector are higher than those for any other sector, and they account for a full 10 percent of the nation's entire energy consumption. One way to help reduce losses is to reduce household energy consumption, including through more energy-efficient homes.

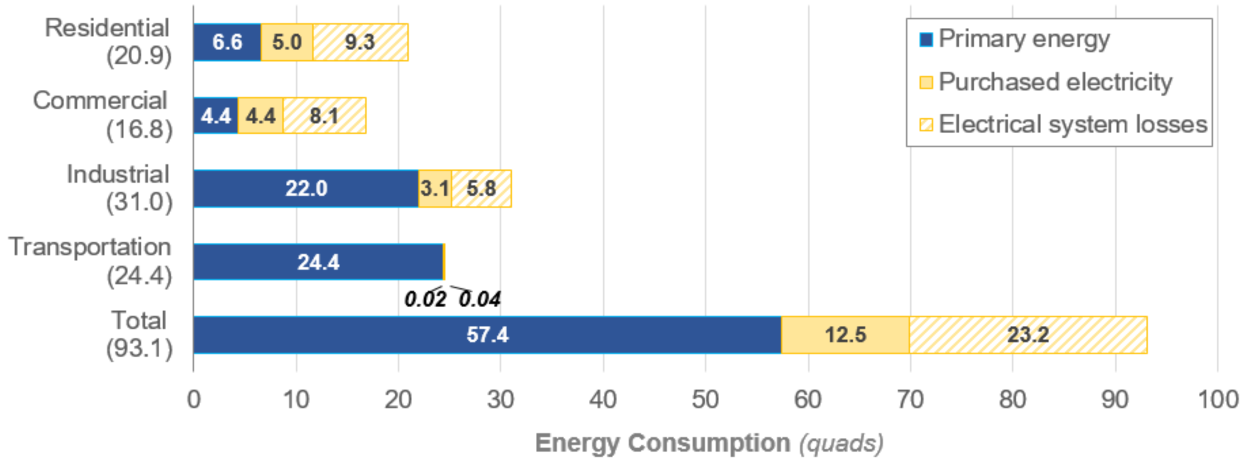


**FIGURE 3.1-4 Contributions to Total Energy Consumption by Sector, 2020**

Data collected in 2015 and 2016 from the EIA residential energy consumption survey provide information about consumption at the household level, including manufactured homes. On a household basis, the EIA reports an average site energy consumption for manufactured homes of nearly 60 million Btu,[2] with the total energy consumed across all manufactured homes estimated to exceed 400 trillion Btu, or 0.4 quad (EIA 2018).

The EIA compares average energy consumption at the household level across U.S. census regions in selected years, as shown in Figure 3.1-5 (EIA 2021b); these data exclude energy losses from the electrical system (EIA 2021c). Figure 3.1-5 shows that the energy efficiency of homes has improved since 1980. It also indicates that energy use in the Northeast and Midwest is higher than in other regions, which reflects higher heating demands. Population migration to warmer climates — notably to the south and west — translates to more new homes in those regions, and new homes tend to be more energy efficient. These population shifts are illustrated in Figure 3.1-6 (EIA 2021b). (See Section 3.4 for more information on the higher prevalence of manufactured homes and shipments of new homes across the southern and western states.)

In addition to assessing energy consumption by the residential sector, it is useful to consider electricity use in homes. Saving energy at this endpoint would lead to fewer electricity transfers, and thus fewer energy losses in the system. In 2020, residential buildings consumed about 1.5 trillion kilowatt-hours (kWh) of electricity, more than any other sector and 38.5 percent of all electricity generated in the country. This electricity consumption by homes was 2 to 3 percent higher than during the previous nine years (2011–2019; EIA 2021a). The typical U.S. household uses more air conditioning, appliances, and consumer electronics today than in the past, but the average energy use per home has declined because building insulation and materials have improved over time; equipment, lighting, and appliances are more energy-efficient; and population has shifted to regions where heating demand is lower.

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[2] For context, a burning match releases about 1 Btu of energy, and 1 kWh of electricity is 3,412 Btu (EIA 2021c).

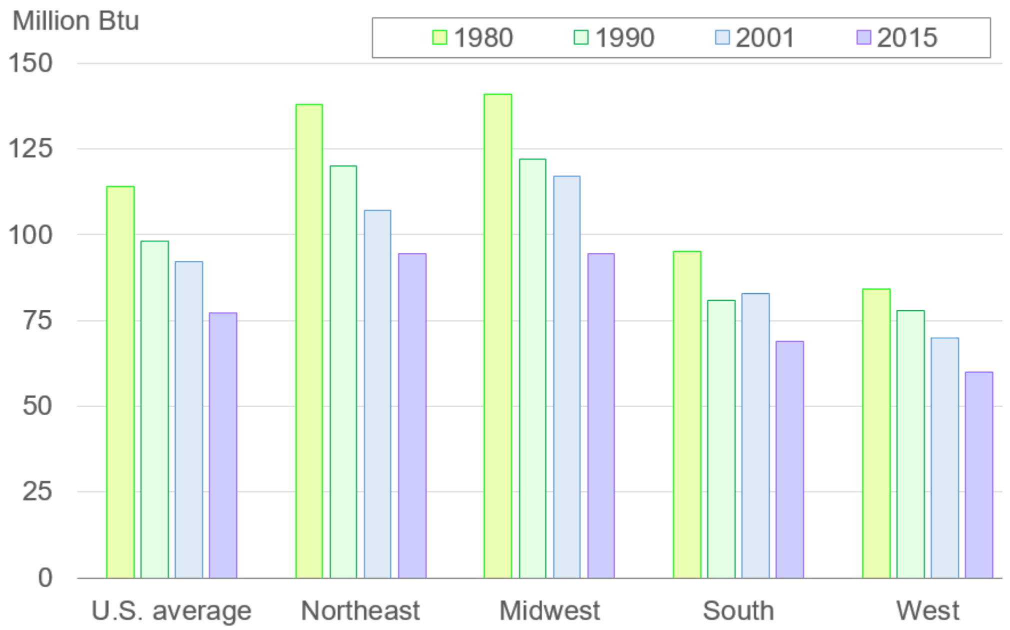

**FIGURE 3.1-5 Average Annual Household Energy Consumption by Census Region in Selected Years (excluding electrical system energy losses)**

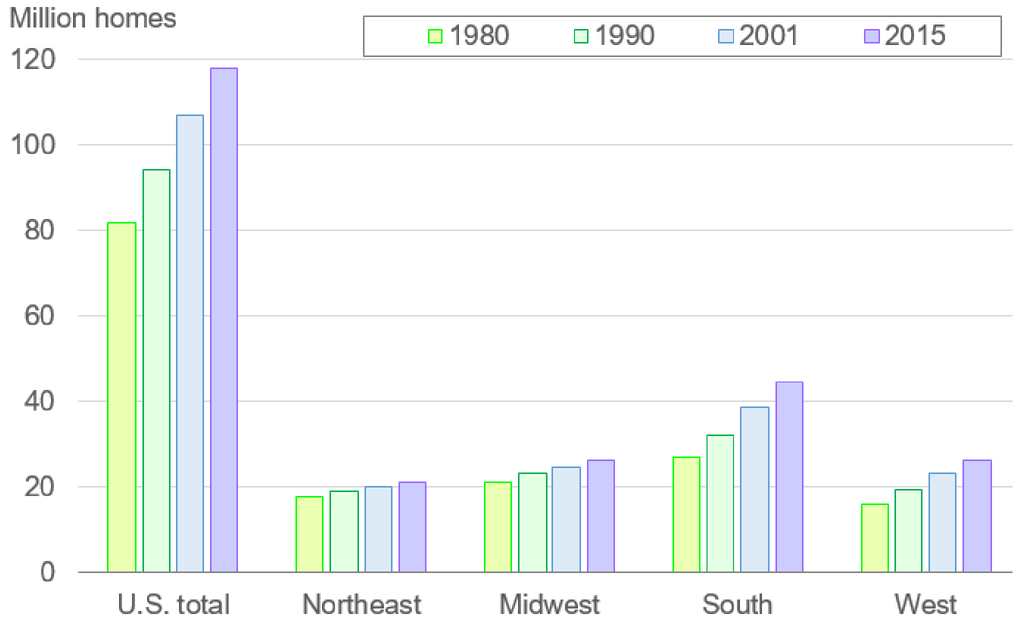

**FIGURE 3.1-6 Number of U.S. Homes by Census Region in Selected Years**

Using the 2015 residential energy consumption survey data, EIA compares average electricity consumption on a household basis for different types of homes by census region, as shown in Figure 3.1-7 (EIA 2019); these data exclude energy losses from the electrical system. (Note that "mobile homes" in these and other figures represent manufactured homes.) On a household basis, the average electricity use in manufactured homes is greater than the average amount used by all homes (green and blue lines in Figure 3.1-7) across all regions. Higher electricity use in the southern states reflects the fact that homes in this region are more likely to have electric heating and use more air conditioning — among the fastest growing energy uses in homes —combined with the population shifts to warmer climates (EIA 2019).

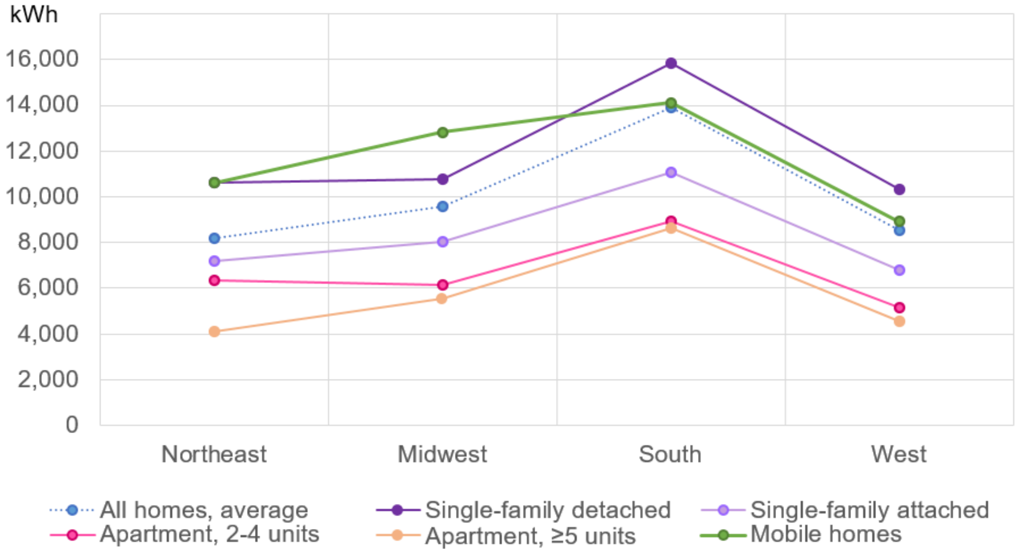

**FIGURE 3.1-7 Average Annual Household Electricity Consumption by Home Type and Census Region, 2015**

As an indirect energy source, electricity represents much more energy input than a primary source that is used directly to meet household energy needs. This is particularly important for manufactured homes because they rely much more heavily on electricity than other types of homes do, and currently many manufactured homes have no access to natural gas. Essentially all U.S. homes have electricity, and three-fourths of homes across the country use at least two energy sources (EIA 2021b). Natural gas is the dominant source of site energy in all homes except manufactured homes. Most other homes use this primary energy source to heat their homes and their water, and many also use it for cooking food and drying clothes.

The EIA (2021b) evaluation of residential data from the 2015 energy consumption survey found that, on average, natural gas is used to meet about 60 percent of household energy demands in homes other than manufactured homes. In contrast, in every region of the country, manufactured homes are most likely to use electricity alone to meet all their household energy needs; natural gas addresses just 25 percent of those needs, on average. The percentages of energy sources/fuels used by different types of homes are illustrated in Figure 3.1-8 (EIA 2018). (Many homes in rural areas use liquid propane to meet most heating and cooking needs. Wood is used to a lesser extent as a main heating fuel in rural areas, although many homes use it for supplemental heating.)

Thus, two factors make overall energy efficiency a challenge when considering manufactured homes and equipment commonly used today: (1) relatively high reliance on electricity, and (2) the relatively low energy efficiency of electricity compared with primary energy sources because of energy losses inherent to the electrical system. Because manufactured homes are generally smaller and are configured differently than site-built homes (affecting energy losses through the envelope), and occupant density per square foot is often higher, it is not surprising that energy expenditures on a square-foot basis are 70 percent higher than for site-built homes, as reported by EIA (2018) and highlighted by ACEEE (2020).

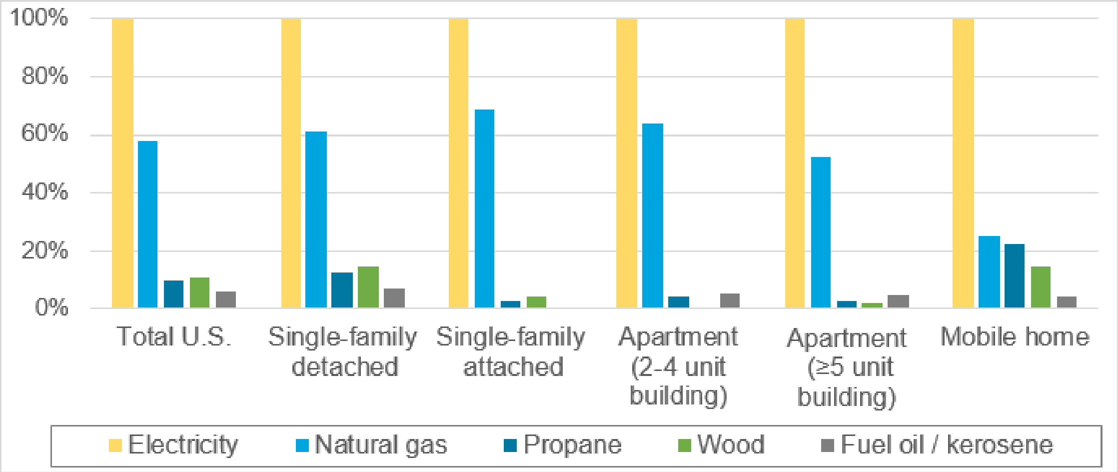

**FIGURE 3.1-8 Percentage of Homes Using Different Energy Sources/Fuels, 2015 (More than one energy source/fuel often applies to a home, given the variety of uses in a household.)**

Although energy is used to power a wide variety of devices and equipment in homes, on average, more than half the site energy used by U.S. households is for space heating and air conditioning. The main contributors to site energy consumption in different types of homes are shown in Figure 3.1-9 (EIA 2021b). Note that the shares displayed in this figure are a percentage of annual site energy consumption, not counting energy losses from the electrical system during electricity generation, transmission, and delivery.

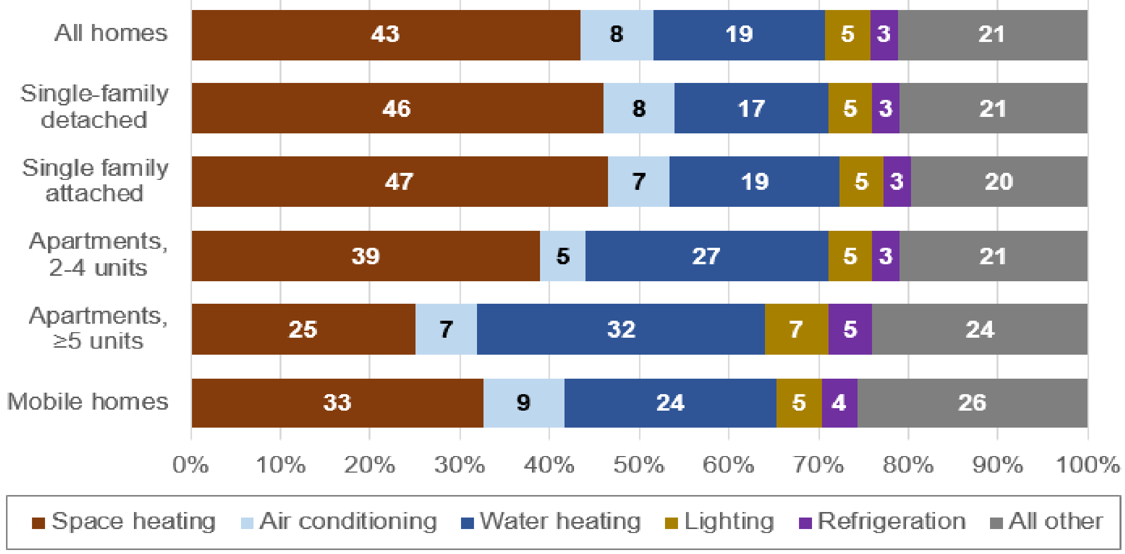

**FIGURE 3.1-9 Average Site Energy Consumption by Use for Each Home Type**

Manufactured homes are typically smaller than site-built homes (many apartments are even smaller), and on average, space heating makes up a smaller fraction of total site energy use (33 percent) compared with site-built homes (46 to 47 percent). However, the fraction of energy used for heating water in manufactured homes (24 percent) is higher than for single-family homes

(17 to 19 percent). The EIA (2021b) reports that average annual site energy use per U.S. home has declined due to better building insulation and materials; more efficient heating and cooling equipment, water heaters, refrigerators, lighting, and appliances; and the population shifts to regions with lower heating demand. The demand for cooling will increase as the climate continues to warm.

The amount of energy a household uses can vary significantly by geographic location and climate; housing type and characteristics; equipment and fuels used; number of people in the household; and the number, type, frequency of use, and efficiency of the devices used. Year-round energy uses include water heating, lighting, and refrigeration. Based on the 2015 survey data, these account for 27 percent of the total annual energy use in homes (EIA 2021b). However, the top two energy uses are mostly seasonal: air conditioning and space heating. EIA reports that on average, homes other than manufactured homes commonly use natural gas (a primary energy source) to address these two main end uses. In contrast, many manufactured homes used electricity (a secondary energy source) to address most or all household energy needs (EIA 2021b).

The EIA (2019) reports that an average U.S. household consumes about 11,000 kWh a year, excluding losses in electricity generation and delivery. Data from the 2015 residential energy consumption survey, shown in Figure 3.1-10 (EIA 2019), identify the main electricity uses for U.S. homes, on average, as air conditioning (17 percent), space heating (15 percent), and water heating (14 percent), followed by lighting and refrigerators. Note that while Figure 3.1-9 shows percent energy consumed by main end uses in different types of homes, Figure 3.1-10 shows electricity consumed by different end uses across all homes. On average, 28 percent of household electricity use is for space and water heating, but these two uses account for a much higher fraction of overall energy use, at 62 percent. Most U.S. homes use natural gas for these needs, while manufactured homes rely more heavily on electricity (EIA 2021b).

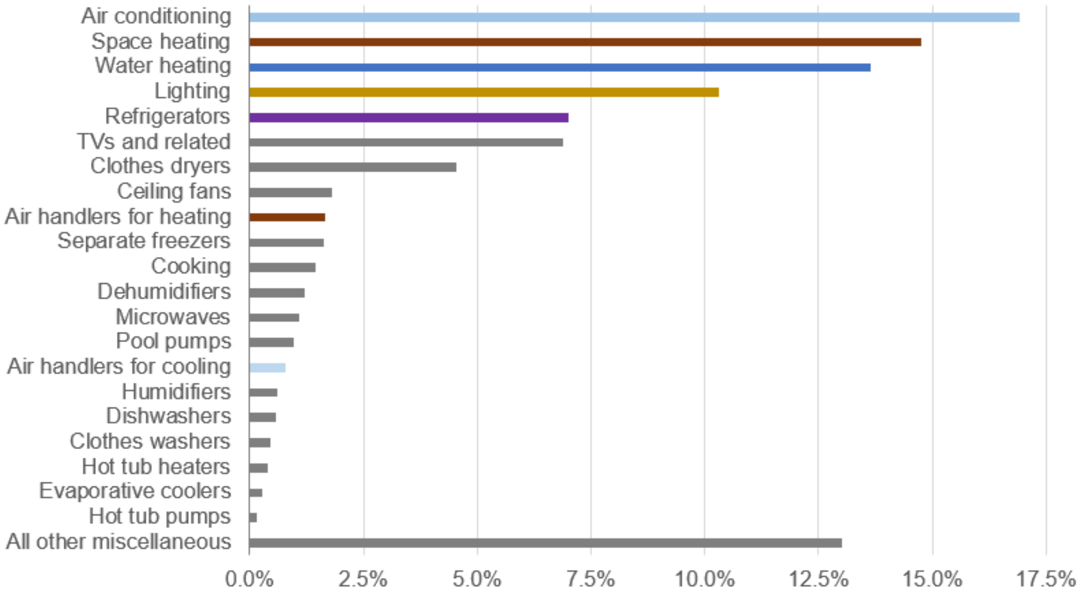

**FIGURE 3.1-10 Percentage of Total Residential Site Electricity Consumption by End Use**

## 3.2 AIR RESOURCES

Air resources encompass several themes that are discussed in the following sections: meteorology, GHG emissions, and climate change (Section 3.2.1); other emissions, focusing on criteria pollutants, mercury, and ambient air quality (Section 3.2.2); indoor air quality (Section 3.2.3); and wildfire impacts on air resources (Section 3.2.4).

### 3.2.1 Meteorology, GHG Emissions, and Climate Change

#### 3.2.1.1 Meteorology

Meteorology influences ambient air quality, which can affect indoor air quality. Meteorological variables include temperature, wind speed, wind direction, relative humidity, and precipitation, including snowfall. Meteorological data for the six illustrative locations are summarized in Table 3.2-1; additional details are provided in Appendix B.

**TABLE 3.2.1-1 Highlights of Meteorological Data for Illustrative Locations**

| Location | Climate Zone and Description | | Temperature (°F) | | Relative Humidity (%) | | Mean Wind Speed (mph) |
|---|---|---|---|---|---|---|---|
| | | | Mean | Daily Min.–Max. | Mean | Daily Min.–Max. | |
| Chicago, IL | 3 | Continental; relatively warm summers, cold winters | 50 | 41–59 | 71 | 60–81 | 9.9 |
| Fresno, CA | 2 | Semi-arid; hot summers; dry and mild winters | 64 | 52–77 | 61 | 41–79 | 6.0 |
| Houston, TX | 1 | Predominantly marine; mild winters, abundant rainfall | 70 | 60–80 | 75 | 60–90 | 7.5 |
| Memphis, TN | 2 | Humid subtropical; hot and humid summers | 63 | 54–72 | 67 | 58–80 | 8.0 |
| Miami, FL | 1 | Subtropical marine; warm summers, abundant rain; mild, dry winters | 77 | 70–84 | 73 | 61–83 | 8.4 |
| Phoenix, AZ | 2 | Desert; low rainfall, low relative humidity; hot summers, mild winters | 75 | 63–87 | 36 | 23–49 | 6.1 |

#### 3.2.1.2 GHG Emissions and Climate Change

Because of their driving impacts on climate change, reducing GHG emissions represents an environmental challenge for the United States and globally.

Two sources of GHG emissions are associated with the U.S. residential sector, which includes manufactured housing: (1) emissions from the generation of electricity, including from burning fossil fuel; and (2) on-site emissions from the use of natural gas, propane, and other fossil fuels for heating, hot water, and cooking. Electricity generation from fossil fuels is the largest source of GHG emissions in the United States. About 92 percent of total $CO_2$ emissions in the United States comes from fossil fuel combustion, and these emissions accounted for about 80 percent of total GHG emissions in 2019 (EPA 2021a).

As described in Section 3.1, residential buildings consumed more than 38 percent of the electricity generated in the United States in 2020. Among all U.S. homes, manufactured homes are most likely to rely entirely on electricity; 44 percent of manufactured homes rely solely on electricity, more than twice the level for single-family detached homes (18 percent) (EIA 2019). Nearly two-thirds of the 900 million metric tons (MT) of $CO_2$ emitted by the residential sector are attributed to electric power generation (about 580 million MT); most of the rest (nearly 260 million MT) is from the direct consumption of natural gas (EIA 2021b). The residential sector now ranks third (at 20 percent) in $CO_2$ emissions from energy consumption, behind transportation and industry (EIA 2021b).

In 2010, 49 billion MT of $CO_2$ equivalent ($CO_2$e) of anthropogenic GHGs were emitted worldwide (IPCC 2014), of which about one-seventh were from the United States. Worldwide, $CO_2$ makes up more than three-fourths of the total GHGs emitted by human activities, and fossil fuel use is the primary source. In the United States, anthropogenic GHG emissions totaled more than 6,500 million MT $CO_2$e in 2019, with $CO_2$ emissions accounting for about 80 percent followed by $CH_4$ (10 percent), $N_2O$ (7 percent) and the F-gases (3 percent). $CO_2$ emissions from fossil fuel combustion (including to produce electricity) are responsible for about three-fourths of total GHG emissions. By sector, GHG emissions span transportation (29 percent), electricity (25 percent), industry (23 percent), commercial and residential (13 percent), and agriculture (10 percent) in 2019 (EPA 2021a).

In addition to $CO_2$, other pollutants that contribute to climate change include methane ($CH_4$), and nitrous oxide ($N_2O$). These three pollutants are briefly described below.

***Carbon dioxide.*** $CO_2$ is the primary GHG emitted by human activities, and various natural sources also exist. The global atmospheric concentration of $CO_2$ has increased nearly 50 percent since pre-industrial times, from 280 to 413 ppm measured in 2021 at the Mauna Loa station in Hawaii (ESRL 2021). Atmospheric concentrations are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere, the land, and oceans is dominated by natural processes such as plant photosynthesis. Although these natural processes can absorb some anthropogenic $CO_2$ emissions, natural systems do not have the capacity to absorb the billions of metric tons that are added to the atmosphere each year from human activities. The predominant sources of anthropogenic $CO_2$ emissions are the combustion of fossil fuels (mostly coal, natural gas, and oil), forest clearing, other biomass burning, and some non-energy production processes such as cement production (EPA 2021a).

***Methane.*** The main anthropogenic sources of $CH_4$ include enteric fermentation from domestic livestock, domestic livestock manure management, landfills, coal mining, natural gas systems, and petroleum systems (EPA 2021a). $CH_4$ is also emitted by natural sources such as microbial degradation of natural organic materials in wetlands. Although the 12-year lifetime of $CH_4$ in the atmosphere is much shorter than that of $CO_2$,[3] $CH_4$ is 25 times more efficient at trapping radiation than $CO_2$ over a 100-year period; that is, $CH_4$ has a global warming potential (GWP)[4] of 25 (EPA 2021a). Total $CH_4$ emissions accounted for about 10 percent of total U.S. GHG emissions in 2019. $CH_4$ is the primary ingredient in natural gas, and production, processing, storage, and transmission of natural gas account for about 59 percent of the energy source emissions (or about 24 percent of total U.S. $CH_4$ emissions) (EPA 2021a).

***Nitrous oxide.*** $N_2O$ is produced by biological processes that occur in soil and water, and by a variety of anthropogenic activities in agricultural soil management, manure management, nitric acid production, wastewater treatment, stationary fuel combustion, and fuel combustion in motor vehicles (EPA 2021a). The GWP of $N_2O$ is 298, meaning it is nearly 300 times more powerful than $CO_2$ at trapping heat in the atmosphere over a 100-year time horizon. In the United States, the combined direct and electricity-related $N_2O$ emissions accounted for about 7 percent of total GHG emissions in 2019 (EPA 2021a). Agriculture is the largest source of these emissions, accounting for nearly 6 percent of the total. Fuel combustion is also a source, although $N_2O$ emissions in the residential sector are small, accounting for about 0.1 percent of total U.S. GHG emissions in 2019.

Ongoing climate change is projected to have widespread impacts on natural resources and human systems. A growing body of evidence points to anthropogenic sources of GHGs, including $CO_2$, as major contributors to climate change (USGCRP 2017). Climate-related changes include rising temperatures and sea levels; increased frequency and intensity of extreme weather (e.g., heavy downpours, floods, and droughts); earlier snowmelts and associated frequent wildfires; and reduced snow cover, glaciers, permafrost, and sea ice. Background information about the general features of climate change along with GHGs and the greenhouse effect is provided in Appendix B. As the climate warms, there will be a higher demand for cooling; that is, heating degree days (HDDs) will decrease and cooling degree days (CDDs) will increase. Current (2017) and projected (mid-century) annual average heating and cooling degree days are presented in Figure 3.2-1.

HDD65 and CDD65 are the number of heating and cooling degree days, respectively, based on 65°F. The 2017 data are from the 2017 American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc. (ASHRAE) handbook. The midcentury (2045–2054) estimates are calculated from regional-scale climate model projections (see Appendix B). To illustrate HDDs: for a winter day with an average temperature of 35°F, an HDD is approximated as $(65-35) = 30$; this indicates heating would be needed. If the average temperature were above 65°F then HDD would be 0, indicating no heating would be needed for that day. Conversely, a CDD indicates how much air conditioning would be needed. Summing the daily differences over a year gives annual

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[3] For a given amount of $CO_2$ emitted, some fraction of the atmospheric increase in concentration is quickly absorbed by the oceans and terrestrial vegetation, some fraction of the atmospheric increase will only slowly decrease over a number of years, and a small portion of the increase will remain for many centuries or more (EPA 2021a).

[4] The GWP of a GHG is defined as the ratio of the accumulated radiative forcing within a specific time horizon (typically 100-year time horizon) caused by emitting 1 kg of the gas relative to that of the reference gas $CO_2$ (EPA 2021a). GWPs for selected GHGs are 1 for $CO_2$, 25 for $CH_4$, 298 for $N_2O$, and 22,800 for sulfur hexafluoride ($SF_6$). Simply, 1 MT of $CH_4$ released into the atmosphere creates the same warming as 25 MT of $CO_2$, assuming that both gases are in the environment for 100 years.

HDDs and CDDs. Cooling a home takes less energy than heating it, because cooling involves moving excess heat out, while more energy is required to create heat.

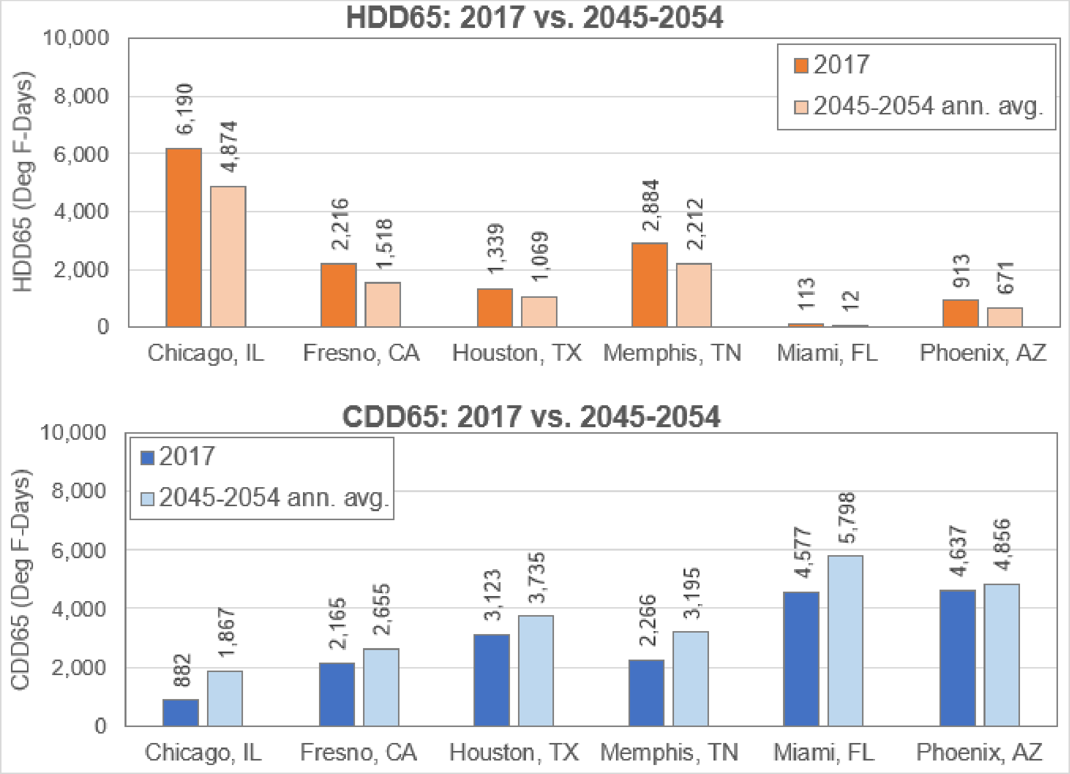

**FIGURE 3.2-1 Current and Projected HDDs and CDDs**

Estimates of social costs of greenhouse gases (SC-GHGs) provide an aggregated monetary measure (in current U.S. dollars) of the future stream of damages associated with an incremental metric ton of emissions and associated physical damages (e.g., temperature increase, sea level rise, infrastructure damage, human health effects) in a particular year. In this way, SC-GHG estimates can help the public and Federal agencies understand or contextualize the potential impacts of GHG emissions and, along with information on other potential environmental impacts, can inform a comparison of alternatives. The SC-GHGs estimated to contextualize potential impacts of DOE's proposal are presented in the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042).

### 3.2.2 Criteria Pollutants, Mercury, and Ambient Air Quality

Criteria pollutants and other pollutants are emitted during source and site energy consumption associated with manufactured homes. These emissions include sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$), which include nitric oxide (NO) and nitrogen dioxide ($NO_2$); these two pollutants react in the atmosphere to form $PM_{2.5}$, and NOx reacts with volatile organic compounds (VOCs) in the atmosphere to form ozone ($O_3$). In 2010, buildings accounted for 17 percent of the $NO_x$ emissions and 54 percent of the $SO_2$ emissions in the United States (DOE 2012). These emissions contribute to smog, acid rain, haze, and global climate change. Park (2013) and others have emphasized the important role of energy-efficient buildings in reducing this air pollution. Mercury (Hg) is emitted from fossil fuel-fired power plants.

The U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, including $NO_2$, $O_3$, particulate matter (PM, both $PM_{2.5}$ and $PM_{10}$),[5] and $SO_2$ (EPA 2021b). The Clean Air Act (CAA)[6] established two types of NAAQS: primary standards to protect public health including sensitive populations (e.g., asthmatics, children, and the elderly) and secondary standards to protect public welfare, including protection against degraded visibility and damage to animals, crops, vegetation, and buildings.

The NAAQS specify different averaging times as well as maximum concentrations.[7] If the air quality in a geographic area meets or is cleaner than the NAAQS, it is called an attainment area; areas that do not meet the NAAQS are called nonattainment areas (EPA 2021c).[8] The attainment status for each of the six study locations is presented in Table 3.3-2. Chicago, Fresno, Houston, and Phoenix are currently nonattainment areas for 8-hour $O_3$. Only Fresno and Phoenix are nonattainment areas for $PM_{2.5}$ and $PM_{10}$, respectively. Both Memphis and Miami are currently in attainment for all criteria pollutants (EPA 2021d).

Ambient air quality for a given location depends on the amount and rate of emissions; the local topography, which can affect dispersion or trapping of air pollutants; and meteorological conditions, such as solar radiation, temperature, rainfall, inversion, stagnation, and wind speed and direction. Of the six criteria pollutants, two are regional issues: $O_3$ and PM, notably $PM_{2.5}$. These are secondary pollutants produced during transport and dispersion and thus are more widespread. Ambient $O_3$ has no primary emission source; it is produced when $NO_2$ reacts with VOCs. Although some atmospheric $PM_{2.5}$ is from combustion sources, most comes from reactions of $NO_2$ (via nitrate) and $SO_2$ (via sulfate).

In contrast, the other four criteria pollutants represent local issues because they are limited to areas near emission sources. Air quality in Fresno is considered the worst in the region of the Central Valley in California, and among the worst in the United States. This is due to its geographic features surrounded by mountain ranges, various emissions (including mobile sources, industry, dust from farming, wildfire smoke from nearby mountains and forests), and the trapping of pollutants by inversion.

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[5] $PM_{2.5}$ and $PM_{10}$ are particles that have aerodynamic diameters less than or equal to 2.5 micrometers (µm) and 10 µm, respectively; $PM_{2.5}$ comprise a portion of $PM_{10}$.

[6] 42 U.S.C. 7401 et seq.

[7] For NAAQS with averaging times of 24 hours or less, the standard values can be exceeded a limited number of times per year; for others, procedures are established to determine compliance. States can establish their own State Ambient Air Quality Standards (SAAQS), which must be at least as stringent as the NAAQS, and they can include standards for additional pollutants (e.g., California has established a standard for hydrogen sulfide). If a state has no standard corresponding to one of the NAAQS, the NAAQS apply.

[8] Once attainment status designations take effect, state and local governments with nonattainment areas must develop implementation plans outlining how areas will attain and maintain the standards by reducing air pollutant emissions. Tribes may elect to develop tribal implementation plans but are not required to do so. Previous nonattainment areas where air quality has improved to meet the NAAQS are redesignated as maintenance areas and are subject to an air quality maintenance plan (EPA 2021c).

## TABLE 3.2-2 Climate, Meteorology, and Air Quality Context for the Illustrative Locations

| Location | Geographic Region | Climate and Meteorology Aspect | | | | | | | | | | Ambient Air Quality Attainment Status and Polluted City Ranking[d] | | Overall Air Quality Indicator |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Thermal Load (based on °F)[b] | | | | | | | | Wind[c] | | | | |
| | | Climate Zone[a] | Total HDDs + CDDs | | HDDs | | CDDs | | | HUD Wind Zone | Speed (avg. mph) | $NO_2$ | $PM_{2.5}$ Annual / 24-hour[e] | |
| | | | Current | Future | Current | Future | Current | Future | | | | | | |
| Chicago | Midwest | 3 | 7,072 | *6,740* | 6,190 | *4,874* | 882 | *1,867* | | I | 9.9 | - | 15 / - | / |
| Fresno | Southwest | 2 | 4,381 | *4,173* | 2,216 | *1,518* | 2,165 | *2,655* | | I | 6.0 | - | 2 / 2 | 🟥 |
| Houston | Central south | 1 | 4,462 | *4,804* | 1,339 | *1,069* | 3,123 | *3,735* | | I | 7.5 | - | 20 / - | / |
| Memphis | Midsouth | 2 | 5,150 | *5,407* | 2,884 | *2,212* | 2,266 | *3,195* | | I | 8.0 | - | - | - |
| Miami | Southeast | 1 (h) | 4,691 | *5,810* | 113 | *12* | 4,577 | *5,798* | | III | 8.4 | - | - | - |
| Phoenix | Southwest | 2 | 5,549 | *5,527* | 913 | *671* | 4,637 | *4,856* | | I | 6.1 | - | 8 / 13 | / |

[a] The climate zones are the same as HUD's thermal zones for U value (thermal transmission coefficient); "h" indicates a humid climate.

[b] Thermal loads underlying the HUD thermal zone designations account for the number of heating and cooling degree days as °F-day, base 65°F (HDD65 and CDD65, respectively); current HDD and CDD are from ASHRAE (2017). Locations with milder climates have fewer combined heating and cooling degree days and are more likely to use natural ventilation (open windows), with increased air exchanges reducing the impact of indoor emission sources on indoor air quality.

c The calculation of future total degree days are annual averages projected for the midcentury period (2045–2054) at a horizontal resolution of 12 km, using the Community Climate System Model Version 4 (bias corrected) that was developed by the National Center for Atmospheric Research. Further information about these projections is presented in Appendix B. In general, HDDs decrease and CDDs increases in the mid-century. Future projections are italics and shaded gray.

[d] Wind zones are defined by HUD to inform structural requirements (not related to indoor air quality). The design wind speeds (mph) are: 70 for zone I, 100 for zone II, and 110 for zone III. Shading for average annual wind speeds (miles per hour) indicates the more to less desired conditions for air flow (which is modeled using these data); this characteristic affects the impact of indoor emission sources on indoor air quality.

[e] Shading shows the relationship of the average outdoor pollutant concentration to the NAAQS for criteria pollutants based on airshed; dark rose = nonattainment area (least desirable air quality), light rose (slash) = less desired, and green (dash) = relatively good ambient air quality. Shading for the overall air quality considers ambient air quality (including nonattainment status for $O_3$ for all but Memphis and Miami) combined with the potential for events that increase ambient pollutant levels (e.g., wildfires). Attainment status is identified in EPA (2021d). Criteria pollutant concentrations were calculated from three years of reported data (2017–2019) from AirData (https://www.epa.gov/outdoor-air-quality-data).

[f] Numbers in the $PM_{2.5}$ column reflect the national ranking within the 25 most-polluted U.S. cities by the American Lung Association (ALA) in its current annual State of the Air report, which reflects data from 2017–2019 (https://www.lung.org/research/sota/city-rankings).

Based on 2017–2019 air monitoring data, Fresno was listed as the fourth-worst-polluted U.S. city for 8-hour $O_3$ and the second-worst-polluted U.S. city for both 24-hour and annual average $PM_{2.5}$ (ALA 2021). Chicago ranked 16th for 8-hour $O_3$ and 15th for annual average $PM_{2.5}$, while Houston ranked 11th for 8-hour $O_3$ and 20th for annual average $PM_{2.5}$. Phoenix ranked 5th for 8-hour $O_3$, 13th for 24-hour average $PM_{2.5}$, and 8th for annual average $PM_{2.5}$. In contrast, both Memphis and Miami were identified as among the cleanest U.S. cities for 24-hour average $PM_{2.5}$ (ALA 2021).

***Nitrogen Oxides.*** Nitrogen oxides is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen. In the context of air pollution, nitrogen oxides generally refer to the gases NO and $NO_2$, abbreviated as $NO_x$. Many nitrogen oxides are colorless and odorless. However, one common pollutant, $NO_2$, can often be seen as a reddish-brown layer over many urban areas. $NO_x$ gases generally form in combustion systems via the reaction of nitrogen and oxygen at high temperatures. The primary anthropogenic sources of $NO_x$ are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fossil fuels. $NO_x$ can also be formed naturally by lightning and, to a small extent, by microbial processes in soils. In the atmosphere, it reacts with other chemicals to form both particulate matter (mostly $PM_{2.5}$) and $O_3$, and it can impair visibility over a wide geographical area as regional haze (EPA 2021e). $NO_x$ also interacts with water, oxygen, and other chemicals in the atmosphere to form acid rain, which can affect sensitive ecosystems, such as lakes and forests.

$NO_x$ emissions from power plants in the United States have decreased substantially over the years, with an 87 percent reduction in 2020 from 1995 levels (EPA 2021f). This is largely due to the implementation of the Acid Rain Program under the CAA through a cap-and-trade program for fossil-fuel powered plants and, to some extent, the shutdown of many coal-fired power plants.

***Sulfur Dioxide**.* $SO_2$ belongs to the family of sulfur oxides ($SO_x$) that are compounds of sulfur and oxygen molecules. The largest sources of $SO_2$ emissions are fossil fuel combustion at power plants, notably coal-fired power plants, and other industrial facilities (EPA 2021g). Other sources include smelting, natural sources such as volcanoes, mobile sources (e.g., marine vessels that use bunker fuel), and heavy equipment that burn fuel with a high sulfur content. $SO_2$ can react with other compounds in the atmosphere to form small particles, mostly $PM_{2.5}$, that can impair visibility over a broad area as regional haze. In addition, $SO_2$ dissolves in rain droplets to form acid rain, which can affect sensitive ecosystems.

Nationally, $SO_2$ emissions from power plants in the United States have decreased substantially over the last decades, with a 93 percent reduction in 2020 from 1995 levels (EPA 2021f). This is largely due to implementation of the Acid Rain Program under the CAA through a cap-and-trade program for fossil-fuel powered plants and, to some extent, shutdown of many coal-fired power plants.

***Mercury**.* Mercury is a naturally occurring chemical element found in rock in the earth's crust, including in coal deposits (EPA 2021h). It exists in three forms: elemental (metallic), inorganic, and organic. Elemental mercury is liquid at room temperature and released into air when fossil fuels are burned. Inorganic mercury is formed when it combines with other elements, such as sulfur or oxygen, to form compounds or salts. Organic mercury forms when microorganic organisms in water and soil combine mercury with carbon, thus converting it from inorganic to organic. Mercury can be released to the atmosphere via both natural and anthropogenic processes (EPA 2021h). Although volcanoes and forest fires can emit mercury into the atmosphere, human activities such as burning coal, oil, and wood as fuel, as well as burning mercury-containing municipal and medical wastes, are responsible for much of the mercury in the environment.

Once airborne, mercury can fall to the earth's surface in rain or snow (wet deposition) or by gravity (dry deposition). From there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation (EPA 2021h). Methylmercury exposures in the United States primarily occur through eating fish and shellfish. Women of childbearing age are regarded as the population of greatest concern because developing fetuses are sensitive to the toxic effects of methylmercury. Children exposed to methylmercury before birth could be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory (Trasande et al. 2006).

In the United States, coal-fired power plants were the largest sources of mercury emissions, accounting for about 50 percent in 2005 and 44 percent in 2014 of all human-made mercury emissions in the country. However, these emissions were significantly reduced to about 13 percent by 2017 (EPA 2021i), primarily due to lower mercury emissions from facilities regulated under the Mercury and Air Toxics Standards. These standards were put in place to reduce emissions of toxic air pollutants, such as arsenic, mercury, and other metals from coal and oil-fired power plants under Section 111 (new source performance standards) and Section 112 (toxics program) of the 1990 CAA Amendments. From 2007 to 2019, facility releases of mercury and its compounds into air that were reported to EPA's Toxics Release Inventory (TRI) decreased by 73 percent, notably by 91 percent from electric utilities; this was considered to be driven by the federal and state regulations (EPA 2021j).

### 3.2.3 Indoor Air Quality

Residential indoor air quality (IAQ) is important because so much of the air we breathe is from the spaces within our homes. In the early 1990s, Americans spent more than two-thirds of their time at home (Klepeis et al. 2001). A recent report (BLS 2021) indicates that time spent inside U.S. homes increased from 2019 to 2020 due to the pandemic, including slightly more time spent sleeping. Many expect this trend of spending more time in homes to continue as telecommuting from home becomes increasingly common. Those most susceptible to air pollution, including the very young, the elderly, and the chronically ill, tend to spend more time at home than others.

IAQ can be characterized by the presence or absence of odors, irritants, and potentially hazardous chemical or biological materials. Thermal discomfort is linked to IAQ, because it impacts our perception of the environment. The conditions perceived as comfortable vary and satisfaction improves with the ability to control conditions. Increased insulation and reduced air infiltration improve thermal control and comfort. The impacts of odors are highly subjective. With requirements for operable windows and mechanical ventilation, manufactured homes provide occupants with the ability to manage odors; for this reason, odor control is not considered in this assessment.

The discussion of IAQ here and in Section 4.3 focuses on exposure that occurs when occupants operate their homes and engage in activities such as cooking, cleaning, personal care, using consumer products, hobbies, physical activity, and recreation. There are established and promoted healthy home practices[9] that are designed to limit IAQ impacts of such activities. These practices include limiting emission sources, using routine ventilation, and using additional ventilation when warranted to address particular air pollutant sources.

Many households do not use mechanical ventilation or open windows routinely during some seasons, and some households do not routinely ventilate at any time of the year (Price and Sherman 2006). Smoking of tobacco or other products is widely understood to be an IAQ hazard, and many households — including those with smokers — have restrictions on indoor smoking. For occupants living with someone who is unable or unwilling to refrain from smoking in the home, it is important to provide intentional extra ventilation and/or active air cleaning to manage IAQ and associated health risks.

This section focuses on the parameters that impact exposure under existing conditions in manufactured homes. (Section 3.3 assesses exposures and health implications under existing conditions.) An overview of irritants and health-relevant chemical and biological contaminants commonly found in U.S. homes, including manufactured homes, is presented below. Factors and data specific to manufactured homes are noted, as available.

#### 3.2.3.1 Residential Air Pollutants and Their Sources

Studies that have measured contaminant levels in many homes have consistently reported large variability in the concentrations of almost all the analytes investigated (Logue et al. 2011). Contaminant levels vary with source emission rates, the volumes of the interior spaces into which contaminants are introduced, removal processes, and contaminant entry from outside. There are many sources of contaminants inside U.S. residences (Table 3.2.3-1); but their presence is not uniform and almost all vary widely in their emissions and impacts on IAQ. For example, in polluted areas, outdoor air can bring in $O_3$, $NO_2$, and/or substantial $PM_{2.5}$ and its components, notably diesel particulate matter, metals, and both organic and inorganic acids. Both the concentrations of those pollutants outdoors and their impacts on indoor air vary over time and geographically; an example discussion for $O_3$ is provided in Nazaroff and Weschler (2021).

**TABLE 3.2.3-1 Important Air Pollutants in U.S. Homes and Their Sources**

| Pollutant | Sources |
|---|---|
| Radon (Rn)[a] | Produced by radioactive decay of natural radium in soils with large geographic variations; enters homes via cracks in foundations and floors; less problematic in homes with vented crawlspaces. |
| Particulate matter (PM)[b] | Enters from outdoors where sources include wildfire smoke events, wood smoke; photochemical air pollution (smog) and vehicle emissions; smoking; from indoors, cooking; candles; household pets; hobbies; resuspension from occupant movements. |

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[9] See https://www.hud.gov/program_offices/healthy_homes/healthyhomes and https://nchh.org/information-and-evidence/learn-about-healthy-housing/healthy-homes-principles/.

**TABLE 3.2.3-1 Important Air Pollutants in U.S. Homes and Their Sources (Cont.)**

| Pollutant | Sources |
|---|---|
| Nitrogen dioxide ($NO_2$)[c] | Enters from outdoors where sources include wildfire smoke events, wood smoke, and smog. Unvented and improperly vented combustion appliances including gas stoves; smoking. |
| Acrolein ($C_3H_4O$)[d] | Heating of cooking oils and fatty foods; smoking; e-cigarettes; natural wood; formation via oxidation of other indoor VOCs; vehicle exhaust. |
| Formaldehyde (HCHO)[e] | Natural and manufactured word products (plywood, particleboard, medium-density fiberboard); floor finishes; wallpaper and paints; smoking; other combustion. |
| Other volatile organic compounds (VOCs)[f] | Household products, including aerosol sprays; cleansers and disinfectants; moth repellents; air fresheners; paints, paint strippers, and other solvents; hobby supplies; dry-cleaned clothing; pesticides; wood preservatives; stored fuels and automotive products; building materials; furnishings; office equipment such as copiers and printers; graphics and craft materials such as glues and adhesives, permanent markers, and photographic solutions. |
| Biological contaminants[g] | Dampness and molds; allergens in pollens, dust mites, saliva and dander of household pets, cockroach droppings and body parts, urine from rats and mice; viruses (including SARS-CoV-2 and influenza), bacteria, and other microbiological pathogens. |

[a] EPA et al. (2016a).

[b] ALA et al. (1994)

[c] EPA (2021w).

[d] Seaman et al. (2007).

[e] ATSDR (2016).

[f] EPA (2021x).

[g] EPA (2021y).

The characteristics of residential air pollutant sources vary widely and include natural processes, construction materials, furnishings, products used in the home, and activities of people in the home. For example, radon gas enters homes from the subsurface soil, and indoor concentrations are determined by variations in the underlying soil, connections to the conditioned spaces of homes, and ventilation.

The EPA has designated areas of low, moderate, and high risk of elevated radon based on extensive measurement data.[10] Unvented combustion from "vent free" gas heating appliances (Francisco et al. 2010) or gas or propane cooking burners (Mullen et al. 2016; Singer et al. 2017) emit $NO_2$ and ultrafine particles, and they can emit CO at problematic levels; however, these appliances are not present in all homes and emissions will vary widely based on usage, leading again to widely varying concentrations across homes. Likewise, when used, recreational combustion such as cigarettes, incense, and candles emit particles, $NO_2$, and many organic chemicals, including irritants and carcinogens that can reach hazardous levels indoors.

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[10] See EPA (2021t).

Activities including cooking and cleaning and use of consumer products generate particles[11] and many organic gases, including some that can present a hazard at high concentrations; as with other pollutants, the amounts emitted into homes vary. Materials used to construct and finish the home and those contained in home furnishings can also be sources of chemical air pollution. Pets, pests, and plants produce and emit proteins and glycoproteins that cause allergic reactions in some people (Woodfolk et al. 2015); molds and other microbes can add to the burden. Many biological contaminants are present in the indoor air of homes.[12] The American Housing Survey (Census 2020b) reported that among manufactured homes, 18 percent had water leakage from inside the structure during the last 12 months, 23 percent had water leakage from outside the structure, and 4 percent had mold (defined as covering an area greater than or equal to the size of a piece of 8.5 × 11 inch paper) in the last 12 months.

Recent studies of indoor microbial bioaerosols identified key source categories of airborne bacteria, viruses, and fungi in buildings: humans, pets, plants, plumbing systems, HVAC systems, mold, resuspension of settled dust, and outdoor air (Prussin and Marr 2015). The formation, dynamics, and functions of indoor bioaerosols are affected by complex interactions of building characteristics, human occupants, and the microbial communities associated with both. Exposure to microbial bioaerosols can be beneficial or hazardous. For example, while exposure to mold is a hazard, studies have found that children exposed to some microbes early in life are less likely to develop wheezing or allergies. A report by the National Academies of Sciences, Engineering, and Medicine (2017) concluded that our current understanding of human exposure to microorganisms in buildings is too limited to be able to manage the microbial communities using building controls.

#### 3.2.3.2 Environmental Factors That Influence Indoor Air Quality

Many of the air pollutants that can exceed hazard thresholds in homes are impacted by environmental conditions. This contributes to the variability of observations in homes.

PM, $O_3$, and $NO_2$ concentration outdoors have diurnal, weekly, and seasonal cycles that vary by climate and geography across the country. The timing of these cycles is impacted by emissions sources such as industrial sites, on-road and off-road vehicles, agricultural activities, burning of wood for home heating, and others. Generally, $O_3$ is highest in the late afternoon and early evening of hot, sunny days. This is because $O_3$ forms by photochemical reactions that require sunlight. $PM_{2.5}$ can be elevated along with $O_3$ as a result of photochemistry.

Ambient $PM_{2.5}$ and $NO_2$ often are elevated during cold winter evenings and nights when temperature inversions trap emissions from evening commutes, residential wood smoke, and residential gas appliance use. The movement of radon through the soil and into ground-connected areas of homes varies with soil moisture and ambient pressure and temperature. The extreme air quality hazards presented by wildfires are much more common in the western United States during the summer and early fall. Uncontrolled air infiltration and related impacts of outdoor air pollutant

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[11] Indoor sources of particulate matter were discussed in depth at a 2016 workshop of the National Academies of Sciences, Engineering and Medicine (2016).

[12] See EPA (2021y).

entry increase with mean wind speed, wind speed variability, and indoor-outdoor temperature differences.

Environmental conditions inside homes also impact indoor air contaminants and associated risks. High relative humidity in the air or at cold surfaces inside the house or in the building envelope creates conditions favorable to dust mites and can lead to condensation, high material moisture content, and consequent dampness and mold-related problems. During winter, water vapor generated by occupants and activities can migrate through interior boundaries and insulation and reach surfaces at low enough temperatures to cause condensation. High-performance homes have vapor retarders to limit this risk,[13] and the HUD Code requires vapor retarders between ceiling and attic and at all exterior walls for this purpose.[14]

Air leaks from the duct system — which pulls air from the home into the forced air heating and cooling system and distributes the thermally conditioned air throughout the home — can also deliver humidified air to spaces with cold surfaces, increasing the risk of condensation. In manufactured homes, this can occur when ducts are located in the belly or in the attic. In hot, humid climates, excessive duct leakage has been associated with condensation and moisture damage, and presents a risk factor for dampness and mold (Moyer et al. 2001). In these climates, the most challenging time for high interior humidity is during the shoulder seasons when air temperatures are moderate enough to not require extended periods of air conditioner operation (which condenses and removes water vapor from the air). It is a common misunderstanding that limiting ventilation during such times is a helpful measure. In fact, because water vapor is added to indoor air by the occupants and their activities, ventilation tends to reduce water vapor concentrations (Walker and Sherman 2007; Rudd and Henderson 2007).

Indoor air pollutant levels are also impacted by increasing emission rates of volatile and semi-volatile organic gases from materials as temperatures increase (Wang et al. 2021). Emissions of formaldehyde increase with increasing temperature and humidity (Liang et al. 2016). Particle concentrations and size distributions can be impacted by temperature-dependent changes to partitioning of organic and inorganic components, as well as by humidity-dependent water uptake and/or release (Nazaroff 2004). Changes to particle size distributions impact deposition rates, which in turn impact concentrations in the air.

#### 3.2.3.3 Physical Processes That Influence Indoor Air Quality

Air pollutant concentrations in homes result from the combination of emission rates, the volume into which emissions are diluted, and the rate at which the contaminants are removed. Emissions can be continuous (e.g., as occurs when a volatile or semi-volatile chemical is contained in a material within the home and “off-gases” over time) or they can occur over a discrete period, such as burning a candle or using a cleaning product.

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[13] See https://www.buildingscience.com/documents/digests/bsd-106-understanding-vapor-barriers.

[14] §3280.504 Condensation control and installation of vapor retarders.

The volume of air into which an emitted contaminant is diluted is initially the room with the source; and mixing around the room occurs within minutes. Additional dilution occurs with mixing between rooms, which typically happens over tens of minutes when there is no mechanical mixing (Singer et al. 2017), or more quickly when a forced air system is operating. Without a forced air system, mixing throughout a home can be impeded by directional airflow, as occurs when windows are open or a ventilation fan extracts or supplies air to one or more rooms at moderate to high flow rates.

Contaminants are removed when indoor air is exchanged with outdoor air, by interactions of air contaminants with surfaces, by chemical reactions in the air, by phase changes of chemicals moving between the gas phase and particle phase, and by active air cleaning or filtration. Outdoor air exchange occurs via infiltration, intentional natural ventilation, and mechanical ventilation.

Infiltration, also called air leakage, is airflow driven by temperature differences and wind-induced pressure differences between the occupied space and outdoor or intervening spaces — which can include the enclosed belly beneath the floor of a manufactured home, or the attic above. Infiltration is uncontrolled airflow and is inefficient, because it occurs at the highest rate when outdoor temperatures are most different from those indoors, which increases heating and cooling loads. The amount of air infiltration increases with the number and sizes of openings (e.g., for plumbing and electrical conduits) and construction imperfections such as perimeter gaps and cracks. Intentional natural ventilation results from open windows and doors. Mechanical ventilation is the operation of fans, including the exhaust fans of clothes dryers, bathroom and kitchen exhaust fans, and whole-house ventilation fans.

Air exchange also occurs due to leaks in forced air heating and cooling ducting outside the home's pressure boundary: air is pushed out on the positively pressurized supply side and pulled in on the negative-pressure return side. This flow can be larger than what occurs from mechanical ventilation systems. Air pollutants can be removed by interactions with surfaces through several mechanisms. Particles larger than a few microns have enough mass that gravity pulls them down to horizontal surfaces. Gases and very small particles interact with surfaces in all orientations. Attractive forces cause particles that come very close to the surfaces to adhere and thus be removed from the air. Gases sorb (stick) to surfaces or react with the material or with organic films on the surfaces.

Air cleaning or filtration can be accomplished by installing a good filter (e.g., with a minimum efficiency reporting value, or MERV, of 8–11 or better) in the return of the central forced air system and by operating the central fan when filtration is desired,[15] or by using one or more stand-alone air cleaners. Simply installing a good filter in the central forced air system has variable effectiveness because central systems only operate intermittently for heating and cooling, with long periods of limited or no operation (Touchie and Siegel 2018). Modern heating and cooling equipment typically can run the blower separately from heating or cooling elements and many modern thermostats enable programming to operate the central fan for a portion of each hour to

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[15] See https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home.

mix and/or filter air in the home.[16] (This focuses on low-cost filtration options for general air pollution; for airborne infectious disease control, MERV13 filtration with high enough airflows to provide particle removal rates of 3/h or more is recommended.)

Outdoor air exchange/ventilation and other removal processes are quantified using the metric of "first order removal rate," a parameter used in chemical engineering to describe behavior in a completely and instantaneously well-mixed cell. The indoor volume of a home is considered with this idealized model even though it is at best a rough approximation, especially for removal processes that happen faster than mixing. Rates are typically expressed as the number of times that air or a contaminant would be changed or removed each hour or the fraction that would be removed in an hour.

An air exchange rate of 0.5 per hour (0.5/h) indicates that roughly half the air in a room is exchanged each hour, and a removal rate of 0.5/h indicates that roughly half the quantity of air in room is removed in an hour. The inverse of the removal rate is used as an indicator of the time it takes for a process to occur, and it allows comparisons of process time scales. For example, a home that complies with the HUD Code may have an infiltration-induced outdoor air exchange rate that varies from 0.2 to 1.0/h from over different days and that may increase by 0.2/h or more when a HUD-code-compliant whole-house ventilation fan is operating. Opening many windows or operating a large exhaust fan at 200–300 cfm can provide ventilation rates of >3/h.

Deposition and sorption can remove indoor contaminants at rates substantially faster than infiltration or minimum whole house ventilation. For example, removal rates of >0.5/h have been reported for $PM_{2.5}$ (Wallace et al. 2013), 0.5–1/h for $NO_2$, and >2/h for $O_3$ (Nazaroff and Weschler 2021).

The propensity of a building shell to allow air leakage is most commonly characterized by the amount of airflow that occurs when the conditioned area is pressurized or depressurized to a difference of 50 Pa with the outdoors, using a blower door. This parameter is often called cfm50. This parameter can be divided by the conditioned air volume of the house and multiplied by 60 (minutes per hour) to calculate the air change rate per hour at 50 pascals (Pa) pressure differential , ACH50.[17] Air leakage through the forced air heating and cooling system ductwork is specified as the amount of airflow that occurs when the ducts are pressurized to 25 Pa (relative to outdoors), normalized or related to the conditioned floor area (square feet), presented as the cfm25/ft$^2$. As an illustration, a 1,000-ft$^2$ home with 0.06 cfm25/ft$^2$ duct leakage to outside and a forced air system operating at 25 Pa, would have 60 cfm of duct leakage to the outside.

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[16] See https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home. The use of filtration as a mitigation for indoor particulate matter exposures was discussed at a recent workshop; see https://www.nationalacademies.org/our-work/indoor-exposure-to-fine-particulate-matter-and-practical-mitigation-approaches---a-workshop.

[17] ANSI/RESNET/ICC 380-2019. *Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems*. Available at https://www.resnet.us/wp-content/uploads/ANSIRESNETICC_380-2019_vf1.24.19_cover%5E0TOC-2.pdf.

### 3.2.3.4 Air-Tightness and Ventilation Requirements for Manufactured Homes

It is generally accepted that in modern, airtight homes, air leakage alone is not enough to ensure adequate IAQ (ASHRAE 2020). Many studies have addressed the need for mechanical ventilation, as captured by the phrase "build tight, ventilate right." An example is provided by Sherman et al. (2011). The HUD Code (24 CFR 3280) has provisions designed to limit excess air infiltration through the envelope (§3280.505), limit air leaks from the forced air heating and cooling system ducting (§3280.715), reduce the risk of condensation (§3280.504), and ensure robust venting of combustion appliances (§3280.710). Because forced air systems in manufactured homes typically have open returns connecting the conditioned area to the heating and cooling system, most leakage is through the supply ducts, which are typically in the enclosed belly under the floor or sometimes in the attic (McIlvaine et al. 2003).

The HUD Code requires exhaust fans in all bathrooms and kitchen areas, as well as a "whole house" ventilation system, specified in section 103(b). The Code sets minimum airflow rates of 0.035 cfm per square foot of conditioned floor area with lower and upper limits of 50 and 90 cfm. Subsection (b)(1) specifies that the system must not create positive pressure in thermal zones 2 or 3 (most of the United States) or negative pressure in thermal zone 1 (southern United States), and that "mechanical systems must be balanced" with "adequately sized inlets or exhaust to release any unbalanced pressure."

The HUD Code expressly allows mechanical ventilation to be provided by a system that is integral to the heating or cooling equipment, in subsection 103(b)(3). The lowest first-cost version of this approach is an uncontrolled central fan integrated supply (CFIS) system[18] which has a duct connecting the return side of the forced air heating and cooling system to the outside. A schematic of this type of system is shown in Figure 3.2.3-1. Because the return side is at negative pressure when the forced air system is operating, air from outdoors is pulled in and distributed throughout the home via the supply ducts. These systems can have dampers to reduce air leakage to outdoors when the heating and cooling system is not operating and separately can be linked to timers if CFIS airflow capacity exceeds the minimum requirement; however, neither is required in the HUD Code and both add cost.

### 3.2.3.5 Air-Tightness Performance and Ventilation Equipment

Recognizing the importance of ventilation for indoor air quality, the HUD Code requires that the control switch has a label that says "WHOLE-HOUSE VENTILATION" (subsection (b)(5)). Section (b)(6) requires that the homeowners manual include "Instructions for correctly operating and maintaining whole-house ventilation systems" and "encourage occupants to operate these systems whenever the home is occupied." In a home that is occupied most or all the time and equipped with a CFIS ventilation system, using the ventilation as directed can require continuous operation of the central fan.

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[18] See https://www.buildingscience.com/documents/information-sheets/information-sheet-ventilation-system.

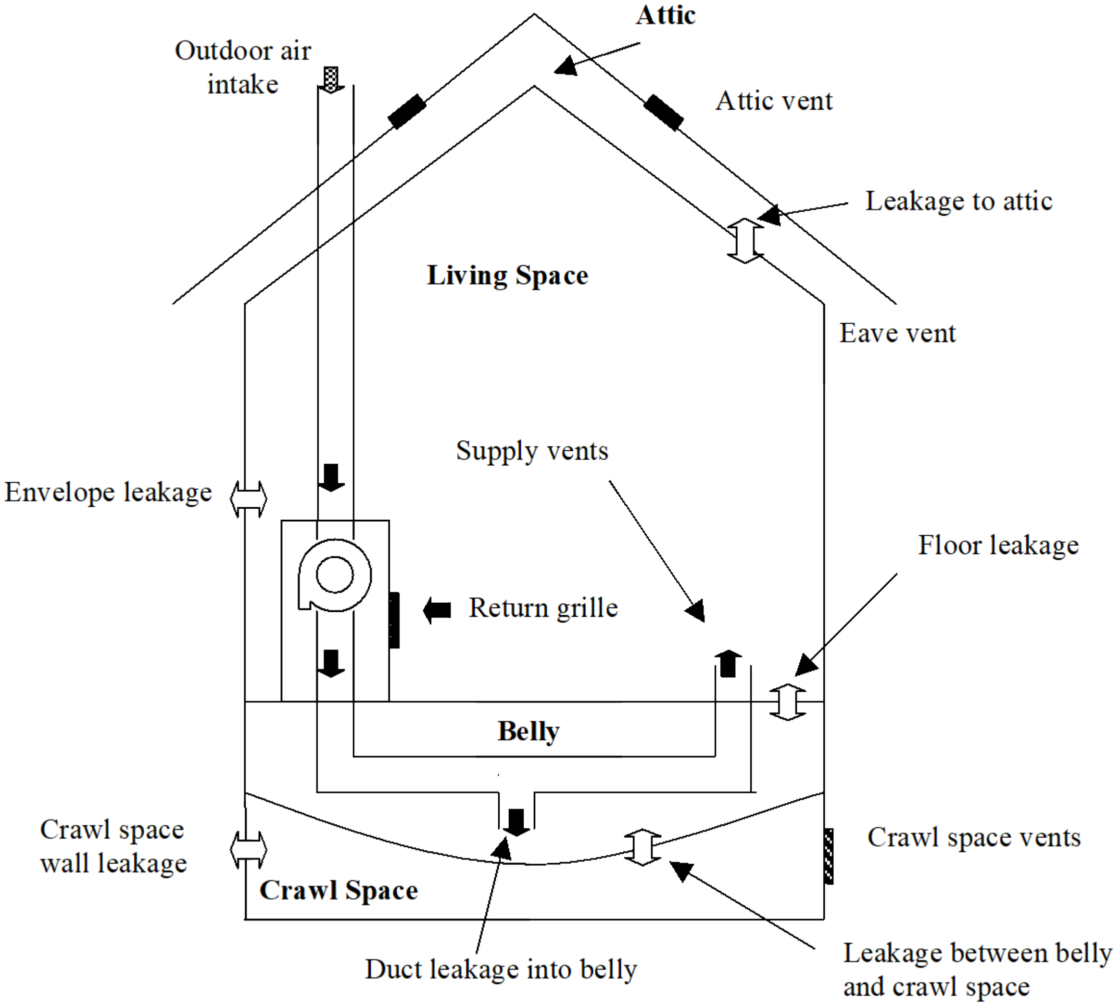

**FIGURE 3.2.3-1. Schematic of Central Fan Integrated Supply Ventilation (Source: Nabinger and Persily 2008)**

The basic mechanical ventilation systems required in the HUD Code — bathroom, kitchen, and whole-house ventilation systems — are similar to the core requirements of the ASHRAE/ANSI Standard 62.2, Ventilation and Acceptable Indoor Air Quality in Residential Buildings.[19] The ASHRAE standard has been updated on a 3-year cycle since 2004, and the most recent version was published in 2019. There are some important distinctions among the HUD Code, Standard 62.2, and IECC-2021, as noted in the comparison presented in Appendix B (Section B.3.2.3). Among the differences are requirements for airflow verification and exhaust fan sound limits that are in the 62.2 but not the HUD Code — and airflow rates required for the whole-house ventilation system are somewhat different. A 2012 Government Accountability Office (GAO) report identified lack of ventilation airflow verification in manufactured homes as a concern. A January 2021 revision to the HUD Code allowed but did not require that provisions of

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[19] See https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_62.2_2019.

the 2010 version of Standard 62.2 could be used in place of the requirements in subsections 103(b) and 103(c).

Two studies conducted in the past decade provide data on air-tightness in manufactured homes produced to meet the HUD Code, but not additional standards such as Energy Star. These studies suggest envelope air leakage of approximately 8 ACH50 for a minimally compliant HUD Code home, with only about 10 percent of the homes having higher air leakage (the unit of ACH50 is explained in Section 3.2.3.3). The data also show that many manufactured homes produced since 2000 have tighter envelopes, with mean values of 5 to 6 ACH50. See Appendix B for study details.

The average and range of leakage from the forced air heating and cooling distribution ducts to the outside is uncertain, but almost certainly much lower than the total duct leakage values that were used to calculate energy losses.

As discussed in McIlvaine et al. (2003), duct leakage measurements can report total air leakage from the ducts or air leakage to the outside. For the most common configuration of a forced air system located in a closet with a louvered return directly connecting the unit to the living space, all or almost all ducting will be on the supply side and leakage will be out via the supply ducts. Ducts are most commonly located in the enclosed belly, beneath the floor of the unit, and sometimes in the attic. Some of the air that leaks from ducts into the belly space will return into the conditioned space as air infiltrates from the belly up through the floor.

Pigg et al. (2016) reported results of onsite measurements of duct leakage for homes in Minnesota. They noted that leaks are common at the joints connecting the furnace through the floor, at the boots for supply registers and at the junctions connecting the duct systems of the individual sections. They used several measurement techniques to distinguish leakage to the outside from total leakage. For homes built since 2000, they reported an average of 72 percent leakage to outside. Data from the study (provided by the lead author) indicate mean and median total leakage (by duct pressurization test) of 0.06 and 0.05 cfm25/sf.

As supply duct leakage moves air from the conditioned space into the belly or attic, it appears to conflict with the intent of section 103(b)(2) of the HUD Code which stipulates "The ventilation system or provisions for ventilation must not draw or expel air into the floor, wall, or ceiling/roof systems, even if those systems are vented." For a 1,500-ft$^2$ home, total duct leakage of 0.06 to 0.12 cfm25/ft$^2$ translates to 90 to 180 cfm of airflow into the area containing the ducts.

Substantial published data about the current prevalence of each type of ventilation system (balanced, exhaust, CFIS) in U.S. manufactured homes are not available. The available information suggests that continuous exhaust and CFIS systems are common, and balanced systems are much less common. A recent study conducted by the Aries Collaborative (Levy et al. 2016), which works with manufacturers throughout much of the United States, used a CFIS system in two test homes that were built to represent "a design meeting best-practice codes according to the U.S. Department of Housing and Urban Development (House A)" and "a manufactured home conforming to typical ENERGY STAR® ratings (House B)." In describing the choice of ventilation system, the report noted that "whole-house ventilation in House A and House B is achieved through the air handling unit, as is typical for manufactured homes." It is noteworthy that the continuous airflow rates measured when the CFIS systems were operating in houses A (HUD Code) and B (Energy Star) were only 44 and 36 cfm (i.e., below the minimum requirement of the HUD Code). Although no other data about ventilation airflows in operational CFIS ventilation systems in manufactured homes were identified, there have been several studies that reported on the performance of CFIS systems in site-built homes (Sonne et al. 2015; Martin et al. 2020). These studies found that CFIS systems often have airflow rates that are less than the requirements of HUD Code or 62.2.

The study of manufactured homes in Minnesota (Pigg et al. 2016) identified other concerns about inadequate mechanical ventilation. Site visits found low bath fan airflow in 52 of 99 homes, with average airflow of 27 cfm, a third of fans moving less than 20 cfm, and one in seven moving less than 5 cfm. The report noted examples of bath fans being improperly vented into the attic and causing moisture damage on the ceiling around the bath fan. Inadequate mechanical ventilation can result in high indoor humidity, and lead to dampness and mold problems.

#### 3.2.3.6 Use of Ventilation

Management of IAQ in manufactured homes and specifically air pollutant concentrations depend on effective use of the HUD Code-required mechanical ventilation equipment (Sherman et al. 2011). While data were not found about the frequency of mechanical ventilation use in manufactured homes, but available data from site-built homes provide insights. First, evidence suggests that there is substantial difference between homes with continuous exhaust ventilation and those with CFIS systems. Several field studies found that in site-built homes with CFIS, the systems typically were not operating to provide ventilation at the rate required by the standard. Even when a system had the capacity to meet the standard, it was often turned off or set to operate for only a fraction of the time required (Sonne et al. 2015; Martin et al. 2020). A recent study in California found that in site-built homes with continuous exhaust ventilation and reasonably clear signage on the on/off ventilation fan controller, 58 percent (7 of 12) had the system running when researchers arrived (Chan et al. 2020). By contrast, only 2 of the 42 homes (5 percent) with exhaust ventilation and on/off switches without a clear label had ventilation operating.

An important factor impacting the use of CFIS whole-house ventilation in manufactured homes may be cost. If one considers a central forced air system that provides the required minimum airflow and operates 20–30 percent of all minutes during the year to provide heating and cooling (Touchie and Siegel 2018), the system would need to operate for ventilation during the other 70 to 80 percent of the time, about 6,100–7,000 hours. If the central fan requires 150–300 W of power, the annual energy cost to run the fan continuously for ventilation would be 920–2,100 kWh. At an average electricity price of $0.13/kWh, the annual cost for ventilation would be about $120–270.

#### 3.2.3.7 Pollutant Concentrations

Many studies have measured and reported air pollutant concentrations and other IAQ parameters in U.S. homes, but few have reported data specifically from manufactured homes. The one prominent exception is a study of the IAQ impacts of weatherization reported by Pigg et al. (2014, 2018), which included 113 manufactured homes. The study provides relevant data for radon (results are provided later in this section),; however, the data reported for formaldehyde are not relevant to current conditions because most of the homes in the study were built years to decades ago, well before the Formaldehyde Standards for Composite Wood Products Act of 2010.[20] In addition, the carbon monoxide concentrations measured in that study are the result of degraded gas and propane appliances that are not representative of equipment that would be installed in homes built today or in the future. Also note that multiple DOE requests for information related to this standard yielded no submissions of new field data. An assessment of typical values and ranges of air pollutant concentrations in manufactured homes is therefore not straightforward and must rely on careful consideration of studies conducted primarily or exclusively in site-built homes.

In a broad assessment, Logue et al. (2011) compiled published data on chemical air contaminants in homes using results from 77 studies conducted through the mid-2000s, including all types of residential buildings, and as well as studies from other developed nations in addition to the United States. They compared the reported concentrations to safety targets for non-cancer and cancer hazards and identified nine contaminants that were often above established safe levels: acetaldehyde, acrolein, benzene, 1,3-butadiene, 1,4-dichlorobenzene, formaldehyde, naphthalene, nitrogen dioxide, and $PM_{2.5}$. The compiled data also showed that activities (including unvented heater use) could produce short-term levels of $PM_{2.5}$, formaldehyde, CO, chloroform, and $NO_2$ that can, under some conditions, approach or exceed hazard thresholds.

A follow-up analysis by Logue et al. (2012) calculated the aggregate harm caused by many physical and chemical contaminants, based on reported concentrations and health risk multipliers. That analysis identified the dominant contributors to health impacts from non-biological air pollutants in homes as $PM_{2.5}$, secondhand smoke (SHS), radon in the homes of smokers, formaldehyde, acrolein, radon in the homes of nonsmokers, $O_3$, and $NO_2$. In a 2009 review, Weschler (2009) noted that concentrations of many air pollutants had decreased in U.S. homes over the prior two decades, but others had increased.

Although the studies described above are informative, they cannot be used to develop estimates of pollutant concentrations and exposures in U.S. manufactured homes today. The following paragraphs explain the studies that were selected for this purpose. The goal was to identify data that met as many of the following criteria as possible: broadly representative of the general population or focusing on low-income households; single-detached homes located outside of urban centers preferred; providing data focused on specific sources such as smokers for $PM_{2.5}$ and gas cooking burners for $NO_2$; for formaldehyde, constructed with materials that are compliant with current emission regulations; preference for larger studies and longer sampling periods; and emphasizing studies conducted in the United States or Canada because construction materials, building standards, and occupant activities may vary greatly in other countries. The selected studies are described in Appendix B (Section B.3.2.3), including summary statistics. They are also summarized in the figures and discussion below.

Representative $PM_{2.5}$ concentrations from the selected studies are plotted in Figure 3.2.3-2. The most significant factor for $PM_{2.5}$ is whether smoking occurs in the home. The selected studies include several that sampled both in homes with smokers and with no smokers, enabling direct comparisons. The impact of smoking is informed by Wallace et al. (2003), who reported a mean

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[20] See https://www.federalregister.gov/documents/2016/12/12/2016-27987/formaldehyde-emission-standards-for-composite-wood-products.

increment of about 37 $\mu g/m^3$ based on 101 homes with smokers and 193 homes without smokers. The studies reported in Williams et al. (2003; also described in Wallace et al. 2006) and Doll (2017) were modest in size but done in homes and communities in North Carolina that are relevant to manufactured housing by construction type and region, and both had some homes with smoking.

The Kang et al. (2022) study was in Chicago, but focused on weatherization; it provided data about the benefits of mechanical ventilation. Zhao et al. (2021) featured a substantial amount of cooking in a collection of low-income apartments. The study of recently constructed California homes reported by Singer et al. (2020) is included as a bounding case of large homes with low occupant density and operating mechanical ventilation. The Relationship of Indoor Outdoor and Personal Air study reported by Weisel et al. (2005) had a diverse range of housing types. Too few data are available for a high-confidence conclusion, but it is notable that the data from recent years (Doll 2017; Kang et al. 2022; Singer et al. 2020; Zhao et al. 2021) report much lower $PM_{2.5}$ than older studies, and the Weisel et al. (2005) data in particular are much higher than data from other studies.

Representative $NO_2$ concentrations from the selected studies are plotted in Figure 3.2.3-3. For $NO_2$, the focus was on studies conducted in homes with gas cooking burners. Mullen et al. (2016) oversampled homes with higher risk factors, such as smaller size. Logue et al. (2014) was a simulation study, but used measured data for all relevant parameters, including an actual sample of home sizes and self-reported cooking frequencies. Zhao et al. (2021) reported $NO_2$ concentrations in low-income apartments with gas burners, as well as a 40-home subset of the homes from Singer et al. (2020) that had substantial cooking activity.

Representative acrolein concentrations from the selected studies are plotted in Figure 3.2.3-4. These data are from measurements made by Health Canada in hundreds of homes in Canadian cities in 2005–2010. They also provide a limited subsample of from homes with smokers. Reports of these studies and summary data are provided on the Health Canada public website. The data presented for chloroform, p-dichlorobenzene, and naphthalene are from a Canadian national study reported by Zhu et al. (2013), which included a broadly representative sample of thousands of homes and households that are similar to U.S. homes.

Formaldehyde is a challenging pollutant to evaluate because (1) concentrations decrease over the first few years after a home is built and continue to decrease over time, so older homes cannot be used to represent newer homes (Park and Ikeda 2006); and (2) the homes had to be built after the regulations limiting formaldehyde emissions from manufactured wood products took effect. These criteria are satisfied by a California-based study of recent model years as described by Singer et al. (2020) and a study that used similar methods to sample homes in Colorado and Oregon (PNNL 2020). The health implications of the residential air pollutant concentrations presented here are discussed in Section 3.3

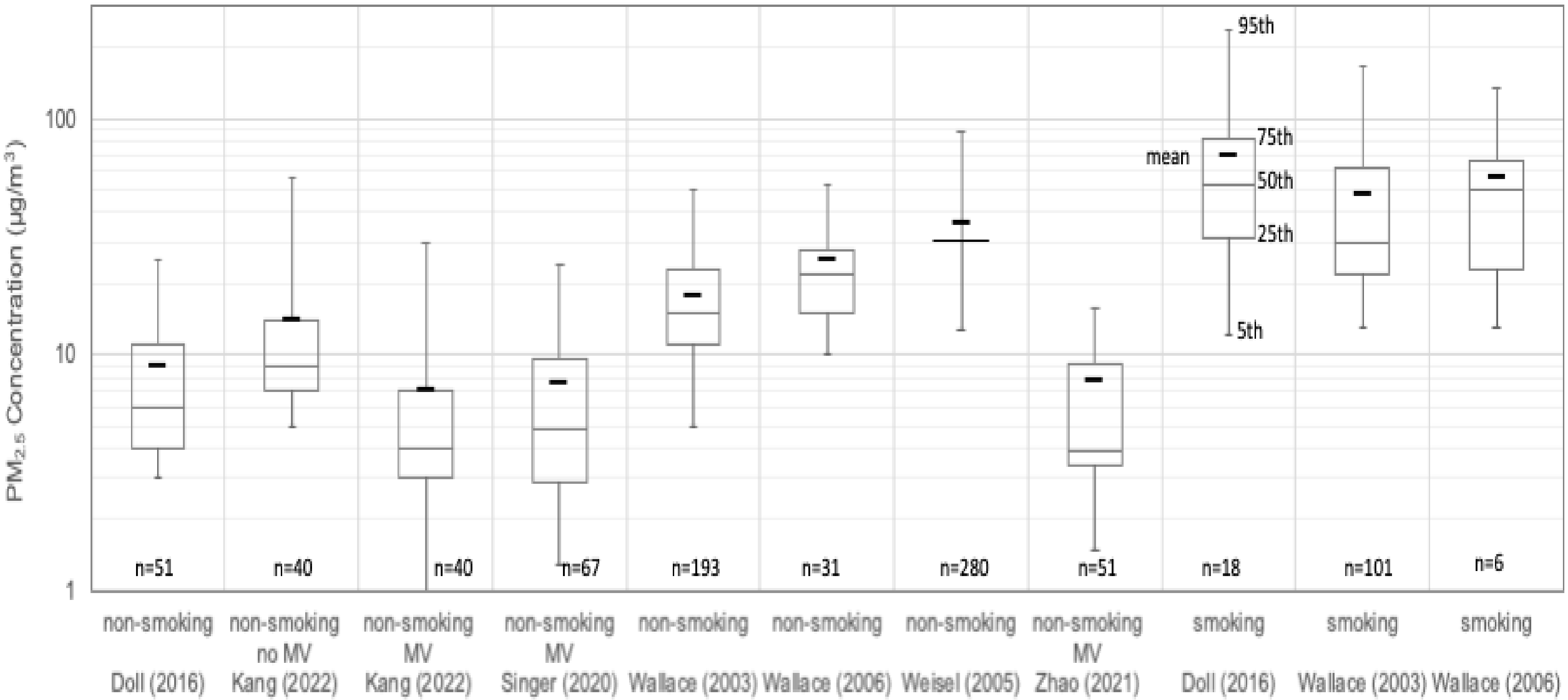

**FIGURE 3.2.3-2 PM$_{2.5}$ Reported in Studies Selected as Potentially Informative of Conditions in U.S. Manufactured Homes Produced in Recent and Upcoming Years** *(MV is mechanically ventilated)*

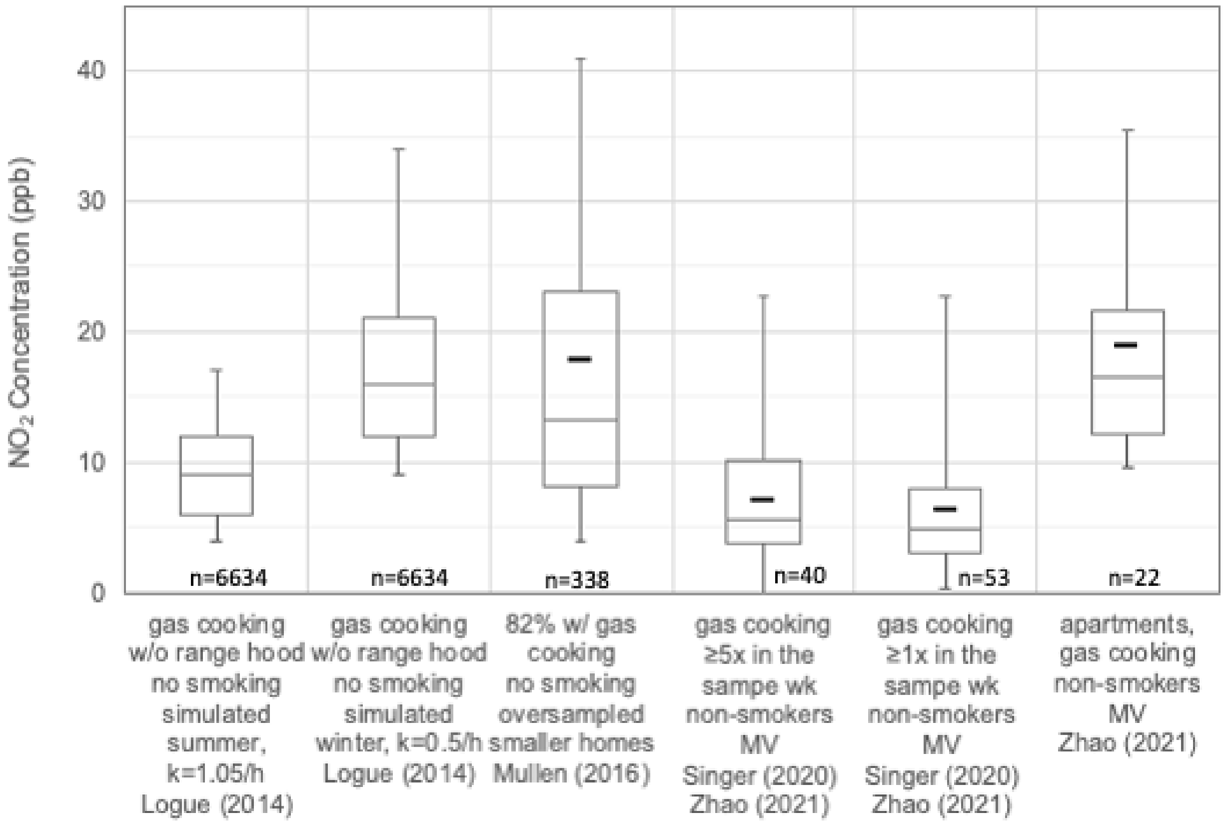

**FIGURE 3.2.3-3 $NO_2$ Reported in Studies Selected as Potentially Informative of Conditions in U.S. Manufactured Homes Produced in Recent and Upcoming Years** *(MV is mechanically ventilated)*

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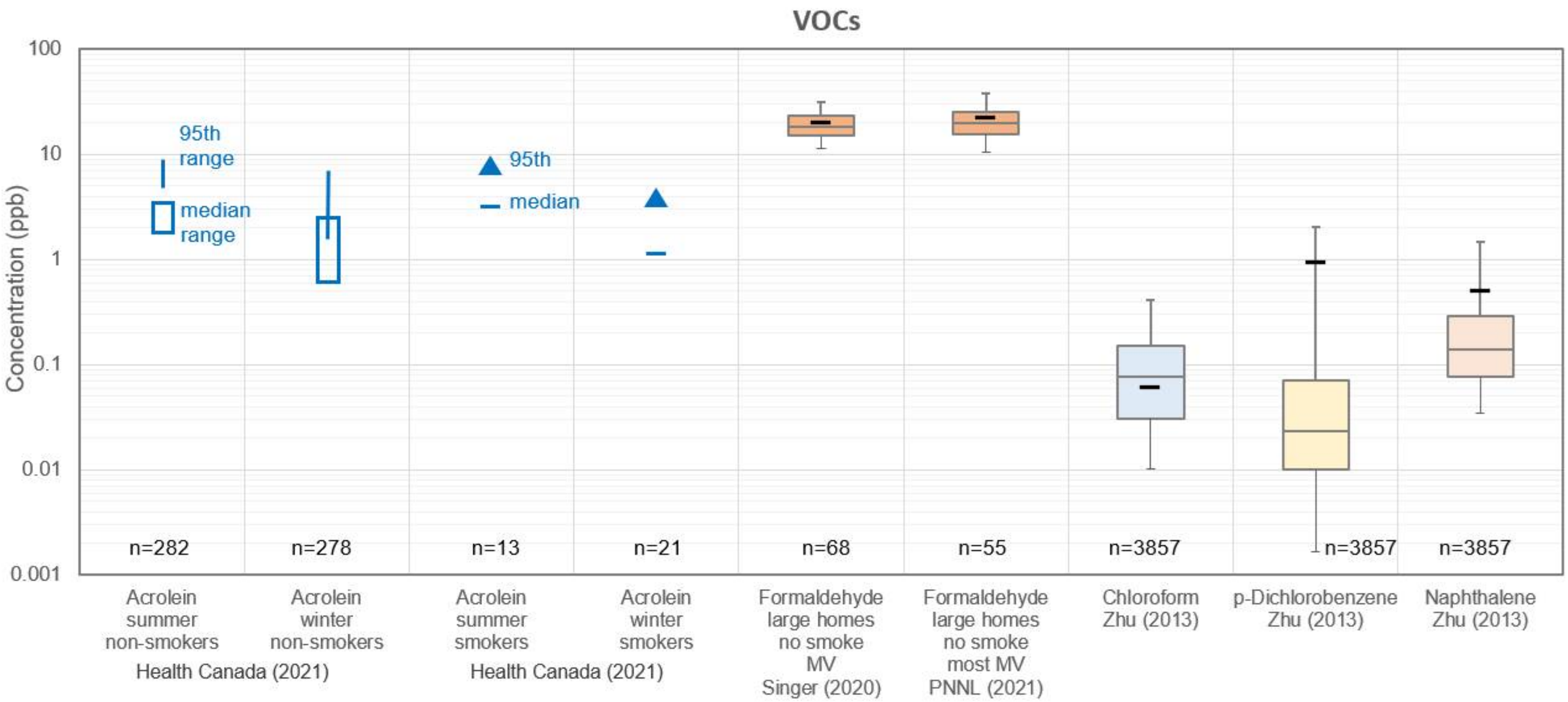

**FIGURE 3.2.3-4 Acrolein, Formaldehyde, and Other VOCs Reported in Studies Selected as Potentially Informative of Conditions in U.S. Manufactured Homes Produced in Recent and Upcoming Years**

#### 3.2.3.8 Humidity, Dampness, and Mold

Despite the requirements in the HUD Code for vapor retarders and ventilation systems, it was recognized in the early 2000s that dampness and mold issues were present in many manufactured homes, and several studies were conducted to identify the causes and solutions. For example, a study of 25 moisture-damaged manufactured homes in hot and humid climates (Moyer et al. 2001) found that all 25 homes had a forced air distribution system that would generally be considered oversized. Most had significant duct leakage that caused the building to operate at negative pressure. Ventilation systems were usually not used, or were disabled. The belly board (vapor retarder) contained numerous holes, penetrations, and tears. They were typically repaired with duct tape that subsequently failed.

Inadequate mechanical ventilation can result in high indoor humidity, which can lead to dampness and mold problems. The concern of inadequate ventilation was raised by Baylon et al. (2009) for Northwest Energy Efficient Manufactured Homes (2006) homes and by Pigg et al. (2016) for HUD Code manufactured homes in Minnesota. Both studies noted that ventilation fans were undersized and many also performed below specifications, leading to low airflow from ventilation systems installed in manufactured homes. Examples of nonfunctioning ventilation equipment or ventilation systems turned off by occupants are common. Pigg et al. (2016) also noted examples of bath fans improperly vented into the attic, which caused water damage on the ceiling around the bath fan. Occupants and their activities add substantial humidity to homes. Tenwolde and Walker (2001) and Walker and Sherman (2007) summarize the various sources and their magnitudes.

### 3.2.4 Wildfire Impacts on Air Quality

Wildfires are occurring with increasing frequency and intensity due to accumulated fuels from fire suppression over many decades, combined with extended hot, dry conditions associated with climate change (Abatzoglou and Williams 2016; Dennison et al. 2014; Schoennagel et al. 2017, USGCRP 2018; Westerling et al. 2006). To illustrate, 5 of California's 20 largest wildfires in history occurred during 2020 (CAL FIRE 2021).

The contribution of wildfires to ambient $PM_{2.5}$ concentrations has markedly increased over the past decade, now accounting for up to half of overall $PM_{2.5}$ exposures in the western United States. Although many large fires have occurred in the west, their impact on air quality extends far beyond that region, as the smoke is transported across midwestern and eastern states (Burke et al. 2021).

A single wildfire event can produce $PM_{2.5}$ levels that exceed the NAAQS over large regions for days to weeks (EPA 2021a; Nazarenko et al. 2021; Ryan et al. 2021). For example, daily average concentrations of ambient $PM_{2.5}$ in Fresno, California, intermittently exceeded the NAAQS during four and a half months in late summer through fall of 2020, as shown in Figure 3.2.4-1. This figure illustrates EPA ambient monitoring data during two of California's major fire events, the August Lightning Siege wildfires and the Creek Fire that burned between early September and late December 2020.

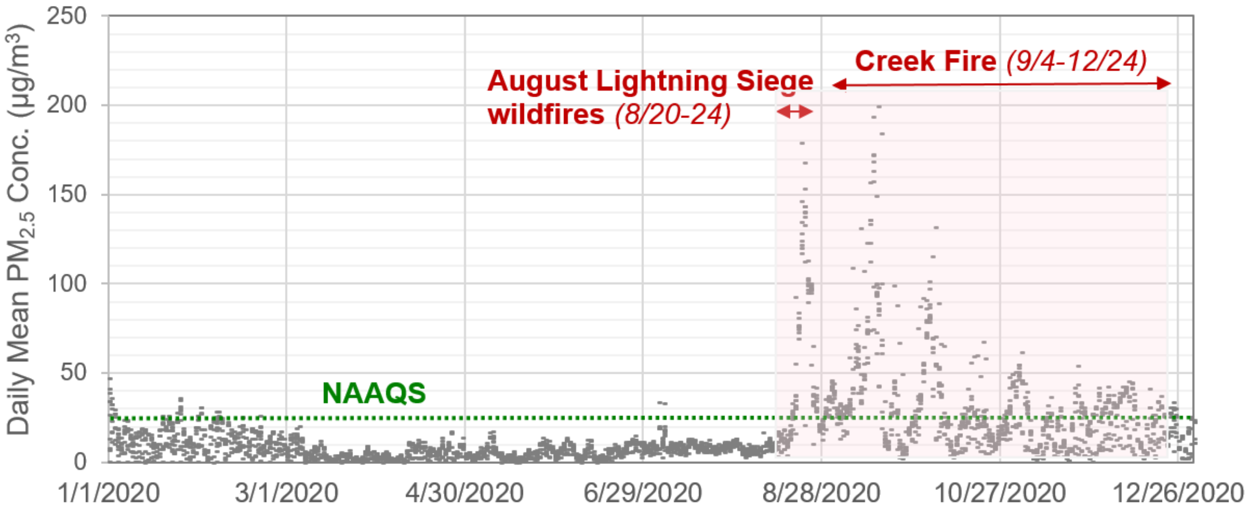

**FIGURE 3.2.4-1 Daily Mean $PM_{2.5}$ Concentrations during the 2020 Wildfire Season in Fresno, California (data source: EPA 2021b)**

A common public health recommendation during wildfire smoke events is to stay indoors with the windows closed (EPA 2021a). Using crowdsourced data from a network of low-cost air quality monitors placed inside and outside of homes, Liang et al. (2021) showed that the infiltration factor (IF) for a home (i.e., the ratio of indoor-to-outdoor concentrations of outdoor $PM_{2.5}$) was much lower during several 2020 California wildfire events (geometric mean [GM] of 0.2) compared to non-fire days (GM of 0.4). May et al. (2021) reported a similar pattern.

Both envelope and duct air-tightness help reduce the indoor concentration of outdoor particles (Stephens 2015) and thus improve the protective quality of homes under wildfire conditions. One distinct challenge of minimizing infiltration of outdoor particles during a fire event is the role of duct leakage in driving airflow, because air conditioning is often needed and used (as wildfires typically occur when conditions are hot and dry). Air-sealing of ducts is therefore particularly helpful in reducing indoor exposure to wildfire smoke.

The smoke from wildfires contains $PM_{2.5}$, $NO_2$, and a number of hazardous air pollutants, including acrolein and formaldehyde (EPA 2021a; O'Dell et al. 2020). Exposures to elevated levels of wildfire smoke have been linked to adverse respiratory health outcomes in adults and children, including bronchitis and asthma (Aguilera et al. 2021a; Cascio 2018; Leibel et al. 2020; Liu et al. 2021b; Matz et al. 2020). Furthermore, there is evidence that fine particles from wildfires may be more harmful to respiratory health than fine particles from other sources (Aguilera et al. 2021b).

The health risks from exposure to indoor air pollutants under existing conditions (described in Section 3.3 for $PM_{2.5}$, $NO_2$, acrolein, and formaldehyde) would increase during wildfire events because of outdoor contributions to indoor concentrations. These increases would be greater in homes that have higher air leakage, assuming windows are closed during wildfire events and mechanical ventilation is turned off to avoid actively bringing the more polluted outdoor air inside.

Both individual- and community-level vulnerability and risk factors exist for health impacts associated with exposures to wildfire smoke. These factors include county prevalence rates for asthma, chronic obstructive pulmonary disease, hypertension, diabetes, and obesity; as well as percentage of the population age 65 or older and indicators of socioeconomic status that include poverty, income, and unemployment (Rappold et al. 2017). Note that poverty is also a factor considered in assessing environmental justice, as described in Section 3.5.

## 3.3 HEALTH and SAFETY

This section addresses health and safety aspects of indoor air pollutants in manufactured homes. It is organized according to the four main elements of the risk assessment process:

- Hazard identification: Assess pollutants commonly present in indoor air of existing homes at concentrations that could exceed health-based standards and guidelines, and identify the nature of potential health effects from inhaling these pollutants.
- Exposure assessment: Estimate the amount of exposure a hypothetical manufactured home resident might experience (i.e., how much could be taken in, how often, for how long).
- Toxicity assessment: Determine whether a standard inhalation toxicity reference value or cancer risk estimator has been developed by EPA, California EPA (CalEPA), or other expert group through a peer-reviewed process that represents current understanding of the exposure- (dose-) response relationship (i.e., the exposure levels corresponding to adverse effects); alternately, determine whether a health-based standard or guideline is available.
- Risk characterization: Combine the exposure estimate with the appropriate toxicity value to estimate the potential for an adverse noncancer effect or risk of cancer incidence, or compare to a health-based standard or guideline.

The hazard identification step for this risk assessment of residential indoor air pollutants under existing conditions is discussed in Section 3.3.1. The exposure assessment is described in Section 3.3.2, and the toxicity assessment is discussed in Section 3.3.3. The risk characterization is presented in Section 3.3.4. Supporting details are presented in Appendix B.

### 3.3.1 Hazard Identification

To define the set of indoor air pollutants for this evaluation, the indoor air literature was examined and public comments on the June 2016 draft EA-RFI and July 2021 EIS scoping were reviewed to understand health concerns and pollutants of interest to the public (see Appendix A). Several categories of indoor air pollutants are considered.

The CAA designated a set of criteria air pollutants that were known at the time to cause harm at levels present in air at a number of locations across the country. These criteria pollutants include $NO_2$, $O_3$, and particulate matter. The CAA Amendments of 1990 specified a list of 190 chemicals that were mass produced for industrial uses and were understood to pose a potential health hazard at elevated exposure levels; these were designated hazardous air pollutants, or air toxics. For many of these pollutants, the concentrations that would pose a health concern only occurred around industrial activities; however, some are present in materials and products used in homes or otherwise related to residential activities. Other indoor air pollutants are naturally occurring, such as radon and biological materials. Air pollutants often found in indoor air and the types of hazards (health effects) that have been linked to elevated exposure levels are identified in Table 3.3-1. This set includes several specifically suggested in response to the request for information that accompanied the 2016 draft EA.

The hazards linked with elevated exposure to these pollutants include both cancer and noncancer endpoints, such as lung cancer, respiratory and cardiovascular diseases, risk of premature death, and symptoms related to irritant properties, allergies and other immune system challenges (CDC and HUD 2011; EPA 2021a). This set of pollutants includes three criteria pollutants, several air toxics, radon, and biological contaminants, which are discussed as a group. Secondhand tobacco smoke is also discussed as a mixture that includes $PM_{2.5}$, $NO_2$, acrolein, and other air toxics. Brief descriptions follow the table.

**TABLE 3.3-1 Health Effects Associated with Pollutants Found in Indoor Air**

| Pollutant | Health Effects |
|---|---|
| Acrolein | Can cause general respiratory congestion and irritate eyes, nose, and throat. |
| Biological contaminants | Molds and mildews release natural toxins that can cause sneezing, watery eyes, coughing, shortness of breath, dizziness, lethargy, fever, and digestive problems; animal dander as well as feces and body parts of dust mites and other pests can trigger allergic reactions, such as hypersensitivity pneumonitis, allergic rhinitis, and some types of asthma. Virus transmission occurs via respiratory aerosols that are expelled during sneezing, coughing, speaking and even normal breathing. |
| Chloroform | High doses affect the central nervous system (brain), liver, and kidneys. |
| 1,4-Dichloro-benzene | Acute exposure to high concentrations can result in irritation of the skin, throat, and eyes. Chronic inhalation exposure results in effects on the liver, skin, and central nervous system. |
| Fine particulate matter ($PM_{2.5}$) | Linked to premature death in people with heart or lung disease, nonfatal heart disease, aggravated asthma, decreased lung function; irritates eyes, nose, and throat; aggravates coronary and respiratory disease symptoms. |
| Formaldehyde | Can irritate eyes, nose, throat, and skin; can increase breathing problems for those with asthma, chronic obstructive pulmonary disease, and other conditions; exposure to relatively high concentrations havs been associated with some types of cancer. |
| Naphthalene | Acute exposure is associated with hemolytic anemia, damage to the liver, and neurological damage. Chronic exposure reported to cause cataracts and retina damage. |
| Nitrogen dioxide ($NO_2$) | Irritates airways; aggravates respiratory disease, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing, or difficulty breathing). |
| Ozone ($O_3$) | Can cause coughing, shortness of breath, asthma or bronchitis symptoms, and irritation and damage to airways. Long-term exposure linked to aggravation of asthma. |
| Radon | Leading cause of lung cancer in non-smokers. Increases risk in smokers, causing an estimated 21,000 total deaths and 2,900 deaths of nonsmokers each year in the United States. |
| SHS | Can cause cancer, emphysema, chronic obstructive pulmonary disease, cardiovascular and other diseases, and respiratory problems and middle-ear infections in children. |

#### 3.3.1.1 Acrolein

Acrolein is emitted from materials and from heating of oils during cooking. The data presented in Section 3.2.3 from large studies in four Canadian cities suggest that concentrations in U.S. homes commonly exceed the inhalation reference value discussed in Section 3.3.3.As a chemical emitted primarily from indoor sources, acrolein concentrations are sensitive to air exchange and would be impacted by changes to air infiltration rates with air sealing.

#### *3.3.1.2 1,4-Dichlorobenzene.*

The main sources in the home are mothballs and toilet deodorizers. Several large studies including the Canadian national study reported by Zhu et al. (2013) reported very high concentrations of dichlorobenzene that exceed reference levels; but only in a very small percentage of the homes studied. This suggests that it is a problem related to the overuse of products containing the chemical, and not one that will be impacted by changes to air infiltration related to air sealing.

#### 3.3.1.3 Formaldehyde

The largest source of formaldehyde in homes is manufactured wood products, and emissions from those are regulated by the Formaldehyde Standards for Composite Wood Products Act. Data presented in Section 3.2.3 from two recent studies that measured formaldehyde in homes built with materials meeting the standard showed lower levels relative to prior studies, but concentrations still exceed reference values, as discussed in Section 3.3.3.Similar to acrolein, formaldehyde levels in homes would be impacted by changes to outdoor air exchange rates from air sealing.

#### 3.3.1.4 Fine Particulate Matter ($PM_{2.5}$)

$PM_{2.5}$ enters residences from outdoor air and is emitted indoors by cooking, residential combustion, and various other activities. Using the metric of disability-adjusted life years, Logue et al. (2012) assessed that $PM_{2.5}$ is responsible for more harm than any other air pollutant in homes. Both the entry of $PM_{2.5}$ from outdoors and the clearance of $PM_{2.5}$ emitted from indoor sources are affected by outdoor air exchange rate and thus by changes to air leakage. The $PM_{2.5}$ data discussed in Section 3.2.3 indicate that the NAAQS annual average target of 12 $\mu g/m^3$ was commonly exceeded in nonsmoking U.S. homes two decades ago. Studies that reported measurements in homes in more recent years (mid- to late 2010s) — including in low-income homes (Doll et al. 2016; Zhao et al. 2021; Kang et al. 2022) and specifically in a sample with a high proportion of manufactured homes (Doll et al. 2016) — suggest that $PM_{2.5}$ may be substantially lower now. The relatively small sample sizes of recent studies and the dearth of data from manufactured homes leave considerable uncertainty about the number of manufactured homes with concentrations above the NAAQS today.

***3.3.1.5Naphthalene.*** The primary source of naphthalene in homes is mothballs. Similar to 1,4-dichlorobenzene, naphthalene appears to be present at concentrations that exceed reference levels for safety in only a very small percentage of homes, with most homes having concentrations well below the reference. It is therefore not considered further in the assessment of impacts.

#### 3.3.1.6 Nitrogen Dioxide ($NO_2$)

The main sources of $NO_2$ in homes are entry from outdoors, recreational combustion (principally smoking), and emissions from the use of natural gas cooking burners. A substantial record of published data — including a measurement study of hundreds of homes with oversampling for higher risk conditions (Mullen et al. 2016) and data-supported simulations at the population level (Logue et al. 2014) — indicate that it is unlikely that the NAAQS annual average benchmark concentration is exceeded in manufactured homes. Measurement (Singer et al. 2017) and simulations (Logue et al. 2014) indicate that the 1-hour NAAQS standard of 100 parts per billion (ppb) is likely exceeded in a substantial fraction of homes that have and use natural gas cooking burners. However, the exceedance of the this 1-hour standard is determined by the intensity of specific cooking events and whether or not kitchen ventilation is used effectively. (It is not substantially impacted by envelope or duct airtightness or any other element of the manufactured housing efficiency standards being proposed.)

#### 3.3.1.7 Ozone ($O_3$)

Outdoor air is the main source of indoor $O_3$. The mean indoor/outdoor ratio of $O_3$ has been reported to vary from less than 0.10 to greater than 0.60 in studies conducted over the past 30 years, as summarized by Nazaroff and Weschler (2021). Studies conducted since 2000 had a lower range, 0.05 to 0.29. This is mostly because $O_3$ is a strong oxidant that interacts with other gases and surfaces inside the home, and its lifetime is short — a few tens of minutes (Liu et al. 2021a) — with a deposition rate likely exceeding 2/h (Nazaroff and Weschler 2021). Measured concentrations in residences are generally well below the ambient air quality standard of 70 ppb averaged over 8 h. $O_3$ concentration in homes is expected to be reduced by increasing air-tightness, because this would slow the supply of $O_3$ from outdoors relative to removal.

#### 3.3.1.8 Radon

The EPA estimates that indoor radon is elevated in as many as 6 million U.S. homes (ALA et al. 1994) and that it is responsible for about 21,000 lung cancer deaths a year (EPA 2021aa). The EPA's action level above which mitigation is recommended is 4 picocuries per liter (pCi/L), which translates to a risk of about 7 additional cancers for every 1,000 people exposed at that level over a lifetime. The risk for smokers is estimated to be about 8.5 times higher (EPA et al. 2016, 2021aa). Owing to the common architecture of a ventilated crawl space below the sealed belly on the underside of manufactured homes, the conditioned areas tend to be less connected to the ground, resulting in lower radon concentrations. In a study of weatherization impacts on IAQ, Pigg et al. (2018) reported pre-weatherization geometric mean radon levels of 0.5 pCi/L compared to a geometric mean of 1.3 pCi/L for site-built homes. The study also reported a decrease of 0.3 pCi/L in radon concentrations among the manufactured homes post-weatherization, which included air sealing and installation of mechanical ventilation.

In a study of 51 homes at the Navajo Nation, Yazzie et al. (2020) reported that mobile (i.e., manufactured) homes had the lowest radon of any of the home types measured; roughly half that of the homes built on site with wood or wood and brick. It is unknown how many manufactured homes in the United States have long-term radon concentrations in excess of the action level. HUD, the CDC, and the EPA all recommend that every home be tested for radon, especially if it is in an area that has been determined to have either moderate or higher radon concentrations; additional information on the locations of elevated radon (which generally do not coincide with areas of substantial manufactured housing) is presented in Appendix B.

#### 3.3.1.9 Secondhand Smoke (SHS)

Also called environmental tobacco smoke (ETS), SHS is comprised of the smoke emitted from the burning end of the cigarette and pollutants exhaled by the smoker. SHS contains largely the same mixture of chemicals present in the smoke inhaled by the smoker, including fine particular matter, ultrafine particles, acrolein, formaldehyde, and other air toxics. In the United States, the EPA estimates SHS is responsible for about 3,000 lung cancer deaths each year among nonsmokers (EPA 2021aa). About 1 in 5 U.S. adults 18 and older reported using tobacco products, and about 80 percent of these adults use combustible products (Cornelius et al. 2020); this translates to about 17 percent of U.S. adults smoking cigarettes, cigars, or pipes, and the percentage increases as annual household incomes decrease (see Figure 3.3-1). Considering the median household income for manufactured homes (see Section 3.4), these data suggest a likely smoking prevalence of more than 20 percent among occupants of manufactured housing.

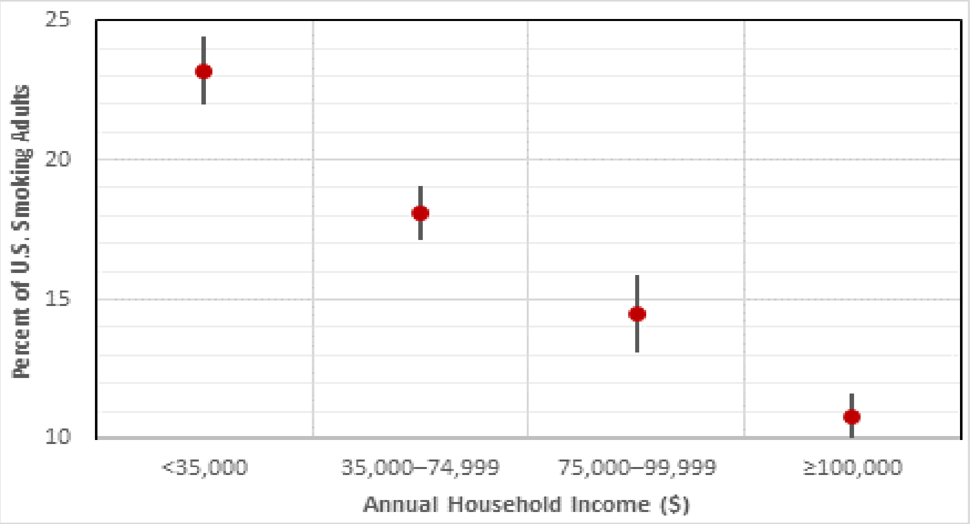

**FIGURE 3.3-1 Percentage of Smokers by Annual Household Income (circles = means; bars = 95th percentile confidence intervals)**

Many households, including many with smokers, have bans or restrictions on indoor smoking. In many others, smoking behaviors may be modified to reduce impacts on nonsmoking cohabitants, for example through use of supplemental ventilation (windows, exhaust fans, etc.), and physical and temporal spacing. The prevalence of smoking bans, restrictions, and controls of SHS in manufactured housing is not known. In homes employing no controls, exposure changes can be estimated from the analysis conducted for general activity-related $PM_{2.5}$. Based on the compilation of measured $PM_{2.5}$ in homes with smokers (see Section 3.2.5), it is very likely that when smoking routinely occurs in a home, $PM_{2.5}$ concentrations will exceed the annual and often also the daily NAAQS for $PM_{2.5}$.

#### 3.3.1.8 Biological Contaminants

Indoor dampness and mold are associated with increases in coughing, wheezing, asthma exacerbation, shortness of breath, and other respiratory effects (Mendell et al. 2011). An estimated 21 percent (ranging from 12 to 29 percent) of U.S. asthma cases are attributable to mold and dampness (Mudarri and Fisk 2007). The following information is summarized from Lawrence Berkeley National Laboratory (2021). Meta-analyses of published literature indicate increases of 30 to 70 percent in the prevalence rates of adverse health effects in homes with dampness or mold, as determined visually or detected by mold odor. Mycotoxins can be released by some molds, but it is not known whether indoor air concentrations caused by microbial growth in damp buildings can reach levels high enough to cause any health effects. Studies of mite allergens in house dust indicate that when concentrations exceed about 2 µg allergen per gram of dust, susceptible people are at higher risk of being sensitized, which can result in effects such as rhinitis (runny nose or congestion), increased risk of asthma, and skin rash. The presence of these contaminants varies substantially by geographic location and is influenced by cleaning and other occupant activities (not affected by the proposed rule).

The impacts of infiltration air exchange on biological contaminants are uncertain and likely vary seasonally and with climate (based on the importance of humidity) and may also vary with other factors that are not yet well understood, as noted in Section 3.2.3. There is at least one study from Canada (Lajoie et al. 2015) in which adding ventilation was associated with a significant reduction in airborne mold spores during winter sampling. Information about how potential exposures and effects can be mitigated has been developed by the CDC and HUD (2011), the EPA, and other agencies and public health organizations.

### 3.3.2 Exposure Assessment

Individuals more likely to be adversely affected by indoor air quality include infants, the elderly, and the infirm, who are indoors a greater proportion of the time than the general population (Sexton 1993). Even lower concentrations of air pollutants can lead to health effects over time because indoor exposure is more frequent and more prolonged than exposure to ambient (outdoor) air (Smith 1993). Infants and children whose systems are still developing are vulnerable to certain effects such as neurodevelopment impairment.

The emphasis of this evaluation is on daily exposures over the long term, rather than temporary, acute exposures. The latter are impacted almost exclusively by the characteristics of the emission event and whether occupants use ventilation, air cleaning, or other control measures. For example, modest changes to the air infiltration rate would have a very small impact on the 1-hour average concentration of $NO_2$ that results from cooking with gas burners. Infiltration and air leakage will impact the daily average concentrations.

Inhalation is the dominant exposure route for indoor air pollutants. These pollutants can deposit on surfaces (via dry deposition), resulting in the potential for dermal and incidental ingestion exposures, notably for toddlers per their mouthing behaviors. Because the processes that affect exposures to deposited pollutants are largely impacted by cleaning and other occupant behaviors (not affected by the proposed rule), and because the assessment of inhalation exposures already illustrates the potential health implications of indoor pollutants, these other pathways are not quantitatively assessed in this EIS.

The exposure concentration used to assess chronic inhalation exposures is calculated as follows, in accordance with EPA (2009) guidance.

$$EC = (CA \times ET \times EF \times ED) / AT$$

Where: EC = exposure concentration (μg/m$^3$)

CA = concentration in air (μg/m$^3$)

ET = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

AT = averaging time (hours)

CA is an estimate of the average concentration in air. This can be combined with upper-bound estimates for exposure time and central tendency values for the other parameters to characterize a reasonable maximum exposure.

ET, EF, and ED combine to represent the total amount of exposure, over hours per day, days per year, and number of years. The exposure duration reflects how long an individual is assumed to live (and be exposed) at a given location. For this assessment, a resident is assumed to stay in the home 24 hours a day, 350 days per year, for 30 years.[21] These assumptions are commonly applied to assess the residential scenario, in accordance with the EPA's risk assessment approach and standard exposure factors handbook (EPA 2011a, 2011b). A central tendency value can be used to assess a more typical (average) exposure case. The generic ET and EF assumptions for manufactured homes would be the same as for site-built homes.

Recent census data from the American Community Survey for home occupancy periods are shown in Figure 3.3-2 (Census 2020). In 2019, 7 percent of manufactured home residents had lived in their home at least 30 years, and the five-year average (2015 through 2019) was 6 percent. The percentages are similar to those for all U.S. homes, with a 2019 and five-year average of 11 percent. Thus, 30 years represents the 93rd percentile for residential occupancy of manufactured homes. A considerable number of manufactured home communities are for adults aged 55 and older, also supporting 30 years as a somewhat bounding assumption.

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[21] An exposure duration of 30 years is consistent with the lifetime assumed for a manufactured home (86 FR 47744; DOE 2021; 86 FR 59042).

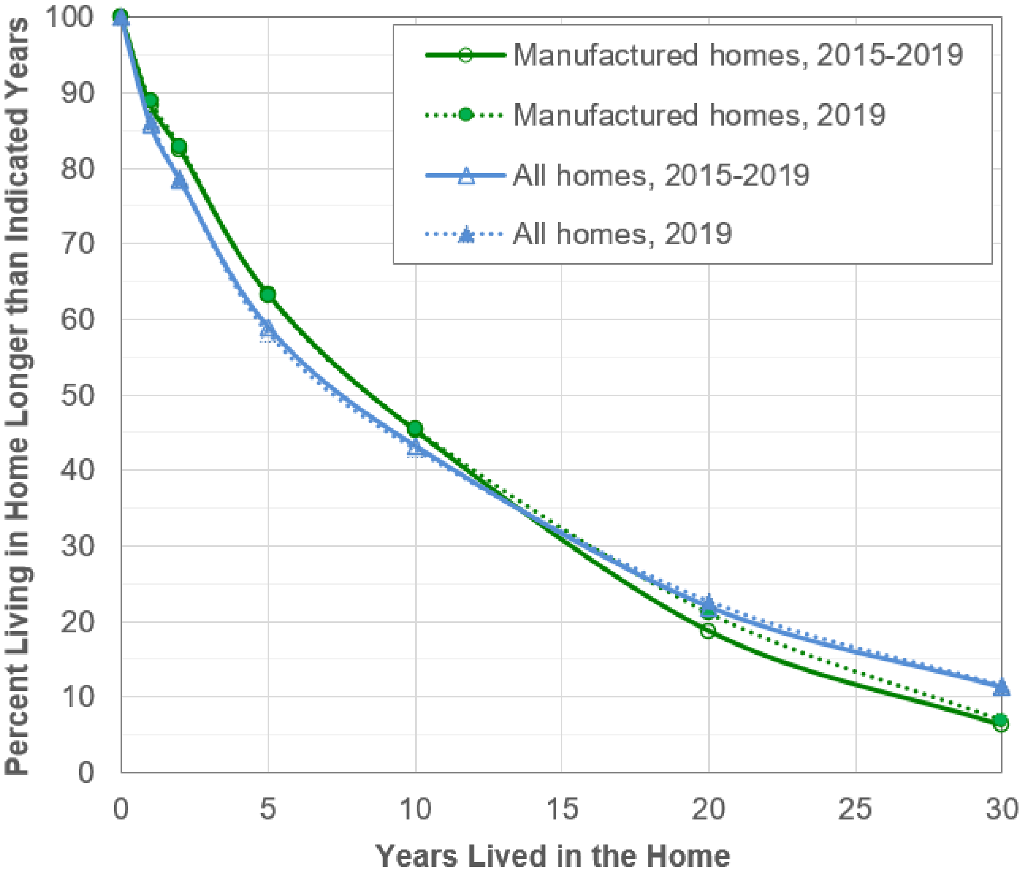

**FIGURE 3.3-2 Residential Occupancy in Manufactured Homes and in All U.S. Homes**

AT is the same as the exposure duration, in days, when assessing noncancer effects. When assessing cancer risk, intakes are calculated to account for the lifetime average daily dose, to estimate the potential for incurring cancer over a lifetime (assuming 70 years), in days. This approach aligns with the conservative linear no-threshold extrapolation model underlying standard cancer toxicity estimators.

### 3.3.3 Toxicity Assessment

No U.S. consensus standard exists for the criteria pollutants in indoor air. The EPA's extensive analyses of health effects linked to ambient concentrations or those directly related to exposures to criteria pollutants are presented in Integrated Science Assessments (ISAs). Health endpoints include respiratory effects, cardiovascular effects, metabolic effects, nervous system effects, reproductive and developmental effects, and cancer. The ISAs identify an association with increased health effects (e.g., hospital admission) per 10 $\mu g/m^3$ or 10 ppb increase in criteria pollutant. These data on associations are presented for a variety of endpoints from multiple studies in the ISA for each pollutant (e.g., see EPA 2016, 2019), rather than providing a single toxicity value. Toxicity reference levels for chronic (long-term) exposures to criteria pollutants have not been established. Therefore, the risk evaluation of criteria pollutants in indoor air considers the NAAQS as health-based comparison benchmarks for residential exposures. The NAAQS for $PM_{2.5}$

and $NO_2$ relevant to the discussion of air tightness impacts on IAQ in manufactured homes are shown in Table 3.3-2 (EPA 2021d).

**TABLE 3.3-2 NAAQS for $PM_{2.5}$ and $NO_2$**

| Pollutant, Unit | Averaging Time | NAAQS |
|---|---|---|
| $PM_{2.5}$, µg/m$^3$ | Annual | 12 |
| | 24-hour | 35 |
| $NO_2$, ppb | Annual | 53 |

Source: EPA (2021d).

The EPA's Integrated Risk Information System (IRIS) is the standard source of peer-reviewed toxicity reference values used to assess whether hazardous air pollutants are at a level that potentially could convey risk, and to quantify the risk for cancer (EPA 2021b). The reference concentration (RfC) is used to assess the potential for noncancer effects. It represents a continuous exposure level that is likely to be without an appreciable risk of any adverse effect for the human population, including sensitive subgroups. The inhalation unit risk (IUR, or cancer risk per unit concentration inhaled) is applied to estimate the incremental risk (probability) of incurring cancer over a lifetime. It represents the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a unit concentration of the pollutant in air (1 µg/m$^3$).

Many IRIS values were established years ago, and in some cases new data have become available to inform updated derivations. These include values developed by the CalEPA Office of Environmental Health Hazard Assessment (OEHHA). Updated and peer-reviewed toxicity reference values developed by agency authors are also evaluated for use in risk assessments. The inhalation reference values used in this assessment are as follows. For acrolein, the inhalation reference value of 0.82 µg/m$^3$ is used to assess the potential for noncancer effects. This value is derived by Blessinger et al. (2020) (with EPA authors) and represents the most recent peer-reviewed inhalation reference value from the most recent, relevant toxicological study. For formaldehyde, the reference exposure level of 9 µg/m$^3$ developed CalEPA OEHHA is used to assess potential noncancer effects, and the unit risk (cancer potency estimator) of $6 \times 10^{-6}$ per µg/m$^3$ developed by CalEPA OEHHA is used to assess the incremental risk of developing cancer from the estimated exposures over a lifetime. Additional details about the inhalation toxicity values are provided in Appendix B.

### 3.3.4 Risk Characterization

In accordance with EPA (2009) guidance, the potential for a noncancer effect and/or incremental cancer risk is calculated by combining the estimated exposure concentration with the respective toxicity reference value. For the noncancer endpoint, the estimated exposure concentration is divided by the inhalation reference value to produce a hazard quotient (HQ) —the ratio of the estimated exposure to a reference level that is unlikely to result in any adverse effect. The cancer risk is estimated by multiplying the exposure concentration by the inhalation unit risk, as an estimate of risk per exposure level. These calculations are illustrated below:

HQ = exposure concentration / RfC

Cancer risk = exposure concentration × IUR

When multiple pollutants are assessed, the HQs are summed to produce the hazard index (HI). An HQ or HI at or below 1 indicates the exposure is unlikely to cause an adverse noncancer effect. When the HQ or HI exceeds 1, this does not mean the effect would occur, because the RfC is designed to be protective, not predictive. It is also important to note that the potential for an effect does not increase linearly if the HI approaches or exceeds 1 because RfCs are not probabilistic. The HI represents a screening estimate, and when it exceeds 1, the contributors are assessed to determine whether segregating the HI by health endpoint would produce a segregated HI that is at or below 1.

#### 3.3.4.1 Acrolein

To estimate the potential for a noncancer effect from residential exposures, the exposure concentration was divided by the inhalation reference value of 0.82 $\mu g/m^3$ derived by Blessinger et al. (2020). The distribution of exposure concentrations is taken from a series of Health Canada (2021) studies that collectively measured concentrations in hundreds of site-built homes in four Canadian cities, during both summer and winter in 2005–2010. Results are reported as a median and 95th percentile value for each city and season combination. HQs were calculated for the mean values of the reported median and 95th percentile results for each season, and for homes without and with smokers.

#### 3.3.4.2 Formaldehyde

To estimate the potential for a noncancer effect from residential exposures, the exposure concentration was divided by the CalEPA reference exposure level or 9 $\mu g/m^3$, as the most recent, peer-reviewed agency toxicity value. HQs are calculated for the median and 95th percentile concentrations reported in the published study by Singer et al. (2020) and data obtained from a recent study conducted by Pacific Northwest National Laboratory and described in a 2020 internal report (PNNL 2020). These measured data likewise were used to estimate cancer risk for individuals residing for their entire lives in homes having these concentrations. The median and 95th percentiles of measurements were multiplied by the potency estimator derived by CalEPA, which reflects the more recent peer-reviewed agency analysis.

Representative exposure concentrations from the literature were used to calculate the example HQs for acrolein and formaldehyde and the incremental risks for formaldehyde. Results are shown in Figures 3.3-4 and 3.3-5, and the calculations are briefly described in the following paragraphs.

Results for acrolein and formaldehyde demonstrate that existing conditions pose a potential health concern for residents.

Results for acrolein, shown in Figure 3.3-4, indicate that acrolein was very commonly present in Canadian homes at levels that far exceeded the inhalation reference value, in some cases by about 8 times (for the median) and 19 times (for the 95th percentile) the acceptable daily exposure level.

Given the similarity of materials, products, and activities in Canadian and U.S. homes, and the large scale and representative sampling approach used in the Canadian studies, it is reasonable to consider that concentrations in U.S. manufactured homes could also routinely exceed reference levels.

For formaldehyde, the HQ is about 3 at the median level and 5 at the 95th percentile concentration, as shown in Figure 3.3-5. Note that the data from these two studies are from home that were built with formaldehyde materials that comply with California and U.S. federal formaldehyde emission standards and were operated with continuous mechanical ventilation (i.e., with accepted best-practice controls in place). Note that these homes had air-tightness levels that are consistent with those of the proposed standards. Formaldehyde reference levels are thus commonly exceeded in modern U.S. site-built homes equipped with best-practice controls.

As shown in Figure 3.3-6, the estimated cancer risk ranges from $6 \times 10^{-6}$ to slightly above $1 \times 10^{-4}$, which is just above the upper end of the target range for incremental lifetime risk (EPA 1990): (In the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), EPA (1990) established the target range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$, or 1 in 10,000 to 1 in a million, for the incremental risk of cancer incidence associated with pollutant exposures.[22] To put this range in perspective, it is estimated that one in three Americans will develop cancer from all sources (including diet, smoking, and other behavioral factors) over their lifetime. Thus, the EPA target range for incremental risk from pollutant exposures represents a small fraction of the background cancer rate.[23])

The estimated cancer risk represents the increased probability (above a background rate) that an individual will develop cancer over a lifetime from the assumed exposures. For comparison, recent U.S. data indicate that men have a nearly 1 in 2 risk ($5 \times 10^{-1}$, or 0.5) of developing cancer over a lifetime from all causes combined, while the risk for women is slightly above 1 in 3 ($3 \times 10^{-1}$, or 0.3) (ACS 2021).

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[22] Excess risk means above the general background rate for the population. This target risk range and the target for noncancer systemic effects of a ratio of 1 or less from the NCP have been broadly applied to assess pollutant exposures across multiple programs

[23] For example, a risk estimate at the upper end of the target range ($10^{-4}$) means that if 10,000 people were assumed to be repeatedly exposed to the given contaminant(s), one additional person could potentially get cancer as a result of those exposures compared with the estimated 3,333 cancer cases expected from all other causes, based on statistical analyses.

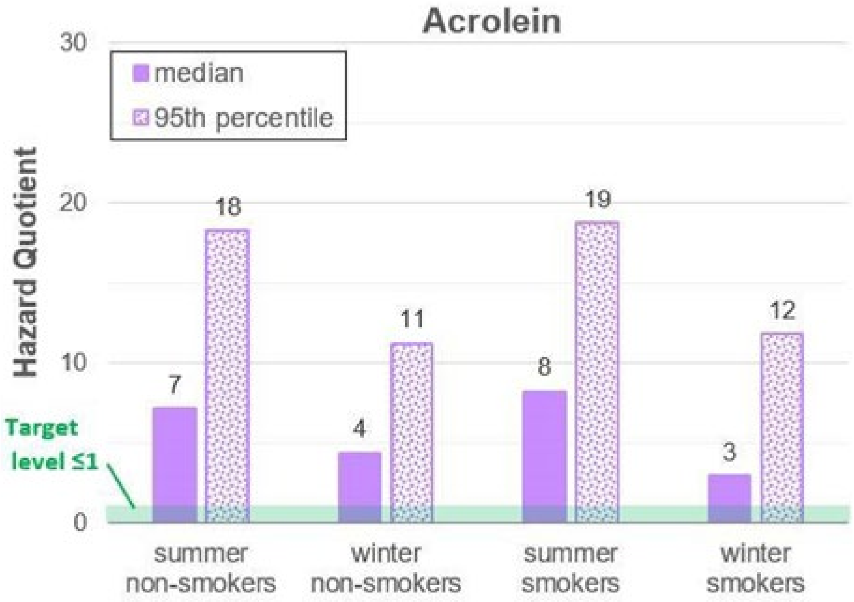

**FIGURE 3.3-4 Illustrative HQs for Hypothetical Residential Exposure to Acrolein under Existing Conditions**

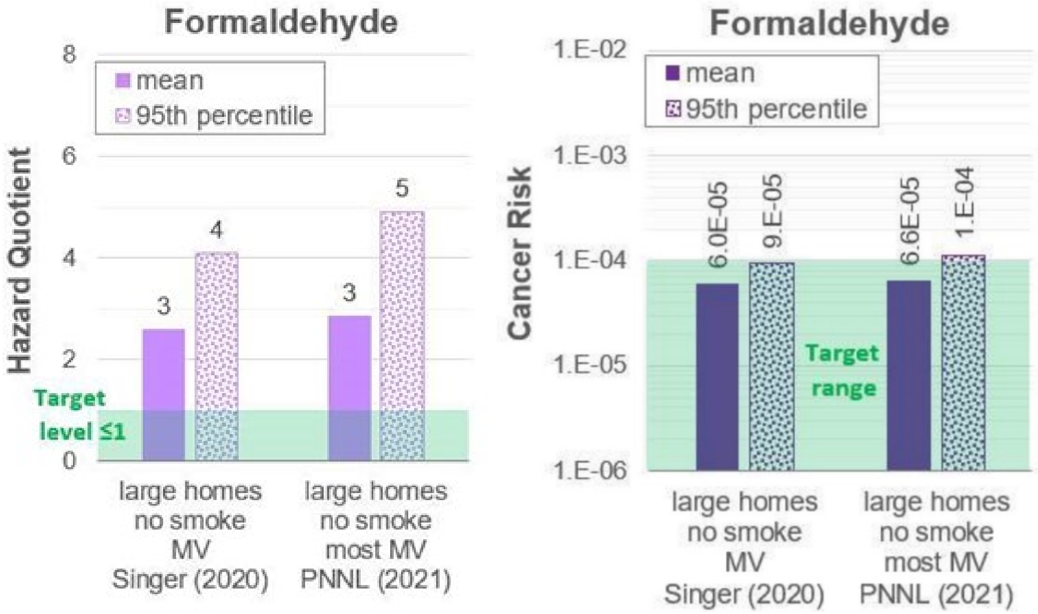

**FIGURE 3.3-5 Illustrative HQs and Cancer Risks for Hypothetical Residential Exposure to Formaldehyde under Existing Conditions**

## 3.4 SOCIOECONOMIC RESOURCES

Demographic data relevant to proposed energy conservation standards for manufactured housing include geographic characteristics, income, employment status, home ownership, housing prices and availability, and race/ethnicity. The socioeconomic descriptions presented here also provide baseline information for environmental justice (see Section 3.5). The U.S. Census Bureau is a primary source of demographic data,[24] and their definition of a manufactured home[25] is similar to that in the HUD Code.

The data presented in this section describe the current environment for existing manufactured homes, which includes older homes; the demographics of future buyers and occupants of newer manufactured homes might differ from the overall population. Where possible, data from recent manufactured home shipments are used to capture locations and prices to reflect the current environment. The geographic characteristics of manufactured housing are described in Section 3.4.1. Income and employment levels for residents of manufactured homes are presented in Section 3.4.2, and housing characteristics are identified in Section 3.4.3. Financing is described in Section 3.4.4, and energy insecurity issues are discussed in Section 3.4.5.

### 3.4.1 Geographic Characteristics

Ownership of manufactured homes varies widely by location. Most manufactured homes are located outside of metropolitan areas and across the southern United States. Manufactured housing represented 6 percent of the U.S. housing stock in 2019 and comprised 13 percent of occupied housing in rural communities and small towns. The presence of manufactured homes as a percentage of all occupied housing units in 2019 is illustrated by county in Figure 3.4-1 (Census 2019a, 2019b). This figure also shows the six metropolitan areas assessed in this EIS to illustrate existing conditions (in this chapter) and potential impacts of the proposed standards (in Chapter 4).

The percentage of occupied manufactured homes by census division is presented in Figure 3.4-2 (Census 2020). Most of these occupied homes (56 percent) are in the three southern census divisions: South Atlantic, East South Central, and West South Central. This figure also identifies the percentage of manufactured homes shipped in 2021 by census division (data from Census 2021b); these represent new homes that became available during the pandemic. Taken together, these data suggest greater activity for new homes in the two South Central divisions.

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[24] Among many other data, the U.S. Census Bureau reports data for households living in manufactured homes, including older manufactured homes. The demographics of purchasers of new manufactured homes are not provided, and their characteristics might differ from those discussed in this section existing data.

[25] The U.S. Census Bureau (2021a) defines a manufactured home as a "movable dwelling, 8 feet or more wide and 40 feet or more long, designed to be towed on its own chassis, with transportation gear integral to the unit when it leaves the factory, and without need of a permanent foundation." Mobile home (an earlier term) is also used; for example, in the 2015 Residential Energy Consumption Survey, mobile home is defined as "A housing unit built off-site on a movable chassis and moved to a home site. A mobile home may be placed on a permanent or temporary foundation and may contain one or more rooms. A prefabricated or modular home assembled on site is a single-family housing unit and not a mobile home" (https://www.eia.gov/consumption/residential/terminology.php#m).

Both occupied homes and shipments are generally similar in the North Central to Eastern census divisions. Shipments by state in 2021 are shown in Figure 3.4-3 (Census 2021b).

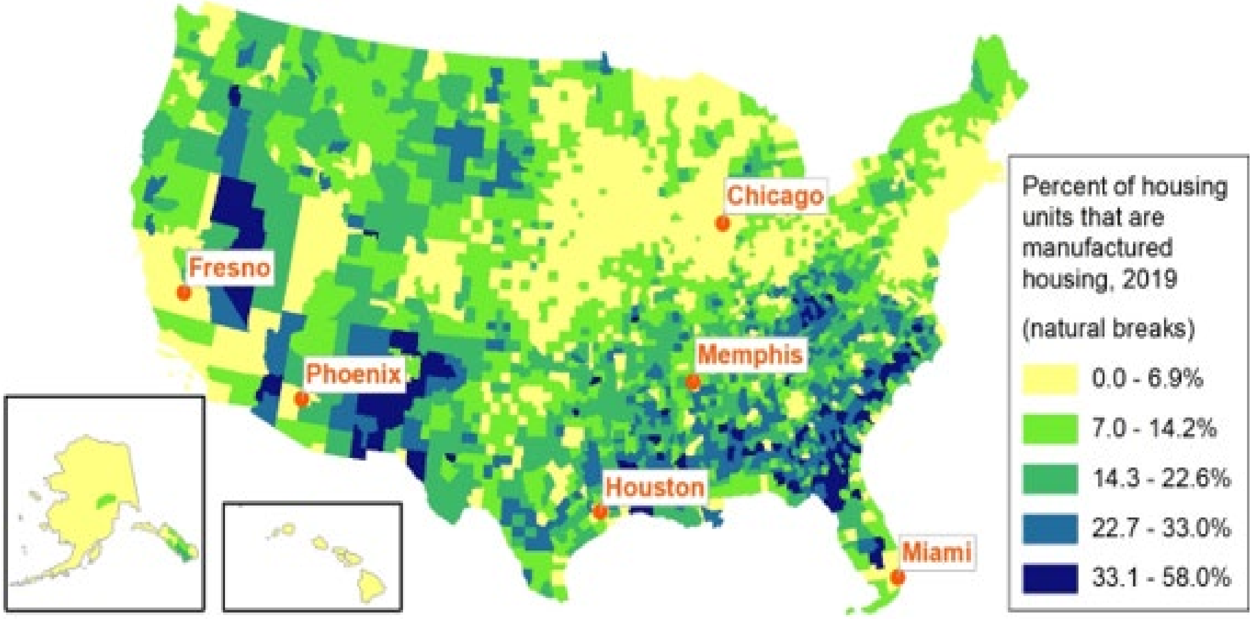
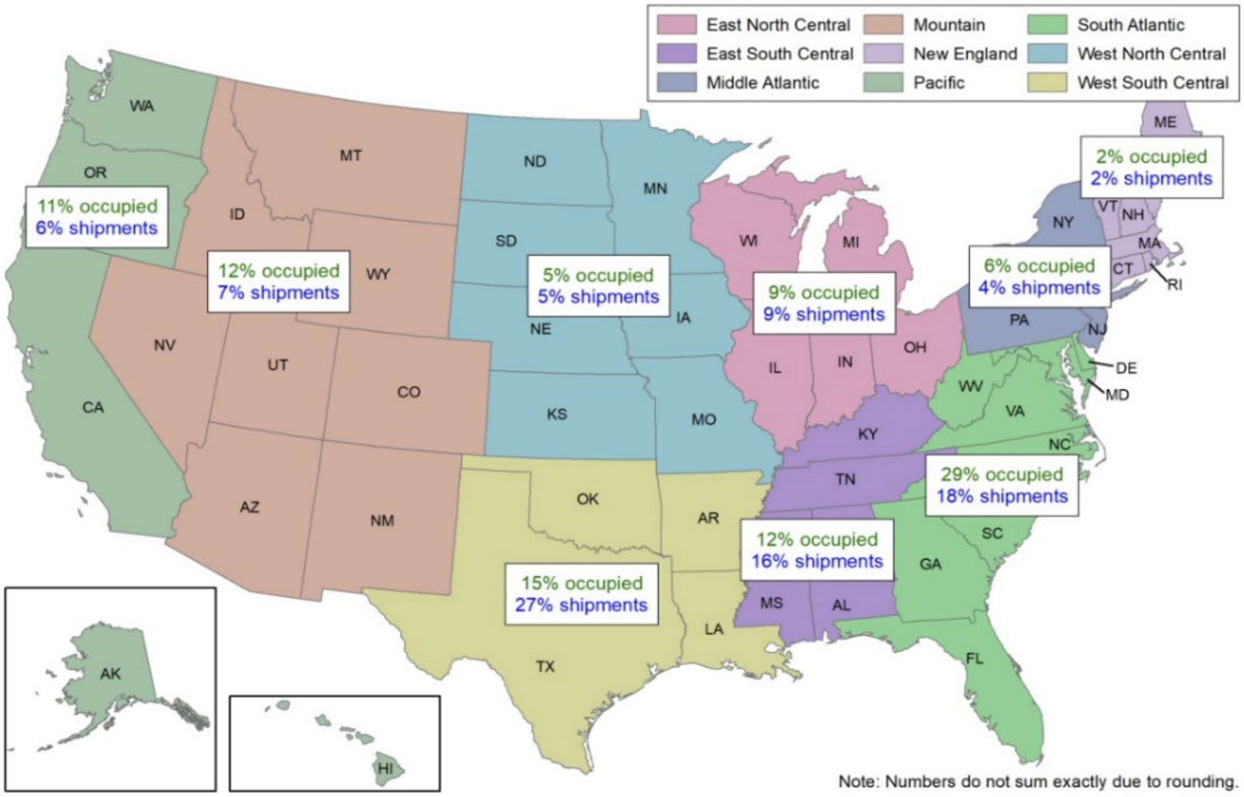


**FIGURE 3.4-1 Manufactured Homes by County as a Percentage of Occupied Housing Units**



Note: Numbers do not sum exactly due to rounding.

**FIGURE 3.4-2 Percentage of Occupied Manufactured Homes and Shipments by Census Division**

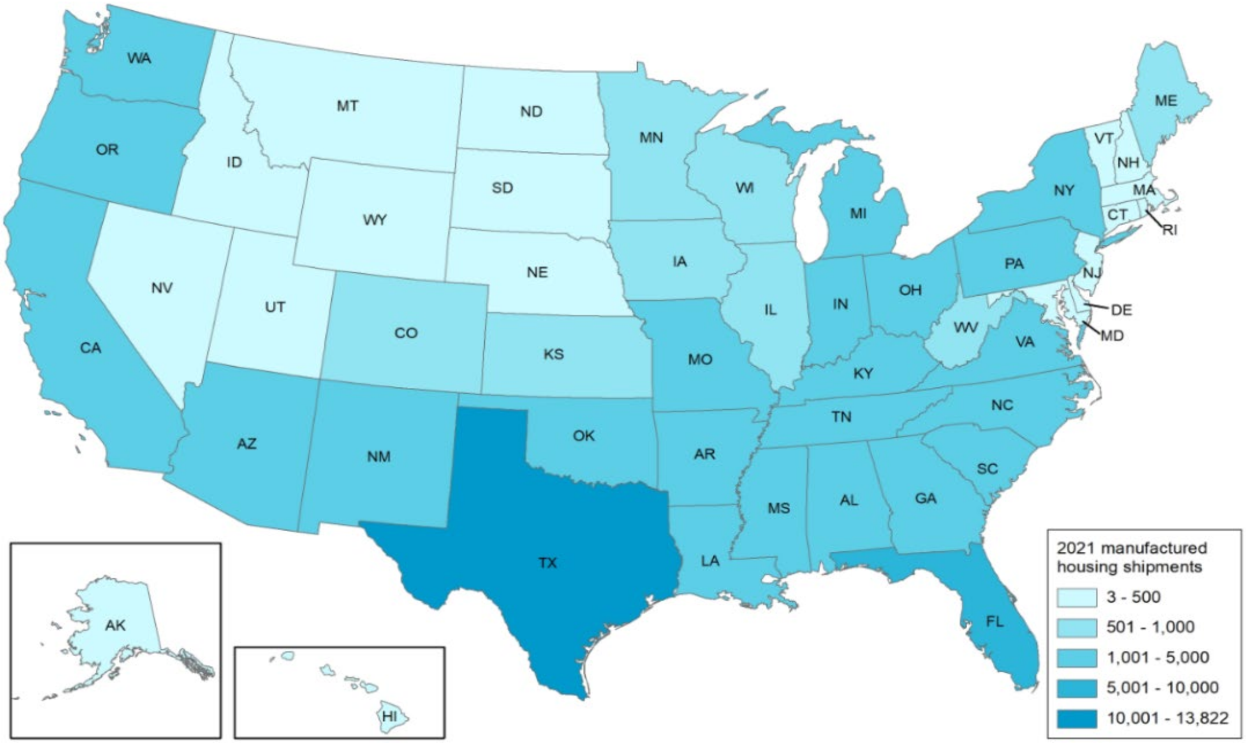


**FIGURE 3.4-3 Number of Manufactured Home Shipments by State**

As historical context, shipments of manufactured housing boomed in the late 1990s then dropped significantly until 2008. After a gradual rise, shipments were generally stable from 2017 through 2019, then slightly decreased in 2020, as shown in Figure 3.4-4 (CFPB 2021). For comparison, the annual rate of authorized construction for new single-family housing units is presented in Figure 3.4-5 (Census 2020i). This graph shows a similar trend to that of manufactured housing beginning in the mid to late 1980s, with a dip in new construction followed by a rise in the 1990s. While manufactured housing shipments began to decline in the early 2000s, new residential construction did not fall off until late 2005 and early 2006. After the financial crisis, both manufactured housing shipments and new residential construction have rebounded, although the increase for residential construction is much more pronounced.

In a 2021 evaluation of data from the 2019 American Community Survey (reflecting pre-pandemic conditions), the Census Bureau estimates that in 2019 there were 17.4 million people living in 8.5 million manufactured homes, accounting for about 6 percent of 140 million housing units in the United States (Census 2021b). Combining Census Bureau data with proprietary 2018 data, the Manufactured Housing Institute (MHI) estimated that in 2018 there were 22 million people living in manufactured homes and that 9 percent of new single-family home starts are manufactured homes (MHI 2021). This information provides useful context for pre-pandemic conditions; pandemic impacts, including supply chain interruptions and labor shortages, have altered the socioeconomic landscape for all housing since the spring of 2020.

**FIGURE 3.4-4 Shipments of Manufactured Housing, 1980–2020**

**FIGURE 3.4-5 Annual Rate of Single-Family Housing Units Authorized in Permit-Issuing Places, Seasonally Adjusted, 1980–2020 (thousands of units)**

This draft EIS considers six illustrative metropolitan areas — Chicago, Fresno, Houston, Memphis, Miami, and Phoenix — to assess a variety of environmental conditions. Across these areas, manufactured housing represents an average of 2.4 percent of all occupied housing. Phoenix had the highest percentage (5.7 percent), followed by Houston (3.0 percent), Fresno and Miami (2.1 percent), Memphis (1.3 percent), and Chicago (0.8 percent) (Census 2019c). The portion of the population in these areas living in census blocks containing manufactured housing communities ranges from 2 percent in Chicago to 5 percent in Memphis, 6.5 percent in Miami, 8 percent in Fresno, 11 percent in Phoenix, and 12 percent in Houston.

### 3.4.2 Income and Employment Characteristics

Household income and employment characteristics are important considerations when evaluating the potential impacts of energy conservation standards that could increase the price of new homes. Manufactured homes represent an affordable housing option for millions of Americans because they cost less on average than site-built homes and are one of the least expensive forms of housing available without government subsidies (CFPB 2021; MHI 2021). Manufactured homeowners tend to have lower incomes than site-built homeowners. From 2019 data, the median household income for all occupied manufactured homes was $34,800 (Census 2020). For comparison, the national median household income in 2019 was twice that amount, at $69,560 (Census 2021c). Household income data from Census (2020) are illustrated in Figures 3.4-6 and 3.4-7.

Occupied housing includes all who live in manufactured homes, regardless of purchase date. Data on median income for recent purchasers of manufactured homes are not available. The Consumer Finance Protection Bureau (CFPB) reports borrower characteristics for both manufactured housing loans and site-built home loans. The 2021 report indicates that in 2019 median incomes of borrowers for manufactured homes (new or used) were $52,000 for borrowers of personal property (chattel) loans and $53,000 for borrowers using mortgage loans, compared to $83,000 for borrowers using mortgage loans for site-built homes (CFPB 2021). These income levels are higher than the median household income reported for occupied manufactured homes by the U.S. Census.

Low-income populations looking to purchase manufactured homeowners could be more price-sensitive than those looking to purchase site-built homes (EERE 2021). Changes that could affect the costs of manufactured homes could affect this population's ability to afford a new home. The official poverty rate in 2020 was 11.4 percent, an increase of 1 percent from 2019 and the first increase after five consecutive years of declines (Census 2021c). This translates to 37.2 million people in poverty, an increase of about 3.3 million compared with 2019 (Census 2021c). For comparison, the poverty rate in 2017 was 12.3 percent, meaning more people (40 million) were at the poverty level several years ago.[26]

Eighty percent of manufactured homes are owned by households of three or fewer people, and this analysis assumes an average household size of two, the approximate median household size. The U.S. Department of Health and Human Services (HHS) publishes poverty guidelines based on household size. These guidelines are used to determine eligibility for certain public programs, such as the HUD Low-Income Home Energy Assistance (IRP 2021). For a two-person household, the 2019 poverty guideline was $16,910. This translates to about 26 percent of manufactured homeowners living at the poverty level in 2019, a rate more than 2.5 times that for all homeowners (which was less than 10 percent). In 2021, the poverty guideline for a two-person household was $17,420 (HHS 2021). For comparison, the guideline for a three-person household was $21,960 (HHS 2021).

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[26] See https://aspe.hhs.gov/topics/poverty-economic-mobility/poverty-estimates-trends-analysis.

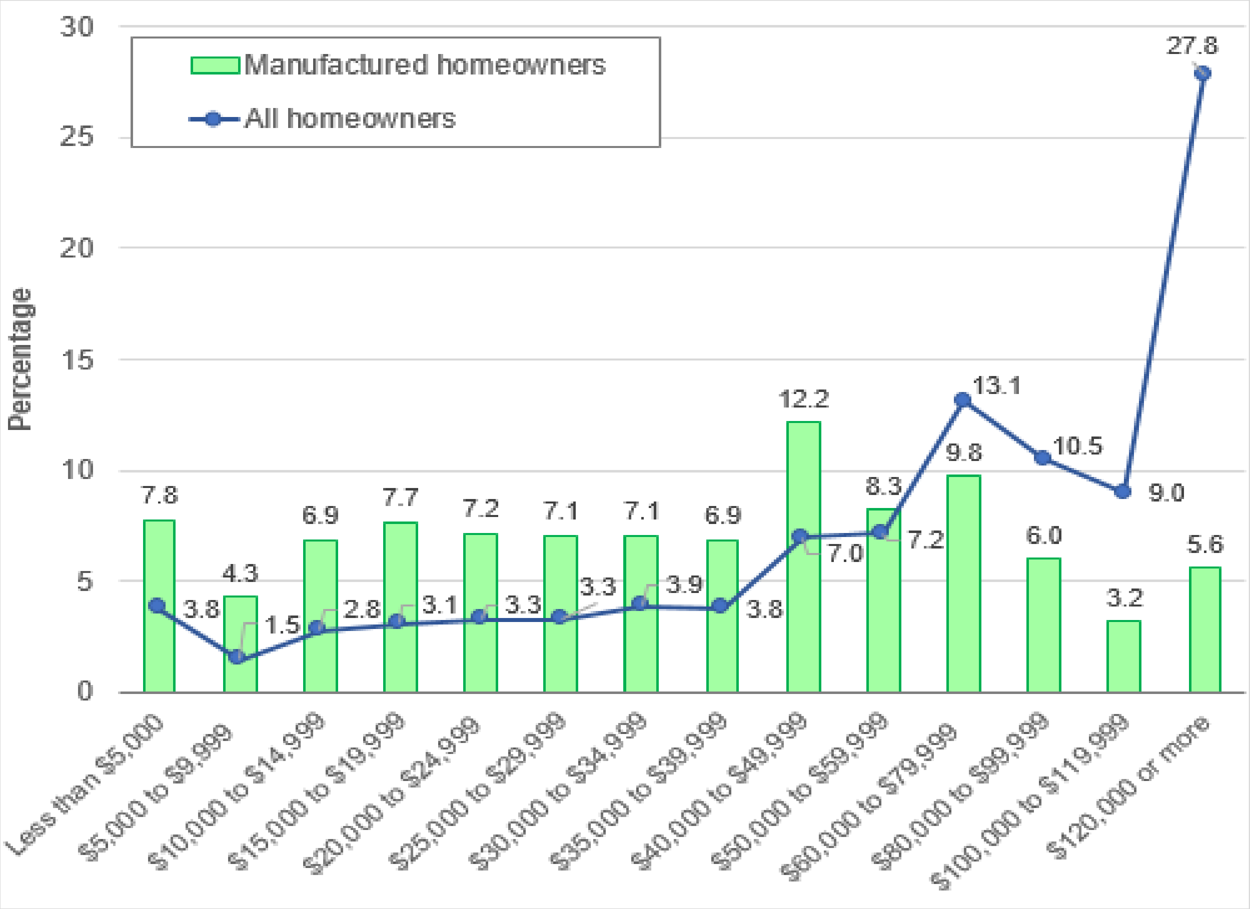

**FIGURE 3.4-6 Household Incomes of U.S. Homeowners in 2019**[a]

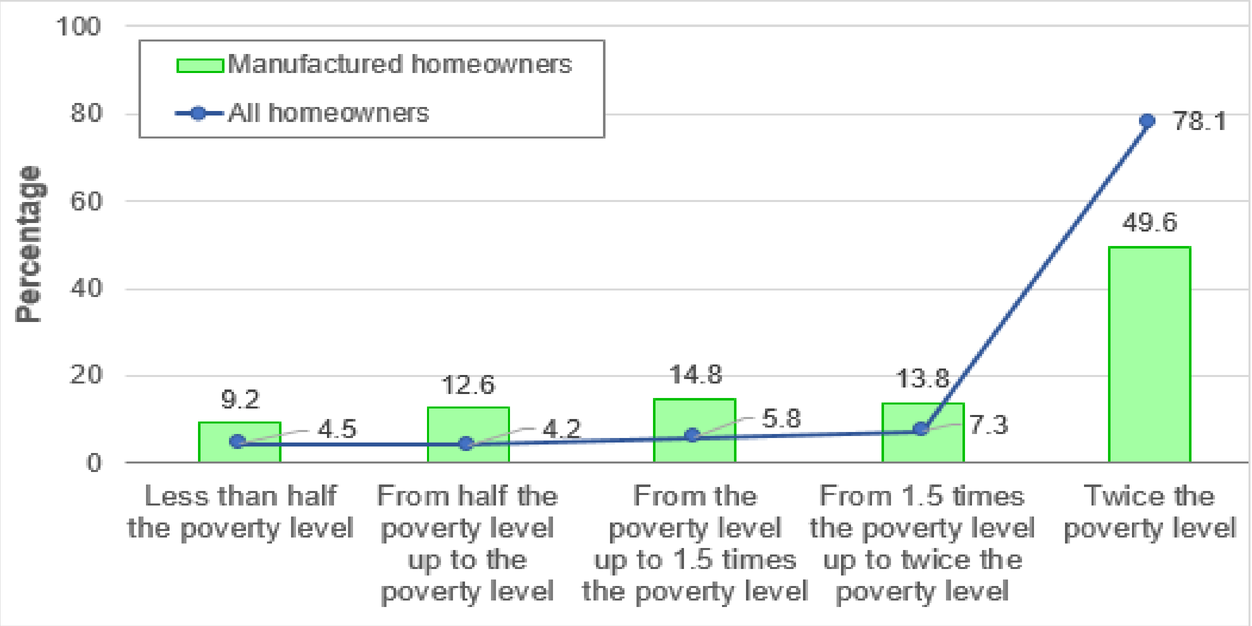

**FIGURE 3.4-7 Household Incomes Relative to Poverty Levels in 2019**

Characteristics of the total population, household income, unemployment, and housing vacancy in the six metropolitan areas illustrated in this EIS are presented in Table 3.4-1. These data are from the American Community Survey 2015–2019 (Census 2019a, 2019b), and are the most recent data available for these metrics. Median household incomes are calculated as the average of the median household incomes for the census block groups in the given metropolitan area. Relative comparisons among the three indicators for each metropolitan area are illustrated in Figure 3.4-8.

**TABLE 3.4-1 Population, Household Income, Unemployment, and Housing Vacancy in Illustrative Metropolitan Areas**

| Location | Total Population | Median Household Income | Unemployment Rate (percent of population) | Vacant Housing Units (percent of unoccupied housing units) |
|---|---|---|---|---|
| Chicago metropolitan area census block groups with manufactured housing communities | 174,200 | $58,200 | 7.1 | 11.1 |
| Chicago metropolitan area | 8,775,400 | $77,540 | 6.1 | 9.5 |
| Fresno metropolitan area census block groups with manufactured housing communities | 59,580 | $46,150 | 10.6 | 4.5 |
| Fresno metropolitan area | 724,380 | $57,840 | 8.5 | 5.9 |
| Houston metropolitan area census block groups with manufactured housing communities | 719,130 | $59,360 | 5.7 | 8.3 |
| Houston metropolitan area | 5,934,920 | $70,780 | 5.6 | 9.4 |
| Memphis metropolitan area census block groups with manufactured housing communities | 57,960 | $45,320 | 7.5 | 14.8 |
| Memphis metropolitan area | 1,145,100 | $53,920 | 6.9 | 14.0 |
| Miami metropolitan area census block groups with manufactured housing communities | 393,140 | $47,790 | 6.6 | 18.5 |
| Miami metropolitan area | 6,047,100 | $66,870 | 5.6 | 19.2 |
| Phoenix metropolitan area census block groups with manufactured housing communities | 452,850 | $44,160 | 6.3 | 22.1 |
| Phoenix metropolitan area | 4,197,670 | $71,070 | 5.0 | 12.7 |

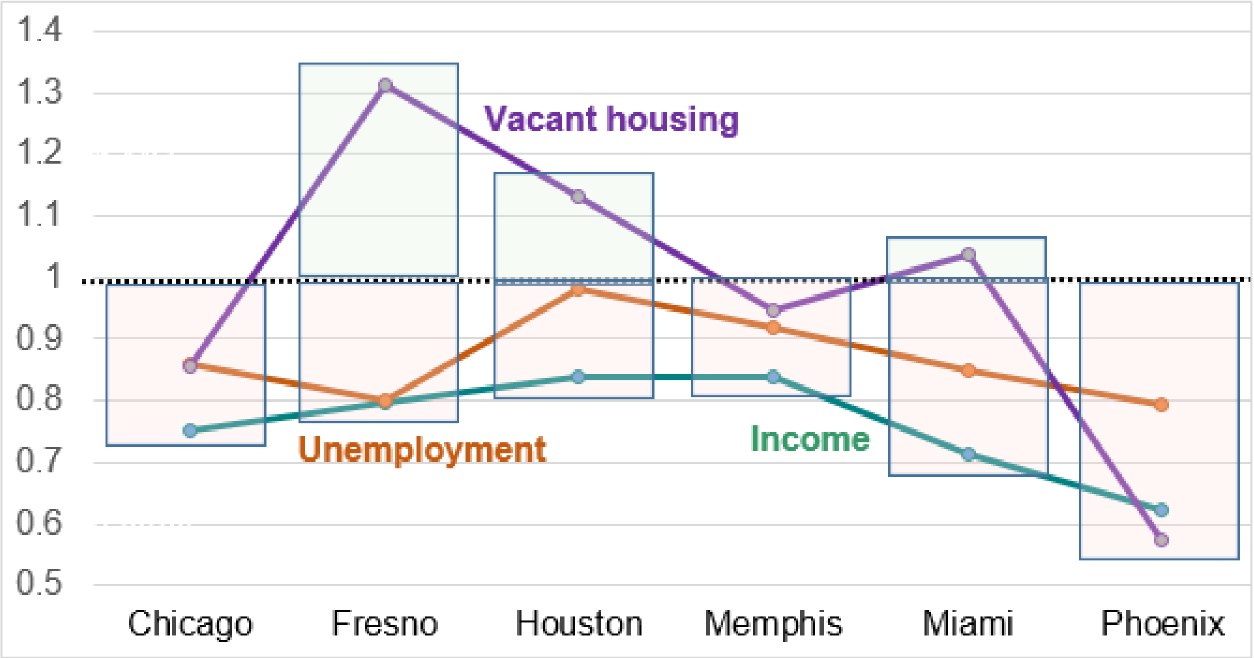

**FIGURE 3.4-8 Ratios of Three Economic Indicators for Census Blocks with Manufactured Housing Communities Compared to Other Census Blocks in Each Metropolitan Area (>1 indicates conditions are better in census blocks with manufactured housing communities; <1 indicates conditions are better in census blocks without manufactured housing communities)**

In Houston, 12 percent of the metropolitan population lives in census blocks that contain manufactured housing communities, and the median household income is 16 percent lower than in the larger metropolitan area. The unemployment rate is nearly the same for both areas, 5.7 and 5.6 percent for manufactured housing communities and the entire metropolitan area, respectively. Housing vacancy rates are slightly lower in census blocks with manufactured housing communities, 8.3 percent compared to 9.4 percent in the entire Houston metropolitan area.

In Memphis, 5 percent of the metropolitan population lives in census blocks that contain manufactured housing communities. The median household income is 16 percent lower than in the entire metropolitan area. The unemployment rate in the Memphis manufactured housing community is slightly higher than in the entire metropolitan area, 7.5 percent compared to 6.9 percent. Housing vacancy rates are high for both the census blocks with manufactured housing communities and the Memphis metropolitan area (14.8 and 14.0 percent, respectively).

In Miami, 6.5 percent of the metropolitan population lives in census blocks that contain manufactured housing communities, and the median household income is 29 percent lower than in the Miami metropolitan area. The unemployment rate is 1 percent higher in manufactured housing communities than in the entire metropolitan area, and housing vacancy rates are high for both census blocks with manufactured housing communities and the metropolitan area, 18.5 and 19 percent, respectively.

In Phoenix, 11 percent of the metropolitan population lives in census blocks that contain manufactured housing communities, and the median household income is 38 percent lower in these communities than in the Phoenix metropolitan area. The unemployment rate is 1.3 percent higher in manufactured housing communities than in the entire metropolitan area. The housing vacancy rate for census blocks with manufactured housing communities is the highest of all six metropolitan areas, at more than 22 percent; this is substantially higher than the rate in the Phoenix metropolitan area (12.7 percent).

### 3.4.3 Housing Characteristics

Manufactured housing prices have increased significantly in recent years in response to the pandemic, and the increases are predicted to continue. However, manufactured homes remain much more affordable than site-built homes. Manufactured housing is reported to be 35 to 47 percent less expensive per square foot than new or existing site-built homes (CFPB 2021; MHI 2021).

In 2020, the U.S. housing market experienced sharp price increases due to pandemic-related issues. The rising cost of lumber and other raw materials, combined with a labor shortage, resulted in an increase in the price of housing, including affordable housing (NAHB 2021). As a result, the average cost per square foot for a new manufactured home rose 5 percent from 2019 to 2020; it has risen 30 percent overall since 2014 (Census 2021d). These increases are slightly higher than for new single-family site-built homes, for which the average cost per square foot rose 3 percent from 2019 to 2020, and the overall increase since 2014 is 26 percent (Census 2021d).

The average sales price in 2020 for single-section manufactured housing was $57,233, and that for a two-section home was $108,583. Sales prices increased significantly in 2021. To illustrate, in June 2020, the average sales price of a single-section manufactured home was $52,900 and that for a multi-section home was $109,800 (Census 2021e). By June 2021, the average sales prices of single- and multi-section homes had soared to $70,200 and $128,100, increases of 33 and 17 percent, respectively. The average sales prices for new manufactured housing from 2017 through 2020 are shown in Figure 3.4-9 (Census 2021e; FRED 2021a).

For comparison, this figure also shows the average sales prices of all new homes sold in the United States, which jumped 24 percent from August 2020 to October 2021. Having been fairly stable from 2017 to 2020, the average price of new homes increased from $418,600 in January 2021 to $478,200 by October 2021 (Census 2021h). Baseline data and forecasts[27] of average manufactured home prices from 2015 through 2025 are shown in Figure 3.4-10 (Census 2021f).

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[27] The triple exponential smoothing model was applied to develop these forecasts. This approach is common for data that show both trend and seasonality ttps://www.itl.nist.gov/div898/handbook/pmc/section4/pmc435.htm).

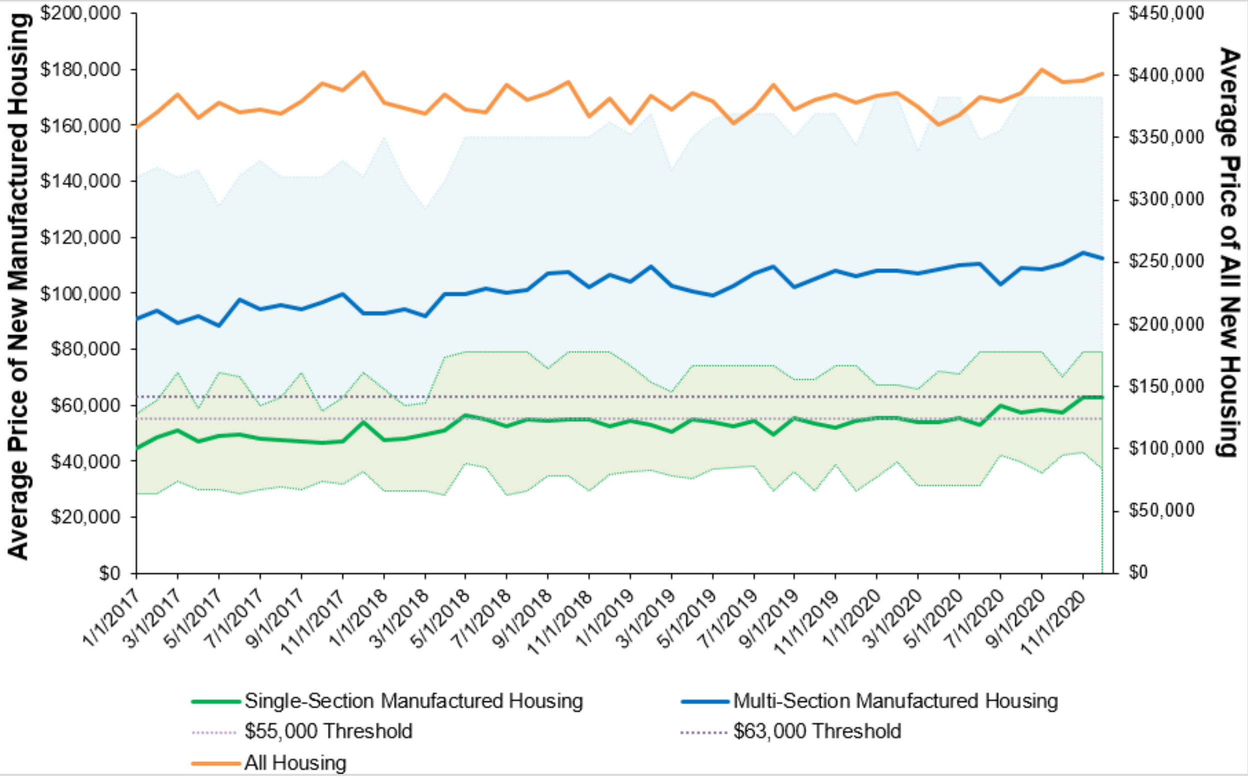

**FIGURE 3.4-9 Average Price for New Manufactured Housing and All New Housing, 2017–2020 (Shading indicates the 5th and 95th percentiles of average prices for single-section and multi-section manufactured housing; these prices are not seasonally adjusted.)**

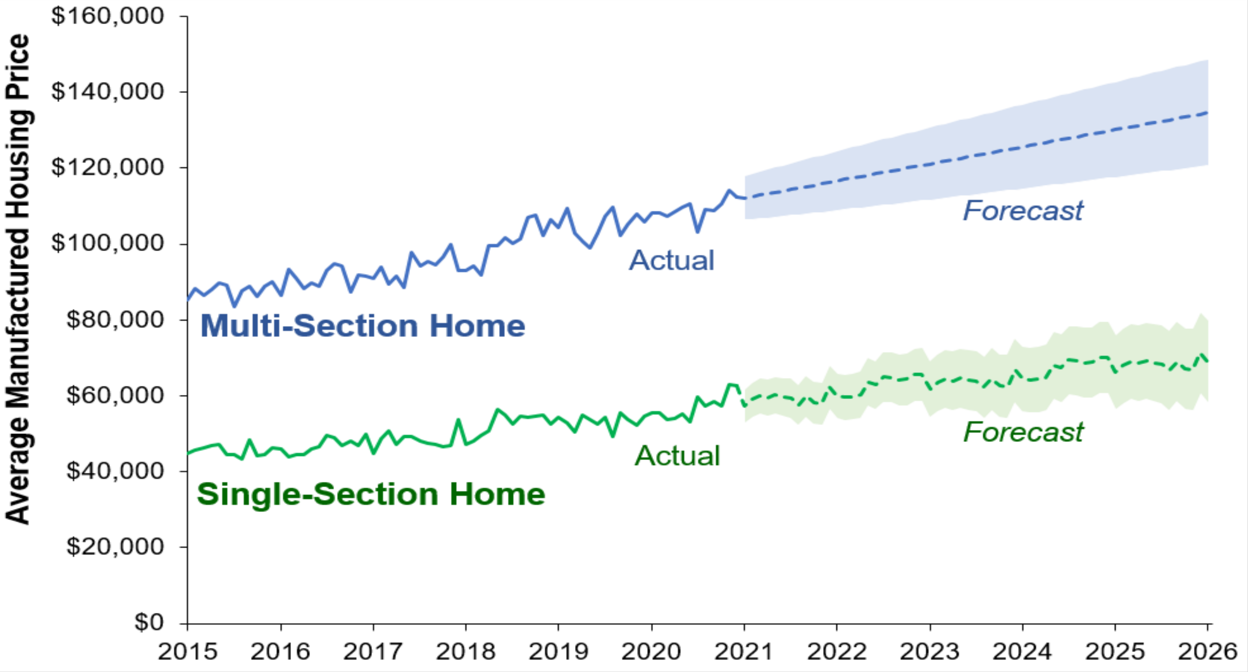

**FIGURE 3.4-10 Baseline Data and Forecasts of Average Price for Manufactured Homes**

Although sales prices for manufactured homes are similar between census regions, sales prices vary between states. In 2019, 25 percent of manufactured home shipments had a sales price of $55,000 or lower (the price reflected in the SNOPR; 86 FR 59042), and in 2020, 65 percent of manufactured home shipments had a sales price greater than $63,000 (the price reflected in the NODA; DOE 2021). Using the 2020 data to evaluate manufactured home shipments by size, 55 percent of all shipments were two-section homes, 44 percent were single-section homes, and only 1 percent had three or more sections (Census 2021f). The sales prices of single- and multi-section manufactured homes by census region in 2020 are illustrated in Figure 3.4-11 (Census 2021f; EERE 2021).

These data show that prices are fairly similar within census region, particularly the average and minimum prices for single-section homes. Overall, the average sales price for a single-section home was $57,000, compared with $108,583 for a two-section home. The West had the highest average price for both single- and two-section homes ($61,747 and $118,282, respectively). The South had the lowest average price for single-section homes ($56,798), and the Midwest had the lowest average price for two-section homes ($104,987). Sales prices vary by state, as shown in Figure 3.4-12 (Census 2021g). In 2020, average sales prices in the western United States and Massachusetts were higher than across the Midwest and Louisiana, Mississippi, and Alabama in the south.[28]

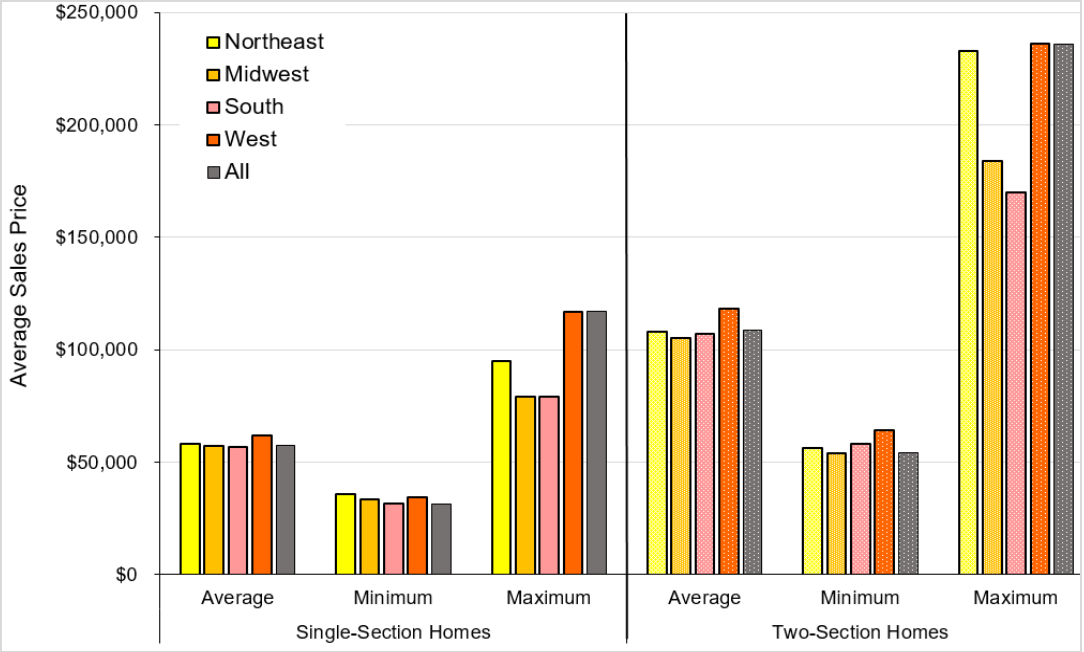

**FIGURE 3.4-11 Average Sales Prices of Manufactured Housing by Census Region in 2020**

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[28] As discussed in Section 2.5.3, DOE is not analyzing in detail alternatives based on sales or purchase price or a location-based standard. The retail list price is more appropriate than basing the tiers on the sales or purchase price, which may not be known until after a manufactured home leaves the manufacturer. And a location-based standard based on differences in sales prices among regions or states would be impractical to establish or administer because it could require manufacturers to comply with up to 50 different standards. State-level sales price data are presented in this section as part of describing the conditions against which the environmental consequences of the four Alternatives (A-D) are compared,

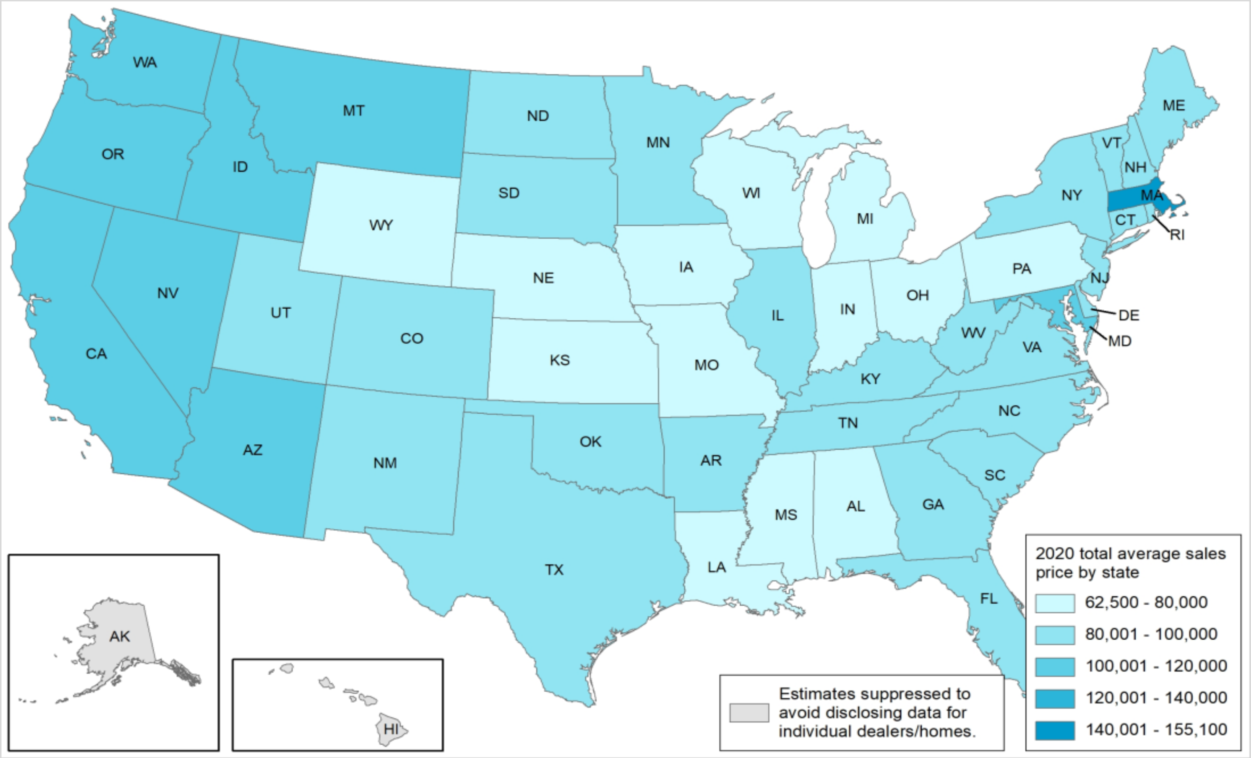

**FIGURE 3.4-12 Average Sales Prices of Manufactured Housing by State in 2020**

In terms of occupancy, the number of years residents live in their manufactured homes is similar to the number of years residents live in other types of homes (see Figure 3.3-2). The trends are very similar for both population groups, based on data for 2019 as well as data for 2015 through 2019. Nearly 90 percent of manufactured housing residents live in their homes for at least a year, slightly more than for all U.S. homes. Slightly more residents of manufactured homes live in their homes at least 10 years (45 percent) compared with residents all homes (43 percent). About 30 percent of each population group lives in their homes at least 15 years, and slightly fewer residents of manufactured homes live in their homes for at least 30 years compared with residents of all homes.

### 3.4.4 Financing Considerations

Financing for manufactured homes can be obtained through real estate property and/or personal property loans. These loans have higher interest rates and lower approval rates and down payments compared to those obtained for site-built homes. Owners of manufactured homes might own or rent the land on which the home is placed, and the financing available typically depends on whether the land is owned or leased. Manufactured houses are financed through real estate property and/or personal property loans. In general, a house that is set on a permanent foundation on land owned by the homeowner is titled as real estate property and is eligible for a mortgage loan. A house placed on leased land is titled as personal property, and it is financed through a personal property loan known as a chattel loan.

The CFPB (2021) estimates that 42 percent of manufactured home loans are chattel loans (CFPB 2021), and the MHI estimates that this number is 76 percent (MHI 2021).[29] Like other homes on leased land, manufactured homes are financed through personal property loans when only the house is being financed. When a manufactured home and land are financed together, the home can be secured as personal property and the land as real property (MHI 2021). In 2019, more than 60 percent of manufactured home borrowers owned the land where their home was located, which made them eligible for a mortgage loan; however, 17 percent of those borrowers took out a chattel loan (CFPB 2021).

Interest rates depend on the type and amount of the loan, the amount of the down payment, the term of the loan, the age and size of the house, the location, and the borrower's credit (CFPB 2014a, 2021). Manufactured homes titled as personal property often have higher financing costs, shorter loan terms, and weaker consumer protections than homes titled as real estate property (CFPB 2021). In addition, chattel loans are not covered under the Real Estate Settlement Procedures Act or the Coronavirus Aid, Relief, Economic Security Act, and are not eligible for foreclosure protections in cases of default (CFPB 2021).

Compared with loans for site-built homes, manufactured housing mortgages tend to have higher interest rates, smaller loan amounts, fewer refinances, and less of a secondary market (CFPB 2021). The National Low Income Housing Coalition reported that in 2014, about 75 percent of manufactured home loans (including those for used homes) were classified as having a substantially high interest rate, which was more than six times the percentage for loans for newly constructed single-family homes (NLIHC 2016).

According to data collected under the HMDA, nearly 94 percent of chattel loans secured in 2019 were higher-priced mortgage loans (HPMLs),[30] which was more than eight times the rate for newly constructed single-family homes (CFPB 2021). Of the non-chattel loans, more than half (52 percent) were HPMLs (CFPB 2021). Down payments for loans used for manufactured homes have been reported to range from 10 to 20 percent (MHI 2016). The CFPB has evaluated differences between mortgage loans for manufactured and site-built homes, and the borrower demographics are presented in Table 3.4-2 (CFPB 2021).

Loan applications for manufactured homes are financed at much lower rates and rejected at much higher rates that loan applications for site-built homes. The CFPB found that only about a fourth (27 percent) of loan applications for manufactured homes were financed, compared to nearly three-fourths (74 percent) for site-built homes. Half the people who applied for chattel loans and a third of those who applied for manufactured housing (MH) mortgages were denied loans, which is more than 4 to 7 times higher than loan denials for site-built homes (7.4 percent). These data are

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[29] Differences in these estimates reflect differences in the underlying data. For example, the Home Mortgage Disclosure Act (HMDA) dataset used by the CFPB includes used housing, while the Manufactured Housing Survey only reflects shipments of new homes; and based on Texas data, chattel loans are more likely to be secured by newly constructed homes, while mortgages are more likely for used homes (CFPB 2021).

[30] A HPML has an APR higher than the average prime offer rate (APOR), for example, ≥1.5 percentage points higher for a first-lien mortgage, or ≥2.5 percentage points higher for a jumbo loan (CFPB 2020; see https://www.consumerfinance.gov/ask-cfpb/what-is-a-higher-priced-mortgage-loan-en-1797/).

illustrated in Figure 3.4-13, with both total numbers of applicants and percentages (note that MH in this figure is manufactured housing) (CFPB 2021).

**TABLE 3.4-2 Borrower Demographics for Home Loans**

| Aspect | Chattel Loan | Manufactured Home Mortgage | Site-Built Home Loan |
|---|---|---|---|
| Median credit score | 676 | 691 | 739 |
| Median income | $52,000 | $53,000 | $83,000 |
| Median loan amount | $58,672 | $127,056 | $236,624 |
| Median combined loan-to-value ratio | 87.0 | 96.5 | 95.0 |
| Median debt-to-income ratio | 35.7 | 38.9 | 38.7 |
| Median loan term (years) | 23 | 30 | 30 |
| Median interest rate | 8.6 | 4.9 | 4.1 |
| Median rate spread | 5.2 | 1.6 | 0.4 |
| Percent of loans that are HPML | 93.8 | 52.4 | 11.1 |
| Percent of loans that are Home Ownership and Equity Protection Act (HOEPA) loans | 0.7 | 0.2 | 0.1 |
| Loan applications denied (percent of total applications) | 50.1 | 32.7 | 7.4 |

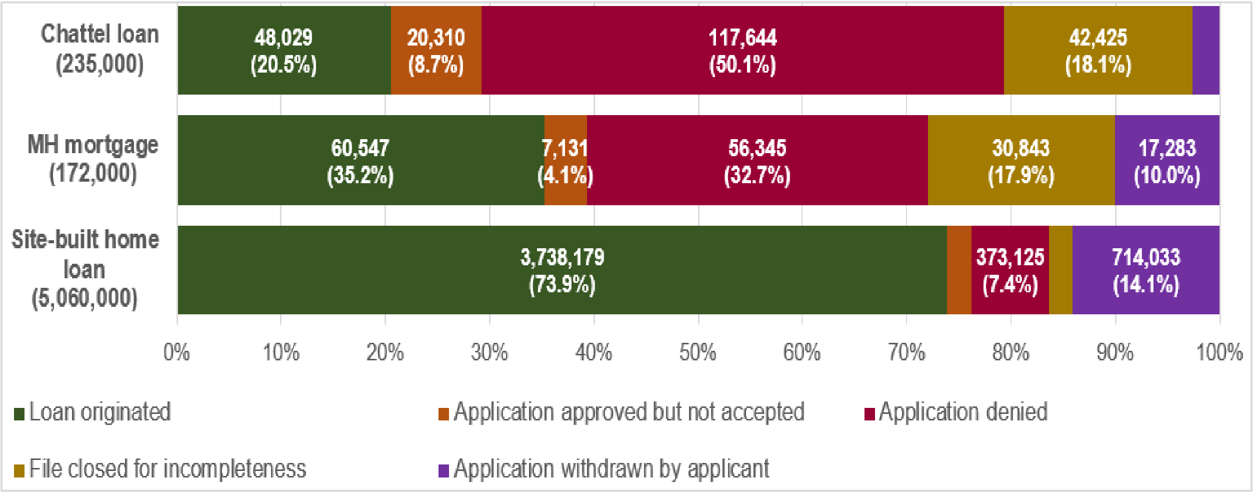

**FIGURE 3.4-13 Approval Rates for Manufactured Housing Loans**

The median loan value for manufactured-housing purchasers who finance their home using a chattel loan is $59,000, while the median loan value for mortgages is $127,000. In comparison, the median loan value for site-built mortgages is $237,000. The percentage of chattel loans by state in 2019 is illustrated in Figure 3.4-14 (CFPB 2021).

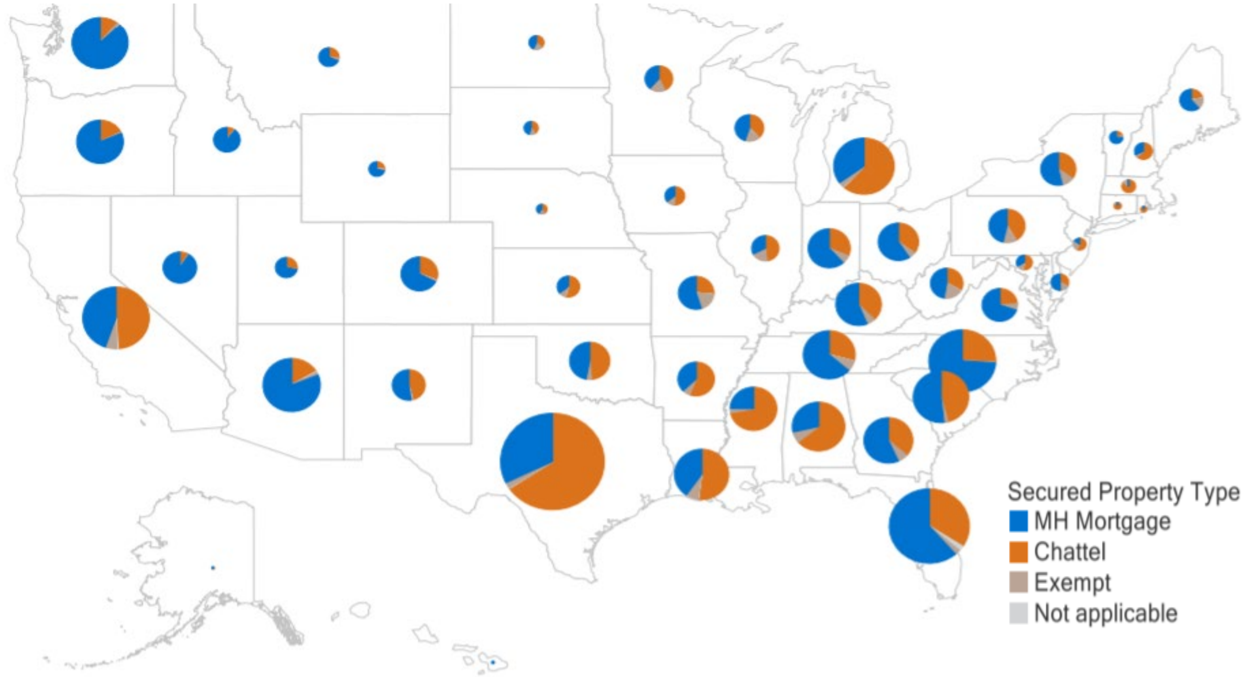

**FIGURE 3.4-14 Proportion of Home Purchase Loans for Manufactured Housing as Chattel**

The ethnicity and race of borrowers of manufactured housing and site-built housing are identified in Figure 3.4-15 (CFPB 2021). The racial and ethnic composition of borrowers differs substantially between chattel and mortgage loans for manufactured housing. Even when controlling for land ownership, the data show that Hispanic, Black and African American, American Indian and Alaskan Native, and elderly borrowers are more likely to take out chattel loans.

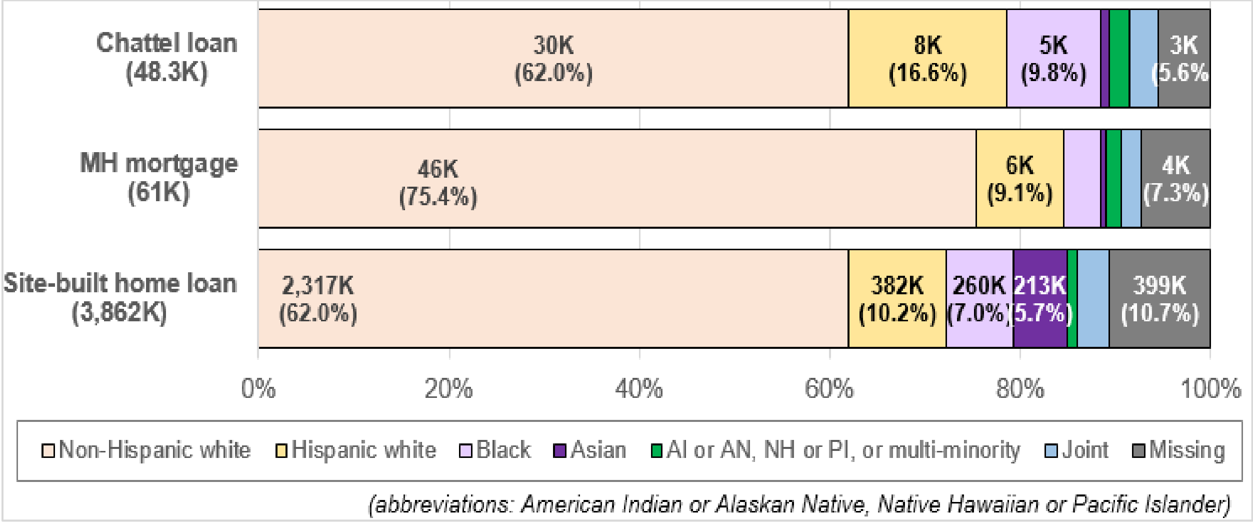

**FIGURE 3.4-15 Ethnicity and Race of Borrowers of Manufactured and Site-Built Housing**

Blacks and African Americans are the only racial group underrepresented in lending for manufactured housing compared to site-built homes, and they are overrepresented in chattel lending compared to site-built homes. Among borrowers who owned the land, Blacks and African Americans, Hispanic whites, and American Indians and Alaskan Natives had a much higher percentage of chattel loans than non-Hispanic whites, as shown in Figure 3.4-16 (CFPB 2021). (Direct owners are borrowers who own the land on which the manufactured housing is located.)

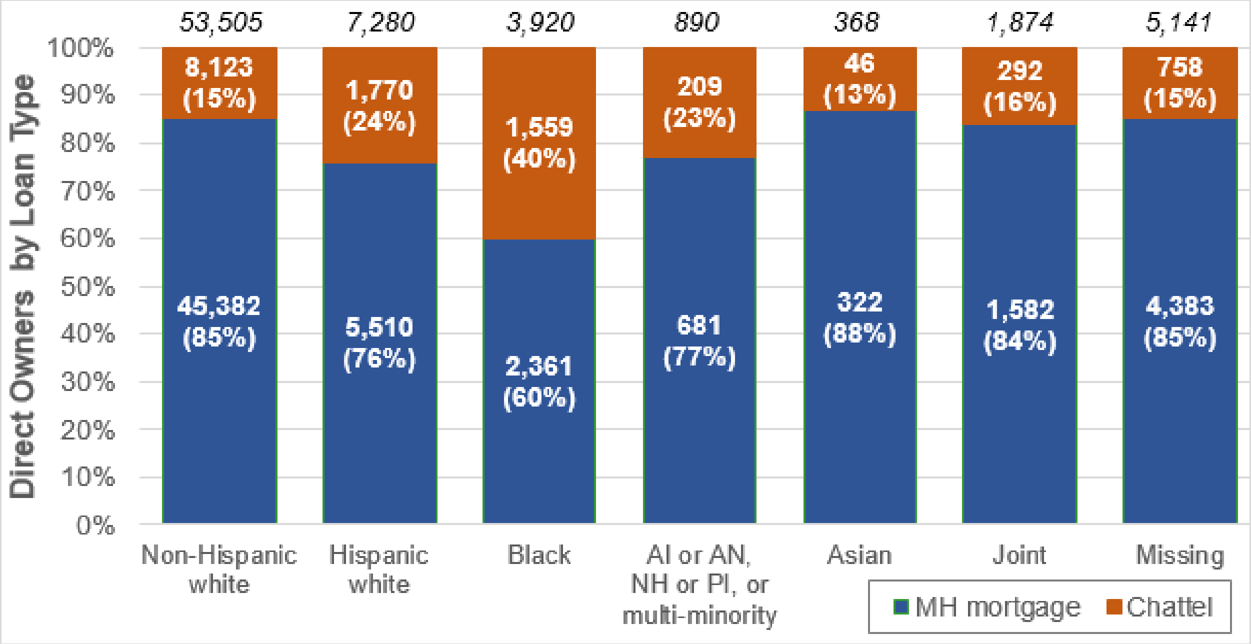

**FIGURE 3.4-16 Type of Manufactured Housing Property Secured for Direct Ownersy Ethnicity and Race**

Improvements to the current financing situation are an important part of addressing substantial disparities for manufactured homeowners. Under the HOEPA of 2014, certain mortgage loans with APRs or fees above certain levels were granted specific protections and disclosures on loan features; additional disclosure requirements apply for mortgage originators of first-lien loans under the HMDA[31] (CFPB 2021). Examples of federal resources that support development and financing of affordable manufactured housing include HUD-HOME (HUD 2021b), USDA Rural Development (USDA 2020), and the National Housing Trust Fund (NLIHC 2021).

### 3.4.5 Energy Insecurity

Energy insecurity is a particularly relevant indicator when framing the evaluation of potential socioeconomic impacts of proposed energy conservation standards for manufactured housing. Energy insecurity generally refers to the uncertainty a household can face about being able to pay utility bills (Brown et al. 2020). This condition involves difficult tradeoffs such as reducing or forgoing basic necessities to pay energy bills, keeping the home at unsafe or unhealthy temperatures to minimize energy bills, receiving disconnection or stop-delivery notices, and being unable to maintain heating or cooling equipment in safe, functional condition (EIA 2018c).

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[31] The disclosure applies to first-lien loans with a rate spread between the APR and the APOR (which is the hypothetical APR a financial institution may offer a prime mortgage borrower in a given week) (CFPB 2021).

The following overview highlights information from EIA's analysis of responses to the 2015 Residential Energy Consumption Survey[32] (EIA 2018a, 2018c). More than half (56 percent) of households living in manufactured homes reported experiencing challenges in paying their energy bills or sustaining adequate heating and cooling, which is substantially higher than for U.S. households overall (31 percent). One in five households had to get by with less or do without basic necessities like food and medicine to be able to pay their energy bill (a monthly challenge for nearly 30 percent of these households). One in seven households received a disconnection notice, with more than 10 percent of those households receiving such a notice every month (EIA 2018c).

EIA (2018c) found that differences across geographic regions and between urban and rural respondents were minor, suggesting that a household's ability to afford energy and maintain heating and cooling equipment is more related to structural features and demographic characteristics than to geography and associated climates. Households experiencing higher energy insecurity included those with low incomes or those who identified with a minority racial group or as Hispanic. The greater difficulties with household energy insecurity faced by residents of manufactured homes compared with residents of all U.S. homes are illustrated in Figure 3.4-17 (EIA 2018c).

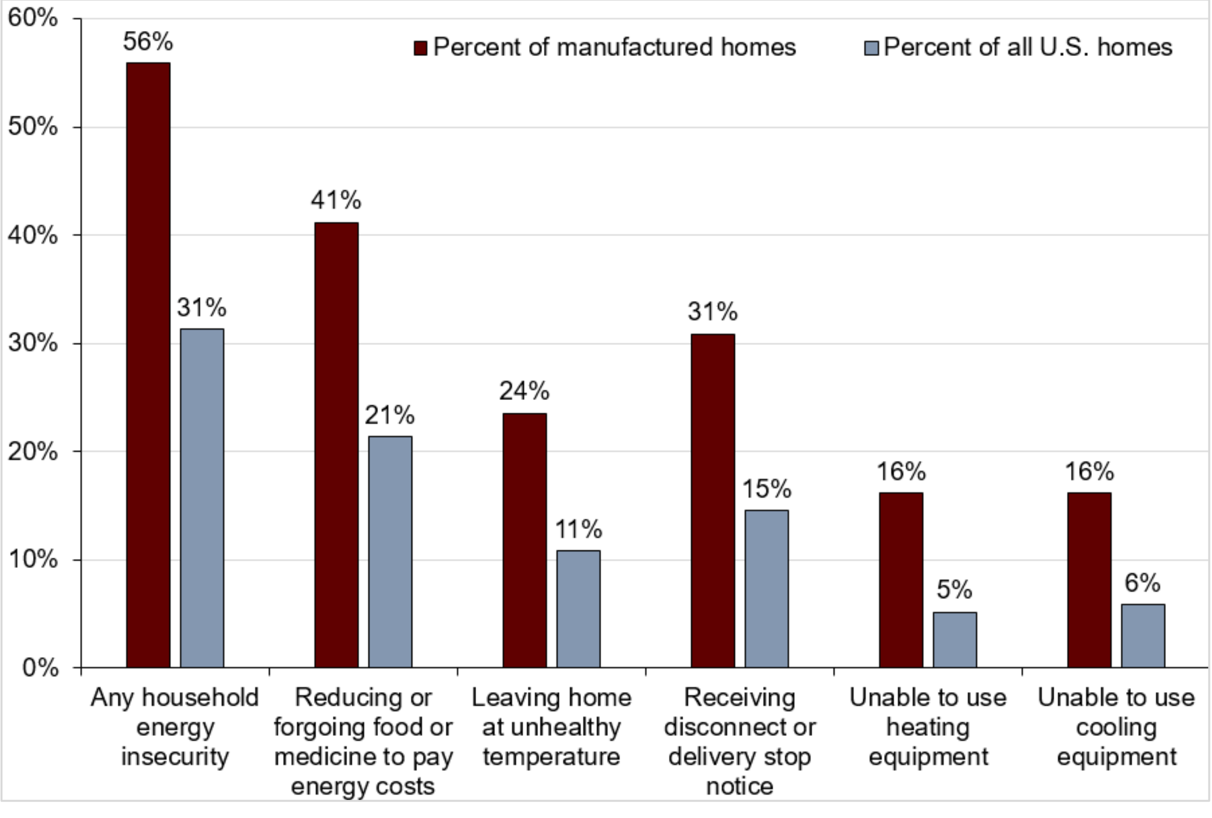

**FIGURE 3.4-17 Percentage of Homes Facing Energy Insecurity**

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[32] The survey reports data from households living in manufactured homes, which include households living in older manufactured homes. Purchasers of new manufactured homes might have higher incomes than those discussed here.

Energy burden is the measure of energy costs as a percentage of household income, and a high burden can lead to energy insecurity. An energy burden above 6 percent is considered high, and above 10 percent is considered severe (Brown et al. 2020). A recent study by the American Council for Energy Efficient Economy (ACEEE) found that people spend an average of 3.1 percent of their household income on home energy bills (ACEEE 2020a). This study also identifies an average burden of 5.3 percent for manufactured housing, and 8.1 percent for low-income households, defined as those with incomes at or below twice the federal poverty level (ACEEE 2020a; EERE 2021).

Nearly half (45 percent) of U.S. households living in manufactured homes have a high energy burden, and a quarter of these have a severe energy burden (more than 10 percent of household income spent on home energy bills) (ACEEE 2020a). Of 17 subgroups with high energy burdens, manufactured homes rank third, with only low-income households (which include many households in manufactured homes) and low-income multi-family households (five or more units) having a higher percentage of households with high energy burdens. Other subgroups with lower percentages than manufactured housing include Black, Native American, and Hispanic households and households with older adults (age 65 and older). Factors that can influence high energy burdens for low-income families include energy-inefficient homes and higher-cost fuels (such as propane) (ACEEE 2020a; EERE 2021).

The EIA (2018a) reports that annual energy expenditures for manufactured homes totaled nearly $12 billion in 2015, which translates to $1,750 for each household (EIA 2018c). Utility costs are typically higher for manufactured homes than for site-built homes, and on average the energy cost per square foot for a manufactured home is 70 percent higher than for a single-family home (EIA 2018a; ACEEE 2020b).

Nationwide, ACEEE reports that the median energy burden for residents of manufactured homes is 39 percent higher than for residents of single-family homes (ACEEE 2020a). The ACEEE also reports median energy burdens for a number of metropolitan areas, including four evaluated in this EIS: Chicago, Houston, Memphis, and Miami. The median energy burden for low-income populations within these metropolitan areas (i.e., households whose income is at or below twice the federal poverty level) is more than twice as high as the burden for the full metropolitan area, and in each city they meet the definition of high energy burden (more than 6 percent of household income spent on home energy bills).

In Chicago, the median energy burden for the metropolitan area is 2.7 percent, while it is 8 percent for the area's low-income population. In Houston, the median energy burden is 3 percent for the metropolitan area but 7.1 percent for the low-income population. In Miami, the median energy burden is 3 percent for the metropolitan area but 6.9 percent for the low-income population. In Phoenix, the median energy burden is 3 percent for the metropolitan area but 7 percent for the low-income population (ACEEE 2020a). In each city, the median for the low-income population meets the definition of a high energy burden (exceeding 6 percent).

Combining energy burdens with financing considerations, many residents of manufactured homes are burdened by both high energy costs and high loan payments, as illustrated in Figure 3.4-18 (data are from the American Community Survey, Census 2019c). The utilities cost is the sum of the average monthly gas cost plus the average monthly electric cost for manufactured homes. Ownership cost is the sum of the average monthly gas cost plus the average monthly electric cost plus the average first mortgage payment for manufactured homes. Average household income is adjusted to be in constant yearly dollars.

The average energy costs for manufactured homes are similar to the mortgage costs in the western United States (5-6 percent compared to 7 percent), noting that manufactured homes are most expensive in this region (see Figure 3.4-11). Across the Northeast, Midwest, and South, the cost of monthly utilities exceeds that of the mortgage — reaching nearly twice the mortgage amount in the South and more than twice the mortgage amount in the Midwest. This information highlights the importance of energy-efficient homes, particularly in light of the lower median household incomes for the population served by manufactured housing (see Section 3.5).

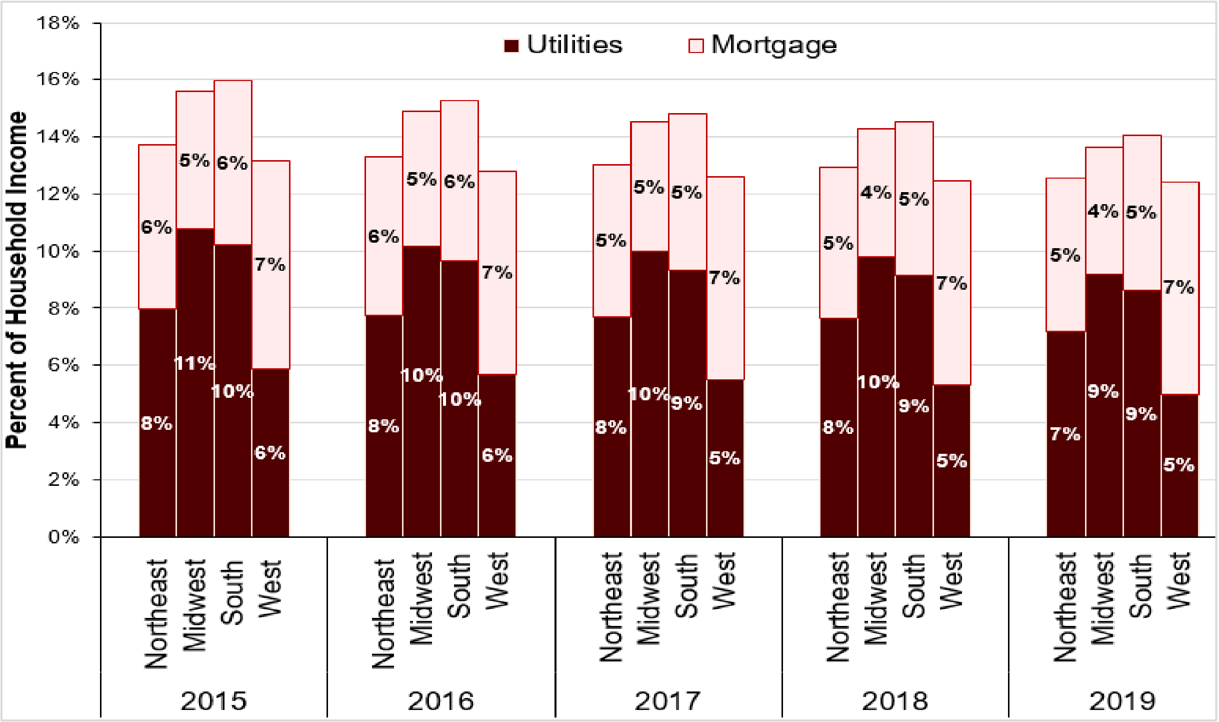

**FIGURE 3.4-18 Ownership Costs as a Percentage of Average Monthly Household Income for Manufactured Homes, by Census Region**

## 3.5 ENVIRONMENTAL JUSTICE

In 1994, Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," directed each federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations," including tribal populations.

The CEQ (1997) subsequently provided guidance for environmental justice analysis in its *Environmental Justice Guidance under the National Environmental Policy Act.* In 2016, an interagency working group (IWG) prepared a Promising Practices report, which provides recommendations that outline guiding principles and best practices strategies for evaluating environmental justice in NEPA (IWG 2016). The three steps for conducting an environmental justice analysis that were outlined in that report have been applied in this EIS. These steps are:

- Describe the geographic distribution of low-income and minority populations in the affected area;
- Assess whether the impacts of establishing energy conservation standards for manufactured housing are high and adverse; and
- If impacts are high and adverse, determine whether these impacts disproportionately affect minority and low-income populations.

This draft EIS uses the definition of minority and low-income population groups from the EPA's documentation for its Environmental Justice Mapping and Screening tool (EPA 2019a). These two terms are defined as follows:

- *Low-income*: The number or percent of a block group's population in households where the household income is less than or equal to twice the federal poverty level.
- *Minority*: The number or percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino.

In January 2021, Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," created the government-wide Justice40 Initiative. The aim of this initiative is to distribute 40 percent of the overall benefits of relevant federal investments to disadvantaged communities. Programs span investments in clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of critical clean water infrastructure.

### 3.5.1 Geographic Distribution of Minority and Low-Income Populations

The affected environment for an environmental justice analysis includes any or all geographic areas where potentially impacted minority populations and low-income populations could experience impacts related to any resource analyzed in this EIS. The affected environment for the DOE's proposed energy conservation standards for manufactured housing can include communities and areas across the United States. Although there is no way to know where future manufactured homeowners will live, the demographics of future homeowners can be estimated based on the demographics of current manufactured homeowners (Table 3.5-1). Figure 3.5-1 presents the geographic distributions of populations in poverty, minority populations, and manufactured housing locations. These data are from the 2019 biennial American Housing Survey (Census 2020).[33] All three population groups are generally more prevalent in the southern United States, across the southeast to the southwest and west.

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[33] Survey results are released about 12 months after the data are collected; the next release is anticipated in 2022. Note that this survey uses the term mobile homes to represent manufactured homes. The latter term is used here.

In the United States, about 28 percent of households living in manufactured homes are minority households and about 53 percent are low-income, while slightly more than 37 percent of total U.S. households are minority and about 30 percent are low-income (Census 2020). A baseline characterization of socioeconomic conditions within the affected environment is discussed in Section 3.4, including income and employment, housing characteristics, financing aspects and borrower characteristics, and energy insecurity considerations.

TABLE 3.5-1 Total U.S. Minority and Low-Income Populations in 2019[a]

| Category | Households Living in Manufactured Homes | Total Households |
|---|---|---|
| Total population | 6,756 | 124,135 |
| White, Non-Hispanic | 4,939 | 81,639 |
| Hispanic or Latino | 949 | 17,299 |
| Non-Hispanic or Latino | 922 | 28,956 |
| One race | 813 | 27,136 |
| Black or African American | 601 | 17,114 |
| American Indian or Alaska Native | 151 | 1,432 |
| Asian | 61 | 6,377 |
| Pacific Islander alone | 0 | 393 |
| Two or more races | 109 | 1,820 |
| Total minority | 1,871 | 46,255 |
| Total low-income | 3,598 | 37,715 |
| Percent minority | 27.7 | 37.3 |
| Percent low-income | 53.3 | 30.4 |

[a] Because Hispanics may be any race, data for "Hispanic or Latino" can overlap slightly with other groups. Most Hispanics report themselves as white, but some report themselves as Black or in other categories. Data source: Census (2020).

This EIS considers six metropolitan areas to illustrate existing conditions and provide a baseline for evaluating potential consequences of the proposed action and alternatives. These six are Chicago, Fresno, Houston, Memphis, Miami, and Phoenix. The DOE recognizes that most manufactured homes are located in suburban and rural areas rather than in cities. To more accurately represent the populations of future manufactured homeowners in this assessment, the affected environment is taken to include all the census block groups that contain manufactured home communities within each of these metropolitan areas. Using only the larger metropolitan or urban areas as the affected environment would skew the data away from the disadvantaged communities because it would incorporate dense urban areas and populations where location-specific zoning rules exclude manufactured housing.

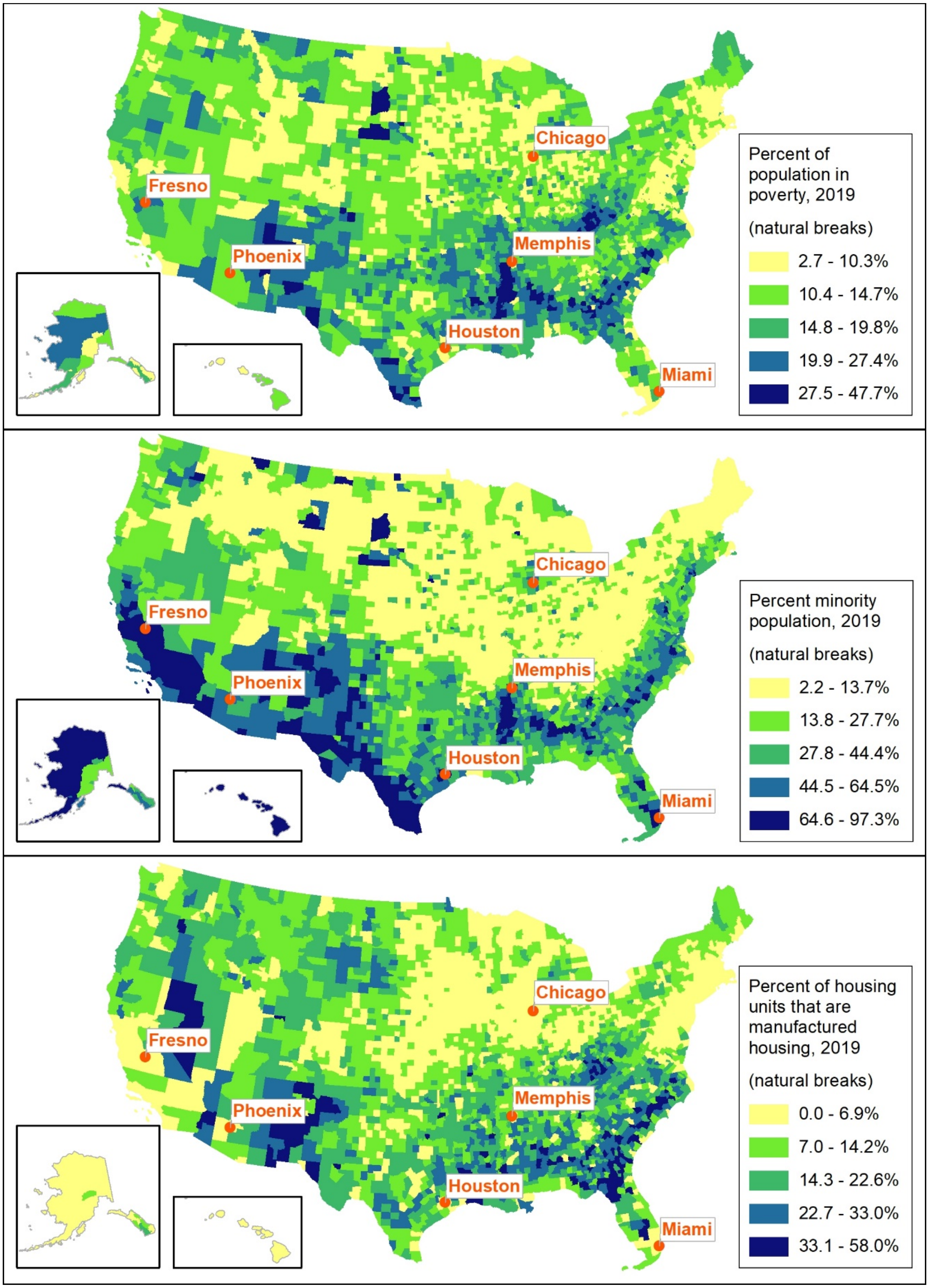


**FIGURE 3.5-1 Percent of Population in Poverty, Minority Population, and Housing Units That Are Manufactured Homes, 2019**

As described in the Promising Practices report, the affected environment should be a unit of geographic analysis that may include a governing body's jurisdiction, neighborhood, census tract, or other similar unit that is to be chosen so as to not "artificially dilute or inflate the affected minority population" (IWG 2016). The affected environment does not need to be contiguous, and in this analysis, the affected environment for each illustrative location is dispersed across the metropolitan area. Because local zoning laws and other land use regulations can prohibit the placement of manufactured houses, by identifying the affected environment as a subset of the metropolitan areas, it is reasonable to assume that those locations are areas in which new manufactured homeowners could realistically place a newly purchased home without "diluting" the presence of minority or low-income populations.

For minority populations, the 1997 CEQ guidance proposed that minority populations should be identified where either (1) the minority population of the affected area exceeds 50 percent, or (2) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis (CEQ 1997).

The Promising Practices report recommends that a meaningfully greater analysis — which compares the percentage of minority population in the affected area to a reference community population using a reasonable subjective threshold to define "meaningfully greater" — should follow a 50 percent analysis (IWG 2016). In keeping with the CEQ guidance and IWG recommendations, the reference communities for the meaningfully greater analysis in this EIS are the total metropolitan areas for each city. Table 3.5-2 displays minority populations in each of these metropolitan areas as the number of minority individuals and also as a percentage of their total population.

The number of minority individuals living in census block groups with manufactured housing communities exceeds the 50-percent threshold in Fresno, Houston, Memphis, and Miami, with Fresno being the highest at nearly 76 percent. Figures 3.5-2 through 3.5-7 show census block groups within the affected environment whose minority population exceeds 50 percent. Additional minority populations are identified using 20 percent as the threshold for the meaningfully greater analysis, that is, where the minority population of a census block group exceeds the minority population in the reference community (metropolitan area) by 20 percent or more. These groups are also shown in Figures 3.5-2 through 3.5-7, as are the manufactured housing communities.

The 1997 CEQ guidance does not propose thresholds for identifying low-income populations, but recommends agencies consider either a group of individuals living in geographic proximity to one another, or a set of individuals, where either type of group experiences common conditions of environmental exposure or effect (CEQ 1997). The 2016 Promising Practices report recommends conducting a low-income threshold criteria analysis, where the agencies select an appropriate poverty threshold and geographic unit of analysis in the affected environment as well as an appropriate reference community and an appropriate threshold for determining whether a particular geographic unit of analysis is identified as low income (IWG 2016).

**TABLE 3.5-2 Minority and Low-Income Populations in Affected Areas and Reference Communities (2019)[a]**

| Location | Total Population | Minority Population | Low-Income Population | Percent Minority | Percent Low Income |
|---|---|---|---|---|---|
| Chicago metropolitan area census block groups with manufactured housing communities | 177,728 | 79,313 | 63,995 | 44.6 | 36.0 |
| Chicago metropolitan area | 8,811,067 | 4,312,071 | 2,477,217 | 48.9 | 28.1 |
| Fresno metropolitan area census block groups with manufactured housing communities | 59,156 | 44,914 | 31,647 | 75.9 | 53.5 |
| Fresno metropolitan area | 722,003 | 484,867 | 316,607 | 67.2 | 43.9 |
| Houston metropolitan area census block groups with manufactured housing communities | 671,953 | 465,375 | 249,646 | 69.3 | 37.2 |
| Houston metropolitan area | 5,847,390 | 3,926,416 | 1,935,536 | 67.2 | 33.1 |

**TABLE 3.5-2 Minority and Low-Income Populations in Affected Areas and Reference Communities (2019)[a] (Cont.)**

| Location | Total Population | Minority Population | Low-Income Population | Percent Minority | Percent Low Income |
|---|---|---|---|---|---|
| Memphis metropolitan area census block groups with manufactured housing communities | 54,004 | 30,387 | 23,377 | 56.3 | 43.3 |
| Memphis metropolitan area | 1,143,034 | 681,807 | 429,877 | 59.7 | 37.6 |
| Miami metropolitan area census block groups with manufactured housing communities | 339,596 | 238,884 | 171,927 | 70.3 | 50.6 |
| Miami metropolitan area | 6,028,755 | 4,160,394 | 2,189,873 | 69.0 | 36.3 |
| Phoenix metropolitan area census block groups with manufactured housing communities | 427,465 | 211,247 | 210,668 | 49.4 | 49.3 |
| Phoenix metropolitan area | 4,127,467 | 1,792,687 | 1,353,700 | 43.4 | 32.8 |

[a] Data source: EPA (2019a).

There are a number of different ways to define low-income populations because cost of living varies between states and cities across the United States. In defining eligibility conditions for its assisted housing programs, HUD considers a low-income home to be any household earning less than 80 percent of the area median income (HUD 2021a, 2021b; DOE 2021). The HHS determines eligibility for its Low Income Home Energy Assistance Program (LIHEAP) by those earning less than 150 percent of (1.5 times) the federal poverty level. The state median income can also be used to determine eligibility for state-specific programs. For example, to acknowledge the differences between state incomes, LIHEAP defines low income as 150 percent of the poverty level, except in states where the state median is 60 percent higher (DOE 2021). In this EIS, the low-income threshold is taken to be 200 percent of the poverty level (2 times the level), which is the threshold defined by the EPA (2021) for EJSCREEN.

### 3.5.2 Environmental and Economic Indicators for Minority and Low-Income Populations

The affected environment for low-income populations is the same as for minority populations: the census block groups that contain manufactured housing communities within each of the six metropolitan areas. The reference communities are the larger metropolitan areas. Table 3.5-2 displays low-income populations in the six metropolitan areas that comprise the affected environment as the total number of low-income individuals and also as a percentage of the total populations. Figures 3.5-2 through 3.5-7 show census block groups within the affected environment whose low-income population exceeds the low-income population in the reference community (the metropolitan area). Low-income populations live in all six of the metropolitan areas evaluated in this EIS.

In Chicago, minority populations are present in 45 census block groups containing manufactured housing communities, representing 40 percent of the block groups in the affected environment (45 percent of the total population). There are 74 census block groups with low-income populations, which represents 66 percent of the block groups in the affected environment (36 percent of the total population). More than a third (36 percent) of all census block groups with manufactured housing in Chicago have both minority and low-income populations.

In Fresno, minority populations are present in 25 census block groups containing manufactured housing communities, representing 81 percent of the block groups in the affected environment (76 percent of the total population). There are also 25 census block groups with low-income populations (54 percent of the total population). More than two-thirds (71 percent) of all census block groups with manufactured housing in Fresno have both minority and low-income populations.

In Houston, minority populations are present in 178 census block groups containing manufactured housing communities in Houston, representing 74 percent of the block groups in the affected environment (69 percent of the total population). There are 164 census block groups with low-income populations, which represents 69 percent of the block groups in the affected environment (37 percent of the total population). Fifty-nine percent of all census block groups with manufactured housing in Houston have both minority and low-income populations.

In Memphis, minority populations are present in 17 census block groups containing manufactured housing communities, representing 57 percent of the block groups in the affected environment (56 percent of the total population). There are 19 census block groups with low-income populations, which represents 63 percent of the block groups in the affected environment (43 percent of the total population). Nearly half (47 percent) of all census block groups with manufactured housing in Memphis have both minority and low-income populations.

In Miami, minority populations are present in 142 census block groups containing manufactured housing communities, representing 74 percent of the block groups in the affected environment (70 percent of the total population). There are 138 census block groups with low-income populations, which represents 72 percent of the block groups in the affected environment (nearly 51 percent of the total population). Almost two-thirds (64 percent) of all census block groups with manufactured housing in Miami have both minority and low-income populations.

In Phoenix, minority populations are present in 119 census block groups containing manufactured housing communities, representing 47 percent of the block groups in the affected environment (49 percent of the total population). There are 193 census block groups with low-income populations, which represents 76 percent of the block groups in the affected environment (49 percent of the population). Nearly half (45 percent) of all census block groups with manufactured housing in Phoenix have both minority and low-income populations.

Environmental and economic indicators can be used to estimate baseline conditions for minority and low-income populations. The economic conditions at national, regional, and metropolitan levels for manufactured home residents as well as for the general population are discussed in Section 3.4. That section also includes a discussion of financing options available for manufactured homeowners, which can be less favorable than for site-built homeowners, particularly for low-income and minority households. Existing environmental conditions and building characteristics of manufactured homes that can impact indoor air quality with associated health implications are described in Section 3.2.3.

The EPA's environmental justice screening and mapping tool, EJSCREEN, combines environmental and demographic indicators to provide information at the state, city, or census block group level. Results of an example screening analysis of Fresno with EJSCREEN are presented in Figures 3.5-8 through 3.5-10. Fresno was selected for this illustration because most census block groups with manufactured housing have both minority and low-income populations, and ambient air quality is often a concern, including when affected by wildfires.

### 3.5.3 Justice40

Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* created the government-wide Justice40 Initiative. The White House Environmental Justice Advisory Council (WHEJAC) whose role is to advise the Federal Government on how to increase its efforts to address environmental injustice through strengthening environmental justice monitoring and enforcement, published an interim final report in May 2021 that provides recommendations on Justice40, the Climate and Economic Justice Screening Tool and Executive Order 12898 Revisions. The report provided recommendations for Justice40 to identify programs and policies, define investment benefits, and define disadvantaged communities (EPA 2021c). The WHEJAC recommended that underserved communities include:

- Majority minority communities
- High rate of health disparities
- Non-attainment of clean air and water standards

- Formerly redlined
- Food insecurity and child nutrition levels
- Children receiving school lunch program
- Income and percent of households on supplementary income benefits
- Numbers of superfund, waste, landfills and toxic facilities
- Low education attainment and low high school graduation rates
- High maternal and infant mortality rates
- High asthma rates and deaths
- Poorly maintained stock of housing
- Lack of grocery stores, proliferation of (cent stores and fast-food outlets)

One of the programs and areas targeted for Justice40 is safe, affordable, and sustainable housing and communities. The report provides recommendations for existing Federal programs including housing assistance (HUD Project-based Section-8, Conventional Public Housing, Section 202, Section 811, and Housing Vouchers HUD), EPA and HUD Clean Water State Revolving Fund, HHS Low Income Home Energy Assistance Program, and disaster and emergency relief assistance.

The report provides recommendations for HHS, EPA, HUD, and DOT to establish a grant programs for cities and towns to address infrastructure deficits and environmental protection that do not exist in many EJ and other communities. The interim final report does not provide any recommendations specifically targeted for manufactured homes. Lastly, the report provided recommendations for the climate and economic justice screening tool, which includes identifying the goal and purpose of the tool and identifying indicators. The report does recommend including manufactured homes as infrastructure indicators. The Justice40 program will continue to evolve; disadvantaged communities will be identified and programs and policies will be developed and implemented, as appropriate.

The EJSCREEN tool (EPA 2020) references the EPA 2014 National Air Toxics Assessment (NATA) (EPA 2018). NATA is also a screening tool, and it combines emissions data for the location of interest with dispersion and exposure modeling to estimate average health risks from chronic exposures at the census tract level. The 2014 NATA assessment, which was released in 2018, accounts for emissions during 2014 from both stationary and mobile sources to estimate ambient concentrations, as well as indoor concentrations resulting from the transport of outdoor pollutants indoors.

The EJSCREEN results for ambient $PM_{2.5}$ in Fresno are shown in Figure 3.5-8. For comparison, the EPA's health-based NAAQS for annual $PM_{2.5}$ is 12.0 $\mu g/m^3$ (see Section 3.2.3). These results illustrate that every census block group in Fresno containing manufactured housing communities exceeded the health-based standard for this pollutant.

Figure 3.5-9 presents both respiratory hazard indices (top panel) and cancer risks (bottom panel) estimated by EJSCREEN for inhalation of hazardous air pollutants in Fresno. As described in

Section 3.3, a HI of 1 or lower indicates the exposure is unlikely to cause an adverse noncancer effect, here a respiratory effect (EPA 2021). The EJSCREEN results in the top map show that the hazard indices for all census blocks containing manufactured housing communities are less than 1, indicating that inhalation of hazardous air pollutants is unlikely to cause an adverse noncancer effect.

The bottom panel of Figure 3.5-9 presents EJSCREEN estimates of the lifetime risk of getting cancer from inhaling these air pollutants. The risks estimated for Fresno are higher than the national average, but they are less than 55 per million, this is within the EPA's target range considered acceptable in terms of risk management priorities (Section 3.3). (The upper end of the EPA's acceptable risk range is 100 in 1 million, or 1 in 10,000.)

Figure 3.5-10 shows that ratios of all acrolein concentrations in ambient air to the inhalation reference value for this chemical of 0.82 $\mu g/m^3$ are well below 1. (This reference value was derived by Blessinger et al. [2020]; see Section 3.3.) These results indicate that acrolein exposures are unlikely to cause an adverse noncancer effect.

Regarding the potential for health effects from exposures to formaldehyde in ambient air, the concentrations in Figure 3.5-11 show that they are all below the inhalation reference value of 9 $\mu g/m^3$ (derived by CalEPA). Therefore, all ratios of the concentrations to this value would be less than 1. This indicates that these exposures are unlikely to cause an adverse noncancer effect. Similarly, multiplying these concentrations by the IUR of $6 \times 10^{-6}$ per $\mu g/m^3$ (derived by CalEPA) would produce risks that are less than 100 in 1 million, which is within the EPA's acceptable range for incremental lifetime risk.

Summing the estimated cancer risks across the hazardous air pollutants would likewise result in a combined cancer risk that is within the EPA's acceptable risk range. Similarly, summing the ratios of each pollutant concentration to its reference value (across the hazardous air pollutants) to produce the HI indicates that the index does not exceed the target of 1. These results indicate that $PM_{2.5}$ is a primary health concern from exposures to ambient air in Fresno, as it is for many other communities across the country

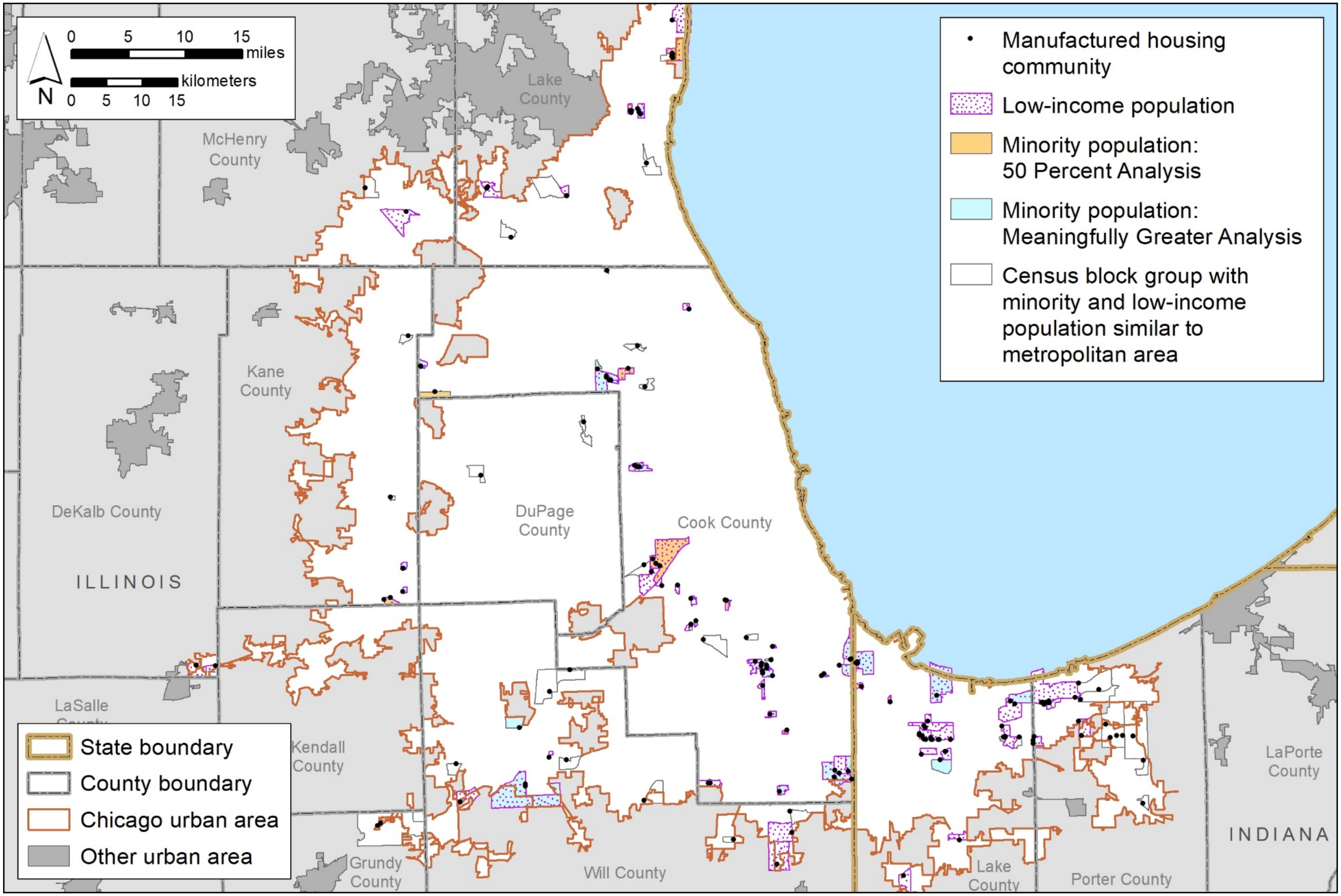


**FIGURE 3.5-2 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Chicago**

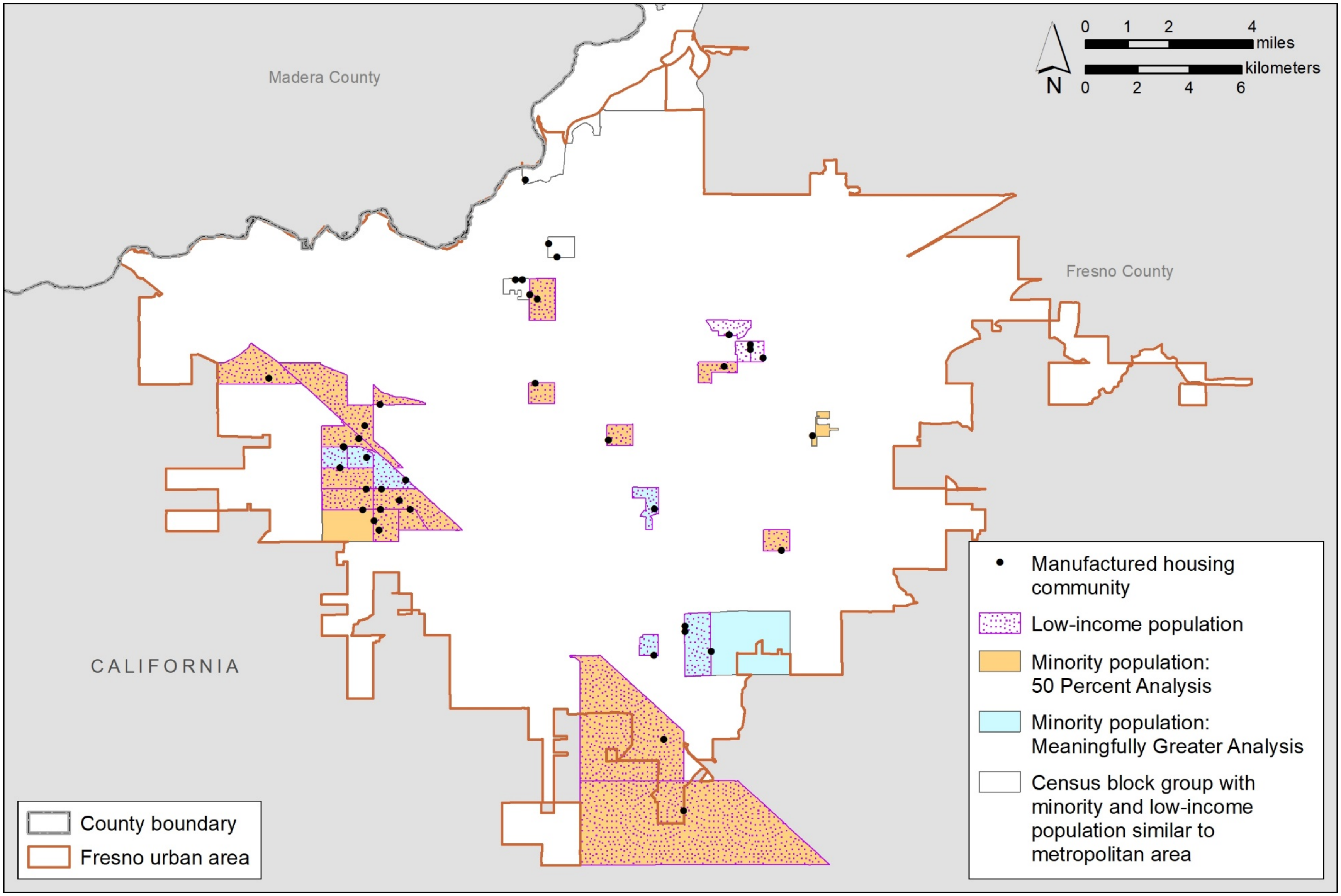


**FIGURE 3.5-3 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Fresno**

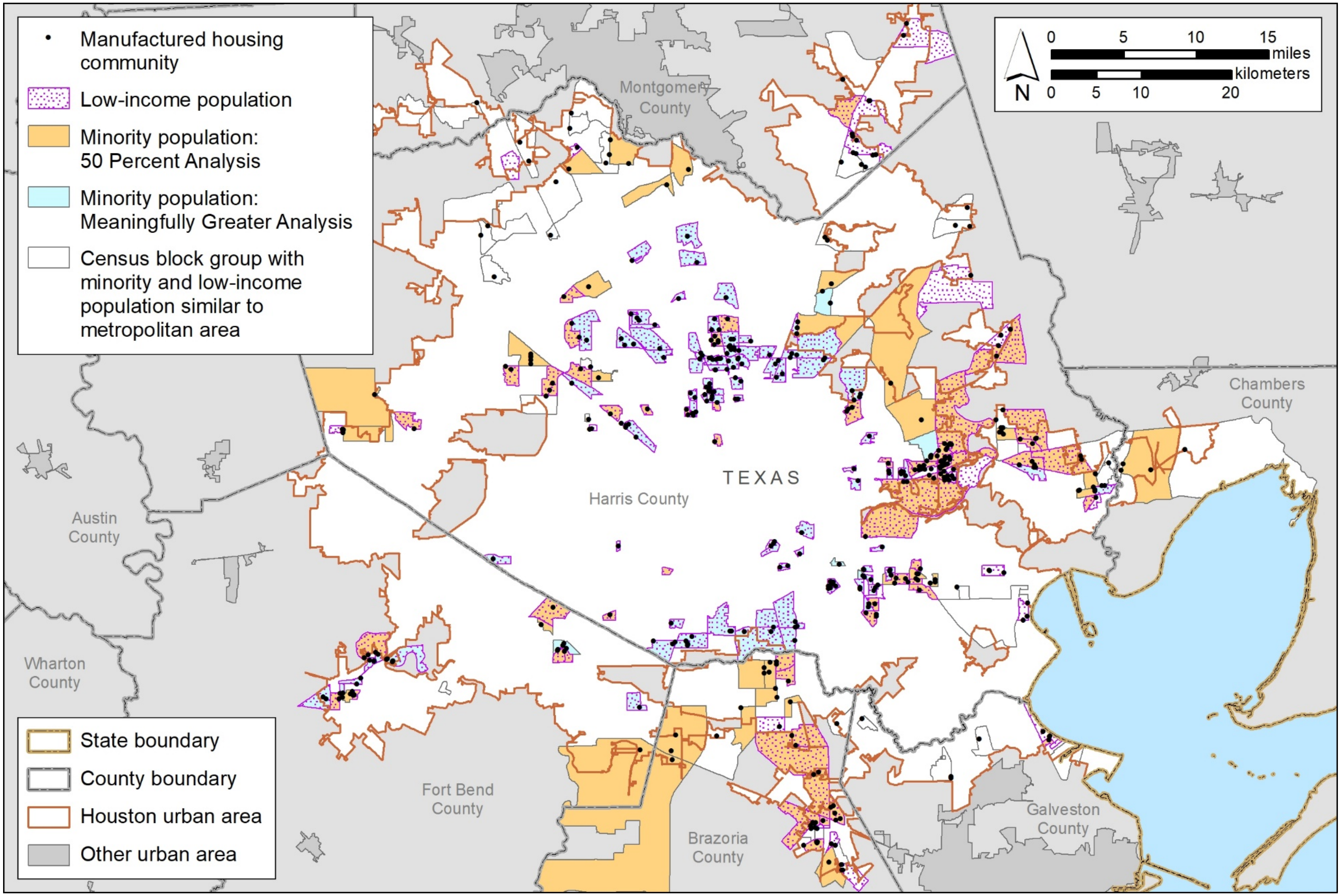


**FIGURE 3.5-4 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Houston**

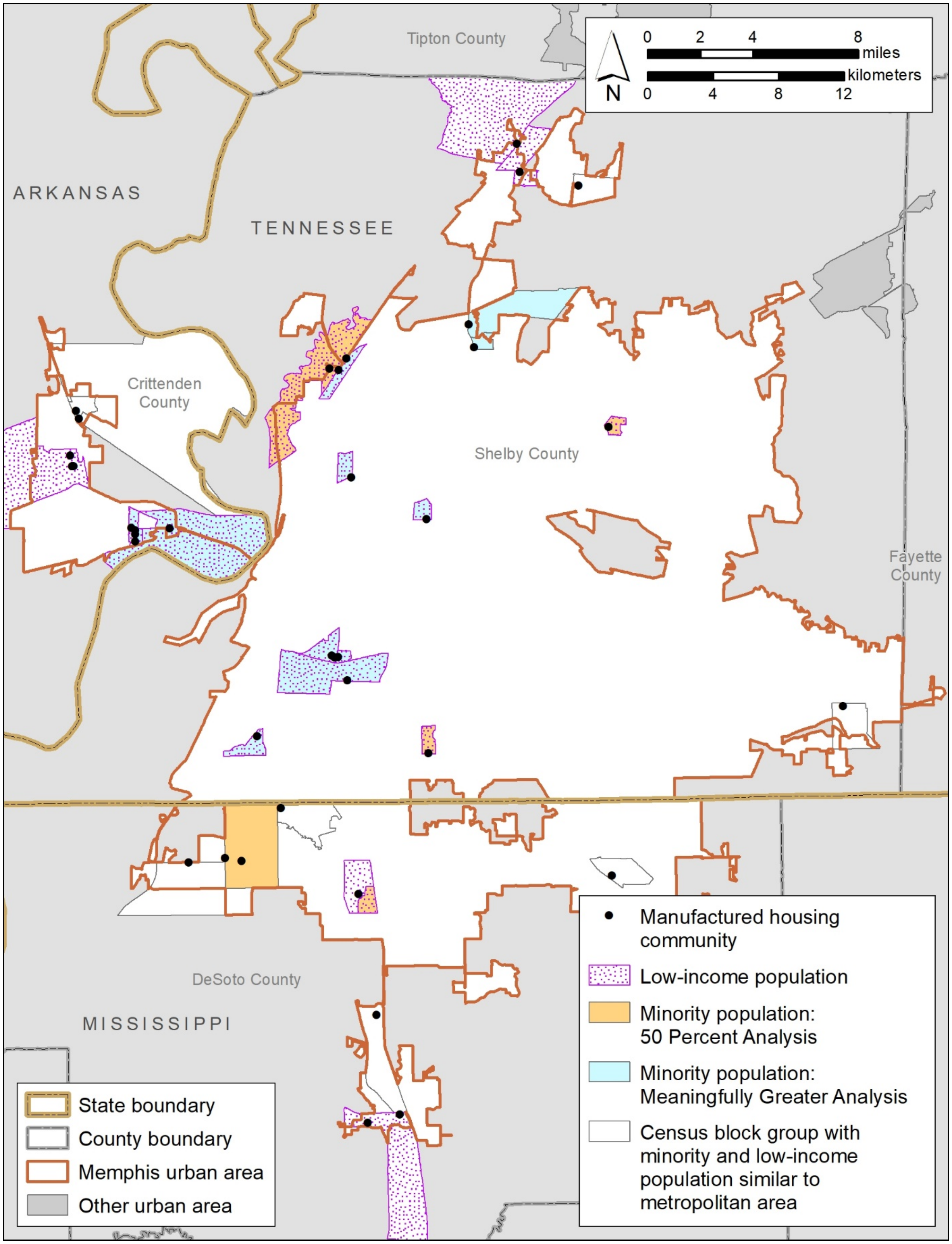


**FIGURE 3.5-5 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Memphis**

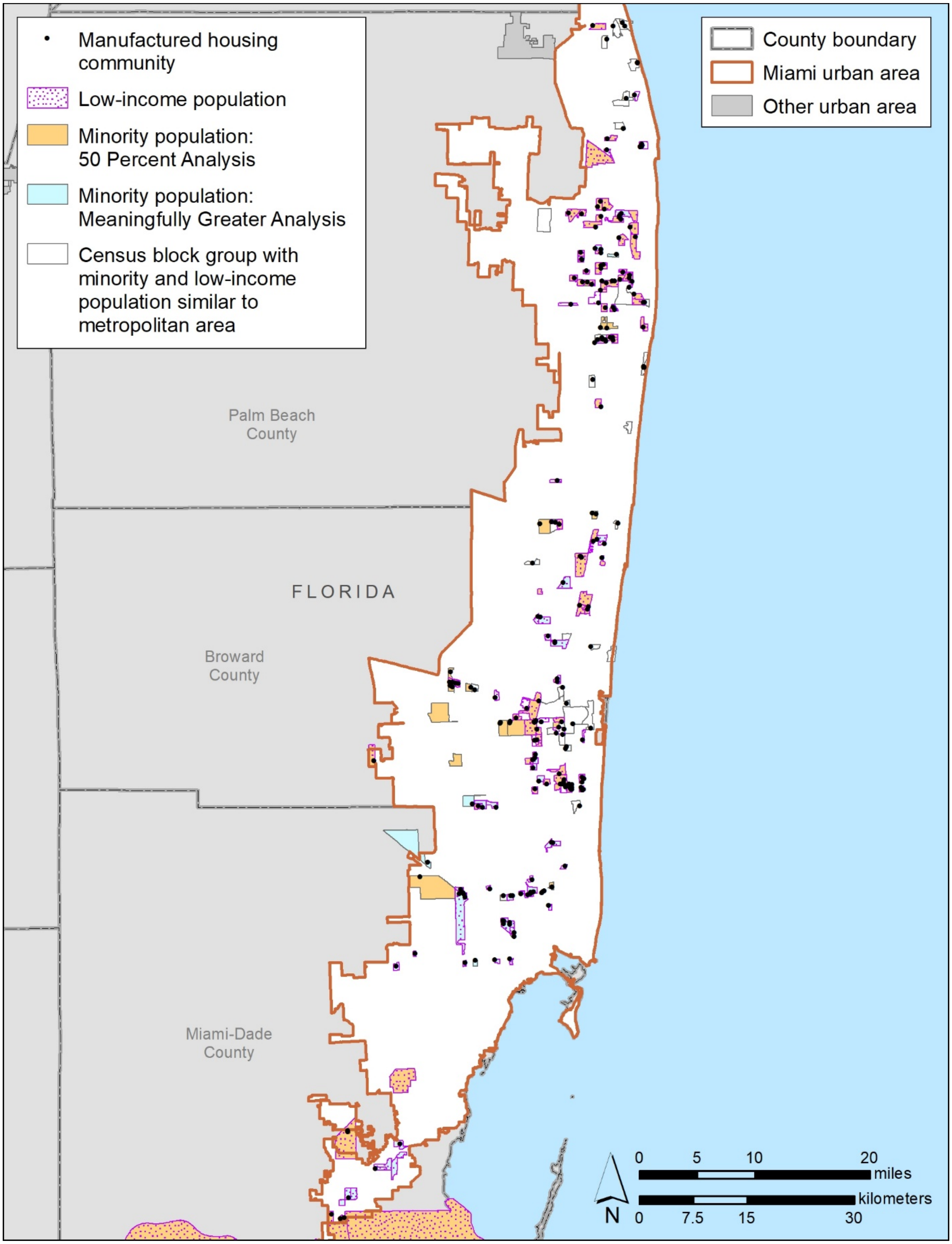


**FIGURE 3.5-6 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Miami**

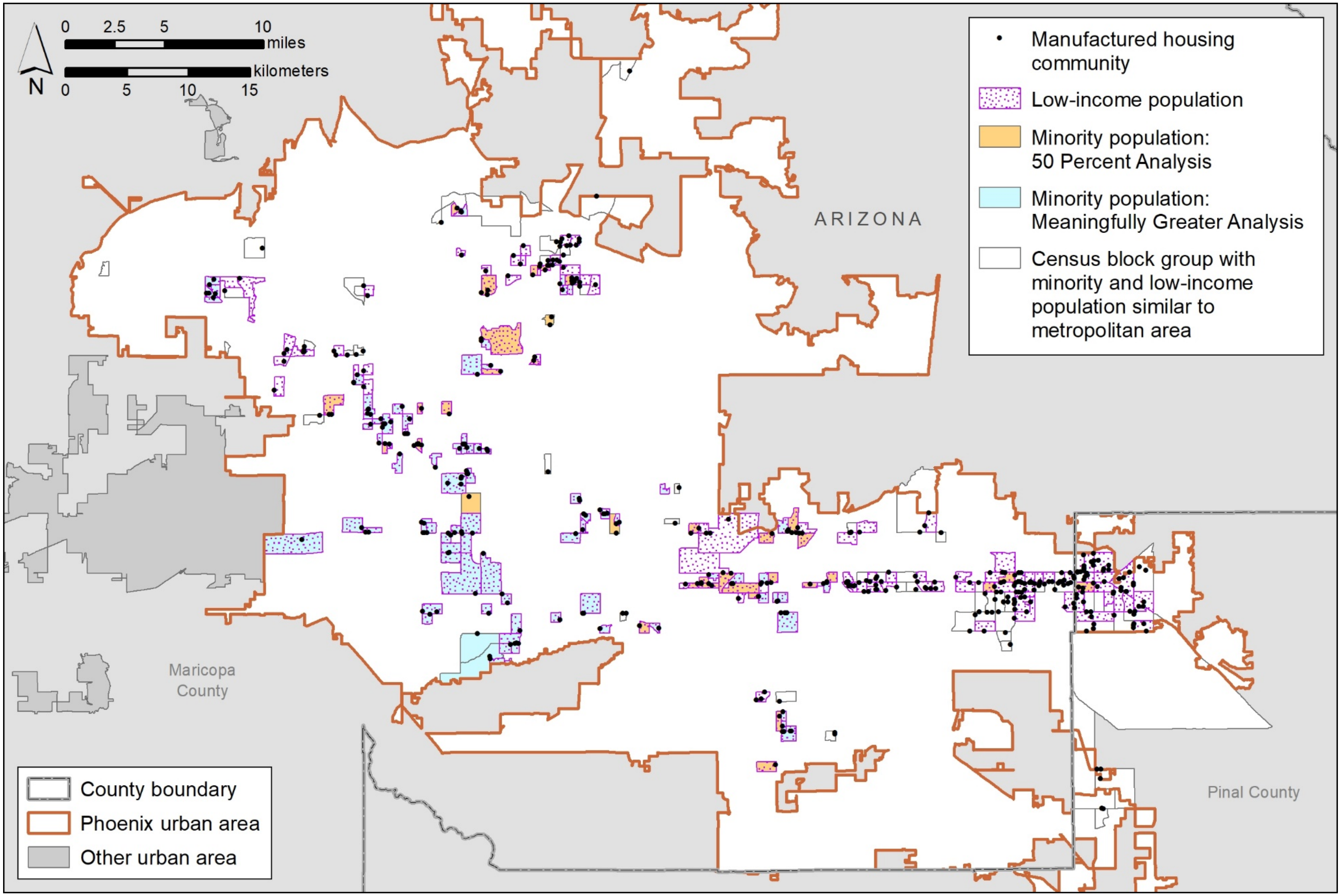


**FIGURE 3.5-7 Minority and Low-Income Populations in Census Block Groups with Manufactured Housing Communities in Phoenix**

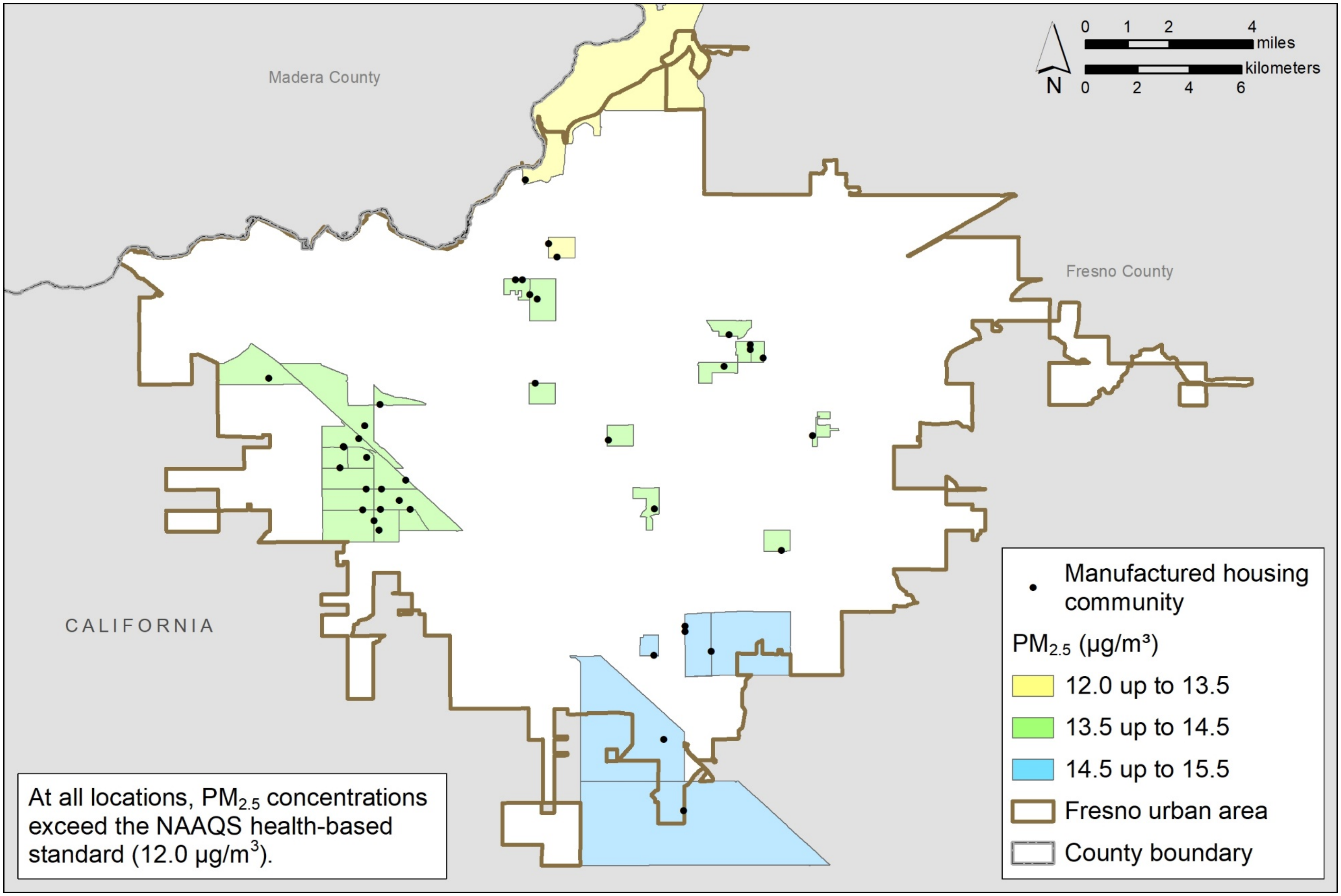


**FIGURE 3.5-8 EJSCREEN Concentrations of $PM_{2.5}$ (Annual) in Ambient Air in Fresno**

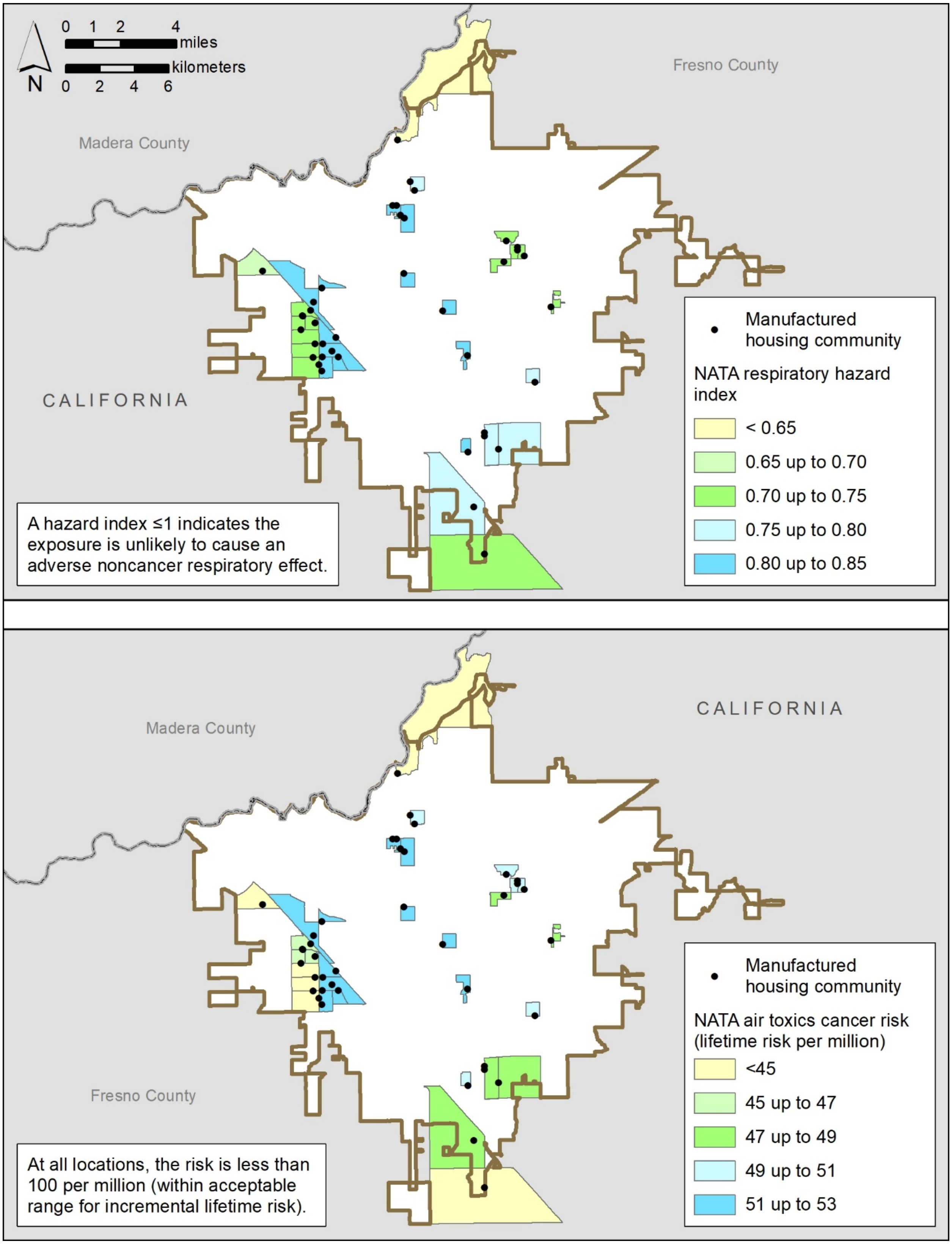
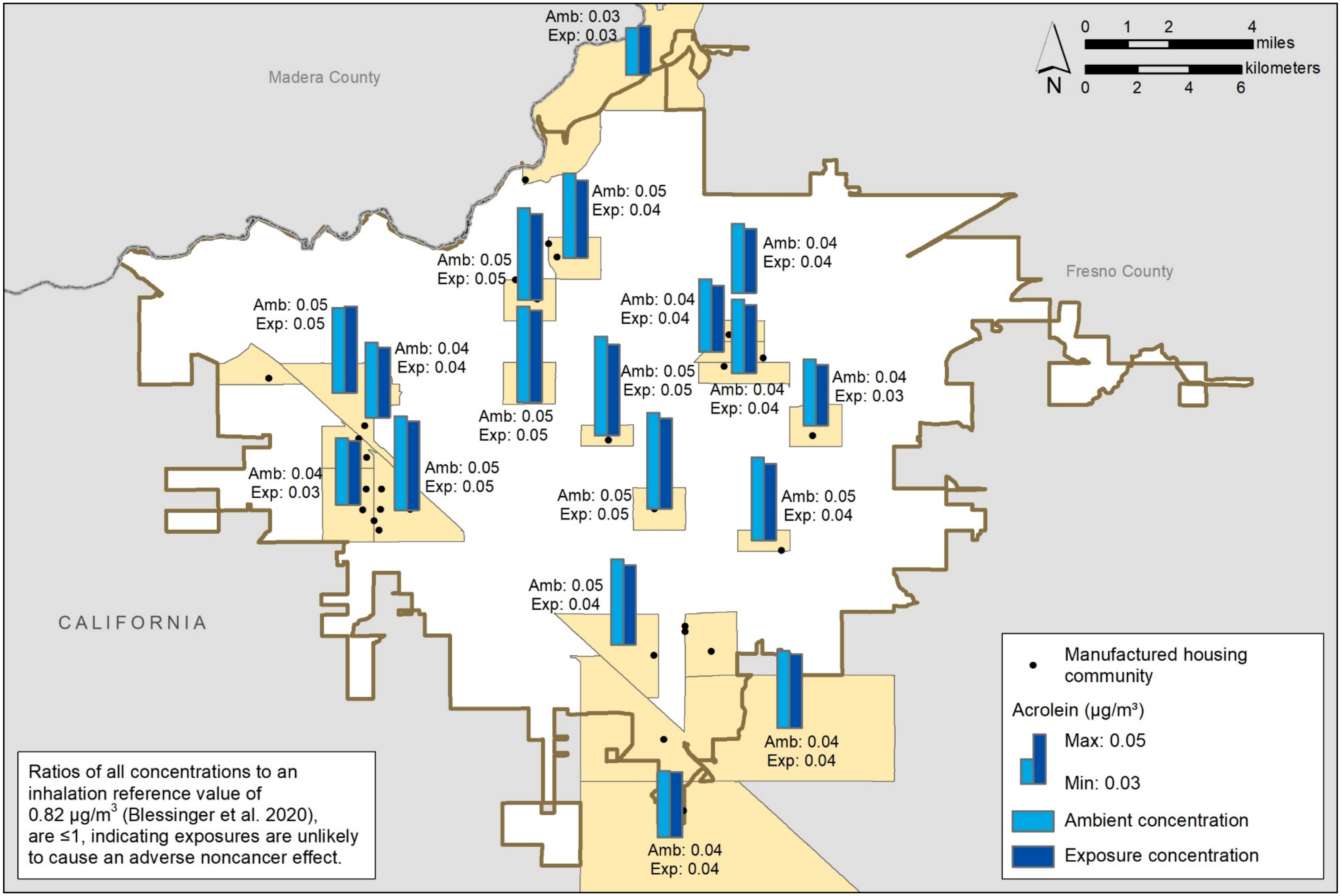
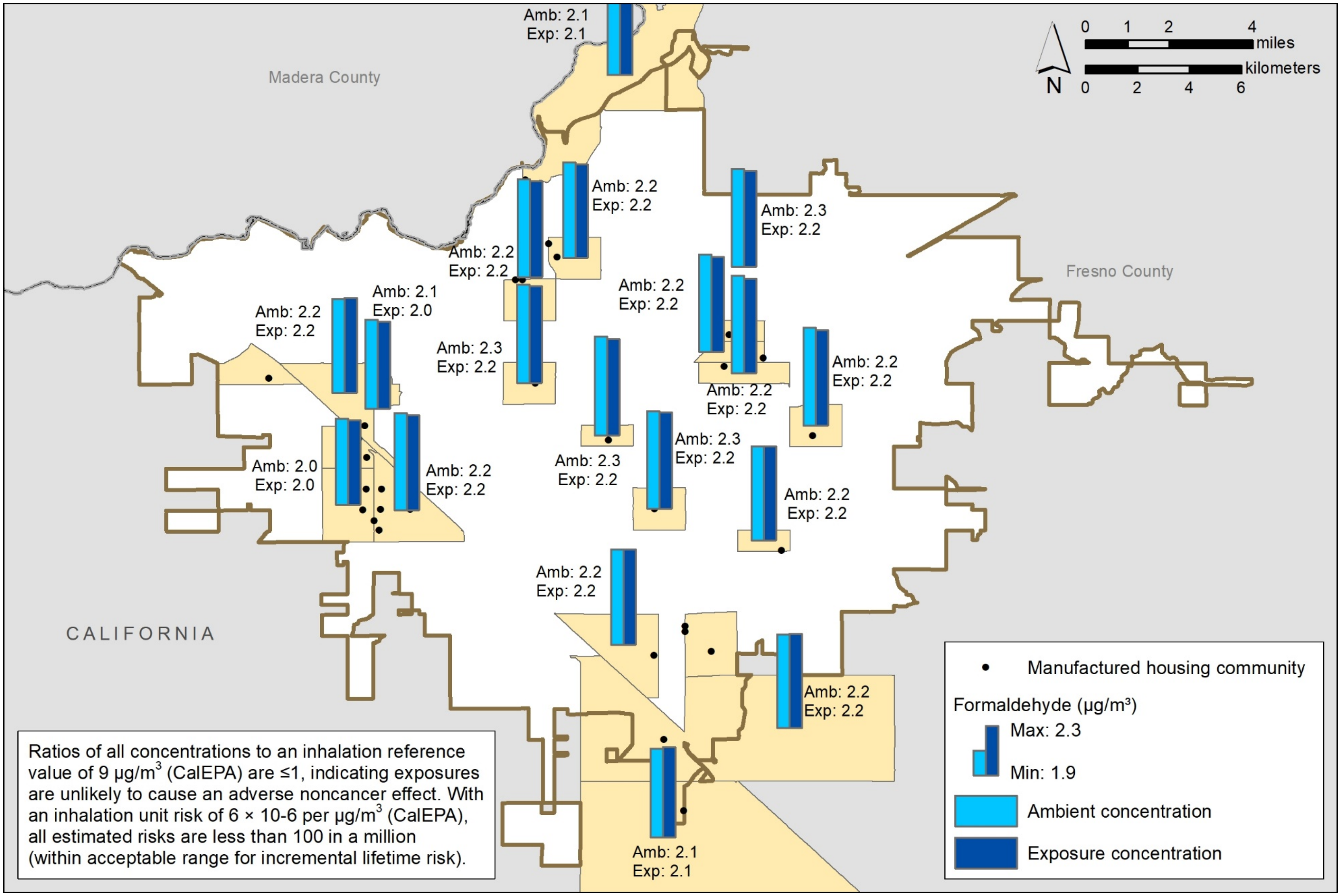


**FIGURE 3.5-9 EJSCREEN Concentrations of NATA Respiratory HI and Air Toxics Cancer Risk in Fresno**



Ratios of all concentrations to an inhalation reference value of 0.82 µg/m$^3$ (Blessinger et al. 2020), are ≤1, indicating exposures are unlikely to cause an adverse noncancer effect.

**FIGURE 3.5-10 EJSCREEN Ambient and Exposure Concentrations of Acrolein in Fresno**



Ratios of all concentrations to an inhalation reference value of 9 µg/m$^3$ (CalEPA) are ≤1, indicating exposures are unlikely to cause an adverse noncancer effect. With an inhalation unit risk of 6 × 10-6 per µg/m$^3$ (CalEPA), all estimated risks are less than 100 in a million (within acceptable range for incremental lifetime risk).

**FIGURE 3.5-11 EJSCREEN Ambient and Exposure Concentrations**

# 4 ENVIRONMENTAL CONSEQUENCES

This chapter describes the potential environmental consequences of DOE's proposed action and alternatives for establishing energy conservation standards for manufactured housing. Much of this information is summarized from the DOE Supplemental Notice of Proposed Rulemaking (SNOPR),[1] Technical Support Document (TSD),[2] and Notice of Data Availability (NODA).[3]

Potential impacts to energy resources are identified in Section 4.1, and those for air resources are presented in Section 4.2, including impacts to indoor air quality. Potential health and safety impacts are discussed in Section 4.3. Potential socioeconomic impacts are addressed in Section 4.4, and those for environmental justice are presented in Section 4.5. Potential unavoidable adverse impacts are discussed in Section 4.6, and the irreversible and irretrievable commitments of resources are addressed in Section 4.7. The relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity is considered in Section 4.8, and other environmental impacts are addressed in Section 4.9. Potential cumulative impacts are discussed in Section 4.10, and potential mitigation measures are identified in Section 4.11.

## 4.1 ENERGY RESOURCES

This section summarizes the energy impact analysis for the proposed energy conservation standards, highlighting information from the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042). In these documents, DOE describes the assessment approach and results of the national energy savings analysis. These savings represent the difference in national energy consumption between the no-action alternative (Alternative D) and the proposed action and action alternatives (Alternatives A–C). The estimated savings combine projections of annual shipments and energy consumption with total incremental cost data from the lifecycle cost analysis.

The national energy savings calculation is based on 30 years of manufactured housing shipments and considers the entire lifetime of each; the home lifetime is assumed to be 30 years. For the NODA (86 FR 59042), the shipment model described in the TSD (DOE 2021) was applied to project shipments of single-section and multi-section manufactured homes through 2052 based on shipment data from 2020. In a given year, the housing stock is the cumulative number of shipments up to that year minus the number of homes that have exceeded their 30-year lifetime. For each year, the total housing stock is multiplied by the unit energy consumption to get annual energy consumption for all housing stock. The national energy savings are then calculated from the annual energy consumption results summed over the entire analysis period.

This national energy savings calculation accounts for savings based on people who could purchase the new manufactured home; it does not consider savings for price-sensitive people who would not purchase the new home because of its higher price. The national energy savings are calculated based on the same number of homes purchased under both the standards case (Alternatives A–C)

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[1] 86 *Federal Register* (FR) 47744.

[2] DOE (2021).

[3] 86 FR 59042.

and the no-standards case (Alternative D), such that there are no energy savings attributed to less homes purchased.

As described in the TSD (DOE 2021), the annual energy consumption per square foot of floor space was modeled for both sizes — single-section and multi-section manufactured homes — for 19 U.S. cities, including the five evaluated in this EIS (Chicago, Houston, Memphis, Miami, and Phoenix). Results were combined with an estimated total floor space for the respective home sizes to calculate the unit site energy consumption per year for each. These unit energy consumption estimates were then converted into primary energy consumption and full-fuel-cycle energy consumption.

For the first conversion, the primary energy savings (power plant consumption) were calculated from site electricity savings (household point of use) by applying a factor to account for the losses associated with the generation, transmission, and distribution of electricity. In the NODA, DOE updated the prior derivation of the annual average site-to-power-plant factors using the primary and full-fuel-cycle energy factors from 2021 (86 FR 59042). These site-to-power-plant factors will change as the projections for the types of power plants and energy sources providing electricity across the United States change over time.

The second conversion involves more extensive calculations because the full-fuel-cycle measure integrates three components of the cycle: (1) energy consumed in extracting, processing, and transporting or distributing primary fuels; (2) energy losses associated with the generation, transmission, and distribution of electricity; and (3) site, or point-of-use, energy consumption. To account for the first component, also referred to as "upstream" activities, DOE applied multipliers using data and projections from the recent version of the U.S. Energy Information Administration (EIA) National Energy Modeling System (NEMS) that EIA used for its 2021 Annual Energy Outlook (AEO; EIA 2021c). The AEO provides information about the energy system, including projections for oil, natural gas, and coal supplies; energy use for oil and gas field and refinery operations; and fuel consumption and emissions related to producing electricity. The data reflected in the 2021 AEO were used to define parameters that represent the energy intensity of electricity production.

The factors used in DOE's analyses of primary and full-fuel-cycle energy consumption for the different fuel types are shown in Table 4.1-1, spanning 2020−2050. Because the updated analysis period goes beyond 2050, DOE applied the primary energy and full-fuel-cycle factors used for 2050 to each year thereafter through 2052. The prices and escalation rates (annual percentage price increases) applied for the different energy (electricity) and fuel types are also presented in this table (DOE 2021).

The estimated cumulative national energy savings for the full fuel cycle under each alternative for manufactured homes purchased during 2023−2052 are presented in Figure 4.1-1 (DOE 2021). (The energy savings are rounded to two decimal places in the figure to simplify the presentation; more detailed tables are provided in Appendix B.) The national energy savings estimated for the six action alternatives are within 0.5 quad of each other, differing by about 25 percent between least and most savings. The national energy savings over 30 years range from nearly 1.9 quads for Alternative B2 (tiered standards based on size with R-21 insulation) to nearly 2.4 quads for

Alternative C1 (untiered standards with R-20+5 insulation). While saving the most energy, Alternative C1 would also be the most expensive to implement (see Section 4.4). Alternative D (the no-action alternative), would achieve no energy savings.

**TABLE 4.1-1 Price and Escalation by Energy Source/Fuel Type, and Primary Energy and Full-Fuel-Cycle Factors Used to Estimate National Energy Savings**[a]

| Energy/Fuel Type | Unit Price ($) | Escalation Rate (percent) | Energy Consumption Factor Type | Energy Consumption Factor (dimensionless) | | | |
|---|---|---|---|---|---|---|---|
| | | | | **2020** | **2030** | **2040** | **2050** |
| Electricity: summer price<br>winter price | 0.133/kWh<br>0.132/kWh | 2.2 | Primary | 2.845 | 2.714 | 2.698 | 2.677 |
| | | | Full fuel cycle | 1.044 | 1.039 | 1.037 | 1.037 |
| Natural gas | 10.1/MBtu | 2.8 | Full fuel cycle | 1.101 | 1.098 | 1.098 | 1.099 |
| LPG | 17.3/MBtu | 3.7 | Full fuel cycle | 1.169 | 1.171 | 1.179 | 1.185 |
| Oil | 17.8/MBtu | 3.8 | Full fuel cycle | 1.169 | 1.171 | 1.179 | 1.185 |

[a] Notes: LPG is liquid petroleum gas. MBtu is million Btu. Prices are in 2020$. Dimensionless energy consumption factor is given in 10-year increments from 2020 through 2050. (Sources: DOE 2021, 86 FR 47744; 86 FR 59042.)

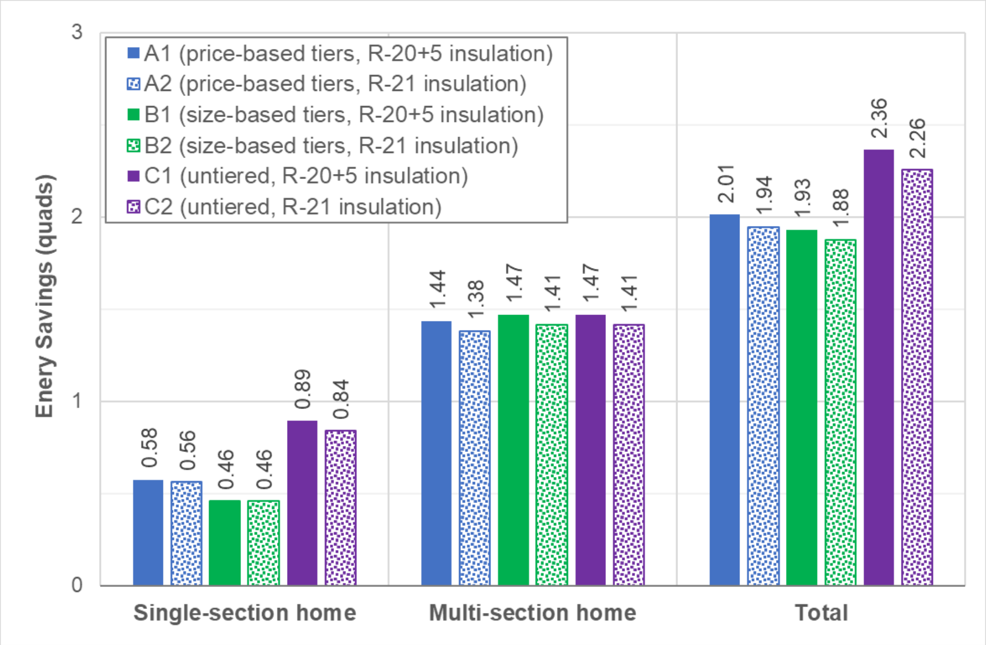

**FIGURE 4.1-1 Cumulative Full-Fuel-Cycle National Energy Savings for Manufactured Homes under Each Action Alternative. Energy savings are estimated for manufactured homes purchased during 2023–2052, assuming a 30-year home lifetime. Insulation options apply to the exterior walls of homes in climate zones 2 and 3. (Data source: DOE 2021).**

The national energy savings estimated for the proposed energy conservation standards would exceed 1.9 quads over the 30-year period. For context, the EIA reports a site energy consumption for manufactured homes of 406 trillion Btu, or slightly more than 0.4 quad, per year (EIA 2018). This site consumption amount does not include energy losses from the electrical system (see Section 3.1), but those losses are included in the national energy savings estimate. For this reason, these results cannot be directly compared. As described in Section 3.1, total energy consumption by the entire residential sector has been fairly stable over the last 20 years at 20 τo 22 quads. This provides general context for the energy savings that have been estimated for manufactured homes under the proposed standards. (If the current residential pattern remains the same during 2023–2052, that would translate to a total residential energy consumption of 600–660 quads.)

The national energy savings estimated for 2023 through 2052 are presented by climate zone in Figure 4.1-2 (DOE 2021). The energy savings patterns are generally similar within climate zones, and the savings in climate zone 2 are the lowest across the three zones. Overall, the fewest savings are predicted for the size-based alternative with R-21 insulation (Alternative B2), at about 0.56 quad. The largest savings are predicted for the untiered alternative with R-20+5 insulation, as specified in the 2021 International Energy Conservation Code (IECC) (Alternative C1), at about 0.82 quad.

The tiered standards based on price (Alternative A) would achieve only slightly more savings than the tiered standards based on size (Alternative B) over the 30-year period. As expected, the three alternatives with relaxed R-21 insulation on the exterior walls (Alternatives A2, B2, and C2) would produce lower energy savings over the 30-year period than their counterparts with the more stringent R-20+5 insulation (Alternatives A1, B1, and C1).

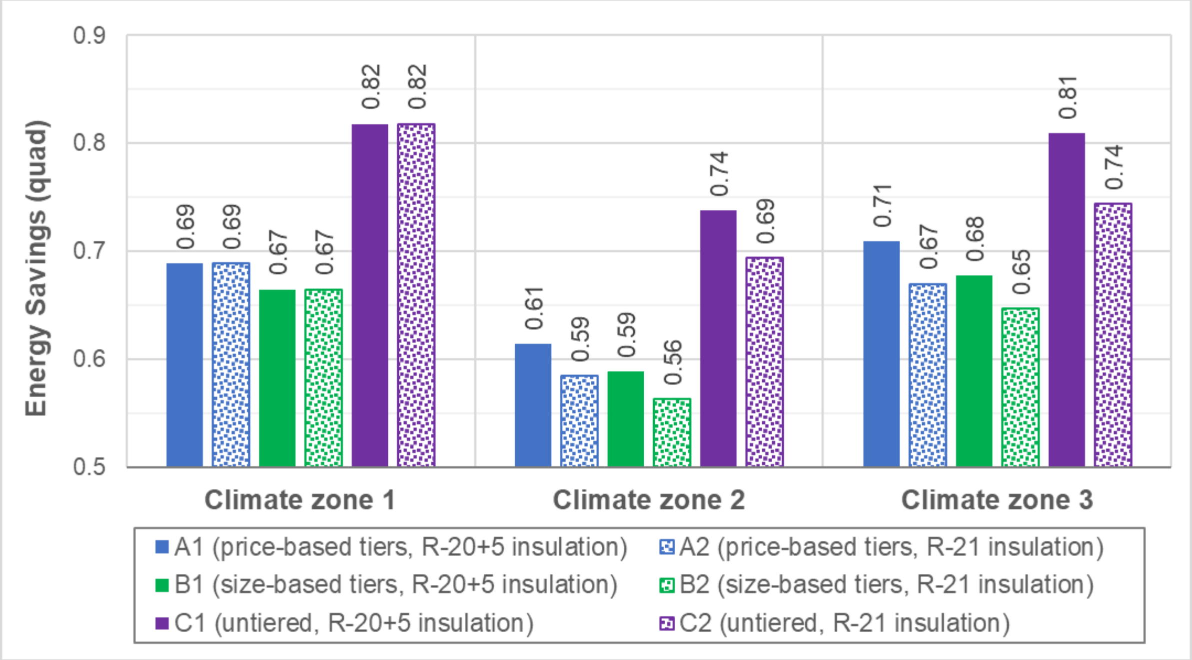

**FIGURE 4.1-2 Energy Savings by Climate Zone for Each Action Alternative (Data source: DOE 2021)**

## 4.2 AIR RESOURCES

Our discussion of potential consequences to air resources are organized as follows: Section 4.2.1 addresses potential impacts of greenhouse gas (GHG) emissions and climate change; Section 4.2.2 describes potential impacts related to criteria pollutants, mercury, and ambient air quality; Section 4.2.3 analyzes impacts to indoor air quality; and Section 4.2.4 discusses the potential impacts of wildfires on air quality, with an emphasis on indoor air quality.

### 4.2.1 GHG Emissions and Climate Change

GHG emissions that would be avoided under the proposed action and action alternatives for energy conservation standards were assessed as part of the analyses presented in the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042).

DOE estimated the environmental benefits in the form of reduced emissions of GHG associated with electricity production. These reductions were assessed for three GHGs: carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). These estimates were based on a 30-year analysis period (2023–2052) for projected manufactured home shipments, assuming a 30-year home lifetime. The reductions associated with the energy savings from these more energy-efficient homes are referred to as “site emissions reductions.” DOE also estimated the reduced emissions due to upstream activities in the fuel production chain, such as extraction, processing, and transporting fuels to the site of combustion. Together, the reductions in site emissions and upstream emissions comprise the full fuel cycle for this analysis. DOE calculated the value of the reduced emissions of $CO_2$, $CH_4$, and $N_2O$ using a range of values per metric ton (MT) of pollutant. Details about the assessment methods and results are provided in the SNOPR and TSD (86 FR 47744; DOE 2021).

Figure 4.2.1-1 shows the estimated emissions reductions for $CO_2$, $CH_4$, and $N_2O$ together with the combined total GHG emissions reductions on a $CO_2$-equivalent basis ($CO_2e$) for all alternatives except no-action (Alternative D). These estimated reductions reflect the national energy savings accumulated over 30 years (2023–2052), based on primary energy savings. The primary energy savings are estimated by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. These savings differ among climate zones because the energy conservation requirements and shipment projections differ across the climate zones. These reduced emissions are relative to the no-action alternative (Alternative D), under which the energy conservation requirements would remain at the levels established in the existing HUD Code. As shown in Figure 4.2.1-1, the cumulative emissions reductions under the proposed action (Alternative A2) would be about 83 million MT of $CO_2$, 502,000 metric tons of $CH_4$, and 840 MT of $N_2O$, totaling about 96 million MT on a $CO_2$-equivalent basis (million MT $CO_2e$).[4] On the $CO_2$-equivalent basis, $CO_2$ and $CH_4$ account for about 87 and 13 percent, respectively, while $N_2O$ contributes a minimal amount (0.3 percent). For both $CO_2$ and $N_2O$, the fugitive emissions that occur during oil and gas production are small compared with their combustion emissions. In contrast, the fugitive emissions for $CH_4$ occur predominantly during oil, gas, and coal production, while the emissions during combustion are very small (DOE 2021).

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[4] GHG emissions on a $CO_2$-equivalent basis can be calculated by summing the masses of the GHGs multiplied by their global warming potentials (see Section 3.2.1.2).

As shown in Figure 4.1-1, the proposed action (Alternative A2) is estimated to save more than 1.9 quads of energy over the 30-year period (2023–2052); the savings estimated for the action alternatives range from nearly 1.9 quads (Alternative B2) to nearly 2.4 quads (Alternative C1). The GHG intensities can be calculated from these energy savings by dividing the reduction in GHG emissions by the reduction in total energy consumption. The total GHG intensities, which combine site and upstream emissions reductions, range from about 0.042 to 0.043 MT $CO_2$ per million Btu for $CO_2$ only, and from about 0.049 to 0.050 MT $CO_2e$ per million Btu for all GHG combined (i.e., summed across $CO_2$, $CH_4$, and $N_2O$). These differences of about 15 percent between the two types of estimates are primarily due to the upstream fugitive emissions of $CH_4$.

Alternative C1 (untiered standards with R-20+5 insulation) would achieve the highest emissions reductions, about 21 percent more than the proposed action (Alternative A2). Alternative B2 (size-based tiers with R-21 insulation) has the lowest emissions reductions, about 3 percent lower than Alternative A2. Overall, the options in Alternative C (untiered standards) would achieve the highest emissions reductions, followed by Alternative A (price-based tiers), while Alternative B (size-based tiers) would have the lowest emissions reductions. Alternatives A1, B1, and C1 would reduce more emissions than their counterparts, Alternatives A2, B2, and C2.

The proposed action and action alternatives would reduce GHG emissions by 80−101 million MT $CO_2$ over 30 years. This would correspond to about 2.7–3.4 million MT $CO_2$ per year, which equates to about 0.3−0.4 percent of the residential sector emissions in 2020; these totaled about 900 million MT $CO_2$ (EIA 2021b). Manufactured housing is a small fraction of all U.S. housing (about 6 percent), but on a household basis consumes more electricity, on average, than other types of homes (see Section 3.1). Therefore, the relative contribution to GHG emissions would be somewhat higher and the reduction in GHG emissions would be more beneficial than what might be inferred from a simple scaling of manufactured housing to all U.S. homes.

The reduction in $CO_2$ emissions under the proposed action (Alternative A2) would be about 0.35 percent of the projected annual $CO_2$ emissions from the residential sector, which average about 793 million MT over the 2020–2050 period for the EIA reference case (EIA 2021c).[5] These reductions would be relatively small compared with the annual average $CO_2$ emissions from the residential sector, representing about 15 percent of the U.S. $CO_2$ emissions in 2019, which totaled 5,256 million MT (EPA 2021a). Nevertheless, any reductions would contribute to efforts across all sectors to reduce GHG emissions and minimize the impacts of climate change on the human environment. Differences in the reductions in emissions of $CO_2$, $CH_4$, and $N_2O$ for each action alternative are compared with those for the proposed action (Alternative A2) in Figure 4.2.1-2. This figure also presents the combined total emissions reductions on a $CO_2$-equivalent basis. The emissions reduction benefits of Alternative C1 are the largest, about 20 million more MT $CO_2e$ than for Alternative A2, while those of Alternative B2 are the smallest, at about 3 million less MT $CO_2e$ than for Alternative A2.

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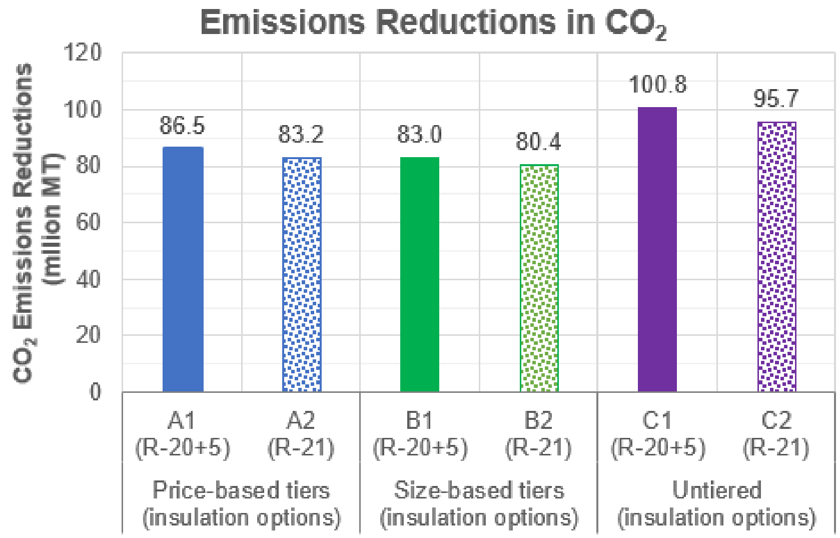
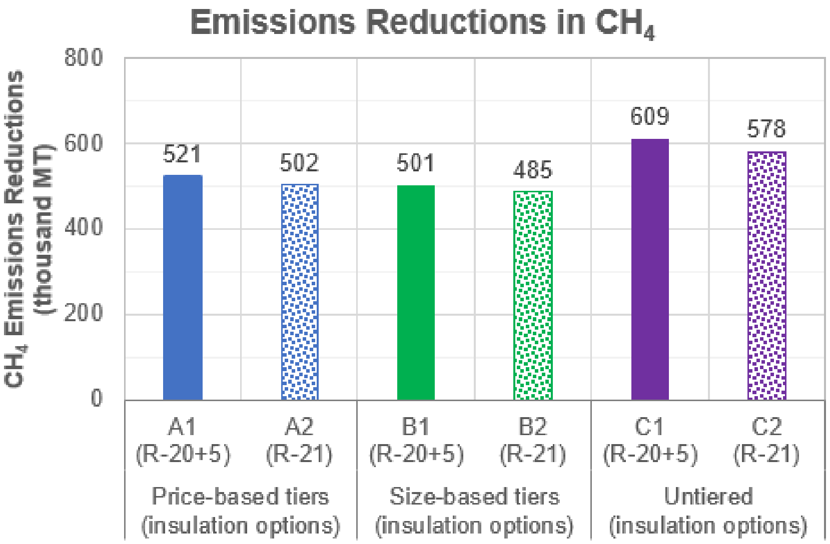
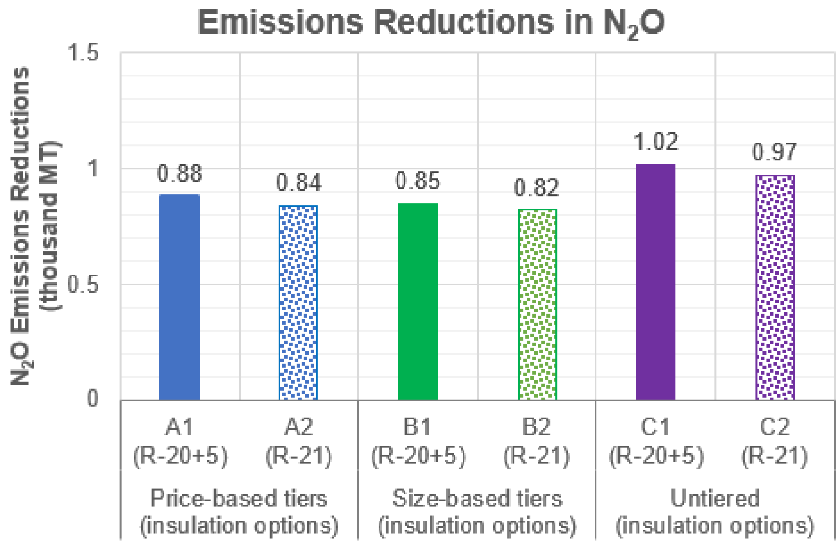
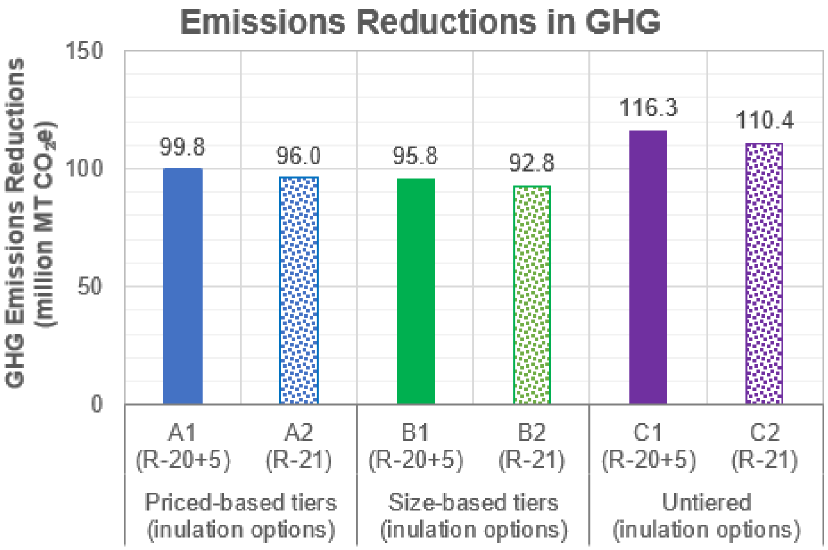
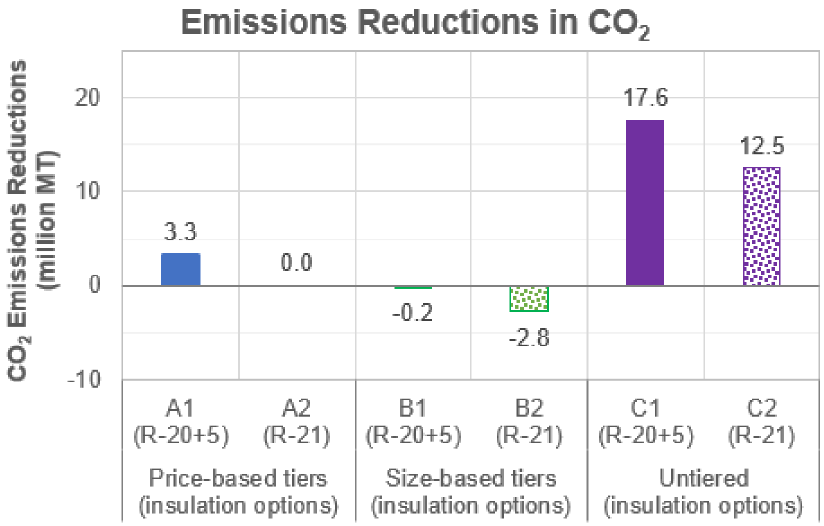
[5] The EIA reference case generally assumes that current laws and regulations affecting the energy sector, including laws that have end dates, remain unchanged throughout the projection period (EIA 2021c). This assumption enables EIA to use the reference case as a benchmark to compare with alternate policy-based cases.

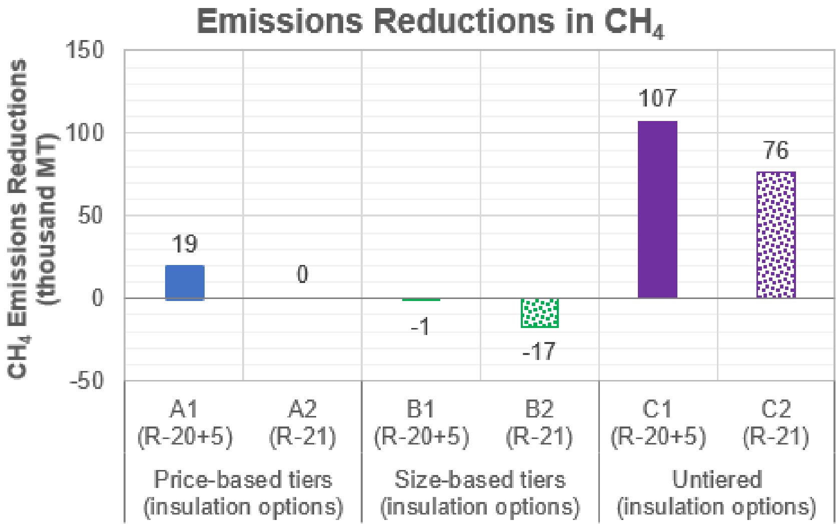

Emissions Reductions in $CO_2$
$CO_2$ Emissions Reductions (million MT)
120
100
80
60
40
20
0
86.5
83.2
83.0
80.4
100.8
95.7
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)

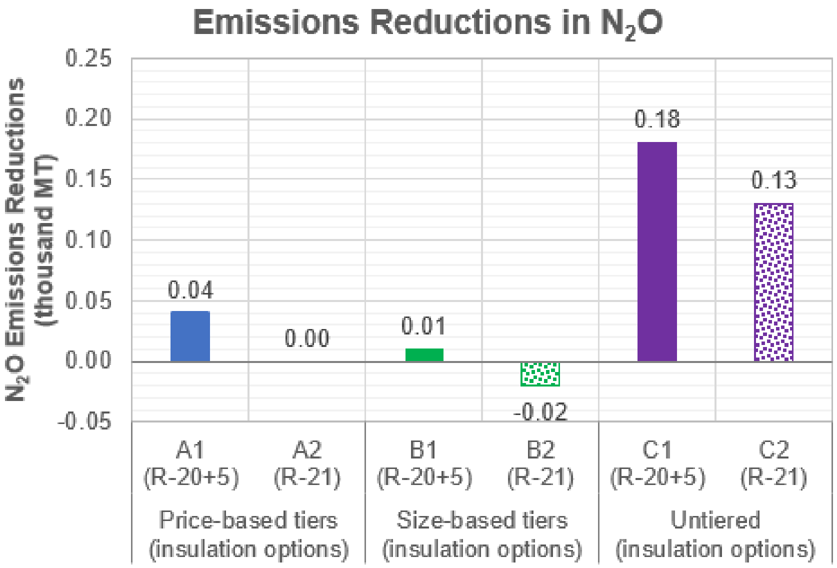

Emissions Reductions in $CH_4$
$CH_4$ Emissions Reductions (thousand MT)
800
600
400
200
0
521
502
501
485
609
578
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)

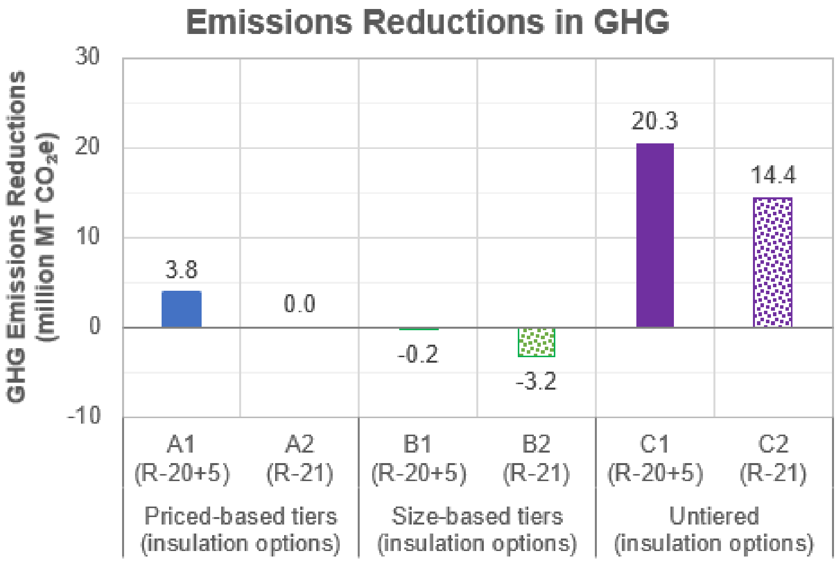

Emissions Reductions in $N_2O$
$N_2O$ Emissions Reductions (thousand MT)
1.5
1
0.5
0
0.88
0.84
0.85
0.82
1.02
0.97
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)


Emissions Reductions in GHG
GHG Emissions Reductions (million MT $CO_2e$)
150
100
50
0
99.8
96.0
95.8
92.8
116.3
110.4
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Priced-based tiers (inulation options)
Size-based tiers (inulation options)
Untiered (inulation options)


Emissions Reductions in $CO_2$


Emissions Reductions in $CH_4$


Emissions Reductions in $N_2O$


Emissions Reductions in GHG

The reduction in $CO_2$ emissions under the proposed action (Alternative A2) would be about 0.35 percent of the projected annual $CO_2$ emissions from the residential sector, which average about 793 million MT over the 2020–2050 period for the EIA reference case (EIA 2021c).[6] These reductions would be relatively small compared with the annual average $CO_2$ emissions from the residential sector, representing about 15 percent of the U.S. $CO_2$ emissions in 2019, which totaled 5,256 million MT (EPA 2021a). Nevertheless, any reductions would contribute to efforts across all sectors to reduce GHG emissions and minimize the impacts of climate change on the human environment. Differences in the reductions in emissions of $CO_2$, $CH_4$, and $N_2O$ for each action alternative are compared with those for the proposed action (Alternative A2) in Figure 4.2.1-2. This figure also presents the combined total emissions reductions on a $CO_2$-equivalent basis. The emissions reduction benefits of Alternative C1 are the largest, about 20 million more MT $CO_2e$ than for Alternative A2, while those of Alternative B2 are the smallest, at about 3 million less MT $CO_2e$ than for Alternative A2.

Estimates of the social cost of GHG (SC-GHG) estimates provide an aggregated monetary measure (in current U.S. dollars) of the future stream of damages associated with an incremental metric ton of emissions and associated physical damages (e.g., temperature increase, sea level rise, infrastructure damage, human health effects) in a particular year. In this way, SC-GHG estimates can help the public and federal agencies understand or contextualize the potential impacts of GHG emissions and, along with information on other potential environmental impacts, can inform a comparison of alternatives. The SC-GHG estimates developed for DOE's proposal to establish energy conservation standards for manufactured housing are presented in the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042).

### 4.2.2 Criteria Pollutants, Mercury, and Ambient Air Quality

The environmental benefits in the form of reduced emissions of air pollutants associated with electricity production estimated to be achieved by the proposed action and action alternatives are presented in this section, summarized from DOE's analyses in the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042). Emissions reductions for mercury and two criteria pollutants, nitrogen oxides ($NO_x$), and $SO_2$, are addressed. As context, the emissions reporting for power plants under the Acid Rain Program, the Cross-State Air Pollution Rule (CSAPR) and CSAPR update, and the Mercury and Air Toxics Standards (MATS) Program[7] indicate that emissions of mercury, $NO_x$, and sulfur dioxide ($SO_2$) have markedly declined in recent years (EPA 2021b).

Figure 4.2.2-1 shows the estimated emissions reductions for mercury, $NO_x$, and $SO_2$ under the proposed action (Alternative A2) and the action alternatives, as well as for the no-action alternative. All emissions reductions are relative to the no-action alternative (Alternative D), under which energy conservation requirements would remain at the levels in the existing

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[6] The EIA reference case generally assumes that current laws and regulations affecting the energy sector, including laws that have end dates, remain unchanged throughout the projection period (EIA 2021c). This assumption enables EIA to use the reference case as a benchmark to compare with alternate policy-based cases.

[7] Detailed information on these programs is available at https://www.epa.gov/acidrain/acid-rain-program; https://www.epa.gov/csapr; https://www.epa.gov/csapr/final-cross-state-air-pollution-rule-update; and https://www.epa.gov/mats.

U.S. Department of Housing and Urban Development (HUD) Code. The cumulative emissions reductions over the 30-year period (2023–2052), shown in Figure 4.2.2-1 under the proposed action (Alternative A2), would be about 0.13 MT of mercury, 132,000 MT of $NO_x$, and 29,000 MT of $SO_2$. Like for the GHG emissions in Section 4.2.1, Alternative C1 would achieve about 21 percent higher emissions reductions than the proposed action (Alternative A2), while Alternative B2 would achieve about 3 percent lower reductions. Overall, the options within Alternative C (untiered) would achieve the greatest emissions reductions, followed by Alternative A (price-based tiered standards). Alternative B (size-based tiered standards) would achieve the lowest emissions reductions. Meanwhile, the three alternatives with the more stringent insulation requirement, R-20+5 (Alternatives A1, B1, and C1), would achieve higher emissions reductions than their counterparts with R-21 insulation, Alternatives B2 and C2.

As context for the estimated reductions, many coal-fired power plants that had accounted for more than half of electricity generation in the United States have been decommissioned since the mid-2000s because of increased competition from natural gas and renewable sources, as well as for environmental reasons (including substantial emissions of GHG and other pollutants) and economic reasons (e.g., high capital investment for emission controls and declining costs of renewable sources). Until recently, mercury emissions from the utility coal boilers of electricity generation units (EGUs) accounted for roughly half of the national total mercury emissions. These emissions declined drastically, from 22.9 tons per year[8] in 2014 to 4.4 tons per year in 2017. Having accounted for 44 percent of the total U.S. mercury emissions in 2014, the contribution from EGU emissions dropped to 13 percent in 2017 (EPA 2021c). This difference is primarily due to lower mercury emissions from the EGUs covered by the MATS.[9]

On an annual basis, the estimated reductions in mercury emissions that would be achieved under the proposed action (Alternative A2) would be equivalent to a reduction of about 0.11 percent of the total U.S. mercury emissions from EGUs in 2017. The contributions to the further mercury reductions estimated for the other alternatives would be similar, ranging from 0.10 percent (Alternative B2) to 0.13 percent (Alternative C1).

$NO_x$ emissions in the United States have decreased substantially in the past two decades, with the emissions in 2020 (0.74 million tons) representing an 87 percent drop from 1995 levels (5.84 million tons; EPA 2021b). This is largely due to implementation of the Acid Rain Program under the Clean Air Act through a cap-and-trade program for fossil fuel-fired power plants and, to some extent, the shutdown of many coal-fired power plants in recent years. Estimated $NO_x$ emissions reductions under the proposed action (Alternative A2) would be a further reduction of about 0.66 percent in the total U.S. $NO_X$ emissions from power plants in 2020. Emission reductions of $NO_X$ that would be achieved by the other action alternatives would contribute to reductions ranging from 0.63 percent (Alternative B2) to 0.79 percent (Alternative C1) of the 2020 total from U.S. power plants.

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[8] To convert from ton to MT, multiply by 0.9072 (i.e., 1 ton is 0.9072 MT).

[9] For EGUs, the decrease is a combination of fuel switching to natural gas, the installation of mercury controls to comply with state rules and voluntary reductions, early compliance with MATS, and the co-benefits of mercury reductions from control devices installed for the reduction of $SO_2$ and particulate matter because of state and federal actions, such as New Source Review enforcement actions.

$SO_2$ emissions in the United States have decreased substantially over the last decades, with a 93 percent reduction in 2020 (0.79 million tons) over 1995 levels (11.83 million tons; EPA 2021b). This is largely due to implementation of the Acid Rain Program under the Clean Air Act through a cap-and-trade program for fossil-fuel powered plants and, to some extent, the shutdown of many coal-fired power plants. $SO_2$ emissions reductions under the proposed action (Alternative A2) would equate to a reduction of about 0.14 percent in the total U.S. $SO_2$ emissions from power plants in 2020. Contributions of these emissions reductions from other action alternatives would be similar, ranging from 0.13 percent (Alternative B2) to 0.17 percent (Alternative C1).

Due in part to air pollutant regulations driven by the Clean Air Act, it is projected that NOx and volatile organic compound (VOC) emissions from anthropogenic sources will continue to decline over the next few decades (Nolte et al. 2018). These emissions reductions are designed to reduce ozone concentrations such that polluted areas of the country meet air quality standards. However, climate change will also influence ozone levels in the United States by altering weather conditions and impacting emissions from anthropogenic and natural sources. The prevailing evidence suggests that climate change alone introduces a climate penalty[10] for ozone over most of the United States from warmer temperatures and increases in natural emissions (Nolte et al. 2018). This climate penalty would partially counteract the continued reductions in emissions of ozone precursors from human activities.

Meanwhile, the modeling analyses for particulate matter <2.5 μm ($PM_{2.5}$) exhibit greater variability in terms of future concentration differences projected to result from meteorological changes in a warmer climate (Nolte et al. 2018). The reduced certainty in the response of $PM_{2.5}$ concentrations to changing meteorological drivers is due to multiple pathways for $PM_{2.5}$ formation and the complexity and high spatial variability of the interactions of meteorological factors on each of those different pathways.

With respect to acid deposition, it is generally accepted that the source-receptor relationship is more or less linear: a given percentage reduction (or increase) in emissions generally causes the same percentage change in acid deposition at a given location. Thus, any emissions reductions associated with the proposed rule would directly decrease acid depositions and their associated impacts.

Differences in the reductions in emissions of mercury, $NO_x$, and $SO_2$ for each action alternative are compared with the reductions in Alternative A2 in Figure 4.2.2-2. The emissions reduction benefits of Alternative C1 are the largest, at about 0.029 MT for mercury, 28,000 MT for $NO_x$, and 6,200 MT for $SO_2$ more than in Alternative A2, while those of Alternative B2 are the smallest, at about 0.005 MT for mercury, 4,300 MT for $NO_x$, and 1,000 MT for $SO_2$ less than in Alternative A2.

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[10] Defined as deterioration of air quality due to a warming climate, in the absence of changes in anthropogenic emissions.

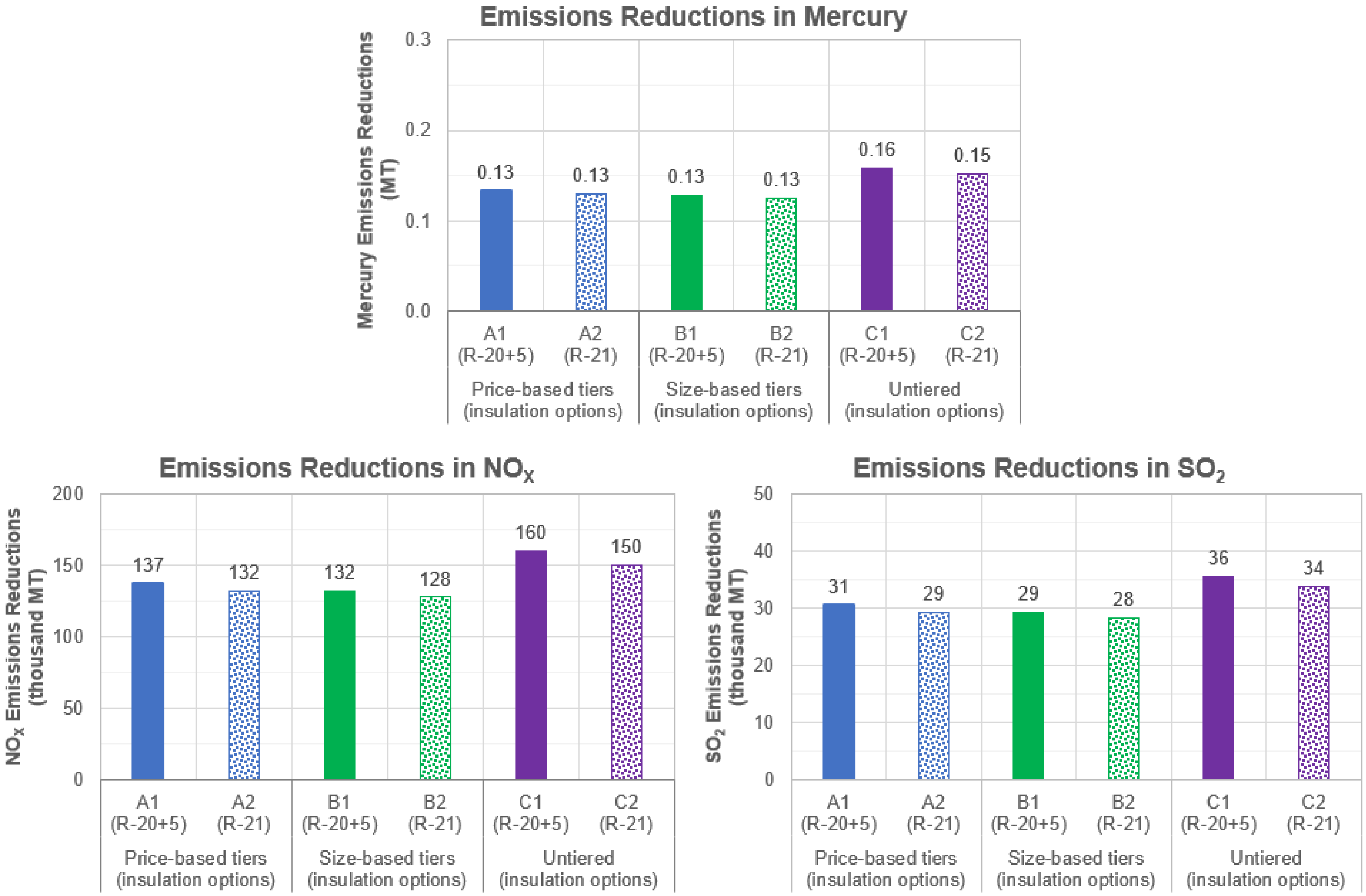
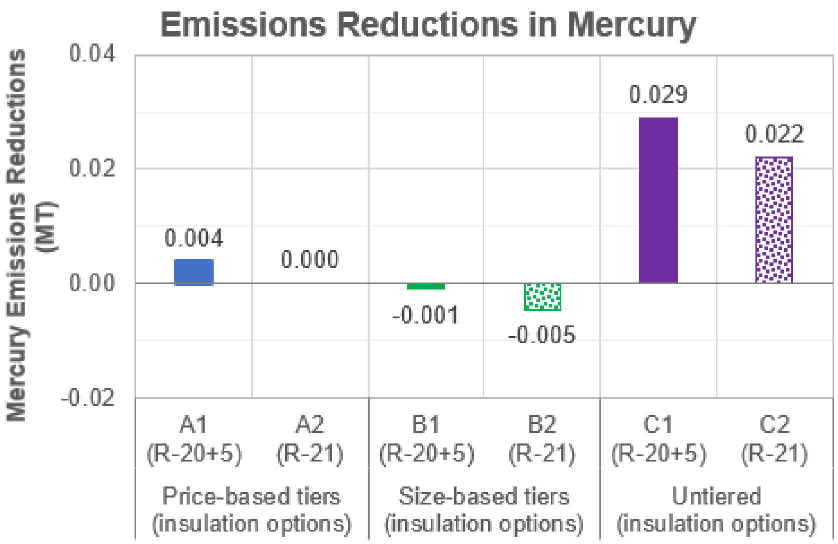
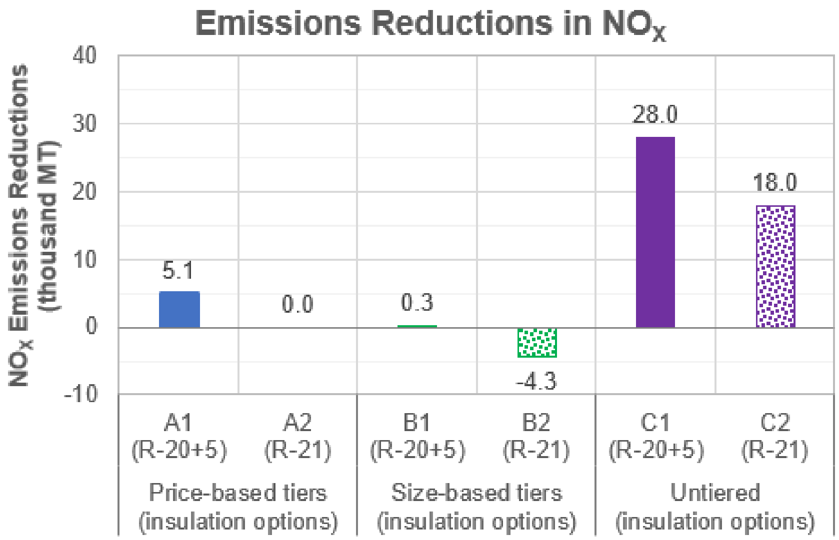
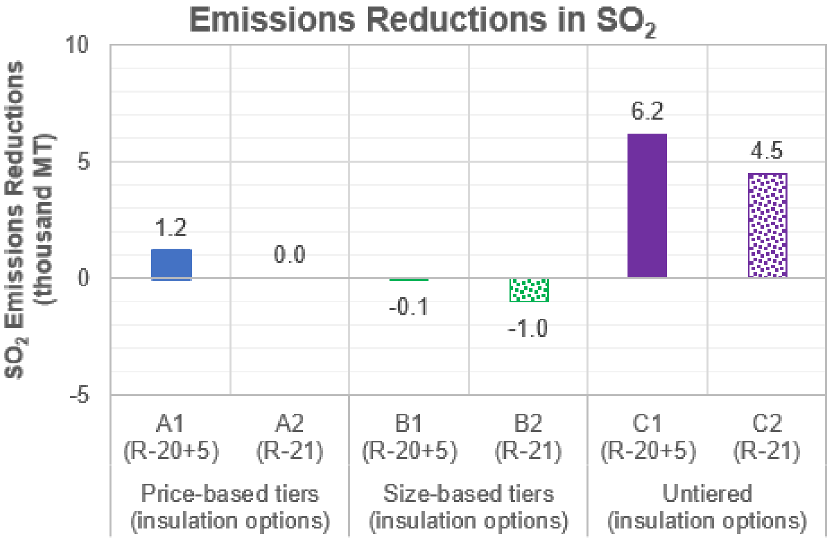


**FIGURE 4.2.2-1 Emissions Reductions of Mercury, $NO_x$, and $SO_2$ Under the Proposed Action and Action Alternatives (Data source: DOE 2021)**


Emissions Reductions in Mercury
Mercury Emissions Reductions (MT)
0.04
0.02
0.00
-0.02
0.004
0.000
-0.001
-0.005
0.029
0.022
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)


Emissions Reductions in $NO_X$
$NO_X$ Emissions Reductions (thousand MT)
40
30
20
10
0
-10
5.1
0.0
0.3
-4.3
28.0
18.0
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)


Emissions Reductions in $SO_2$
$SO_2$ Emissions Reductions (thousand MT)
10
5
0
-5
1.2
0.0
-0.1
-1.0
6.2
4.5
A1 (R-20+5)
A2 (R-21)
B1 (R-20+5)
B2 (R-21)
C1 (R-20+5)
C2 (R-21)
Price-based tiers (insulation options)
Size-based tiers (insulation options)
Untiered (insulation options)

### 4.2.3 Indoor Air Quality

The proposed action and alternatives are expected to impact aspects of indoor air quality (IAQ) in both positive and negative directions. With other factors remaining constant, reducing air leakage through required improvements in envelope and duct airtightness will lead to lower indoor concentrations of some outdoor air pollutants, higher concentrations of pollutants emitted from indoor sources, and an expected lower risk of moisture problems in the belly and attic. Improved air-sealing in combination with improved insulation also should make it easier and less costly for occupants to achieve and maintain thermal comfort conditions.

Air-sealing of the building envelope and ductwork of the forced-air heating and cooling system will reduce the uncontrolled movement of air and water vapor between the occupied space and connected spaces such as the belly and the attic, and also with the outdoors. Air leakage increases thermal conditioning loads and thus energy use, especially since air leakage is highest at times of greatest indoor-to-outdoor temperature difference. Lower air exchange rates should lead to lower indoor concentrations of outdoor pollutants including ozone, $NO_2$, and $PM_{2.5}$. Air-sealing also substantially improves the ability to control exposures to wildfire smoke. This occurs because these pollutants are removed from indoor air through deposition processes that occur naturally. $PM_{2.5}$ also is reduced to some extent even by base-model filters as air is recirculated through the heating and cooling system. These filters also may be upgraded to substantially increase $PM_{2.5}$ removal. Reducing outdoor air exchange will slow the dilution and removal of pollutants emitted indoors, leading to higher indoor air concentrations and related exposures. Quantitative estimates of these processes are provided for several example outdoor and indoor pollutants that commonly exceed health safety guidelines in homes.

Reducing uncontrolled airflow is widely considered among building science experts to be helpful in reducing the risk of condensation and consequent dampness and mold issues. Under hot, humid outdoor conditions, envelope air-sealing reduces the likelihood that humid outdoor air will reach cooled materials in the walls, under floors, and above the ceiling. In the winter, air-sealing reduces the outflow of humidified air from the occupied space and into building cavities, where water vapor can condense on cold surfaces in contact with the exterior. Condensation risk- reduction benefits cannot be quantified as readily as the increase in indoor-emitted chemical air pollutants or the decrease in outdoor pollutants; however, these benefits could be substantial given the disease burden caused by dampness and mold.

Air-sealing is also an element of integrated pest management, as it reduces openings for pest entry, reducing the allergens that are brought inside by pests and the likelihood that chemical pesticides will be used.

None of the alternatives proposed for the standards would be expected to have any substantial impact on the ability of occupants to utilize equipment-based or administrative controls (e.g., ventilation and filtration, and separation of the occupant, as feasible) to mitigate potential exposures to pathogens associated with infectious diseases, including COVID-19.

### 4.2.3.1 Approach to Quantifying Impacts on Indoor Air Quality

The impacts of the proposed energy conservation standards for manufactured homes on the indoor air concentrations of pollutants emitted indoors and those coming from outdoors were analyzed with models that simulate energy, airflow, and air pollutant emissions and dynamics. The analysis was conducted by Lawrence Berkeley National Laboratory with contributions by Argonne National Laboratory; details are presented in a technical report by Delp et al. (2022). An overview of the methods and key results is provided below, and additional details are presented in Appendix B.

IAQ simulations were conducted for a 1,568-ft$^2$ double-section ("double-wide") manufactured home equipped with either a packaged furnace and air conditioner (furnace + air conditioning [AC]) or a heat pump for thermal conditioning, and either a continuous exhaust fan or a central-fan-integrated supply (CFIS) whole-house ventilation system that provides airflow to meet HUD Code requirements. The impacts on indoor pollutant concentrations determined for the continuous exhaust fan can be considered to also represent a continuous-supply fan that provides filtration equivalent to that provided by the building envelope when an exhaust fan is used; this was assumed to be 20 percent, corresponding to a "penetration factor" of 0.8.

Each pair of homes modeled for this analysis were considered to have envelope and duct airtightness consistent with the HUD Code and DOE's proposed standards, respectively. Insulation and thermal conditioning equipment efficiency levels align with the Tier 2 and untiered standards of DOE's proposal. Simulations were run for homes in three climate zones to reflect the climate variability that encompasses the range experienced by most manufactured homes across the United States. These study locations and zones are shown in Figure 4.2.3-1: Chicago (zone 3), Fresno (zone 2), and Houston (zone 1). Each home was simulated with a variety of ventilation practices, as summarized in Table 4.2.3-1.

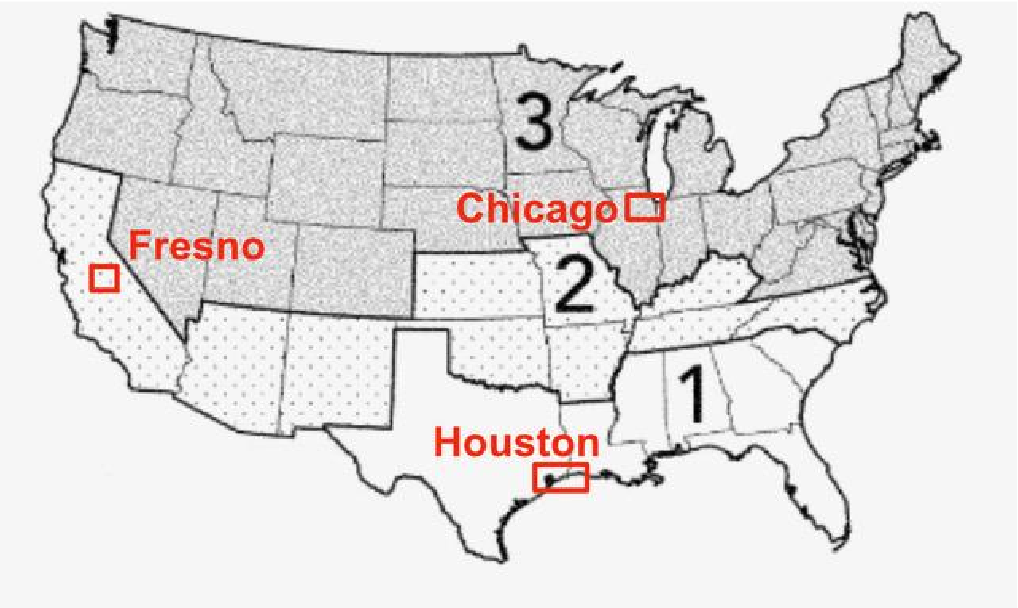


**FIGURE 4.2.3-1 HUD Climate Zones and IAQ Study Locations**

Simulations were conducted to quantify the impacts on four pollutants selected because they represent different types of sources and have intrinsic importance as hazards under some circumstances. The simulations tracked $PM_{2.5}$ and $NO_2$ coming from outdoors; $PM_{2.5}$ and acrolein from cooking; $NO_2$ from gas or propane cooking burners, when present; $PM_{2.5}$ from miscellaneous human activities that occur randomly throughout waking hours; and acrolein and formaldehyde emitted continuously from materials and other sources.

**TABLE 4.2.3-1 Ventilation Use Scenarios[a]**

| Ventilation Scenario(code used in figures) | WHMV System | WHMVOperation | Range Hood Use When Cooking | Bath and Laundry Exhaust | Window Use |
|---|---|---|---|---|---|
| Minimal (CMN) | CFIS | Only when heating or cooling | | Dryer only | |
| Minimal mechanical, window use (CMW) | CFIS | Only when heating or cooling | | Dryer only | Yes |
| Suggested exhaust fan use (CSN) | CFIS | Only when heating or cooling | Yes | Bath fan frequent use + dryer | |
| Suggested exhaust fan use + window (CSW) | CFIS | Only when heating or cooling | Yes | Bath fan frequent use + dryer | Yes |
| Continuous CFIS only (CCN) | CFIS | Continuous 24/7 | | Dryer only | |
| Continuous exhaust fan only (ECN) | Exhaust fan | Continuous 24/7 | | Dryer only | |
| Full mechanical ventilation, CFIS (CFN) | CFIS | Continuous 24/7 | Yes | Bath fan frequent use + dryer | |
| Full mechanical ventilation, exhaust fan (EFN) | Exhaust fan | Continuous 24/7 | Yes | Bath fan frequent use + dryer | |

[a] Each scenario was simulated for a home with a furnace + air conditioner and separately for a home with a heat pump. Gray shading: not used. WHMV: whole-house mechanical ventilation.

The variations in ventilation equipment and usage are indicated by a 3 letter code. The first letter indicates if the home is provided with a continuous Exhaust ventilation fan or a Central Fan Integrated Supply (CFIS) to meet the HUD Code requirement for whole-house ventilation (as described in Section 3.2.3).

The second letter indicates how mechanical equipment was used: M = minimal, only the automatic exhaust fan of the clothes dryer; S = use of kitchen and bath exhaust fans but not continuous whole-house ventilation; C = continuous operation of the available equipment for whole-house ventilation; F = use of bath and kitchen exhaust fans and also continuous operation of the available equipment for whole-house ventilation.

The third letter in the code indicates window use: N = no opening of windows and W = windows opened whenever there is an interval of at least 6 hours of no operation of the central forced-air heating and cooling system.

In the figures that appear later in this section, scenarios are defined by a four-letter code that adds a first letter before the three described above to indicate the type of heating and cooling equipment: F = conventional furnace + air conditioner, H = heat pump.

The pollutant from each source was tracked as a distinct species to enable it to represent other pollutants with similar source profiles and potential for control by ventilation. For example, cooking-associated acrolein is representative of other gases emitted with cooking and use of the range hood to reduce the impact of cooking-related emissions. $PM_{2.5}$ emissions from randomly distributed activities is a surrogate for particles from secondhand smoke (SHS). Continuous formaldehyde and acrolein can be used as surrogates to estimate the impacts of air-sealing and ventilation on pollutants that are continuously or randomly emitted from other sources (such as cleaning products, e.g., dichlorobenzene or naphthalene). These are estimates because other chemicals may act differently than formaldehyde and acrolein.

The simulations used indoor pollutant emission rates developed from published studies of occupied homes, as described in Delp et al. (2022). For cooking, the simulations considered a household that had some cooking during almost every meal: breakfast and dinner seven days per week and lunch five days per week. However, this frequent cooking included only toaster-oven cooking during three breakfasts and two lunches; boiling, sauteing, and oven baking during some meals; and frying occurring during four breakfasts, one lunch, and three dinners each week. Because this frequency of cooking might be more than occurs in most homes, the pollutant levels calculated for this cooking pattern were divided in half when aggregating all sources to calculate totals for acrolein, $NO_2$, and $PM_{2.5}$. The data used to develop cooking frequencies is described in Delp et al. (2022). The emission rate for $PM_{2.5}$ from activities was for nonsmoking homes, but the result could be scaled to estimate quantitative impacts for SHS. Typical profiles of outdoor $NO_2$ and $PM_{2.5}$ were developed by selecting the median concentrations recorded by regulatory air monitoring stations in broad areas around the selected cities.

Simulations were implemented using a suite of modeling tools. EnergyPlus was used to determine time-dependent energy loads for thermal conditioning equipment sizing and base estimates of operating schedules. Python scripts were developed to adjust the hourly operating time based on losses from duct leakage. The CONTAM model was used to calculate and track airflows through the forced-air thermal conditioning equipment, exhaust fans, and leakage through the envelope and ducts. CONTAM was also used to track air pollutant emissions and removal by outdoor air ventilation, deposition, and filtration to calculate concentrations.

Other parameters that affect air pollutant removal were selected from published data. These parameters include indoor deposition rates for $PM_{2.5}$ and $NO_2$ and losses of $PM_{2.5}$ during outdoor air infiltration. The forced-air system is assumed to have a filter with a single-pass removal efficiency of 10 percent for $PM_{2.5}$, roughly corresponding to a basic filter (MERV4).[11] This is a very important element of the simulations for a home with CFIS ventilation, because the continuous operation of the central forced-air system with even modest particle removal has a large impact on $PM_{2.5}$.

For any scenario with the CFIS running continuously, use of a better filter would lead to substantially lower $PM_{2.5}$ and use of a lower-performance filter would lead to higher $PM_{2.5}$. The

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[11] Minimum efficiency reporting value (MERV)4 is an inexpensive air filter. Its rating indicates how effectively it traps dust and other particles from the air that passes through it: a 4 rating indicates the filter removes particles that are 10 microns and larger. This basic filter controls pollen, dust mites, sanding dust, and textile/carpet fibers, and is considered modestly effective against allergy and asthma symptoms.

filter choice should not affect the estimated impact of airtightness on $PM_{2.5}$ for continuous CFIS operation, but it will change the calculated impacts for other systems owing to changes in heating and cooling system run time. The model assumed that outdoor air supplied by the CFIS system entered downstream of the forced-air filter, i.e., it was unfiltered. The simulated activity patterns did not consider intentional use of air filtration for the purpose of IAQ control or the use of windows or whole-house mechanical ventilation to manage routine IAQ challenges.

Simulations were conducted for five combinations of envelope and duct airtightness, as described in Delp et al. (2022). The base conditions of 8 ach50[12] envelope tightness and 0.06 cfm25/sf[13] duct leakage to outdoors correspond to the minimally compliant HUD Code home specified for energy-use modeling, with 50 percent of the total duct leakage of 0.12 cfm25/sf going outside. A home that minimally complies with the DOE-proposed standards was assumed to have 5 ach50 envelope leakage and 0.02 cfm25/sf duct leakage to the outside (50 percent of the nominal 0.04 cfm25/sf total duct leakage). Recognizing that many homes will perform better than the minimum, which is common and consistent with airtightness measurements in existing manufactured homes (see Section 3.2.3), simulations were conducted for a HUD Code home with tighter ducts and two homes with tighter envelopes and ducts than the minimum level assumed for DOE's proposed standards. This EIS presents results only for minimal compliance with the HUD Code and DOE proposal; other results are presented in Delp et al. (2022).

Estimates of the overall impacts of improved airtightness on indoor concentrations of acrolein, $NO_2$, and $PM_{2.5}$ are developed by combining predicted concentrations from continuous (acrolein, formaldehyde) or random (occupant-generated $PM_{2.5}$) sources, cooking, and outdoors ($NO_2$ and $PM_{2.5}$). Because the ventilation choices of occupants affect concentrations from outdoors, dispersed indoor sources, and cooking differently, and because airtightness affects concentrations from each source and each ventilation mode differently, it is impractical to consider all possible variations. If information about the distribution of each key parameter were available, an analysis could be conducted to estimate the distribution of impacts across the population; however, distributional data have not been found for any of the key parameters. The analysis thus relies on typical contributions from each source using information from the literature and related field studies, and considers bounding conditions based on day-to-day and seasonal variability in air exchange rates (AERs) and outdoor air pollutant concentrations.

#### 4.2.3.2 Quantitative Estimates of IAQ Impacts

This section presents a series of figures that show simulated concentrations of pollutants from each of the individual sources, along with totals for the four pollutants measured ($PM_{2.5}$, $NO_2$, formaldehyde, and acrolein). Additional figures are presented in Appendix B. In considering these results, it is important to recognize that the concentrations of pollutants in indoor air will vary with house-specific emission rates and location-specific outdoor pollutant levels. The figures present relative differences across ventilation configurations and with airtightness improvements because

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[12] The metric ach50 is air changes per hour measured at 50 Pa pressure. This pressure is approximately the pressure applied to a building by a 20 mph wind.

[13] The unit cfm25/sf is a metric for duct leakage, as cubic feet per minute at 25 Pa pressure per square foot of conditioned floor area.

these are more generalizable than specific concentrations. Also included are plots of the calculated AERs under the scenarios assessed.

Pollutant results include average and 95th percentile highest days, which are represented in the figures as lines and triangles, respectively. Air exchange results are presented for average and 5th percentile lowest ventilation days. Results for HUD Code homes are presented with orange symbols, and results for DOE's proposed standards are shown as blue symbols. The variations in equipment and ventilation scenarios are described by a four-letter code that is explained in each figure (these codes are also shown with the ventilation scenarios in Table 4.2.3-1).

### *Air Exchange Rates*

An example of how outdoor air exchange is impacted by outdoor conditions and air leakage is shown in Figure 4.2.3-2, which presents the daily average AER for a home in the Chicago region that has either HUD Code or DOE-proposed airtightness and uses no intentional mechanical or natural ventilation other than dryer exhaust. The HUD Code home has an average AER of 0.52/h, with particularly high air exchange (above 1/h) during the coldest winter months owing both to envelope leakage, which increases with wind speed and temperature difference between indoors and outdoors, and duct leakage, which increases with the amount of time that the furnace or air conditioner operates. The standards in DOE's proposed rule would lower the average AER to 0.32/h and greatly reduce uncontrolled airflows during the cold winter months, with an expected improvement in comfort.

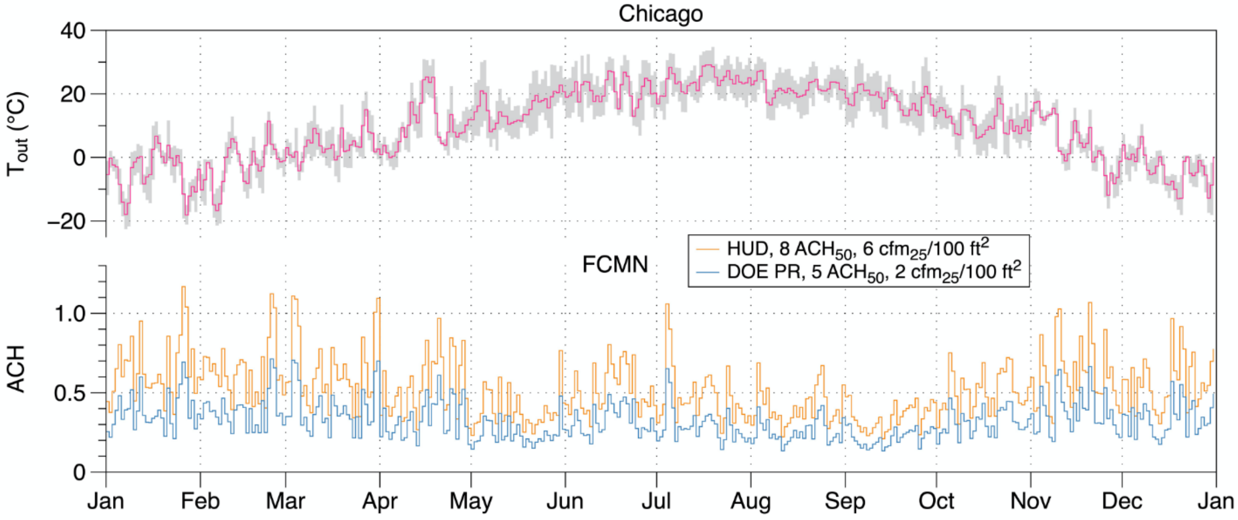

**FIGURE 4.2.3-2 Modeled Daily AER for a 1,568 ft$^2$ Home in Chicago with Envelope and Duct Tightness Meeting HUD Code or DOE-Proposed Standards, and No Intentional Ventilation**

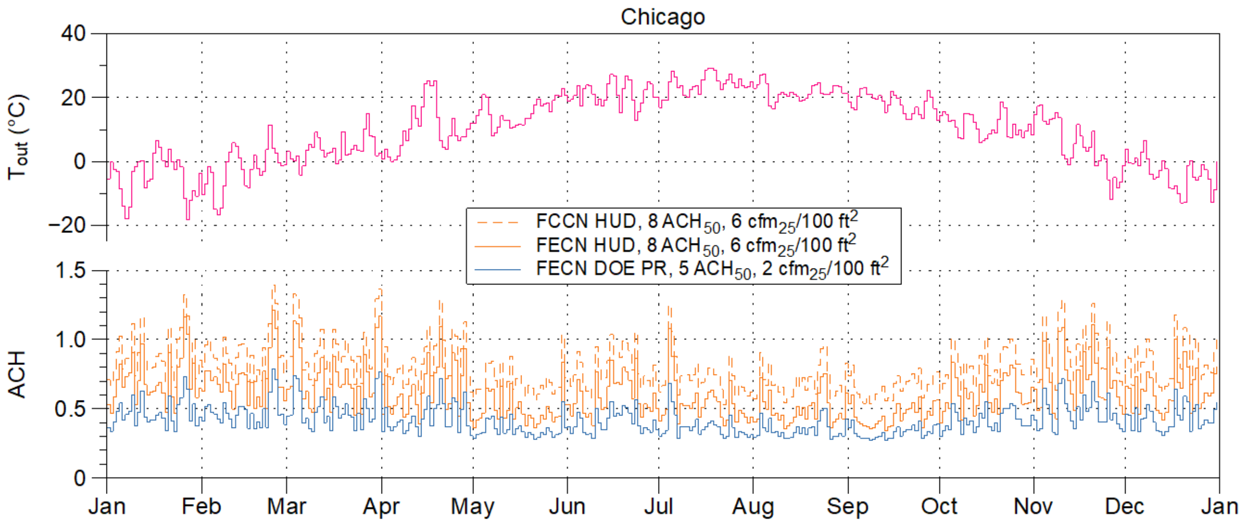

**FIGURE 4.2.3-3  Modeled Daily AER for a 1,568 ft$^2$ Home in Chicago with Continuous Ventilation by CFIS Equipment (FCCN HUD) or Exhaust Fan and Envelope and Duct Airtightness Meeting HUD Code (FECN HUD) or DOE (FECN DOE) Proposed Standards**

For comparison, Figure 4.2.3-3 shows the daily AERs for the same house, but with the fan on the heating and cooling system operating 24/7 to provide ventilation even when it is not being used for heating and cooling, as required to meet HUD Code ventilation guidance in a home that relies on a CFIS ventilation system. That leads to a high average AER of 0.80/h throughout the year.

Use of a continuous, separate ventilation fan in a HUD Code home results in an AER of 0.61/h because it does not have the extra airflow resulting from duct leaks. The DOE-proposed standards would reduce the AER for the home with continuous exhaust ventilation to 0.42/h.

Figure 4.2.3-4 shows the outdoor AERs calculated for the range of ventilation practices considered in this IAQ assessment and for the two heating and cooling systems. Results are shown for the average air exchange rate among all days of the year and the 5th percentile day, which is lower than all but 5 percent of the days of the year. As in the Chicago example, DOE’s proposed standards would reduce leakage-driven average AERs in Fresno and Houston, enabling greater comfort and ventilation control and thus better protection from outdoor air pollution when needed. If windows are opened when no heating or cooling is required for at least 6 hours (scenarios with “W” in the third position of the four-letter code), average AERs are much higher but the lowest daily AERs remain low. The patterns of air exchange across the varied ventilation practices are very similar between the furnace + AC and heat pump for each site and mostly similar among sites.

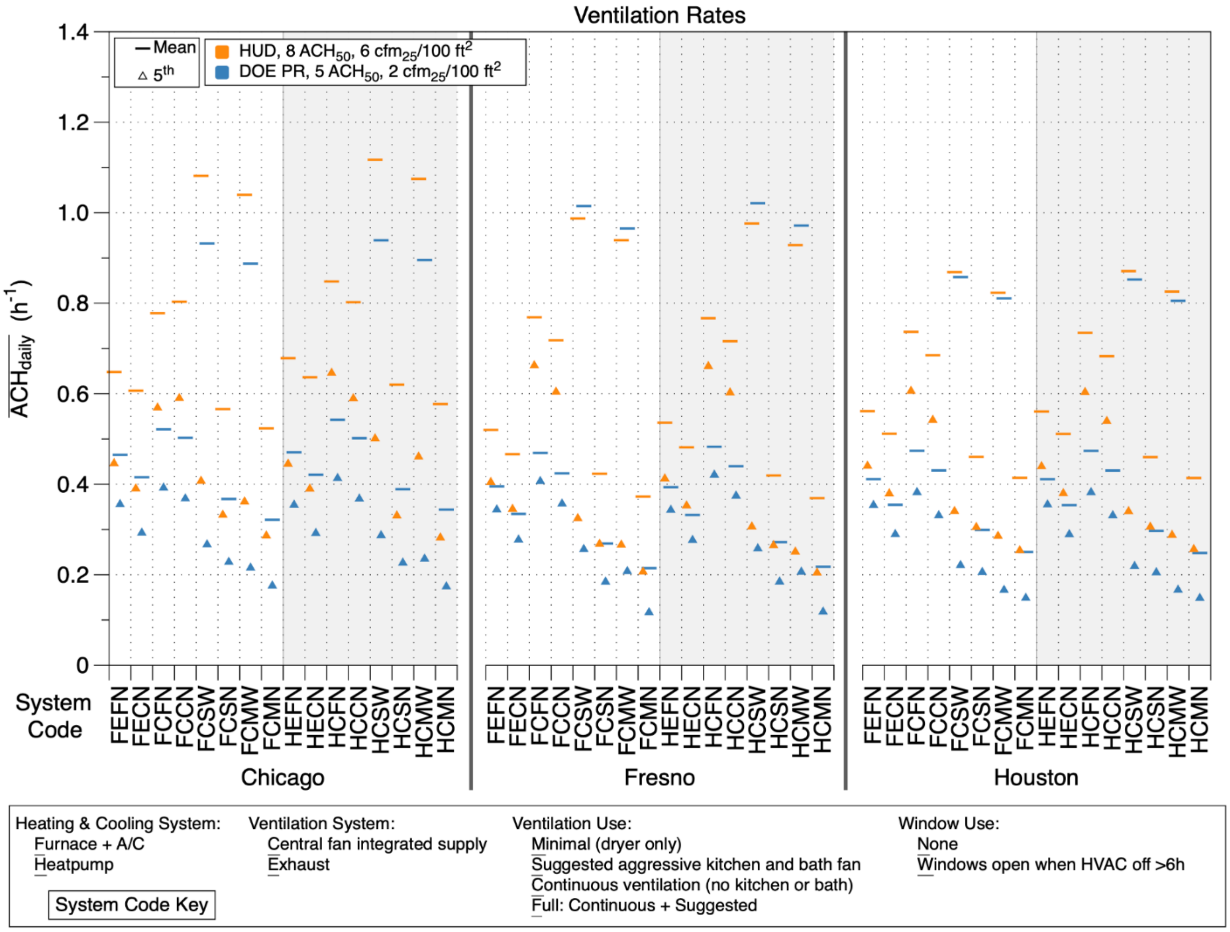

**FIGURE 4.2.3-4 Modeled Air Exchange Rates for a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

### *$NO_2$ and $PM_{2.5}$ from Outdoors*

Estimated average and 95th percentile daily indoor concentrations of $NO_2$ and $PM_{2.5}$ coming from outdoors are presented in Figures 4.2.35 and 4.2.3-6, respectively. The 95th percentile day represents among the highest exposure days, as only 5 percent of the days of the year will have concentrations at this level or higher. For $NO_2$, there are substantial differences across sites that derive from the outdoor pollutant levels. (See Table B.4.2.31 in Appendix B; similar context is provided for $PM_{2.5}$ in Table B.4.2.32.)

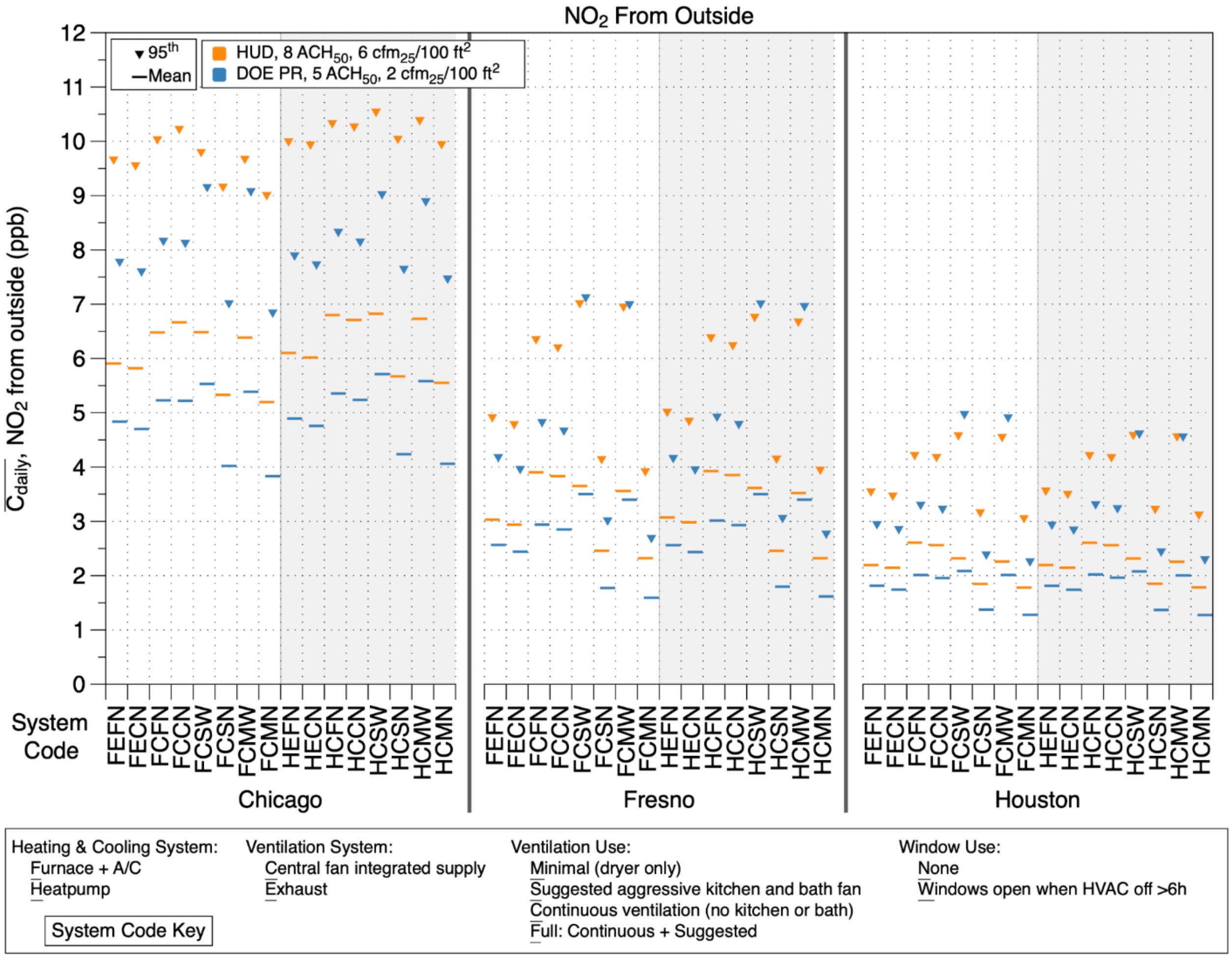

**FIGURE 4.2.3-5 Modeled $NO_2$ from Outside Air for a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

Within each location, there are relatively small variations in the average and 95th percentile daily $NO_2$ for each airtightness level. The conditions that provide higher AERs generally have higher indoor $NO_2$, but the variations are not proportional, as explained in Delp et al. (2022) and Appendix B.

Across all ventilation conditions, the tighter envelopes and ducts that would be required under DOE's proposed standards would lead to reductions in the average indoor concentrations of outdoor $NO_2$ of 15–28 percent for Chicago, 3–31 percent for Fresno, and 10–29 percent for Houston. The largest benefit of improved airtightness occurs under "closed house" conditions of no intentional ventilation, as recommended during outdoor air pollution events; the proposed energy conservation standards would reduce $NO_2$ from outdoor sources by 26–31 percent relative to a HUD Code home for this scenario. For homes with whole-house ventilation fans operating continuously and occupants using the range hood (as recommended), the proposed standards would reduce indoor levels of outdoor $NO_2$ by 15–20 percent.

For $PM_{2.5}$, outdoor levels across the three locations were more similar than they were for $NO_2$, and the highest values occurred in Fresno. Across ventilation conditions, DOE's proposed standards are estimated to reduce the average indoor concentrations of outdoor $PM_{2.5}$ by 13–26 percent in Chicago, -2–30 percent in Fresno, and 8–26 percent in Houston. The smallest changes occur for scenarios that include window opening. Similar to $NO_2$, the largest benefit occurs under closed-house conditions, with reductions of 25–30 percent across the sites. In homes with a whole-house ventilation fan operating continuously and the range hood used during cooking, the airtightness of the proposed standards would reduce indoor concentrations of outdoor $PM_{2.5}$ by 15–29 percent.

### *Formaldehyde, Acrolein, and Other Continuously Emitted Pollutants*

Estimated formaldehyde and acrolein concentrations[14] under each scenario are presented in Figures 4.2.3-7 and 4.2.3-8. As noted, the influence of ventilation practices and airtightness impacts for these two are indicative of those expected for other continuously emitted pollutants.

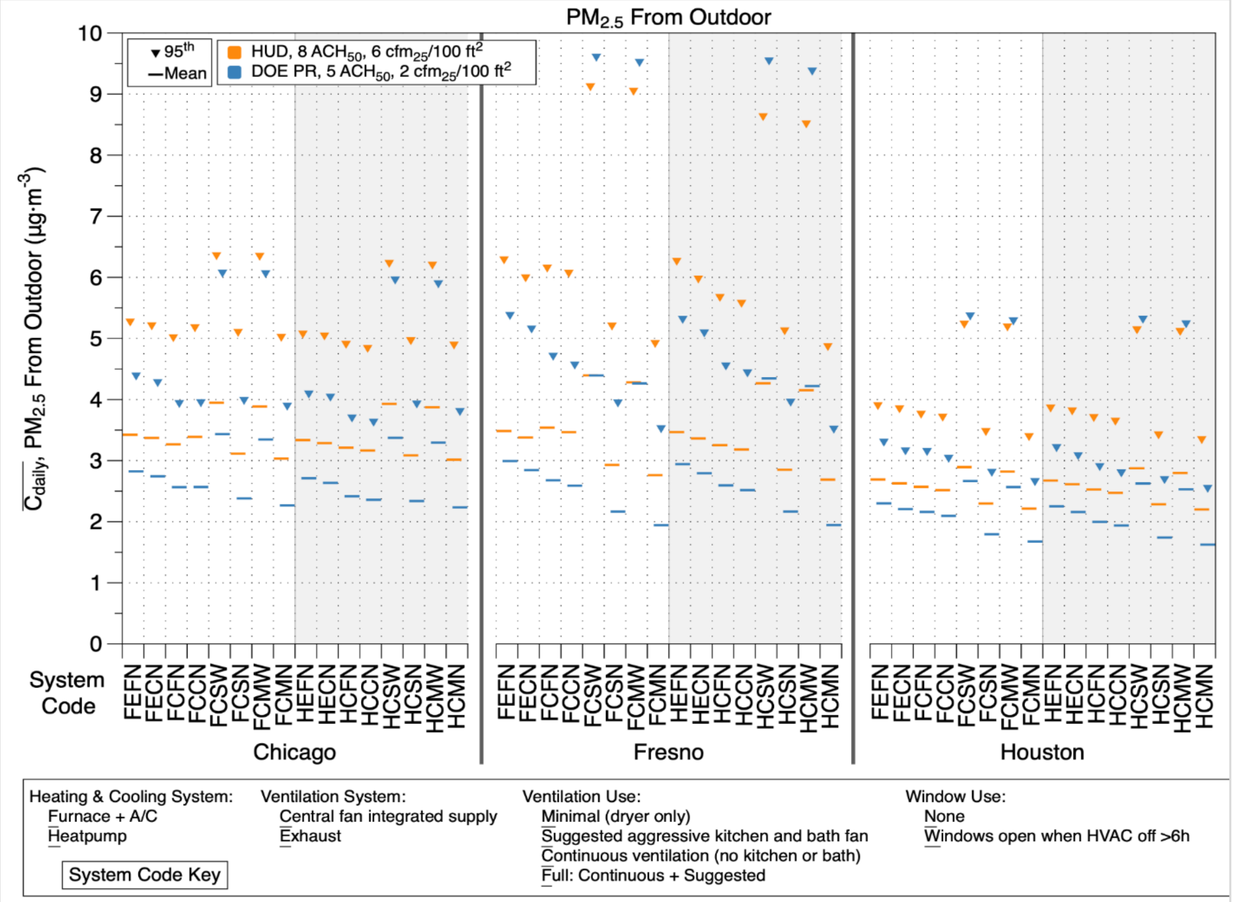

**FIGURE 4.2.3-6 Modeled $PM_{2.5}$ from Outdoor Air for a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

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[14] Concentration values are provided to one decimal place for $NO_2$ and $PM_{2.5}$ because their ranges exceed 10; values for acrolein and formaldehyde are lower, so their concentrations are provided to two decimal places.

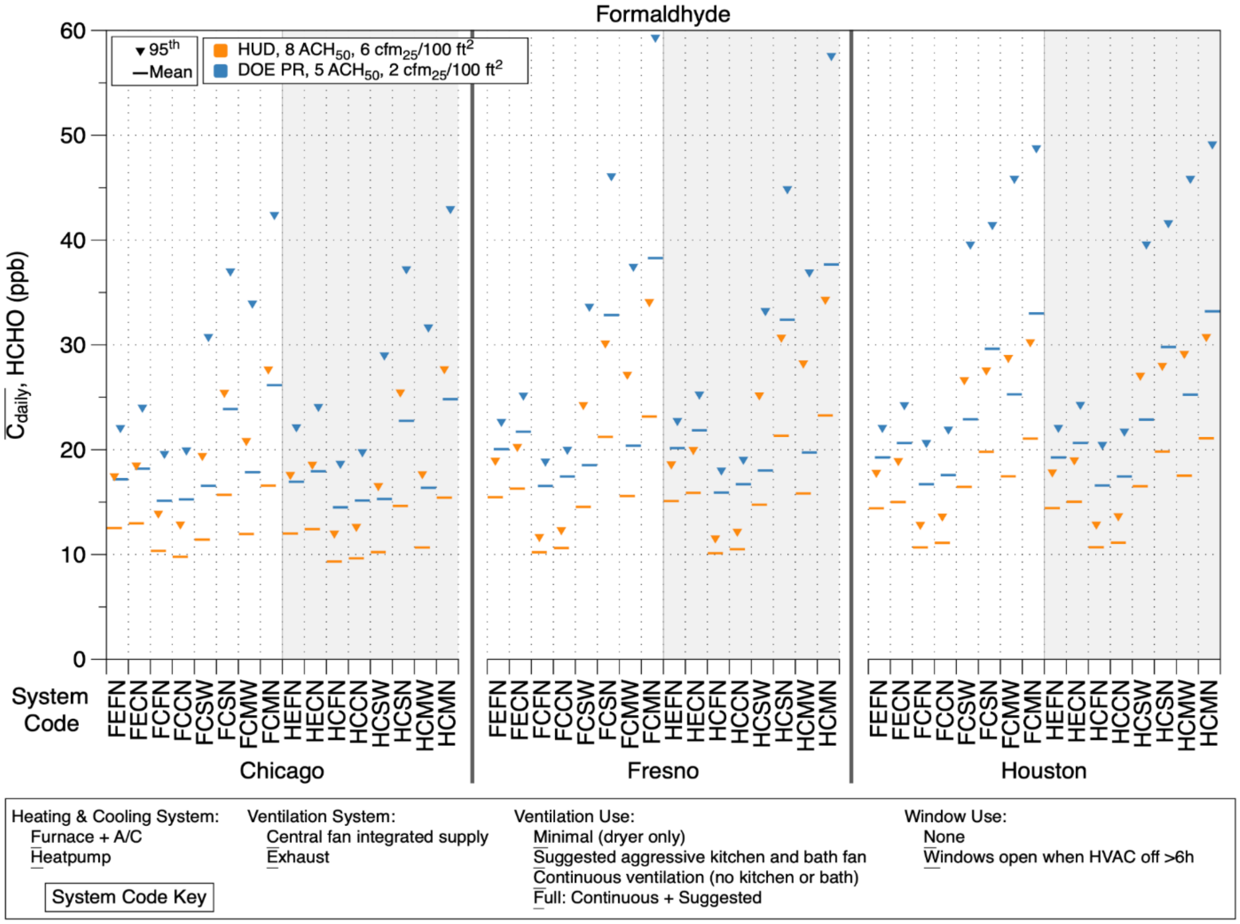

**FIGURE 4.2.3-7 Modeled Daily Mean Formaldehyde from Constant Emissions in a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

Key results for continuously emitted formaldehyde and acrolein are as follows:

- For a HUD Code home, average formaldehyde concentrations under the various scenarios are predicted to vary from 9 to 23 ppb. Use of continuous mechanical ventilation and window opening produce much lower levels than in homes with no intentional ventilation.

- The proposed standards are predicted to increase average concentrations by 22–65 percent, to 15–38 ppb, across ventilation practices. With continuous ventilation, average formaldehyde would remain below about 22 ppb with DOE's proposed standards, similar to what was observed in two recent studies of modern site-built homes with ventilation (Singer et al. 2020; PNNL 2021).

- Simulations predict that the proposed standards would lead to higher 95th percentile (high) days, with increases of 20–79 percent across ventilation scenarios. With continuous ventilation, the high days are predicted to not exceed 25 ppb. Without continuous ventilation, formaldehyde on the high days could reach 43 ppb in Chicago, 59 ppb in Fresno, and 49 ppb in Houston.

- Across the three sites, the proposed standards would have the smallest impacts on formaldehyde and other continuously emitted pollutants in homes using continuous exhaust ventilation, with predicted increases of 30–44 percent for average days and 20–30 percent for 95th percentile days.

- Across the ventilation scenarios, patterns of calculated concentrations are similar for homes with a furnace + AC or a heat pump; patterns are also similar across sites.

- Calculated acrolein concentrations follow an almost identical pattern to those for formaldehyde, demonstrating that results are generalizable to other pollutants that are emitted continuously or randomly throughout the day from other indoor sources. Minor differences result from the small sorption losses assumed for acrolein.

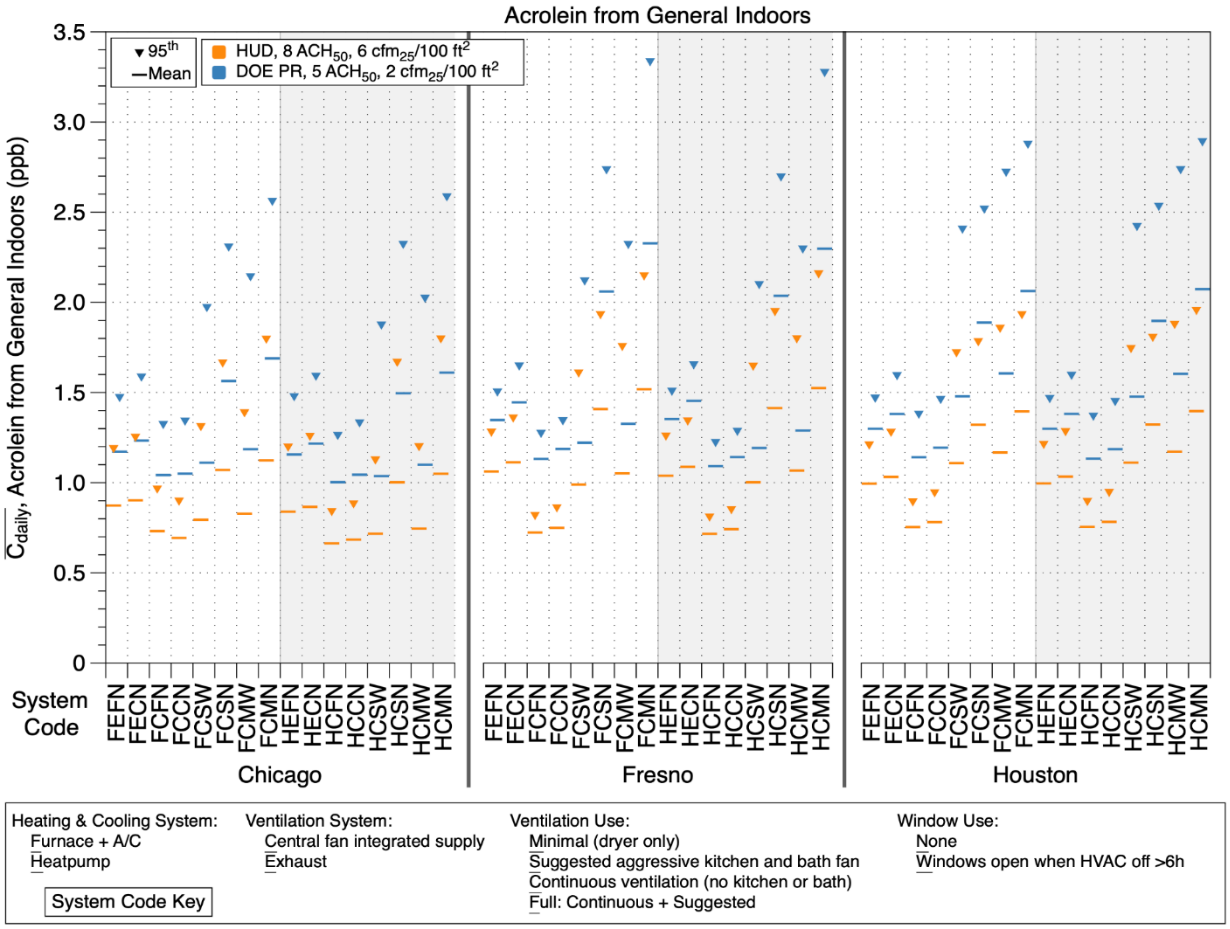

**FIGURE 4.2.3-8 Modeled Acrolein from Constant Emissions in a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

### *$PM_{2.5}$ from Activities*

Calculated concentrations of $PM_{2.5}$ resulting from miscellaneous occupant activities during waking hours are presented in Figure 4.2.3-9. Patterns across ventilation scenarios differ from those of formaldehyde and acrolein primarily owing to filtration in the central heating and cooling system.

Even with a 10 percent efficient filter, the high airflows assumed for the single-speed heating and cooling equipment provide substantial particle removal. This filtration effect is particularly impactful in households that can afford the energy cost and choose to operate CFIS ventilation systems continuously. Average concentrations in homes with continuous CFIS are estimated to be 2.9–3.5 μg/$m^3$ in HUD Code homes, increasing to 3.6–4.1 μg/$m^3$ (+14–29 percent) for homes complying with DOE's proposed standards. The 95th percentile days for HUD Code homes are estimated to be 3.0–4.0 μg/$m^3$, increasing to 3.7–4.4 μg/$m^3$ (+10–28 percent) with the improved airtightness of the proposed standards.

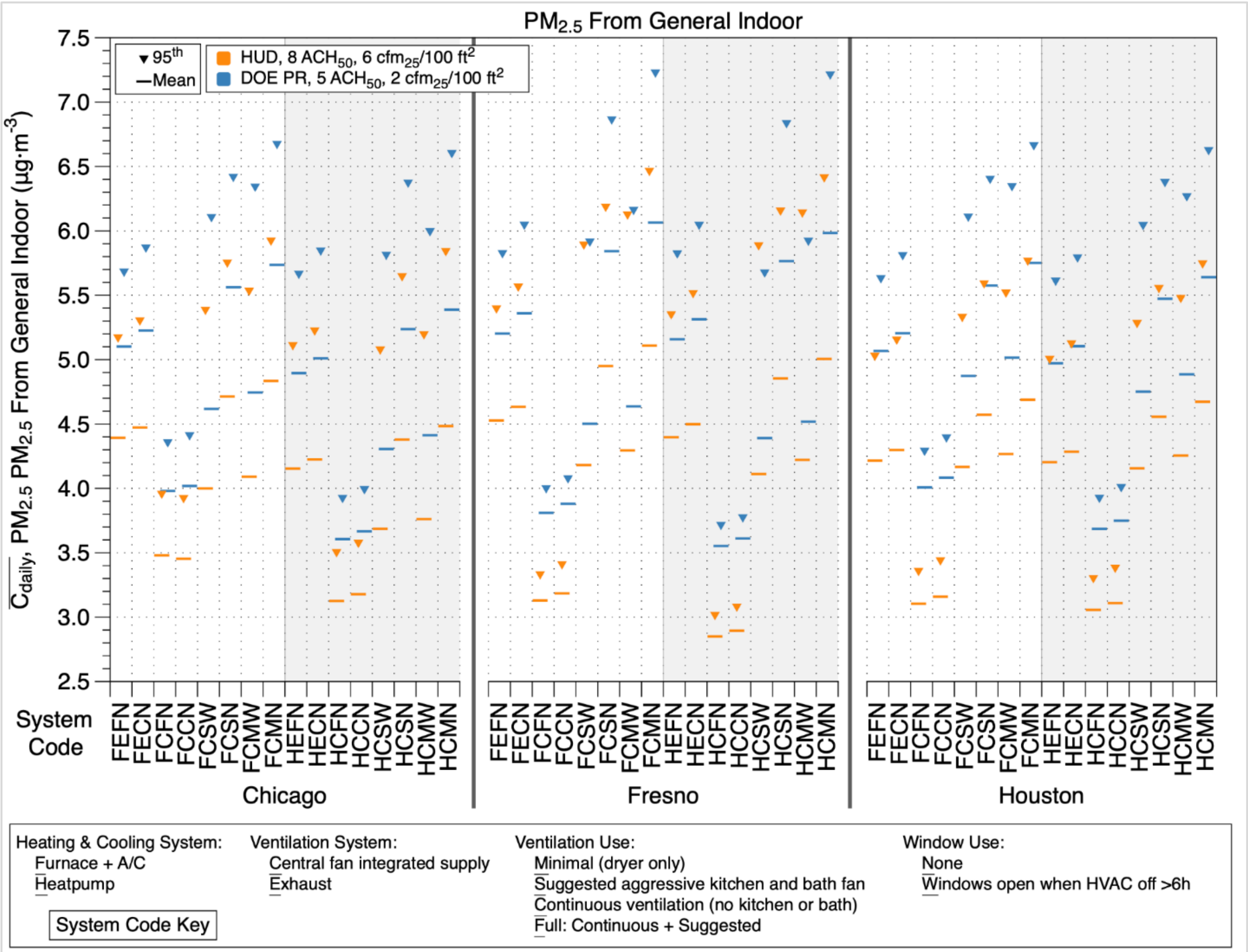

**FIGURE 4.2.3-9 Modeled Daily Mean $PM_{2.5}$ from Occupant Activities in a 1,568 $ft^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

In homes not utilizing intentional ventilation of any kind (FCMN and HCMN), average $PM_{2.5}$ is estimated to be 4.5–5.1 μg/$m^3$ for homes meeting the HUD code and 5.5–6.1 μg/$m^3$

(+19–23 percent) for homes meeting DOE's proposed standards. The 95th percentiles for HUD Code homes are estimated at 5.8–6.5 µg/m$^3$, increasing to 6.6–7.2 µg/m$^3$ (+12–16 percent) with improved airtightness.

### *Acrolein, $NO_2$, and $PM_{2.5}$ from Frequent Cooking*

Results for pollutants emitted from frequent cooking are presented in Figure 4.2.3-10 for acrolein, and in Figures B.4.2.3-1 for $NO_2$ and B.4.2.3-2 for $PM_{2.5}$ in Appendix B.

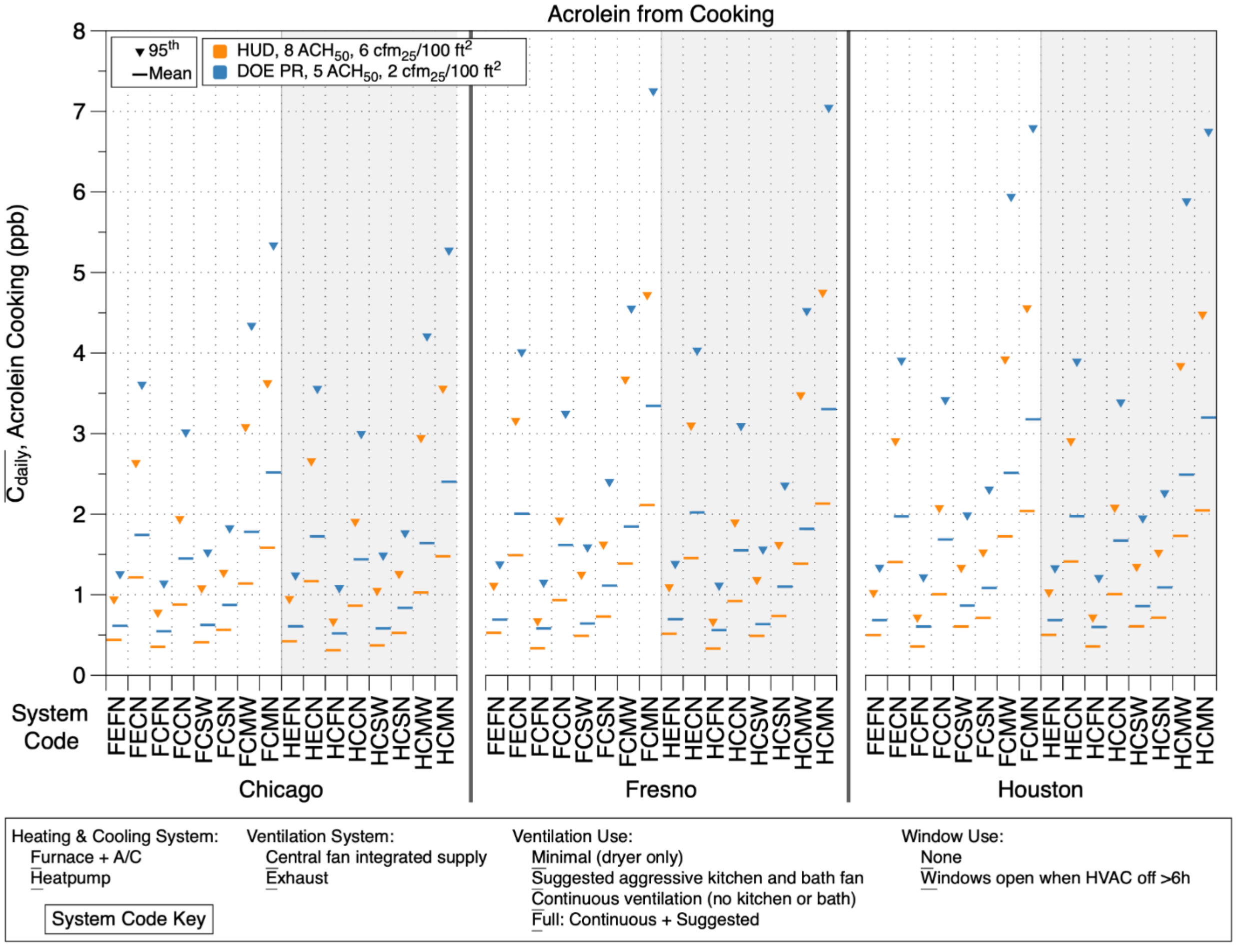

**FIGURE 4.2.3-10 Modeled Daily Mean Acrolein from Frequent Cooking in a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

Both the average and 95th percentile highest daily concentrations for acrolein vary widely based on ventilation, but similar patterns are observed at each site:

- For a HUD Code home, average acrolein from simulated frequent cooking is predicted to vary from 0.31 to 2.13 ppb across ventilation conditions. The improved airtightness of DOE's proposed standards would increase concentrations by 30−73 percent, to 0.52−2.99 ppb.[15]

- On the 95th percentile days in HUD Code homes, acrolein from frequent cooking is estimated to be 0.67–4.75 ppb. In homes constructed to DOE's proposed standards, acrolein from frequent cooking is estimated to be 1.08−7.25 ppb (+24−71 percent).

- Use of a kitchen range hood, which is assumed to remove 60 percent of all cooking-related pollutants before they mix into the home, has the biggest impact on controlling exposures. Average acrolein from frequent cooking is estimated to be 0.31−0.74 ppb in a HUD Code home and increases to 0.52−1.11 ppb in a home meeting DOE's proposed standards when the range hood is used. Without range hood use, average acrolein from cooking in the HUD Code home is estimated to be 0.86–2.13 ppb. In homes meeting the airtightness requirements of DOE's proposed standards, frequent cooking without range hood use is estimated to yield acrolein concentrations of 1.44−3.14 ppb (31−73 percent higher than HUD Code).

The pattern of estimated $NO_2$ concentrations from frequent cooking differs somewhat from acrolein because of the substantially higher deposition rate of $NO_2$:

- Similar to acrolein, $NO_2$ from cooking varies across ventilation scenarios and range hood use effectively lower concentrations. Average and 95th percentile $NO_2$ for scenarios with range hood use are estimated to be 2.2–3.3 ppb and 3.8-6.0 ppb in the HUD Code home. Using the range hood in homes meeting DOE's proposed standards results in average and 95th percentile $NO_2$ from cooking of 3.0–3.9 ppb and 4.9–6.6 ppb, for increases of 13−36 and 5−32 percent.

- When the range hood is not used, intensive cooking is estimated to produce higher average and 95th percentile $NO_2$ concentrations: 6.0–9.2 ppb and 10.5–17.0 ppb in a HUD Code home and 8.1−10.9 ppb and 13.5−18.7 ppb in a home built to meet DOE's proposed standards.

- When not using a range hood, opening windows (-CMW) reduces $NO_2$ compared with not using windows (-CMN). The effect is smaller on the 95th percentiles than the average.

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[15] Acrolein concentrations are presented with two decimal places to maintain precision for numbers that extend from the low single digits, down to below 1.0. Other pollutant concentrations are presented with one decimal place because they are mostly above 3.0. This simplified approach is used in place of the convention of setting a fixed number of significant figures, which would result in varied decimal places for the same pollutant.

Estimated $PM_{2.5}$ concentrations resulting from frequent cooking differ from both $NO_2$ and acrolein due to the effect of filtration with CFIS operation:

- Similar to acrolein and $NO_2$, $PM_{2.5}$ from cooking varies widely across ventilation scenarios at each location and the results follow similar patterns across locations. Use of a range hood greatly reduces concentrations of $PM_{2.5}$ from cooking.

- Average and 95th percentile $PM_{2.5}$ for ventilation scenarios that include range hood use are estimated to be 1.3−3.2 $\mu g/m^3$ and 2.3−6.3 $\mu g/m^3$ for frequent cooking in the HUD Code home. Increasing airtightness to the levels of DOE's proposed standards is predicted to increase average $PM_{2.5}$ by 13−54 percent across scenarios to 1.9−3.9 $\mu g/m^3$, and to increase the 95th percentile daily $PM_{2.5}$ by 2−52 percent to 3.3−7.3 $\mu g/m^3$ when the range hood is used.

- When the range hood is not used, intensive cooking is estimated to produce much higher average and 95th percentile $PM_{2.5}$ concentrations: 3.4−8.7 $\mu g/m^3$ and 6.1−17.4 $\mu g/m^3$ in a HUD Code home, and 5.0−10.8 $\mu g/m^3$ and 8.8−20.3 $\mu g/m^3$ in a home with airtightness consistent with DOE's proposed standards.

- Opening windows when not using the range hood (scenarios labeled as CMW) reduces average $PM_{2.5}$, but this control has a smaller relative impact on the 95th percentiles.

- As seen for PM2.5 from miscellaneous occupant activities, continuous operation of the central fan for ventilation can provide substantial filtration benefit. The "full" ventilation scenarios that include both range hood use and continuous CFIS operation (FCFN and HCFN) result in the lowest cooking-related PM2.5, with average concentrations of 1.3−1.8 µg/m3 for a HUD Code home and 1.9−2.3 µg/m3 for a home complying with DOE's proposed standards.

#### *Total Acrolein from Typical Cooking and Continuous Sources*

Estimates of the overall impacts of improved airtightness on indoor concentrations of acrolein are provided for the three sites and various ventilation scenarios in Figure 4.2.3-11. Across all scenarios, the average total acrolein concentrations for the home with HUD Code airtightness is estimated to be 0.82–2.59 ppb. Values for individual scenarios would increase by 21−64 percent to 1.26–4.00 ppb. The 95th percentile highest days are estimated to be 1.11−4.29 ppb under HUD Code and increase by 20−63 percent to 1.70−6.32 ppb under DOE's proposed standards. Across the three locations, HUD Code homes without use of ventilation are estimated to have average acrolein of 1.79−2.59 ppb.

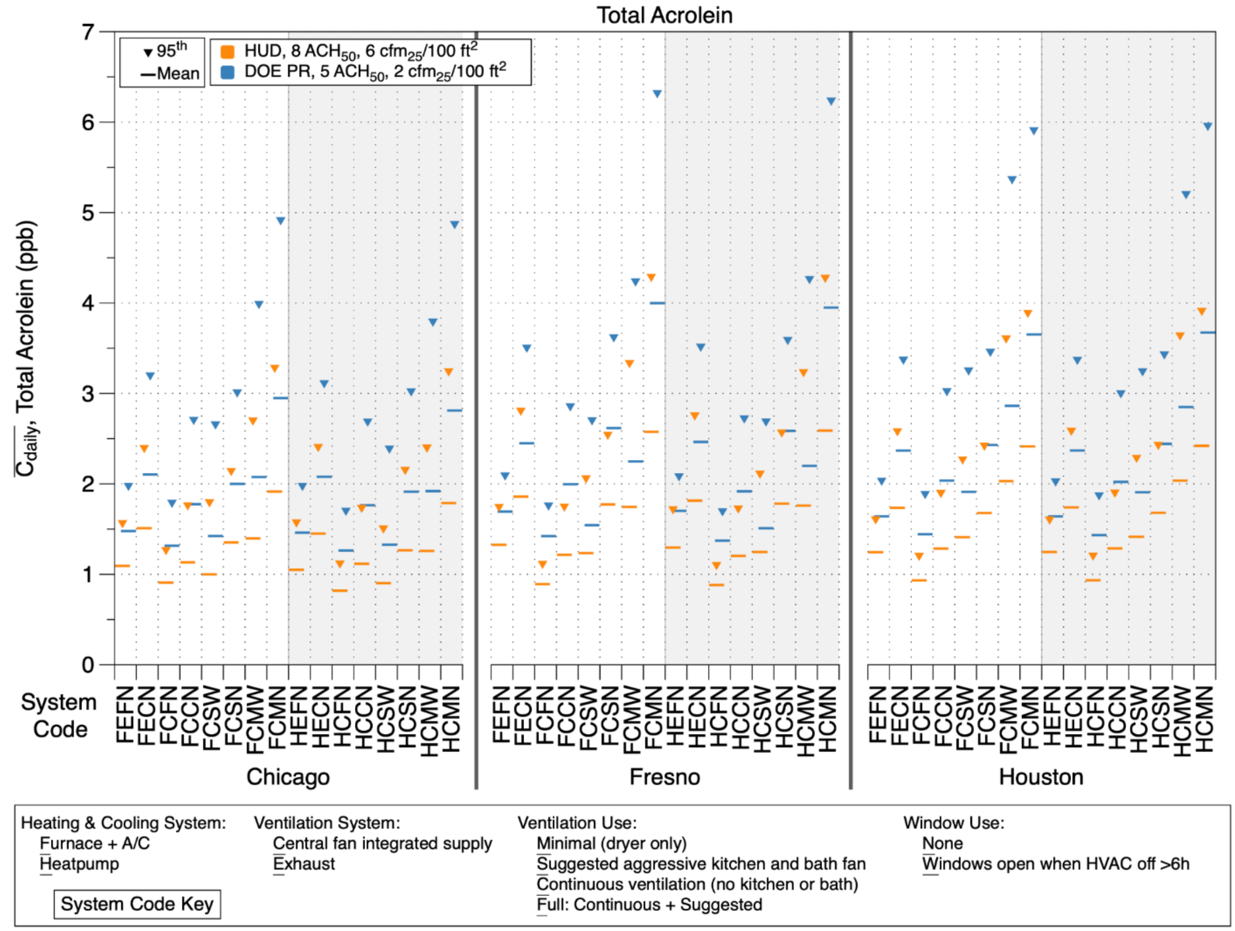

**FIGURE 4.2.3-11 Modeled Daily Mean Acrolein from All Sources in a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

Homes conforming with DOE's proposed standards and using continuous exhaust whole-house ventilation (which requires no action on the part of the occupant other than to leave the fan running) would have average acrolein of 2.08–2.46 ppb. With the same emissions sources, homes at the three locations conforming with DOE's proposed standards and using a 60 percent effective range hood during all cooking but not using continuous whole-house mechanical ventilation would have average acrolein of 1.91–2.62 ppb. Use of a continuous whole-house ventilation fan (not CFIS) and range hood would result in acrolein concentrations of 1.46–1.70 ppb in the same locations and with the same emissions. These results provide examples of how increased ventilation use can mitigate the potential impacts of air-sealing on indoor pollutant concentrations.

### *Total Nitrogen Dioxide from Typical Cooking and Outdoors*

Estimates of the overall impacts of improved airtightness on indoor concentrations of $NO_2$ are provided for the three sites and various ventilation scenarios in Figure 4.2.3-12.

Across all scenarios, the average total $NO_2$ concentrations for the home with HUD Code airtightness is estimated to be 3.5–9.9 ppb. Increasing airtightness and other efficiency measures to meet DOE's proposed standards but keeping other factors constant would produce changes varying from a 15 percent reduction (from lower outdoor $NO_2$) to a 7 percent increase, to a range of 3.3–9.6 ppb. The 95th percentile highest days are estimated to be 5.2–13.8 ppb under HUD Code and change by -17 percent to +9 percent with the improved airtightness of DOE's proposed standards, to a range of 4.9–13.6 ppb.

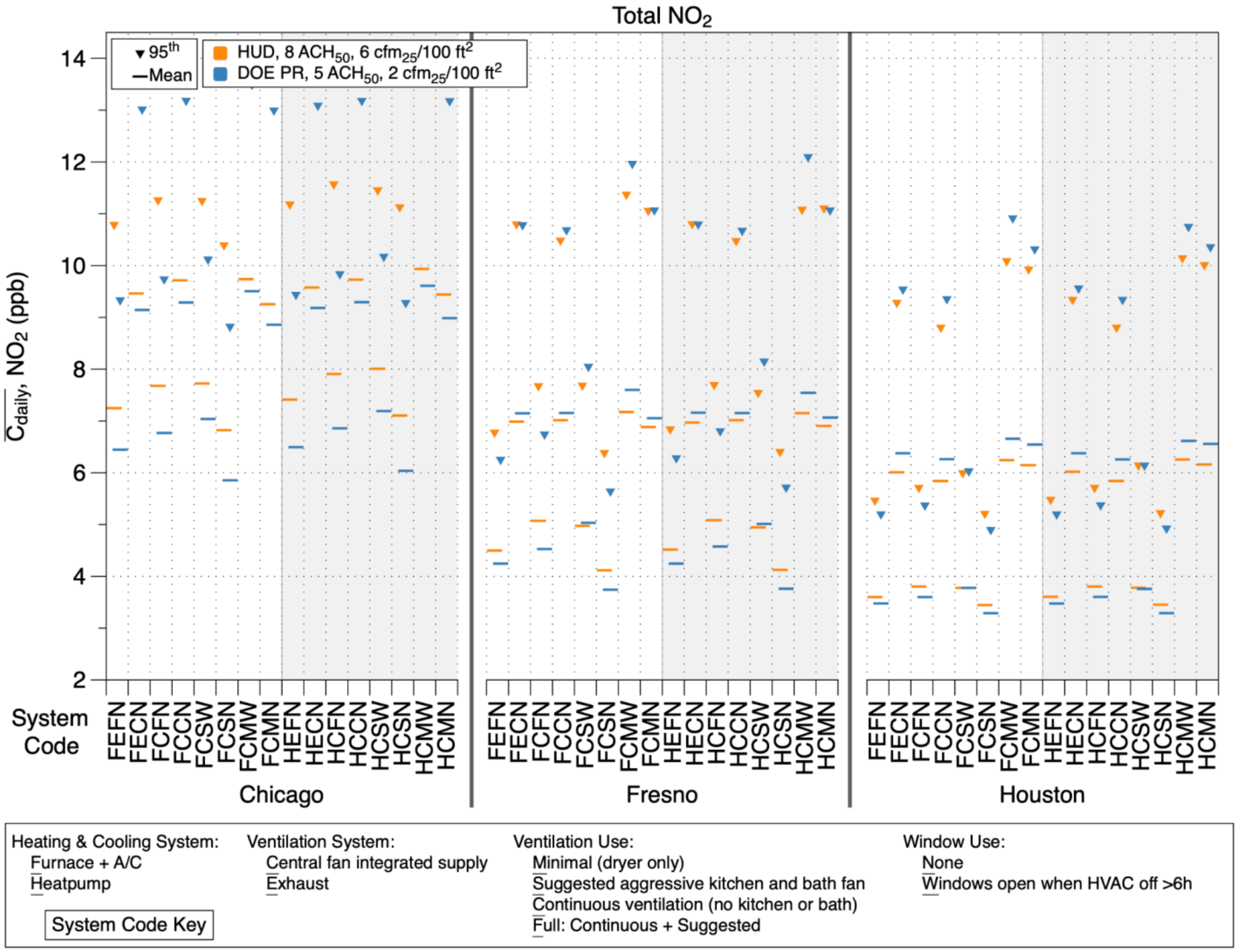

**FIGURE 4.2.3-12 Modeled Daily Mean $NO_2$ from Frequent Cooking and Outdoors in a 1,568 $ft^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

Across the three sites, HUD Code homes without ventilation use are estimated to have average $NO_2$ concentrations of 6.2–9.4 ppb. Homes conforming with DOE's proposed standards and using continuous exhaust whole-house ventilation would have average $NO_2$ concentrations of 6.4–9.2 ppb. Homes using a 60 percent effective range hood during cooking but not using continuous whole-house mechanical ventilation would have average $NO_2$ concentrations of 3.3–6.0 ppb. Use of a continuous whole-house ventilation fan (not CFIS) and range hood would result in $NO_2$ concentrations of 3.5–6.5 ppb in the same locations, with the same emissions. As with acrolein, increased use of continuous whole-house or kitchen exhaust ventilation, or both, could effectively offset any increases from air-sealing.

#### *Total $PM_{2.5}$ from Miscellaneous Occupant Activities, Cooking, and Outdoors*

Estimates of the overall impacts of improved airtightness on indoor concentrations of $PM_{2.5}$ are provided for the three sites and various ventilation scenarios in Figure 4.2.3-13. Across all scenarios, the average total $PM_{2.5}$ concentrations for the home with HUD Code airtightness is estimated to be 6.3–12.2 $\mu g/m^3$. Across the three sites, HUD Code homes without ventilation use are estimated to have average $PM_{2.5}$ of 10.8–12.2 $\mu g/m^3$. Homes conforming with DOE's proposed standards and using continuous exhaust whole-house ventilation would have average $PM_{2.5}$ of 11.6–12.7 $\mu g/m^3$.

Homes using a 60 percent effective range hood during all cooking but not continuous whole-house mechanical ventilation would have average $PM_{2.5}$ of 9.0–10.0 $\mu g/m^3$. Use of a continuous whole-house ventilation fan (not CFIS) and range hood would result in $PM_{2.5}$ concentrations of 8.8–9.8 $\mu g/m^3$ in the same locations and with the same emissions. As with acrolein and $NO_2$, increased use of continuous whole-house or kitchen exhaust ventilation, or both, could effectively offset increases from air-sealing. Operation of an air cleaner or installation of a more efficient central heating and cooling system filter would also reduce $PM_{2.5}$.

### 4.2.3.3 Summary of Model-Predicted IAQ Impacts

The analyses summarized above found that DOE's proposed standards would lead to substantial improvements in the protection that manufactured homes provide to occupants against outdoor air pollution. Under closed-house conditions, with ventilation systems temporarily turned off as recommended during outdoor air pollutant events, homes built to DOE's proposed airtightness standards would have indoor concentrations of outdoor $NO_2$ and $PM_{2.5}$ about 25–30 percent lower than in a HUD Code home.

The analysis also found that concentrations of pollutants from indoor sources may be expected to increase with DOE's proposed standards if all material emissions and behavioral factors are unchanged:

- For continuously emitted VOCs, the increase is estimated to be 22–65 percent across all ventilation practices, but only 30–44 percent in homes using continuous exhaust ventilation.

- $PM_{2.5}$ from occupant activities would increase by -4–28 percent across all scenarios and by 16–21 percent in homes using continuous exhaust ventilation.

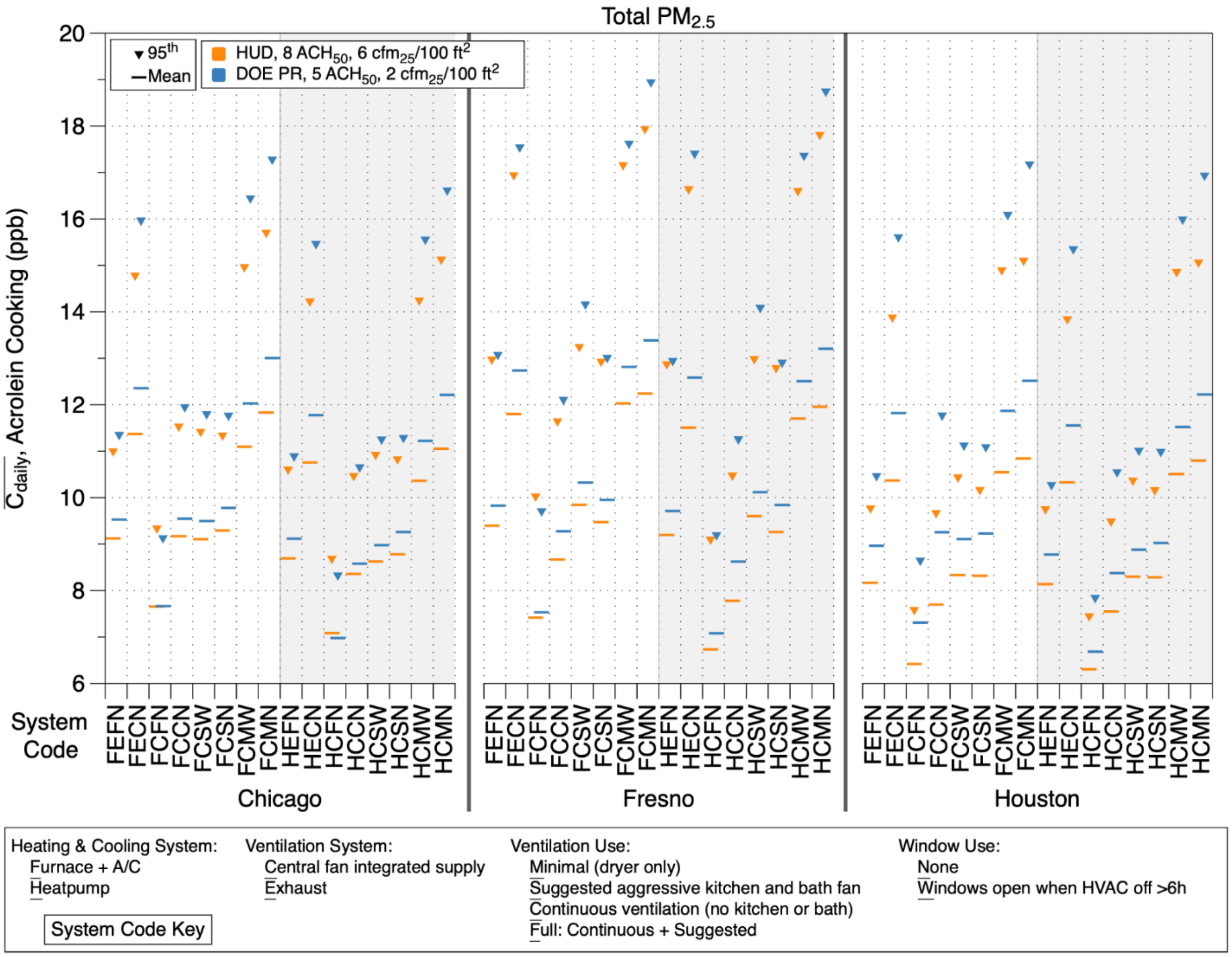

**FIGURE 4.2.3-13 Modeled Daily Mean PM$_{2.5}$ from All Sources in a 1,568 ft$^2$ Home Meeting HUD Code or DOE-Proposed Standards with Varied Equipment and Ventilation**

- Acrolein and other gases from cooking would increase by 30–73 percent across all the ventilation scenarios and by 35–40 percent in homes using continuous exhaust ventilation.

- PM$_{2.5}$ from cooking would increase by 13–54 percent across all ventilation scenarios and by 20–28 percent in homes using continuous exhaust ventilation.

- NO$_2$ from gas cooking burners would increase by 13–36 percent across all ventilation scenarios and by 16–24 percent in homes using continuous exhaust ventilation.

- Increasing the use of ventilation equipment can effectively mitigate the increases in indoor generated pollutants that would otherwise result from improved airtightness of DOE’s proposed standards.

- Compared with a HUD Code home that does not use mechanical ventilation, a home meeting DOE's proposed standards that uses continuous exhaust ventilation would have formaldehyde concentrations that are 6 percent lower to 16 percent higher across the three locations.

- Compared with a HUD Code home that does not use mechanical ventilation, a home meeting DOE's proposed standards that uses a range hood during all cooking would have cooking-related acrolein concentrations that are 43–48 percent lower. The reduction would be 54–57 percent lower for $NO_2$ from gas cooking burners and 53–55 percent for $PM_{2.5}$ from cooking.

This analysis of potential IAQ impacts of the proposed energy conservation standards for manufactured housing uses two example cases that align with Alternative D (no-action) and Alternative C1 (untiered standard with insulation per IECC 2021 specifications). Because this untiered standard would align with Tier 2 of the tiered standards, this analysis also estimates potential IAQ impacts for Tier 2 of Alternative A1 (price-based tiered standard with insulation per the 2021 IECC specifications) and Tier 2 of Alternative B1 (size-based tiered standards with insulation per IECC specifications). Furthermore, the estimated impacts presented in this section are expected to generally apply to the other action alternatives because each action alternative includes improved air-sealing of the envelopes and ducts.

Under the no-action alternative (Alternative D), occupants of manufactured homes would continue to be exposed to air pollutants at widely varying concentrations that depend on where they live (contributions of outdoor air pollutants), the materials used to construct the homes, what they do in the homes (including cooking and recreational combustion such as candles, incense, and smoking), and, very importantly, how they operate ventilation and utilize filtration to manage their indoor air quality.

### 4.2.4 Wildfire Impacts on Air Quality

As described in Section 4.2.3, improvements in the airtightness of the building envelope and the forced-air distribution ducts lead to lower ratios of indoor-to-outdoor concentrations of outdoor $PM_{2.5}$ and $NO_2$. Such a benefit is particularly helpful when outdoor air quality is affected by wildfire smoke. This section presents a wildfire assessment using ambient air quality data and indoor air modeling simulations for Fresno to illustrate the beneficial impacts of air-sealing that would be gained under DOE's proposed standards. Although wildfire smoke contains $NO_2$ and a number of hazardous air pollutants, $PM_{2.5}$ is the primary contributor to potential health effects associated with indoor inhalation exposures. For this reason, the analysis in this EIS focuses on $PM_{2.5}$.

Figure 4.2.4-1 shows the outdoor $PM_{2.5}$ concentrations reported at a regulatory air quality monitoring site in Fresno (in red) and the calculated indoor $PM_{2.5}$ concentrations for two hypothetical manufactured homes. One home represents the envelope and duct leakage corresponding to minimal compliance with the current HUD Code (representing no-action, Alternative D). The other represents the envelope and duct leakage corresponding to minimal compliance with the provisions of the DOE-PR, considering an untiered standards case (Alternative C1). In this figure, the bottom panel shows outdoor and indoor $PM_{2.5}$ when there are no other indoor sources. The second panel from the bottom is the ratio of indoor to outdoor $PM_{2.5}$. The top panel is the hourly fractional run time of the forced-air cooling system, and the second panel from the top shows the outdoor air exchange rate.

This figure illustrates the wildfire scenario for an illustrative manufactured home in Fresno with a CFIS whole-house ventilation system, minimal use of mechanical ventilation, and no window opening. $PM_{out}$ is the outdoor concentration of $PM_{2.5}$. See Section 4.2.3.1 for details about the duct air tightness.

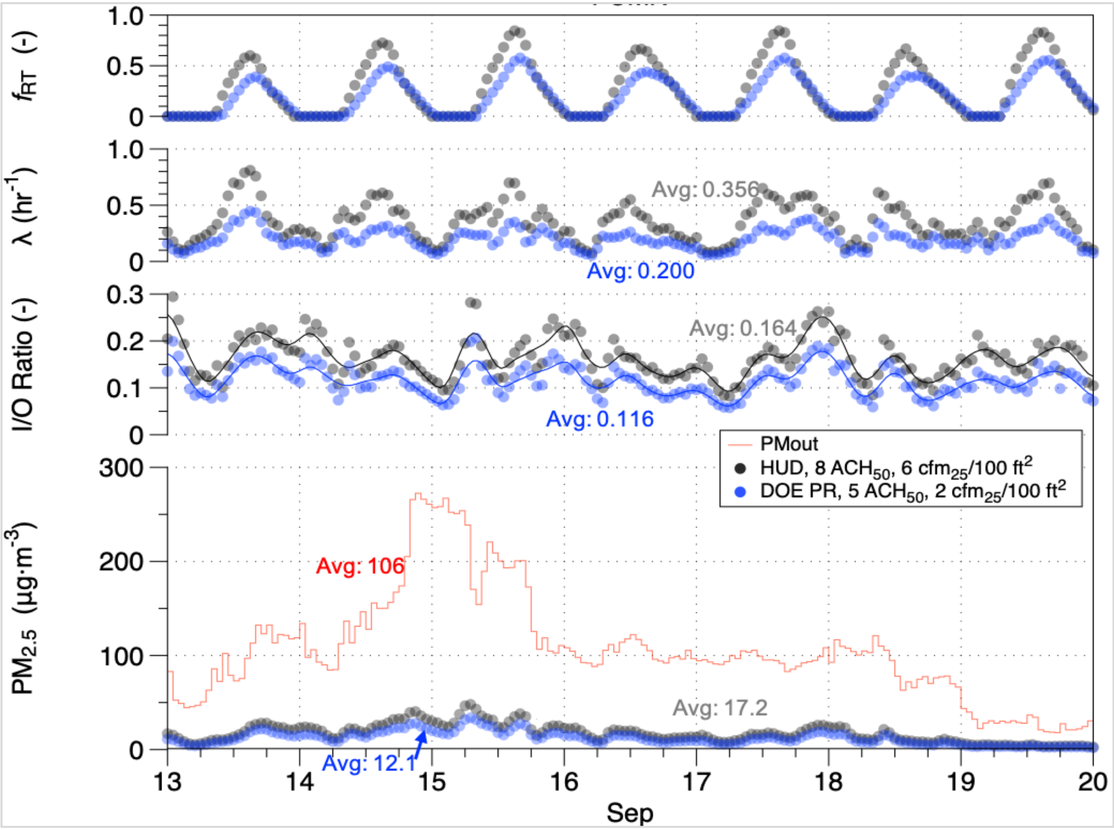

**FIGURE 4.2.4-1 Benefits of Improved Envelope and Duct Air-Tightness on Indoor $PM_{2.5}$**

The period evaluated for this wildfire assessment is a week in mid-September 2020 when regional air quality was affected by the Creek Fire that burned about 380,000 acres between early September and late December. This simulation considers a pair of hypothetical double-section manufactured homes equipped with a furnace and air conditioner and a central fan integrated supply (CFIS) whole-house ventilation system. The homes are assumed to be operating with minimal use of mechanical ventilation (limited to clothes dryer use) and no open windows.

This analysis shows that when operated without continuous whole-house mechanical ventilation and without opening windows, the hypothetical home that meets minimum HUD Code requirements provides substantial protection from outdoor pollutants originating from a wildfire. Estimated indoor concentrations of $PM_{2.5}$ are nearly seven times lower than (roughly 16 percent of) outdoor $PM_{2.5}$. This results from an overall outdoor air exchange rate of 0.356 ACH (air changes per hour). On most of the days modeled, the air exchange rate increased during midday as the forced-air system operated to provide cooling and leaks in the duct system increased outdoor air exchange.

The analysis also shows that a hypothetical home meeting the energy conservation standards under DOE's proposed rule would provide even better protection. Under these standards, the manufactured home is estimated to achieve substantially reduced air conditioner operation and lower duct and envelope leakage. This combination results in an exchange rate of 0.200 ACH and indoor $PM_{2.5}$ concentrations that are another 30 percent lower than those estimated for the example HUD Code home under similar operating conditions. That is, a home minimally compliant with DOE's proposed standards would be 30 percent more protective in reducing exposures to pollutants from wildfire smoke than a home minimally compliant with the HUD Code.

Outdoor $PM_{2.5}$ concentrations from wildfire smoke events can vary widely, and the indoor concentrations under each action alternative will vary somewhat based on the run time of the air conditioner. Nevertheless, compared with the HUD Code home under the no-action alternative, the magnitude of the relative improvement in protectiveness from wildfire smoke that would be achieved by a home with a tighter envelope and ducts as shown here is expected to be similar across all the action alternatives. This is because the tighter envelope and duct sealing designed to reduce uncontrolled air movement are the primary factors in the improved protection that would be gained from a more energy-efficient manufactured home. Similarly, the estimated improvement in protectiveness illustrated here for a double-section home is expected to translate to single-section and triple-section homes meeting the same envelope and duct airtightness standards.

## 4.3 HEALTH AND SAFETY

This section summarizes the assessment of the potential health risks of exposures to indoor air pollutants whose concentrations might change as a result of the proposed energy conservation standards for manufactured homes.

The risk assessment presented in Section 3.3 identified several indoor air pollutants that can be present in manufactured homes at concentrations that exceed an inhalation reference value or exposure guideline. These were carried forward for detailed analysis of the potential for adverse health effects from the proposed energy conservation standards. The analysis also considered whether the indoor air concentrations of each pollutant could substantially increase as a result of the proposed standards, and whether the increase could be quantitatively assessed. The findings were as follows:

- Radon might be present in some manufactured homes at levels that exceed the EPA action level, but air-sealing is expected to reduce radon exposures.

- It is very likely that acrolein is commonly present in manufactured homes at concentrations that exceed the reference (target) concentration of 0.82 $\mu g/m^3$, which is equivalent to 0.36 ppb. Across several studies, the median levels measured in Canadian homes without smoking in summer and winter sampling campaigns were seven and four times this inhalation reference level, respectively.

- Mean formaldehyde concentrations measured in two studies of homes constructed after the federal formaldehyde emission standards were in effect were roughly three times higher than the reference concentration of 9 $\mu g/m^3$ used to assess the potential for noncancer effects.

- The cancer risk posed by formaldehyde at the 95th percentile of measured concentrations in the two field studies barely exceeded 1 in 10,000, the upper end of EPA's acceptable risk range for exposures to environmental pollutants.

- Data from studies of homes that use natural gas cooking burners and have higher risk factors for elevated concentrations indicate that long-term average $NO_2$ concentrations rarely exceed the National Ambient Quality Standards (NAAQS) annual average standard of 53 ppb.

- Based on data from studies that measured $PM_{2.5}$ in homes in recent years, it is uncertain how common it is for the annual average $PM_{2.5}$ in manufactured homes to exceed the NAAQS threshold of 12 $\mu g/m^3$ $PM_{2.5}$ under existing conditions in homes with no smoking. It seems likely, however, that it is not a large fraction of the population.

- Measurements of $PM_{2.5}$ from homes with smoking reported concentrations above the annual NAAQS limit in almost all homes, with hazard quotients of 2–7.

The analyses reported in this section use the simulation results presented in Section 4.2.3 as the basis for estimated changes to air pollutant concentrations and apply the toxicity factors presented in Section 3.3 to estimate cancer risk and the potential for noncancer health effects. As noted in Section 3.2.3, the simulations considered four air pollutants likely to account for much of the harm associated with residential exposures to indoor air pollutants: acrolein, formaldehyde, $NO_2$, and $PM_{2.5}$. The simulations assumed the pollutant sources were: (1) outdoor air; (2) cooking, simulated as discrete events concentrated around mealtimes, which can be mitigated with kitchen exhaust ventilation; (3) continuous sources, or emissions from materials; and (4) randomly distributed events associated with occupant activities such as cleaning, hobbies, and recreational combustion, simulated as continuous emissions during waking hours.

The following reference levels for chronic inhalation exposures were applied, as described in Section 3.3:

- Acrolein: 0.82 $\mu g/m^3$ (0.36 ppb)
- Formaldehyde: 9 $\mu g/m^3$ (7.3 ppb)
- $PM_{2.5}$ (annual): 12 $\mu g/m^3$
- $NO_2$ (annual): 53 ppb

Results for the noncancer endpoints (as hazard quotients) are presented in Table 4.3-1 for a HUD Code home and a home that would align with the DOE-proposed standards (see Section 4.2.3).

Simulations were for a frequent (high-use) cooking scenario, and results were divided by two to represent more typical cooking when calculating results for all sources simulated over time.

**TABLE 4.3-1 Hazard Quotients Estimated for Specific Pollutants and Sources**

| Pollutant and Source | Calculated from Available Data | Simulated Home Meeting the HUD Code | Simulated Home Meeting Proposed DOE Standards |
|---|---|---|---|
| $NO_2$ from outdoors | | 0.03–0.13 | 0.02–0.11 |
| $PM_{2.5}$ from outdoors | | 0.18–0.37 | 0.14–0.37 |
| Acrolein from continuous sources | | 1.9–4.4 | 2.9–6.7 |
| Acrolein from frequent cooking | | 0.9–6.2 | 1.5–9.6 |
| $NO_2$ from frequent cooking with natural gas | | 0.04–0.17 | 0.06–0.21 |
| $PM_{2.5}$ from frequent cooking | | 0.11–0.79 | 0.16–0.90 |
| $PM_{2.5}$ from occupant activities | | 0.24–0.43 | 0.30–0.51 |
| **TOTALS** | | | |
| Acrolein, total | ~4–19 | 2.3–7.4 | 3.6–11.4 |
| Formaldehyde from continuous sources | ~2.1–3.4 [a] | 1.28–3.19 | 1.99–5.24 |
| $NO_2$ total, with natural gas cooking | 0.11–0.43 [a] | 0.07–0.19 | 0.06–0.18 |
| $PM_{2.5}$ total, nonsmoking home | ~0.3–2.3 [a] | 0.53–1.02 | 0.56–1.12 |

[a] Based on estimated concentration range of 15–25 ppb formaldehyde, 6–23 ppb $NO_2$, and 3–28 µg/m$^3$ $PM_{2.5}$ in nonsmoking homes and 22–82 µg/m$^3$ $PM_{2.5}$ in homes with smoking. These are 25th and 75th percentiles from selected studies. See Section 3.2.3 and Appendix B for details.

The incremental cancer risk estimated for formaldehyde exposures that would result from the proposed air-sealing ranges from $9.9\times10^{-6}$ to $4.6\times10^{-5}$, which is below the EPA target range of $1\times10^{-6}$ to $1\times10^{-4}$. This is based on estimated incremental increases of mean annual formaldehyde concentrations of 3.3–15.1 ppb (4.1–18.5 µg/m$^3$) with exposure considered to occur continuously over 30 years and an inhalation unit risk factor of $6 \times 10^{-6}$ per µg/m$^3$ for lifetime exposures established by the California EPA Office of Environmental Health Hazard Assessment (OEHHA 2009).

For most of the emission sources, as well as for the estimated totals by pollutant, the increases in concentrations projected to result from the improved air sealing specified the proposed rule would not significantly change the hazard levels. Even in homes with frequent gas cooking, chronic $NO_2$ exposure would remain well below the NAAQS annual average concentration benchmark. Across all of the ventilation scenarios and the three locations, $PM_{2.5}$ from frequent cooking and occupant activities (excluding smoking) would also remain below the NAAQS benchmark. The emission rates used for the simulations produced a range of hazard quotients that extend to just over 1.0 for total $PM_{2.5}$ in nonsmoking HUD Code homes. The high value is for homes that use no mechanical ventilation and do not routinely open windows. The range of hazard quotients for total $PM_{2.5}$ would extend a bit higher in a home that meets the proposed standards for airtightness with the same indoor sources and outdoor concentrations, but the difference is very small.

While the analysis did not explicitly consider SHS, the results for $PM_{2.5}$ from occupant activities can be used to infer impacts of the proposed rule in homes with SHS. Across the various ventilation scenarios in the three representative cities evaluated, the increase in airtightness is predicted to result in an increase in $PM_{2.5}$ from occupant activities ranging from -4 to 28 percent. The increase is roughly 20 percent for the worst conditions with no ventilation. A 20 percent increase in $PM_{2.5}$ in homes that already have high concentrations of SHS would represent a substantial increase in the hazard level. However, in the no-action alternative, occupants of homes with SHS that is not effectively controlled would continue to be exposed to very high levels of $PM_{2.5}$.

Along with SHS, acrolein and formaldehyde also have incremental hazard quotients with two to four times higher that the target level of 1 in the HUD Code home (no-action alternative). Those hazard quotients likely would increase with air-sealing if there were no changes to occupant ventilation practices. As noted in Section 4.2.3, any potential increases in concentrations for these pollutants could be mitigated with increased use of ventilation. The estimated incremental changes to formaldehyde concentrations would not result in a significant incremental cancer risk from formaldehyde exposure.

## 4.4 SOCIOECONOMIC IMPACTS

This section summarizes the analyses from the SNOPR, TSD, and NODA (86 FR 47744; DOE 2021; 86 FR 59042). DOE analyzed economic impacts of the proposed action and alternatives within three main categories: (1) impacts to consumers; (2) impacts to manufacturers; and (3) nationwide impacts. This section is organized by alternative, with the impact categories from the SNOPR and NODA included as subsections for each alternative. The potential socioeconomic impacts of Alternative A (tiered standards based on price) are discussed in Section 4.4.1, of Alternative B (tiered standards based on size) in Section 4.4.2, of Alternative C (untiered standards) in Section 4.4.3, and of Alternative D (no-action) in Section 4.4.4. Potential socioeconomic impacts are compared across alternatives in Section 4.4.5.

In both the SNOPR and NODA, DOE analyzed lifecycle costs (LCCs)[16] and payback periods (PBPs)[17] to assess economic impacts on individual consumers. The LCC analysis estimated the total consumer expense of the manufactured home as the total installed cost (including purchase expense, including accounting for whether in cash or a loan) plus total operating costs (notably energy costs) over both the lifetime of the home and the ownership period of the first homeowner. These periods were taken to be 30 years and 10 years, respectively. The PBP represents the number of years it would take a consumer to recover the increased purchase cost of a more energy-efficient manufactured home through lower operating costs. DOE compared the total long-run (net present

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[16] For the LCC, DOE discounted future operating costs to the time of purchase and summed them over the estimated 30-year lifetime of the home, as well as over a 10-year period to represent the cost of ownership over the tenure of the first homebuyer.

[17] The PBP was calculated by dividing the incremental increase in purchase cost by the reduction in average annual operating costs estimated to result from the proposed standards.

value) costs of the proposed standards and alternatives with baseline (no-action) conditions (i.e., a home that meets the energy-efficiency standards in the existing HUD Code).

For the manufacturer impact analysis, DOE estimated the potential financial impact of energy conservation standards on the manufacturers of manufactured homes using the Government Regulatory Impact Model (GRIM). GRIM is an industry cash flow model that estimates changes in industry value as a result of energy conservation standards. GRIM uses industry financial metrics, manufacturer production cost estimates, shipments forecasts, conversion costs, and manufacturer markups in its analysis of changes in industry value. The primary output of the GRIM is the industry net present value (INPV), the sum of industry annual cash flows over the analysis period (2023–2052), discounted using the industry average discount rate. The model accounts for a conversion period and conversion costs, allowing time for manufacturers to bring their manufactured homes into compliance ahead of the standard going into effect (which will be one year after the final rule is published) and make upfront investments to meet the energy conservation standards. Although the analysis for manufacturer impacts was performed in the SNOPR using 2019 data, it is retained in this EIS to estimate potential impacts on manufacturers.[18]

For the national impact analysis, DOE assessed national energy savings (NES) and national net present value (NPV) of total consumer costs and savings associated with the conservation standards. The NES and NPV were calculated based on projected annual shipments, projected annual energy consumption, and total incremental cost data from the LCC analyses.

In the NODA, DOE extended from the SNOPR analyses to account for more recent information from the 2021 Consumer Financial Protection Bureau report, 2021 EIA Annual Energy Outlook, 2020 manufactured housing survey (retail price data), and 2020 data for shipments of manufactured housing and Energy Star housing. These more recent data led to updated results of the LCC, PBP, national impact analysis, and emissions analyses and an updated price threshold for Alternative A.

Furthermore, in response to comments and consultations with HUD, DOE presented sensitivity analyses in the NODA that assessed alternate options for the standards. One proposition considered an alternate tier threshold based on size (single-section versus multi-section homes[19]) and the other considered alternate wall insulation requirements for climate zones 2 and 3 for both the tiered and untiered options.

### 4.4.1 Potential Impacts of Tiered Standards Based on Price (Alternative A)

Alternative A represents the tiered approach for energy conservation standards for manufactured homes based on manufacturer's retail list price. To address affordability concerns and cost-effectiveness considerations with respect to the upfront cost of efficiency improvements, DOE

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[18] DOE did not update the manufacturer impact analysis using the 2020 data in its NODA. Therefore, the manufacturer impact analysis is based on 2019 data that uses a price tier of $55,000 found in the SNOPR (86 FR 47744) and TSD (DOE 2021).

[19] Double-section homes are considered to represent all multi-section homes because they constitute the largest market share by shipments (about 98 percent) of all multi-section homes based on 2020 data.

considered a tiered approach to mitigate first-cost impacts for purchasers at the lower end of the price range relative to the retail price and lifecycle energy cost savings.

Two sets of energy conservation standards would be established under Alternative A. The Tier 1 standard would apply to manufactured homes with a retail price at or below $63,000 (in real 2020 dollars) and would require less stringent energy conservation standards that correspond to an approximate $750 incremental price increase, on average. Tier 2 standards would apply to manufactured homes above the $63,000 retail price threshold. DOE proposes that the price threshold would be adjusted for inflation (for the applicable year of compliance) using the most recently available EIA AEO gross domestic product (GDP) implicit price deflator time series. Both Tier 1 and Tier 2 include single-section or multi-section homes and the analyses consider both sizes under each tier.

In an effort to reduce first-cost impacts for Tier 2 (homes with a retail price above $63,000) within Alternative A, DOE is considering two alternatives that would employ less stringent insulation standards for the exterior wall of homes in climate zones 2 and 3 than those specified in the 2021 IECC. Alternative A1 would apply continuous R-20+5 insulation to the exterior wall of homes in Tier 2, in accordance with IECC 2021. This standard would result in an estimated incremental cost of $2,500. Alternative A2 would use the less-stringent R-21 exterior wall insulation standard for Tier 2 homes in climate zones 2 and 3, which would result in an estimated incremental cost of $850 (or $1,650 less than Alternative A1). The Tier 1 standard would be the same under both Alternatives A1 and A2.

#### 4.4.1.1 Alternative A1: Price Threshold at $63,000 with R-20+5 Insulation

##### *Consumer Impacts*

DOE's LCC analysis for Alternative A1 is illustrated in Table 4.4-1. The results of the analysis show that the purchase price for a single-section manufactured home under the Tier 1 standard is estimated to increase by 1.1 percent, or $660. For single-section manufactured homes, DOE estimated that energy-efficiency measures with an average incremental purchase price of $660 with a 10 percent down payment (using a chattel loan) would, on average, result in a positive cash flow within the first year. This positive impact within the first year could be realized by nearly 90 percent of manufactured homeowner residents (see Figure 3.3-2 in Section 3.3). For the Tier 2 standard, the purchase price for a multi-section manufactured home is estimated to increase by 5.1 percent, or $5,267.

Although the initial price of manufactured homes is expected to increase under Alternative A1, the LCC analysis indicates positive savings over both 10-year and 30-year home lifetime periods in both Tier 1 and Tier 2 standards. For a 10-year period, the average lifecycle cost savings a manufactured homeowner could expect from implementing the energy conservation standards for Tier 1 homes is estimated to be $726 for single-section manufactured home and $1,015 for a multi-section manufactured home. However, for Tier 2 standards, the estimated LCC savings for a 10-year home lifetime was reduced to only $78 for single-section and $235 for multi-section homes. Under the Tier 1 standards, the simple payback periods — that is, the amount of time in years a homeowner could expect to recoup the costs of the housing price increase — were 3.7 years and

3.5 years for single-section and multi-section manufactured homes, respectively. Tier 2 standards are estimated to have national average simple payback periods of 11 and 10.6 years for single-section and multi-section homes, respectively. Table 4.4-1 shows the results of the DOE analysis for the Tier 1 and Tier 2 standards under Alternative A1.

An analysis of the LCC for the five cities studied in this EIS that were assessed in the NODA shows that all five locations are estimated to have positive cost savings under both the Tier 1 and Tier 2 standards, as seen in Table 4.4-2. Of the five cities, Miami would have the lowest lifecycle cost savings while Chicago would have the highest cost savings under the Tier 1 standard. Houston would have the highest cost savings under the Tier 2 standards, while Phoenix would have the lowest.

Chicago is estimated to have the shortest simple payback period under the Tier 1 standards: 3.0 years for a single-section home and 2.1 years for a multi-section home. Miami is estimated to have the longest simple payback period at 7.4 and 6.5 years for a single-section and a multi-section home, respectively. Under the Tier 1 standards, Houston is estimated to have the shortest simple payback period at 8.8 and 8.6 years for a single-section home and a multi-section home, respectively. Phoenix is estimated to have the longest payback period at 14.5 and 12.9 years for a single-section home and a multi-section home, respectively. Results for 14 other cities are available in the NODA (86 FR 59042).

According to 2020 data (Census 2021a), the average sales price of a single-section manufactured home was $57,233, and the average sales price for a multi-section home was $108,853. By 2021, the average sales price of a single-section manufactured home had risen to $70,200, and that for a multi-section home had increased to $128,100 (Census 2021b).

The pandemic has tightened the entire housing market, and increased demand has led to substantially increased housing prices from 2019 to 2021 (Anenberg and Ringo 2021). The increase in the cost of building materials combined with labor shortages have contributed to higher prices for new homes, including manufactured homes (Nicholson et al. 2021). As described in Section 3.4.3, sales prices of manufactured homes have been volatile in recent years. From 2014 to 2019, the sales price of manufactured homes fluctuated between -1 and 13 percent. Prices then jumped 25 percent from 2020 to 2021. (See Section 3.4.3 for additional data on historical housing prices as well as forecasts for manufactured homes and the entire housing market).

**TABLE 4.4-1 Potential Impacts on Consumers under Alternative A1, U.S. Average**

| | Single-Section Home | Multi-Section Home |
|---|---|---|
| **Tier 1 Standard** | | |
| LCC savings, 10-year period | $726 | $1,015 |
| LCC savings, 30-year period | $1,606 | $2,205 |
| Increased purchase price | $660 | $839 |
| Annual energy cost savings | $176 | $238 |
| National average simple payback period | 3.7 | 3.5 |
| **Tier 2 Standard** | | |
| LCC savings, 10-year | $78 | $235 |
| LCC savings, 30-year | $2,045 | $3,023 |
| Increased purchase price | $3,902 | $5,267 |
| Annual energy cost savings | $354 | $496 |
| National average simple payback period | 11.0 | 10.6 |

Source: 86 FR 59042.

**TABLE 4.4-2 Potential Impacts on Consumers Under Alternative A1, by Location**

| Category | Chicago | Houston | Memphis | Miami | Phoenix |
|---|---|---|---|---|---|
| **Lifecycle Cost Savings Analysis (2020 dollars)** | | | | | |
| Tier 1 standards, 30 years | $2,443 single-section<br>$3,738 multi-section | $931 single-section<br>$1,541 multi-section | $1,493 single-section<br>$2,364 multi-section | $460 single-section<br>$850 multi-section | $616 single section<br>$1,026 multi-section |
| Tier 2 standards, 30 years | $2,018 single-section<br>$3,239 multi-section | $2,231 single section<br>$3,747 multi-section | $1,491 single-section<br>$2,743 multi-section | $1,345 single-section<br>$2,336 multi-section | $665 single-section<br>$1,763 multi-section |
| **Simple Payback Period (years)** | | | | | |
| Tier 1 standards | 3.0 single-section<br>2.1 multi-section | 5.1 single-section<br>4.6 multi-section | 3.7 single-section<br>3.5 multi-section | 7.4 single-section<br>6.5 multi-section | 6.5 single-section<br>6.0 multi-section |
| Tier 2 standards | 12.1 single-section<br>11.2 multi-section | 8.8 single-section<br>8.6 multi-section | 12.6 single-section<br>11.4 multi-section | 10.8 single-section<br>10.5 multi-section | 14.5 single-section<br>12.9 multi-section |

Source: 86 FR 59042.

DOE established the $63,000 price threshold based on the 70th percentile price for single-section manufactured home prices in 2020 to give a reasonable upper bound for a manufactured home sales price that a price-sensitive low-income purchaser could afford. DOE proposes that the price threshold would be adjusted for inflation. DOE considered several bases for making this adjustment (Figure 4.4-1) and proposes to use the most recently available EIA AEO GDP deflator. DOE recognizes that retail prices for manufactured homes do not always increase at the same rate as inflation, and other measures are also informative for the price threshold.

Figure 4.4-1 is a comparison of the average price of newly sold manufactured homes from 2014 to 2020 and four inflation indices: the EIA AEO GDP price deflator (which is proposed in the NODA to adjust the tier threshold), the Consumer Price Index, the Product Price Index by Industry: Manufactured Homes (PPI), and the Case-Schiller Housing Price Index. Prices for new manufactured housing have risen at a faster pace than either the Consumer Price Index or the AEO GDP Price Deflator since 2014. The Case-Schiller Housing Price Index may be better able to capture the rising prices of the housing market for multi-section manufactured housing but would be expected to overestimate the rising prices for single-section manufactured homes.

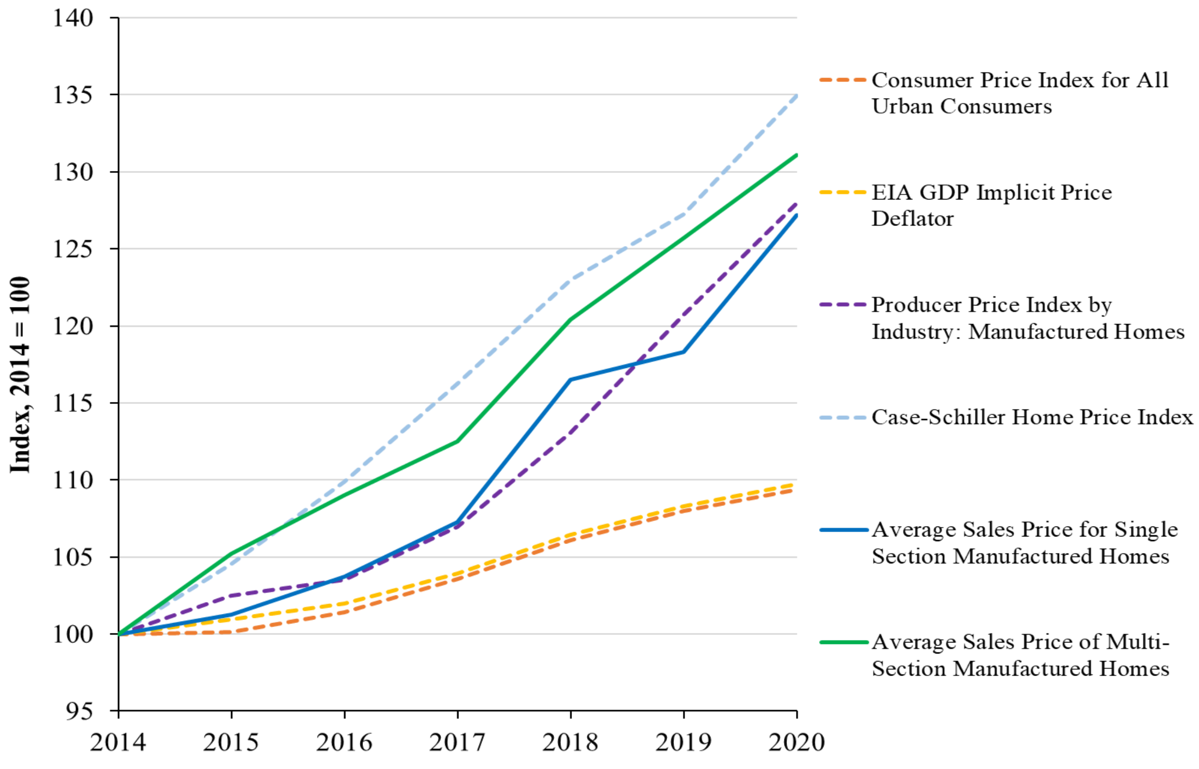

**FIGURE 4.4-1 Average Sales Price for New Houses Sold and Price Indices (Sources: Census 2021a; FRED 2021; EIA 2021c)**

Figure 4.4-2 shows the forecasted average price in real 2020 dollars for manufactured homes and forecasted prices under all the proposed alternatives compared with the $63,000 threshold for Tier 1. The data used for future forecast prices are from the 2015–2020 Manufactured Housing Public Use Files (Census 2021a) and are discounted using the PPI by the manufactured housing industry. From these forecasts, the average price increase of a single-section home, not including increased prices from DOE's proposed energy conservation standards, would already exceed the Tier 1 threshold by more than $5,000 in 2022 before the rule goes into effect. Applying a price threshold as proposed might create complications for both the manufactured housing industry and consumers because it would be more difficult to plan production or purchasing when the threshold would regularly change to a price not yet known.

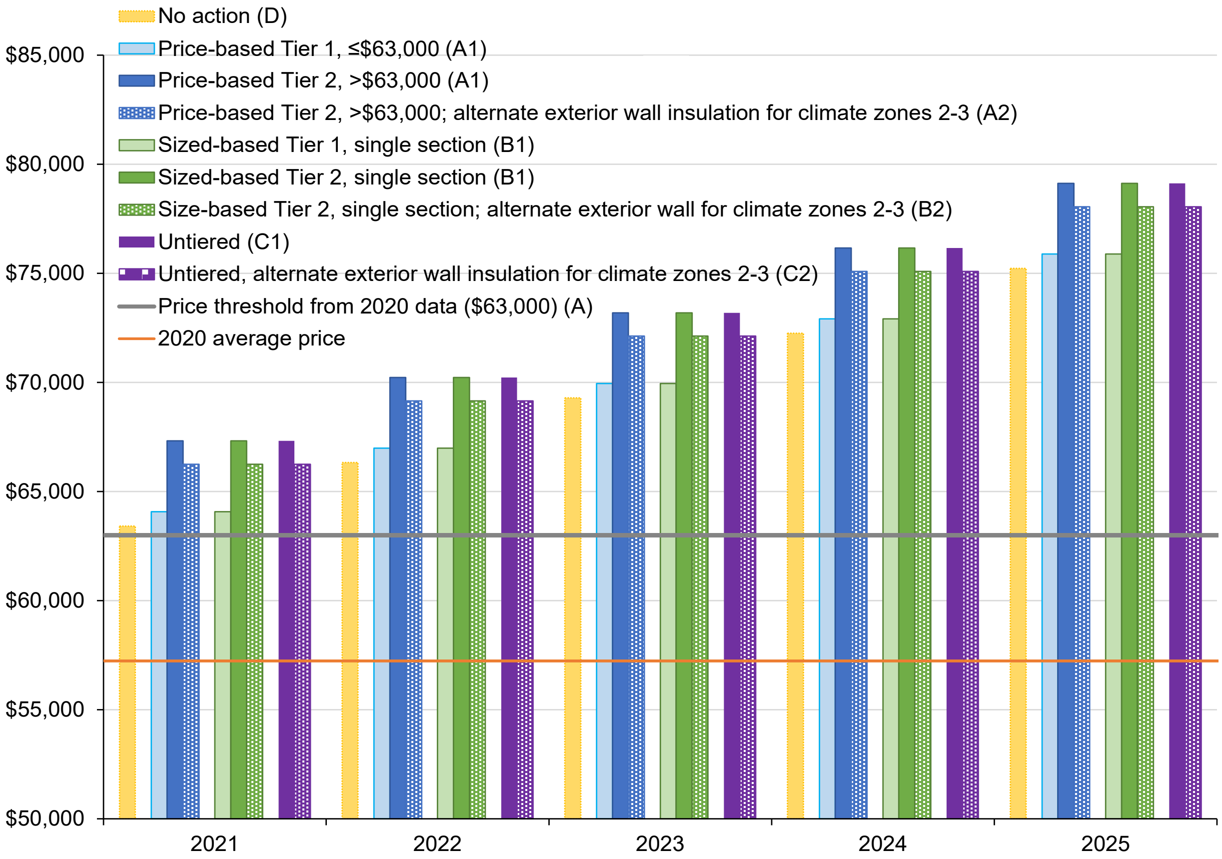

**FIGURE 4.4-2 Forecasted Average Prices for Single-Section Manufactured Housing (Prices are in real 2020 dollars. Source: Census 2021a)**

Section 3.4.2 describes the income and employment characteristics of residents of manufactured homes. The median household income for those living in manufactured homes is less than the median household income for those living in site-built homes. Increases in purchase price could affect the future homebuyers' ability to purchase a new manufactured home depending on their location. For example, the average sales price for manufactured homes in 2020 in the state of Arizona was approximately $40,000 higher than in the state of Tennessee and $60,000 higher than in Alabama. (See Section 3.4.3 for a description of shipments and sales prices per state.) Because prices of manufactured homes can vary widely across locations (e.g., see Figure 3.4-12), the availability of Tier 1 homes could be lower in some locations than others.

Mitigation measures in the form of financial mechanisms could offset the increase in purchase price, making them more affordable for low-income purchasers. As described in Section 4.11, examples of possible mitigation measures include financial incentives for manufacturers (rebates and/or tax credits) or programs that offer financial assistance to future homebuyers to offset incremental first-cost increases.

DOE estimates that the energy conservation standards under this alternative would result in a loss in demand and availability of about 45,562 (1.8 percent) homes over the 30-year analysis period, 2023−2052. As described in Section 3.4, supply chain interruptions and labor shortages due to the pandemic have altered the normal situation on many fronts since the spring of 2020. Impacts on manufactured housing shipments could potentially be greater than DOE estimates if prices continue to increase due to rising building material costs, uncertainty in the manufactured housing market, labor shortages, and other factors not related to the IECC energy conservation standards. A comparison of alternatives in terms of the reduction in shipments for manufactured homes estimated over the 30-year analysis period is presented in Section 4.4.5.

For low-income consumers, Tier 1 establishes energy conservation standards that result in the lowest increase to purchase price and the fastest payback rate, while creating positive lifecycle energy cost savings. However, because retail prices for manufactured homes vary by location, the availability of Tier 1 homes for low-income consumers under a price threshold might differ by location. In addition, manufactured homes under the Tier 1 threshold of Alternative A2 would have less stringent energy conservation standards than Tier 2, and Tier 1 homeowners would not benefit from the full LCC savings available under Tier 2.

#### *Manufacturer Impacts*

The DOE modeled two standard manufacturer markup scenarios (a high case and a low case) that reflect changes in the manufacturer's ability to pass on its upfront investments and increases in production costs to the consumer: (1) preservation of gross margin percentage markup scenario and (2) preservation of operating profit markup scenario. These manufacturer markup scenarios characterize the uncertainty regarding prices and profitability for manufactured home manufacturers following the implementation of the rule.

Under the preservation of gross margin scenario, manufacturers maintain their current average markup even as production costs increase. Manufacturers are able to maintain the same amount of profit as a percentage of revenues, suggesting that they can recover conversion costs and pass the costs of compliance to their consumers. DOE considers this scenario the upper bound to industry profitability. Under the preservation of operating profit markup scenario, as the costs of production increase, manufacturers are required to reduce their markups and manufacturers are not able to recover the conversion-period investments made to comply with the standard. DOE considers this scenario the lower bound to industry profitability.

The INPV estimates the economic impacts on the industry from the energy conservation standards under Alternative A (as shown in Table 4.4-3).[20] DOE's estimated impacts from Alternative A vary widely and could result in a change of industry value ranging from -\$0.07 billion to \$0.10 billion for single-section units. For multi-section units, the impact of Alternative A is estimated to result in a change of industry value ranging from -\$0.20 billion to \$0.22 billion. For

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[20] DOE's industry net present value (INPV) analysis uses EIA's AEO 2020 data for shipment forecasts and reflects a 0.3 percent growth per year.

the entire industry, the impact of Alternative A could result in a change in INPV of -$0.28 billion to $0.32 billion. Industry conversion costs are estimated to total $0.0018 billion, or $52,000 per manufacturer, including product conversion costs and capital conversion costs for investments in equipment. DOE estimates the conversion costs to be less than 0.1 percent of the average small manufacturer's annual revenue.

**TABLE 4.4-3 Industry Net Present Value Results Under Alternative A1**

| | **Preservation of Gross Margin Percentage Scenario** | | **Preservation of Operating Profit Markup Scenario** | |
|---|---|---|---|---|
| | **Single-Section Home** | **Multi-Section Home** | **Single-Section Home** | **Multi-Section Home** |
| No-Action alternative INPV (billion, 2020 dollars) | 4.87 | 11.36 | 4.87 | 11.36 |
| Alternative A1 INPV (billion, 2020 dollars) | 4.98 | 11.58 | 4.80 | 11.16 |
| Change in INPV (billion, 2020 dollars) | 0.10 | 0.22 | -0.07 | -0.20 |
| Change in INPV (percent) | 2.1 | 1.9 | -1.5 | -1.8 |
| Total conversion costs (billion, 2020 dollars) | 0.0005 | 0.0012 | 0.0005 | 0.0012 |

Source: 86 FR 59042.

Under the preservation of a gross margin markup scenario, Alternative A has positive impacts compared with the no-action alternative (Alternative D) but fewer positive impacts on manufacturers than Alternative C. In comparison, under the preservation of a operating profit markup scenario, Alternative A has negative impacts compared with the no-action alternative but fewer negative impacts than Alternative C.

### *National Impacts*

DOE analyzed the net present value of consumer benefits for manufactured homes purchased in 2023–2052 with an assumed 30-year home lifetime. Under this analysis, the net present value of consumer benefits is estimated be $1.73 billion for single-section manufactured homes and $2.47 billion for multi-section homes under a tiered standard, assuming a 3 percent discount rate. Assuming a 7 percent discount rate, the net present value of consumer benefits under the tiered standard is estimated to be $0.56 billion for single-section manufactured homes and $0.48 billion for multi-section homes. Figure 4.4-3 presents these results[21].

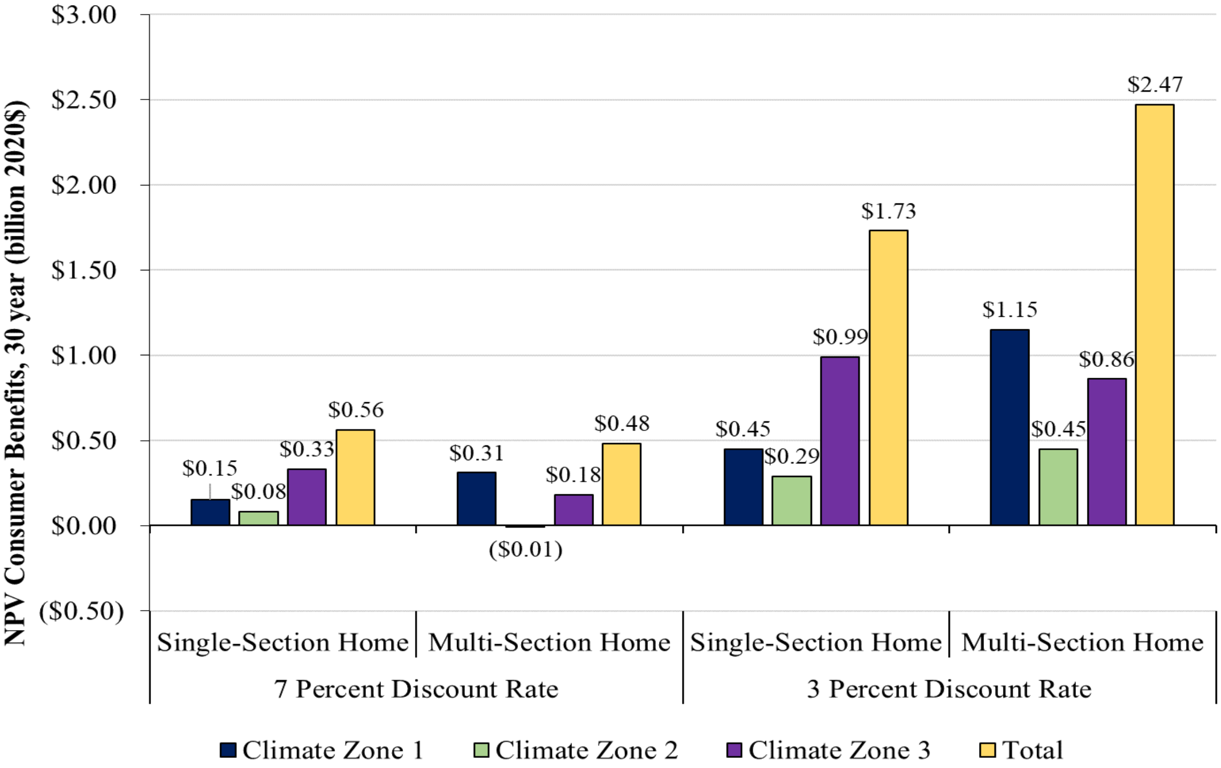

**FIGURE 4.4-3 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative A (Source: DOE 2021)**

#### 4.4.1.2 Alternative A2: Price Threshold at $63,000 with R-21 Insulation

##### *Consumer Impacts*

The LCC savings (10-year and 30-year periods) and the increased purchase price, increased annual energy savings, and simple payback period are estimated to be the same for Tier 1 under Alternative A2 as they are under Alternative A1. This is because the exterior wall insulation option only applies to the Tier 2 standard. Results from the LCC analysis suggest that the average increased purchase price for manufactured homes under the Tier 2 standard are estimated to result in increases of 5.3 and 4.1 percent for single-section and multi-section homes, respectively (Table

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[21] As discussed in Section 2.5.3, DOE is not analyzing in detail alternatives based on sales or purchase price or a location-based standard. The retail list price is more appropriate than basing the tiers on the sales or purchase price, which may not be known until after a manufactured home leaves the manufacturer. And a location-based standard would be impractical to establish at the state level, thus requiring manufacturers to comply with up to 50 different standards. State-level sales price data are presented in this section to support the detailed consideration of potential impacts associated with the four Alternatives (A-D).

4.4-4). The 30-year LCC savings under this alternative were higher than Alternative A1, but the annual energy cost savings were lower. Although the initial price of manufactured homes is expected to increase under this alternative, the LCC analysis indicates positive savings over both the 10-year and 30-year periods for both single-section and multi-section homes. Simple payback periods, the time when the homeowners could expect to recoup the costs of the housing price increase, are estimated to be 8.5 and 8.9 years for single-section and multi-section homes, respectively.

**TABLE 4.4-4 National Average Per-Home Cost Savings Under Alternative A2**

| | Single-Section Home | Multi-Section Home |
|---|---|---|
| **Tier 1 Standard** | | |
| LCC savings, 10-year period | $726 | $1,015 |
| LCC savings, 30-year period | $1,606 | $2,205 |
| Increased purchase price | $660 | $839 |
| Annual energy cost savings | $176 | $238 |
| National average simple payback period | 3.7 | 3.5 |
| **Tier 2 Standard** | | |
| LCC savings, 10-year period | $632 | $788 |
| LCC savings, 30-year period | $2,740 | $3,727 |
| Increased purchase price | $2,830 | $4,222 |
| Annual energy cost savings | $331 | $475 |
| National average simple payback period | 8.5 | 8.9 |

Source: 86 FR 59042.

DOE estimates that the energy conservation standards under Alternative A2 would result in a decrease in shipments of about 36,648 homes, a 1.5 percent decrease over the 30-year period 2023− 2052. (See Alternative A1 for potential implications of the current housing situation on future shipments.) A comparison of alternatives in terms of the reduction in shipments for manufactured homes over the 30-year analysis period is presented in Section 4.4.5.

### *Manufacturer Impacts*

DOE did not analyze manufacturer impacts for the use of R-21 insulation on the exterior walls of manufactured homes in climate zones 2 and 3. However, it is expected that these impacts would be similar to those estimated for Alternative A1 (see Section 4.4.1.2).

### *National Impacts*

DOE analyzed the net present value of consumer benefits for manufactured homes purchased during 2023–2052 with a 30-year home lifetime. Under this analysis, using a 3 percent discount rate, the net present value of consumer benefits is estimated to be $1.9 billion for single-section manufactured homes and $3.2 billion for multi-section homes under a price-based tiered standard with R-21 exterior wall insulation, assuming in climate zones 2 and 3. Using a 7 percent discount rate, the net present value of benefits is estimated to be $0.65 and $0.85 billion for single-section and multi-section homes, respectively. Figure 4.4-4 presents these results.

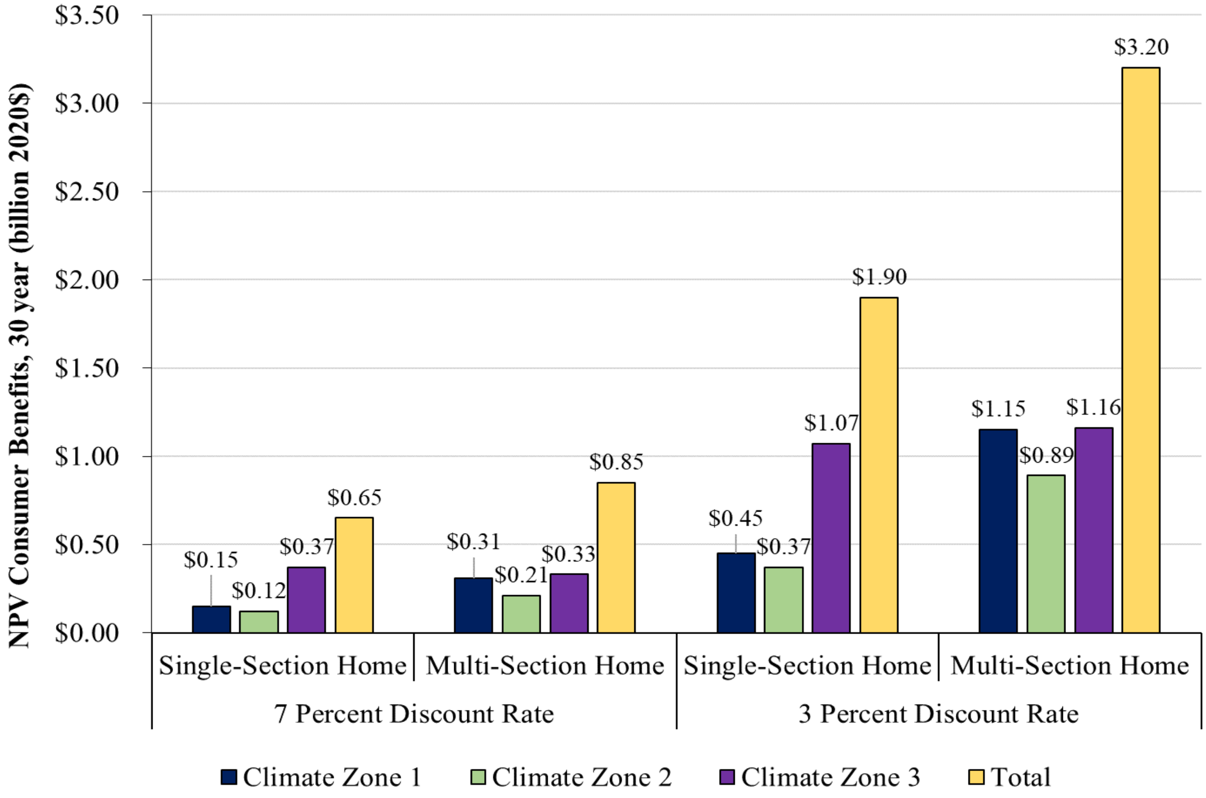

**FIGURE 4.4-4 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative A2 (Source: DOE 2021)**

### 4.4.2 Potential Socioeconomic Impacts of Tiered Standards Based on Size (Alternative B)

Alternative B considers the tiered standards for energy conservation based on size. DOE is considering the tiered approach to mitigate first-cost impacts for low-income purchasers to address affordability concerns and cost-effectiveness considerations with respect to the upfront cost of efficiency improvements relative to the retail price and lifecycle energy cost savings.

Two sets of energy conservation standards would be established under the tiered approach based on the size of the manufactured housing. Tier 1 standards would apply to all single-section manufactured homes and would require less stringent energy conservation standards, with the average approximate incremental price increase at $750. Tier 2 standards would apply to all multi-section manufactured homes. The Tier 1 threshold was established based on the assumption that price-sensitive, low-income purchasers would purchase single-section manufactured homes rather than multi-section homes.

In an effort to reduce first-cost impacts for Tier 2, DOE is also considering an alternative that would require less stringent insulation standards for multi-section homes. Under Alternative B1, manufactured homes would have continuous R-20+5 insulation on exterior walls consistent with the 2021 IECC specifications, which corresponds to an approximate incremental cost of $2,830 cost for Tier 2. Under Alternative B2, homes would use the less stringent R-21 insulation on the exterior walls in climate zones 2 and 3. The approximate incremental cost would be lower than in Alternative B1, at an estimated $850 compared with $2,830. Tier 1 standards would be the same under Alternatives B1and B2.

#### 4.4.2.1 Alternative B1: Size Threshold with R-20+5 Insulation

##### *Consumer Impacts*

The impacts on individual consumers (LCC savings, purchase price, energy cost savings, and simple payback period) for Tier 1 single-section and Tier 2 multi-section homes under this alternative are the same as the impacts for Tier 1 single-section and Tier 2 multi-section homes under Alternative A. This is due to the LCC and PBP analysis evaluating economic impacts on individual consumers of energy conservation, and not the entire nation. The energy conservation standards are the same under each alternative for each tiered threshold.

DOE's LCC analysis for Alternative B1 indicated that the purchase price for a single-section manufactured home under the Tier 1 standard would increase by an estimated 1.1 percent, or $660 (Table 4.4 5). For the Tier 2 standard, the purchase price for a multi-section manufactured home is estimated to increase 5.1 percent, or $5,267. Although the initial price of the manufactured home is expected to increase under this alternative, the LCC analysis indicates positive savings over both the 10-year and 30-year periods for both the Tier 1 and Tier 2 standards.

Simple payback periods, the time when the homeowner could expect to recoup the cost of the increased purchase price, are estimated to be 3.7 and 10.6 years under the Tier 1 and Tier 2 standards, respectively. The LCC analysis results differ among the five locations illustrated in this EIS, although all six would have positive cost savings under both the Tier 1 and Tier 2 standards (see Table 4.4-6). The energy cost savings estimated for Miami are the lowest, while those estimated for Chicago are the highest under the Tier 1 standard, with LCC savings of $460 and $2,443, respectively. Houston is estimated to have the highest savings under the Tier 2 standard, while Phoenix would have the lowest at $3,747 and $1,763, respectively. Results for 14 other cities are available in the NODA.

DOE estimates that the standards outlined under Alternative B1 would result in a decrease in shipments of about 38,288 homes, 1.5 percent over the 30-year analysis period, 2023–2052. (See Alternative A1 for potential implications of the current housing situation on future shipments.) A comparison of alternatives in terms of the reduction in shipments for manufactured homes over the 30-year analysis period is presented in Section 4.4.5.

**TABLE 4.4-5 Potential Impacts on Consumers Under Alternative B1, U.S. Average**

| | |
|---|---|
| **Tier 1 Standard: Single-Section Home** | |
| LCC savings, 10-year period | $726 |
| LCC savings, 30-year period | $1,606 |
| Increased purchase price | $660 |
| Annual energy cost savings | $176 |
| National average simple payback period | 3.7 |
| **Tier 2 Standard: Multi-Section Home** | |
| LCC savings, 10-year period | $235 |
| LCC savings, 30-year period | $3,023 |
| Increased purchase price | $5,267 |
| Annual energy cost savings | $496 |
| National average simple payback period | 10.6 |

Source: 86 FR 59042.

**TABLE 4.4-6 Potential Impacts on Consumers Under Alternative B1, by Location**

| Category | Chicago | Houston | Memphis | Miami | Phoenix |
|---|---|---|---|---|---|
| **Lifecycle Cost Analysis** (2020 dollars) | | | | | |
| Tier 1 standard, 30 year | $2,443 | $931 | $1,493 | $460 | $616 |
| Tier 2 standard, 30 year | $3,239 | $3,747 | $2,743 | $2,336 | $1,763 |
| **Simple Payback Period** (years) | | | | | |
| Tier 1 standard | 3.0 | 5.1 | 3.7 | 7.4 | 6.5 |
| Tier 2 standard | 11.2 | 8.6 | 11.4 | 10.5 | 12.9 |

Source: 86 FR 59042.

Sales prices of manufactured homes have been volatile in recent years. However, unlike Alternative A, Alternative B is based on home size rather than price. Under Alternative B, the standards would be uniformly applied depending on whether the homes are single-section or multi-section manufactured homes.

In 2020, 44 percent of manufactured homes were single-section homes. As the prices for multi-section homes increase, some consumers might choose to purchase a more affordable single-section home with less stringent energy conservation standards, which might result in an increase in single-section home purchases. Section 3.4.2 describes the income and employment characteristics of residents of manufactured homes. The median income of households living in manufactured homes is less than that of households living in site-built homes. Increases in purchase price could affect the future homebuyers' ability to purchase a new manufacture home. The potential impact of the increase in purchase price for manufactured homes would have an additive (cumulative) impact if prices continue to increase at a substantial rate for reasons apart from any new energy conservation standards. (On an absolute versus relative basis, the Tier 1 price increase might be within the range of the market volatility.)

It is possible that mitigation measures in the form of financial mechanisms could offset the increase in purchase price, making the homes more affordable for low-income purchasers (see Section 4.11). For the low-income consumers, the Tier 1 threshold would establish energy conservation standards that result in the smallest increase in purchase price and the fastest simple payback period while creating positive lifecycle energy cost savings. However, because the homes under the Tier 1 threshold would have less stringent energy conservation standards than Tier 2 homes, homeowners would not benefit from the full LCC savings available under Tier 2.

#### *Manufacturer Impacts*

DOE did not analyze manufacturer impacts for the use of R-21 insulation on the exterior wall of manufactured homes in climate zones 2 and 3. However, it is expected that these impacts would be similar to those estimated for Alternative A1 (see Section 4.4.1.2).

#### *National Impacts*

DOE analyzed the net present value of consumer benefits for manufactured homes purchased in 2023–2052 with a 30-year lifetime. Under this analysis, the net present values of consumer benefits is estimated to be \$0.68 billion and \$0.84 billion with a 7 percent discount rate, and \$1.85 billion and \$3.22 billion with a 3 percent discount rate, respectively. Figure 4.4-5 presents these results.

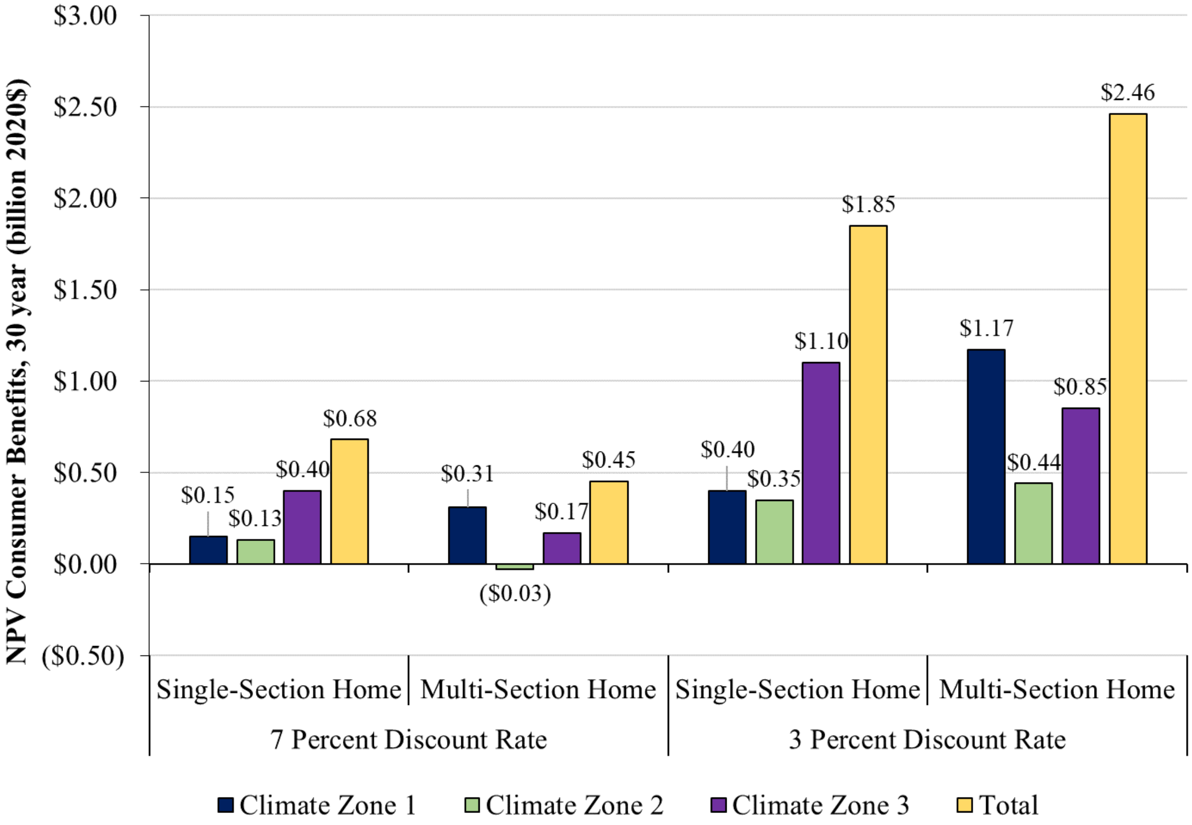

**FIGURE 4.4-5 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative B1 (Source: DOE 2021)**

### 4.4.2.2 Alternative B2: Size Threshold with R-21 Insulation

#### *Consumer Impacts*

Because the exterior wall insulation option only applies to the Tier 2 standard, the impacts on individual consumers (LCC savings, purchase price, energy cost savings, and simple payback period) for Tier 1 single-section homes are the same as the impacts for Tier 1 single-section under Alternatives A1 and B1. The impacts on individual consumers for Tier 2 multi-section homes are the same under this alternative as impacts under Alternative A2. The energy conservation standards are the same under each alternative for each tiered threshold.

Results from the LCC analysis suggest a $660 increase in purchase price for single-section manufactured homes under the Tier 1 standard, which represents a 1.1 percent increase in purchase price (see Table 4.4-7). For the Tier 2 standard, the purchase price for multi-section manufactured homes is estimated to increase $4,222, in which represents a 4.1 percent increase.

**TABLE 4.4-7 Potential Impacts on Consumers under Alternative B2, U.S. Average**

| Tier 1 Standard (Single-Section Home) | |
|---|---|
| Lifecycle cost savings, 10-year period | $726 |
| Lifecycle cost savings, 30-year period | $1,606 |
| Increased purchase price | $660 |
| Annual energy cost savings | $176 |
| National average simple payback period | 3.7 |
| **Tier 2 Standard (Multi-Section Home)** | |
| Lifecycle cost savings, 10-year period | $788 |
| Lifecycle cost savings, 30-year period | $3,727 |
| Increased purchase price | $4,222 |
| Annual energy cost savings | $475 |
| National average simple payback period | 8.9 |

Source: 86 FR 59042.

Although the initial price of the manufactured home is expected to increase under Alternative B2, the LCC analysis indicates positive savings over both the 10-year and 30-year periods for both Tier 1 and Tier 2. Simple payback periods, the time when homeowners could expect to recoup the costs of the housing price increase, are estimated to be 3.7 and 8.9 years, respectively, under both Tier 1 and Tier 2.

DOE estimates that Alternative B2 would result in a decrease of shipments of about 31,956 homes (1.3 percent) over the 30-year analysis period, 2023–2052. (See Alternative A1 for potential implications of the current housing situation on future shipments.) A comparison of alternatives in terms of the reduction in shipments for manufactured homes over the 30-year analysis period is presented in Section 4.4.5.

#### *Manufacturer Impacts*

DOE did not analyze manufacturer impacts for the use of R-21 insulation on the exterior walls of manufactured homes in climate zones 2 and 3. However, it is expected that these impacts would be similar to those estimated for Alternative A1 (see Section 4.4.1.2).

#### *National Impacts*

Figure 4.4-6 shows the total NPV of consumer benefits for manufactured homes with a 30-year lifetime under Alternative B2, with the size-based tier threshold and R-21 exterior wall insulation in climate zones 2 and 3. The total net present value of benefits for single- and multi-section homes are estimated to be $0.68 billion and $0.84 billion with a 7 percent discount rate, and $1.85 billion and $3.22 billion with a 3 percent discount rate, respectively. The NPV of consumer benefits are similar to those for Alternative A2.

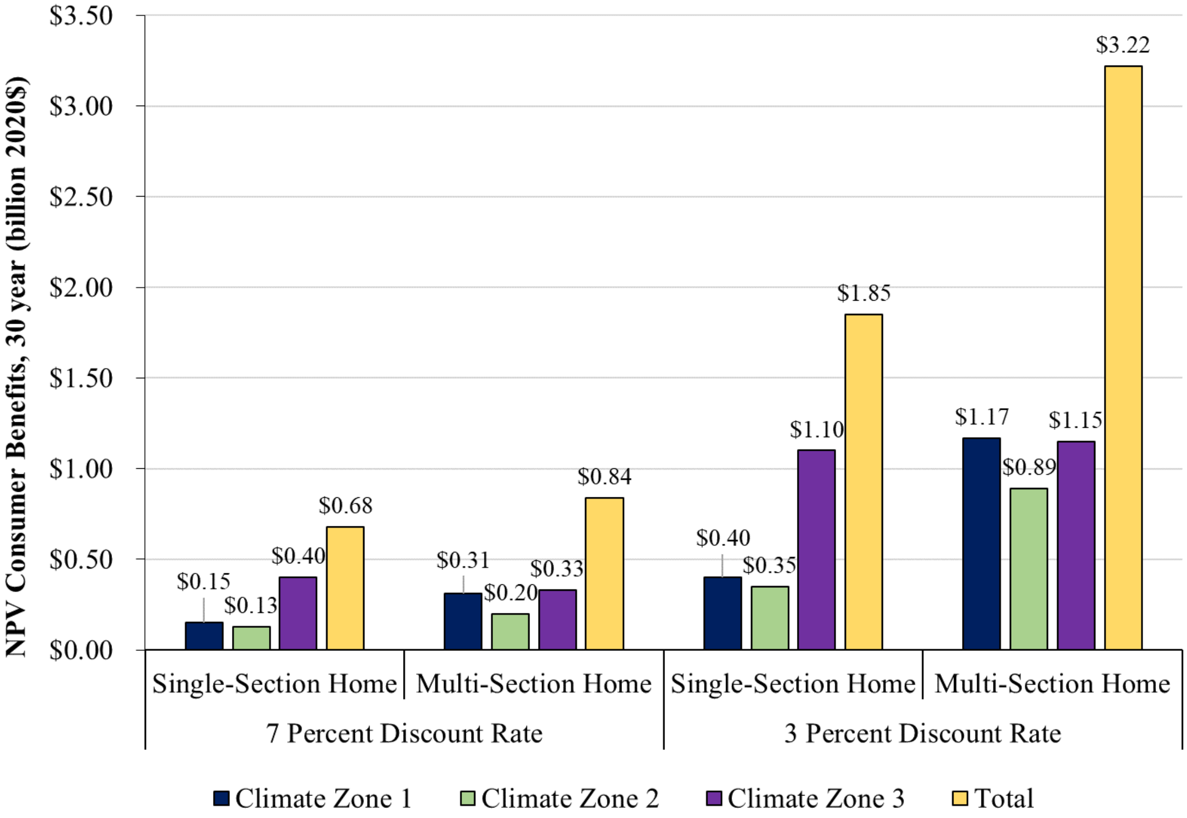

**FIGURE 4.4-6 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative B2 (Source: DOE 2021)**

### 4.4.3 Potential Socioeconomic Impacts of Untiered Standards (Alternative C)

In the NODA, DOE proposed an untiered approach for energy conservation standards for manufactured homes, referred to as Alternative C in this EIS. Under Alternative C, all manufactured homes (single-section and multi-section) would align with the energy conservation standard elements reflected in the DOE rule. The untiered proposal would be the same as the Tier 2 standard in Alternatives A and B because they share the same energy efficiency requirements.

In an effort to reduce first-cost impacts, DOE is considering an alternative that would employ less stringent insulation standards. Alternative C1 uses continuous R-20+5 insulation, which has an approximate incremental cost of $2,830, while Alternative C2 uses the less stringent R-21 exterior wall insulation standard in climate zones 2 and 3, which would result in an approximate incremental cost of $850.

#### 4.4.3.1 Alternative C1: Untiered Standards with R-20+5 Insulation

***Consumer Impacts***

DOE's LCC analysis for Alternative C1 estimated that the purchase price for a single-section manufactured home would increase by 7.3 percent, or $3,902 (see Table 4.4-8). The purchase price of a multi-section manufactured home was estimated to increase by 5.1 percent, or $5,267. Although the initial sales price of the manufactured home is expected to increase under Alternative C1, the LCC analysis indicates a positive savings over the 10-year period for multi-section homes and a positive savings over the 30-year period for both single-section and multi-section homes. There would not be LCC savings for single-section homes in the 10-year LCC analysis period.

**TABLE 4.4-8 Potential Impacts on Consumers Under Alternative C1, U.S. Average**

| | Single-Section Home | Multi-Section Home |
|---|---|---|
| LCC savings, 10-year period | ($57) | $50 |
| LCC savings, 30-year period | $1,733 | $2,585 |
| Increased purchase price | $3,902 | $5,267 |
| Annual energy cost savings | $354 | $496 |
| National average simple payback | 11.0 years | 10.6 years |

Source: 86 FR 59042.

The estimated simple payback periods, the time when homeowners could expect to recoup the costs of the housing price increase, is estimated to be similar for both single-section and multi-section homes (11 and 10.6 years). The lifecycle analysis results differ among the five locations evaluated in this EIS; of these five, Houston has the highest LCC savings (see Table 4.4-9). Results for 14 other cities are available in the NODA.

DOE estimates that the untiered energy conservation standards for manufactured homes would result in a decrease in shipments of about 70,203 homes (2.8 percent) over the 30-year analysis period, 2023–2052. (See Alternative A1 for potential implications of the current housing situation on future shipments.) DOE expects shipments to decrease by 24,641 more under Alternative C1 than Alternative A1. A comparison of alternatives in terms of the reduction in shipments for manufactured homes over the 30-year analysis period is presented in Section 4.4.5.

Section 3.4.2 describes the income and employment characteristics of residents of manufactured homes. Median household income for those living in manufactured homes is less than median household income of those living in site-built homes. Increases in purchase prices could affect the future homebuyers' ability to purchase a new manufacture home.

**TABLE 4.4-9 Potential Impacts on Consumers Under Alternative C1, by Location**

| Chicago | Houston | Memphis | Miami | Phoenix |
|---|---|---|---|---|
| | | **Lifecycle Cost Savings Analysis (2020 dollars)** | | |
| $1,667 single-section home | $1,971 single-section home | $1,176 single-section home | $1,142 single-section home | $403 single-section home |
| $2,751 multi-section home | $3,318 multi-section home | $2,286 multi-section home | $1,998 multi-section home | $1,368 multi-section home |
| | | **Simple Payback Period (years)** | | |
| 12.1 single-section | 8.8 single-section home | 12.6 single-section home | 10.8 single-section home | 14.5 single-section home |
| 11.2 multi-section | 8.6 multi-section home | 11.4 multi-section home | 10.5 multi-section home | 12.9 multi-section home |

Source: 86 FR 59042.

Alternative C1 would have larger adverse first-cost impacts on low-income consumers than Alternative A. Low-income consumers would likely purchase a single-section home, and a 7 percent increase in the price of a single-section home might price some consumers out of the market for a new manufactured home under the proposed alternative.

The simple payback period for single-section homes is also longer for Alternative C1 than for Alternative A1, so although there are positive LCC savings, they would not be recouped until after more than a third of the life of the home. Price increases under this alternative are higher than all other alternatives considered in this EIS. However, because all manufactured homes under this alternative would adhere to the same stricter requirements for energy conservation standards, all homeowners would benefit from the full LCC savings. It is possible that mitigation measures in the form of financial mechanisms could offset the increase in purchase price, making manufactured homes more affordable for low-income purchasers (see Section 4.11).

### *Manufacturer Impacts*

The DOE approach for estimating manufacturer impacts is presented in Section 4.4.2.1. Like for Alternative A1, DOE considers the preservation of gross margin scenario the upper bound to industry profitability, and the preservation of operating profit markup scenario the lower bound to industry profitability.

Table 4.4-10 shows the INPV estimates the economic impacts on the industry from the standards under Alternative C1[22]. For single-section units, the impact of Alternative C1 is estimated to result in a change of industry value ranging from -2.7 percent to 3.0 percent, or a change of -$0.13 billion to $0.15 billion. For multi-section manufactured homes, the impact of Alternative C1 is estimated to result in a change of industry value ranging from -1.8 percent to 2.2 percent, or a change of -$0.21 billion to $0.25 billion. For the entire industry, the impact of Alternative C1 is estimated to result in a change in INPV of -2.1 percent to 2.4 percent, or a change of -$0.34 billion to $0.39 billion. Industry conversion costs are estimated to total $0.0018 billion.

Alternative C1 has positive impacts compared with the no-action alternative under the preservation of gross margin markup scenario and has higher positive impacts on manufacturers than Alternative A. However, under the preservation of operating profit markup scenario, Alternative C1 has negative impacts compared with the no-action alternative and higher negative impacts than Alternative A.

**TABLE 4.4-10 Industry Net Present Value Results Under Tiered Standards Based on Size (Alternative C1)**

| | **Preservation of Gross Margin Percentage Markup Scenario** | | **Preservation of Operating Profit Markup Scenario** | |
|---|---|---|---|---|
| | **Single-Section Home** | **Multi-Section Home** | **Single-Section Home** | **Multi-Section Home** |
| No-action alternative INPV (billion 2020$) | 4.87 | 11.36 | 4.87 | 11.36 |
| Alternative C1 INPV (billion 2020$) | 5.02 | 11.61 | 4.74 | 11.15 |
| Change in INPV (billion 2020$) | 0.15 | 0.25 | -0.13 | -0.21 |
| Change in INPV (percent) | 3.0 | 2.2 | -2.7 | -1.8 |
| Total conversion costs (billion 2020$) | 0.0005 | 0.0012 | 0.0005 | 0.0012 |

Source: 86 FR 59042.

### *National Impacts*

DOE analyzed the net present value of consumer benefits for manufactured homes purchased 2023–2052 with a 30-year lifetime, as shown in Figure 4.4-7. Under this analysis, the net present value of consumer benefits would be $1.28 billion for single-section manufactured homes and $2.23 billion for multi-section homes, assuming a 3 percent discount. The net present value of consumer benefits assuming a 7 percent discount rate would be $0.21 billion and $0.42 billion for single-section and multi-section homes, respectively.

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[22] INPV used AEO 2020 data for shipment forecasts and reflects a 0.3 percent growth per year.

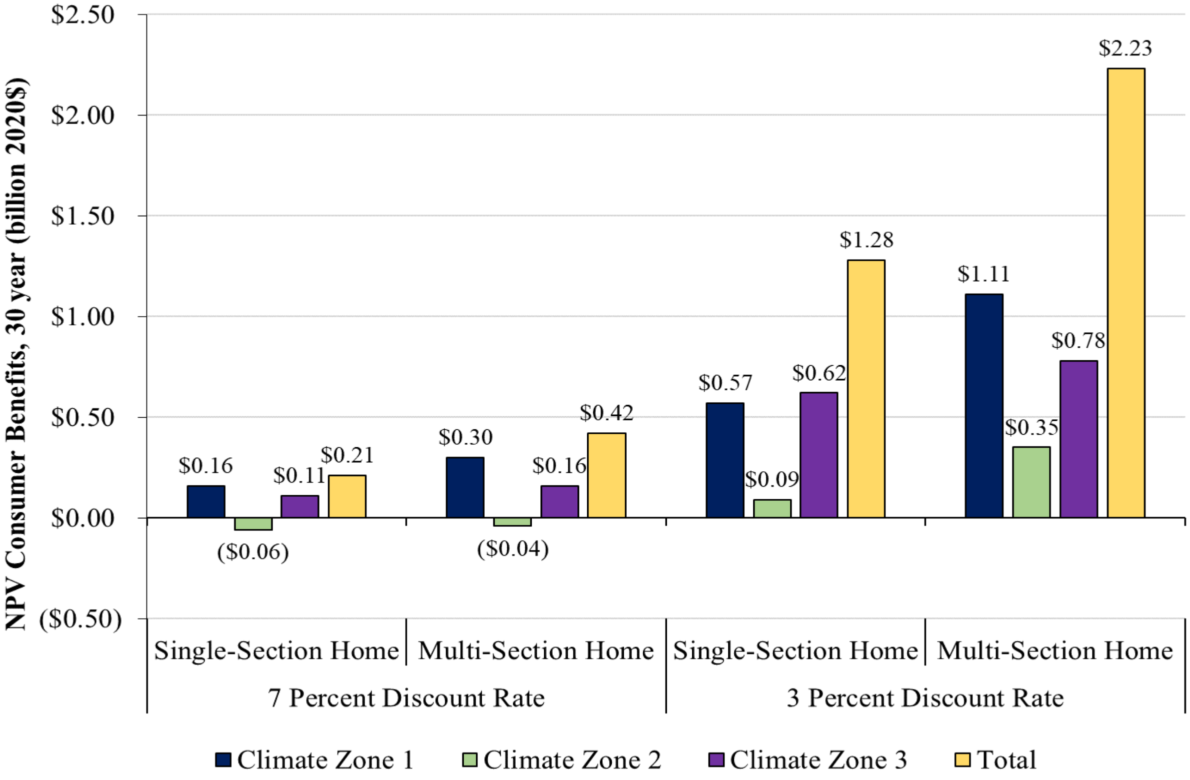

**FIGURE 4.4-7 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative C1 (Source: DOE 2021)**

#### 4.4.3.2 Alternative C2: Untiered Standards with R-21 Insulation

***Consumer Impacts***

The increased purchase price and simple payback period are the same for Alternatives C2 and A2. Results from the LCC analysis suggest that the average increase in manufactured housing purchase price would be 5.3 and 4.1 percent increases in purchase price for single-section and multi-section homes, respectively (Table 4.4-11). These results are lower than the price increases under Alternative C1. The 30-year LCC savings and the annual energy cost savings under the sensitivity analysis were also higher than for Alternative C1. LCC savings over a 30-year lifetime for a single-section and multi-section homes were $2,432 and $3,291, respectively. The simple payback period would be 8.5 years for single-section homes and 8.9 years for multi-section homes, which also lower than the baseline simple payback period under Alternative C1 (Table 4.4-11).

**TABLE 4.4-11 National Average Per-Home Cost Savings Under the Alternative C2**

| Untiered Standard | Single-Section | Multi-Section |
|---|---|---|
| Lifecycle cost savings, 10-year period | $518 | $622 |
| Lifecycle cost savings, 30-year period | $2,432 | $3,291 |
| Purchase price | $2,830 | $4,222 |
| Annual energy cost savings, in 2020$ | $331 | $475 |
| National average simple payback | 8.5 | 8.9 |

Source: 86 FR 59042.

DOE estimates the energy conservation standards under Alternative C2 would result in a decrease in shipments of about 53,185 homes (2.1 percent) over the 30-year analysis period, 2023–2052. DOE expects shipments to decrease by 16,537 more under this alternative than in Alternative A2. (See Alternative A1 for potential implications of the current housing situation on future shipments.) A comparison of alternatives in terms of the reduction in shipments for manufactured homes over the 30-year analysis period is presented in Section 4.4.5.

This alternative would have larger impacts on low-income consumers than Alternative A2, but less than Alternative C1. Low-income consumers would likely purchase a single-section home, and a 5.3 percent increase in price for a single-section home might price some consumers out of the market for a new manufactured home under the proposed alternative. The simple payback period for single-section homes is estimated to be 8.5 years, so it is assumed that the homeowner would recoup positive LCC savings in the first 10 years. Because all manufactured homes under this alternative would adhere to the IECC requirements for energy conservation standards, all homeowners would benefit from the full LCC savings.

#### *Manufacturer Impacts*

DOE did not analyze manufacturer impacts for the use of R-21 insulation on the exterior walls of manufactured homes in climate zones 2 and 3. However, it is expected that these impacts would be similar to those estimated for Alternative C1 (see Section 4.4.3.1).

#### *National Impacts*

DOE analyzed the net present value of consumer benefits for manufactured homes purchased during 2023–2052 with a 30-year home lifetime. Under this analysis, the net present value of consumer benefits using a 3 percent discount rate would be $1.96 billion for single-section manufactured homes and $3.03 billion for multi-section homes. Using a 7 percent discount rate, the net present value of benefits would be $0.6 and $0.82 for single-section and multi-section homes, respectively. Figure 4.4-8 shows the results of the NPV analysis for Alternative C2.

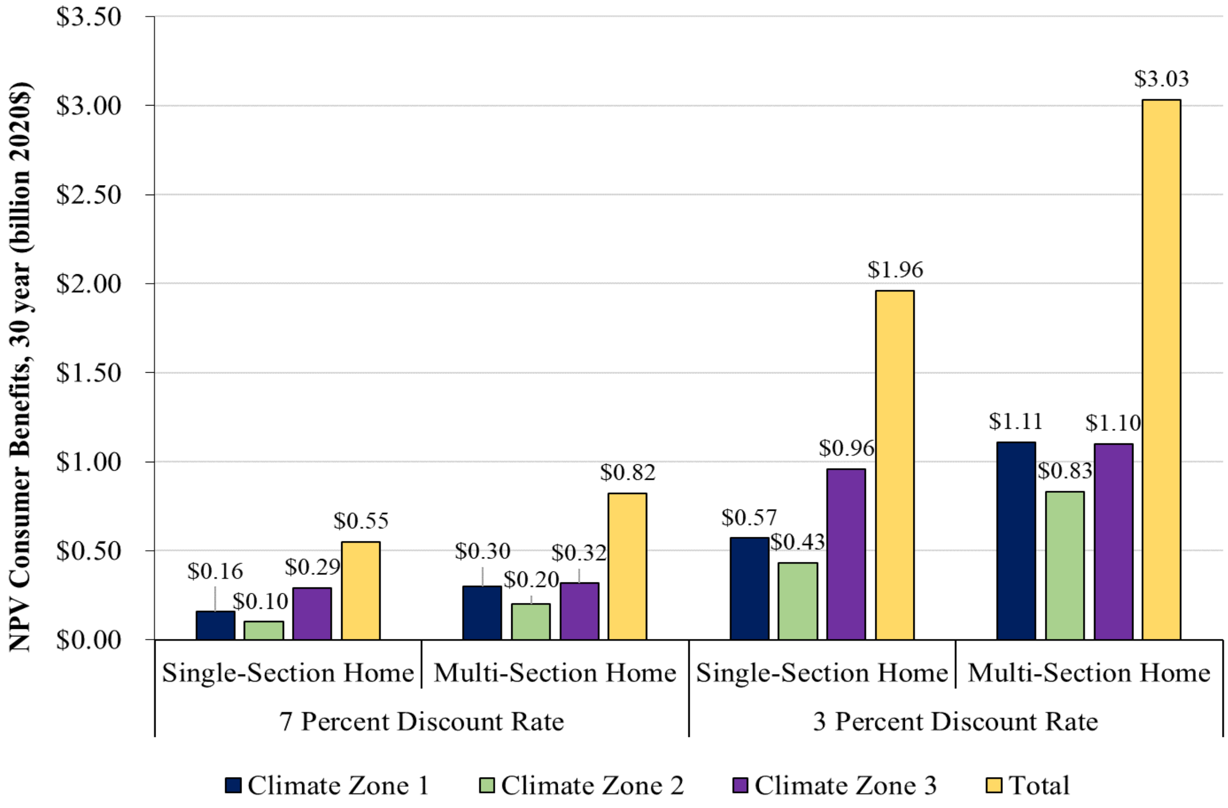

**FIGURE 4.4-8 Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime Under Alternative C2 (Source: DOE 2021)**

### 4.4.4 Potential Socioeconomics Impacts of No-Action (Alternative D)

Under the no-action alternative (Alternative D), DOE would not establish energy conservation standards for manufactured housing, and there would be no change from the existing HUD Code.

For this alternative, there would be no increase in energy savings for consumers due to increased energy efficiency. Similarly, there would be no benefits from GHG emission reductions, as described in the NODA. The purchase price for manufactured homes would not increase because of energy conservation standards, and the availability and demand for manufactured homes would not decrease due to energy conservation standards.

### 4.4.5 Comparison of Alternatives

The estimated impacts to consumers under each of the alternatives considered for the proposed energy conservation standards for manufactured housing are compared in Table 4.4-12. The net present values of consumer benefits under each alternative are compared in Figure 4.4-9, and the reductions in shipments under each alternative are compared in Figure 4.4-10. These data are summarized from the NODA (86 FR 59042).

**TABLE 4.4-12 Comparison of Alternatives: Consumer Impacts**

| | **LCC Savings, 10 years** | | **LCC Savings, 30 years** | | **Increased Purchase Price** | | **Annual Energy Cost Savings** | | **National Average Simple Payback (years)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Alternative** | **Single-Section** | **Multi-Section** | **Single-Section** | **Multi-Section** | **Single-Section** | **Multi-Section** | **Single-Section** | **Multi-Section** | **Single-Section** | **Multi-Section** |
| Alternative A1: Tiered standards based on price, R-20+5 insulation | | | | | | | | | | |
| Tier 1 | $726 | $1,015 | $1,606 | $2,205 | $660 | $839 | $176 | $238 | 3.7 | 3.5 |
| Tier 2 | $78 | $235 | $2,045 | $3,023 | $3,902 | $5,267 | $354 | $496 | 11.0 | 10.6 |
| Alternative A2: Tiered standards based on price, R-21 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | $632 | $788 | $2,740 | $3,727 | $2,830 | $4,222 | $331 | $475 | 8.5 | 8.9 |
| Alternative B1: Tiered standards based on size, R-20+5 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | Same as Alternative A1, Tier 2 | | | | | | | | | |
| Alternative B2: Tiered standards based on size, R-21 insulation | | | | | | | | | | |
| Tier 1 | Same as Alternative A1, Tier 1 | | | | | | | | | |
| Tier 2 | Same as Alternative A2 with R-21 insulation, Tier 2 | | | | | | | | | |
| Alternative C1: Untiered standards, R-20+5 insulation | | | | | | | | | | |
| Untiered | $-57 | $50 | $1,733 | $2,585 | $3,902 | $5,267 | $354 | $496 | 11.0 | 10.6 |
| Alternative C2: Untiered standards, R-21 insulation | | | | | | | | | | |
| Untiered | $518 | $622 | $2,432 | $3,291 | $2,830 | $4,222 | $331 | $475 | 8.5 | 8.9 |
| Alternative D: No-action | | | | | | | | | | |
| No-action | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | 0 | 0 |

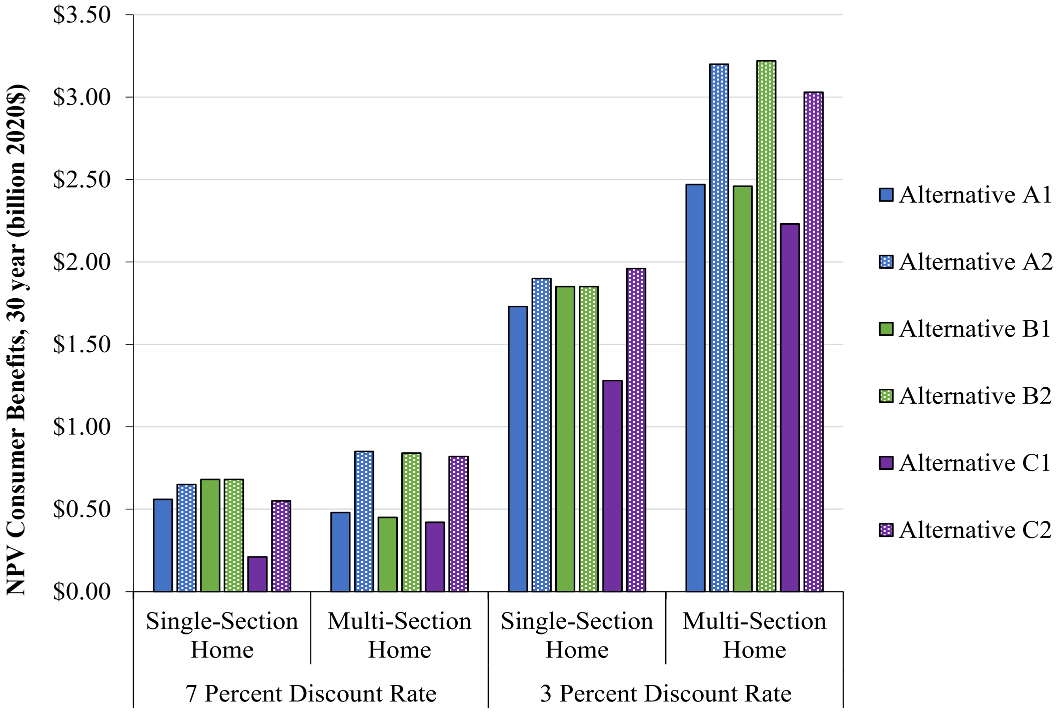

**FIGURE 4.4-9 Comparison of Alternatives: Net Present Value of Consumer Benefits for Manufactured Homes Purchased in 2023–2052 with a 30-Year Lifetime (Source: DOE 2021)**

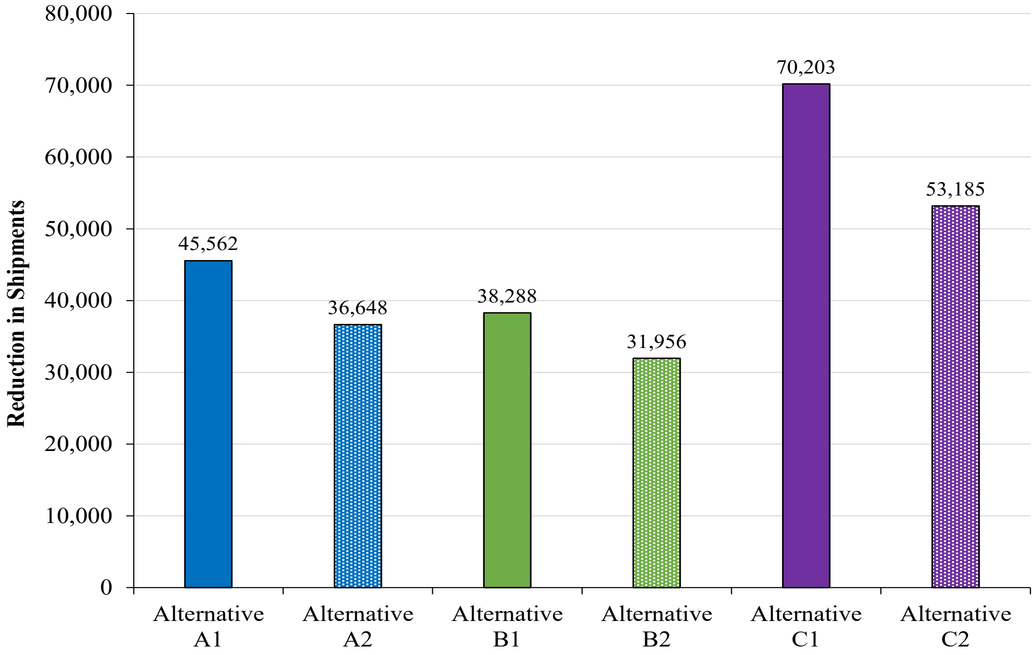

**FIGURE 4.4-10 Comparison of Alternatives: Reduction of Shipments over the 30-Year Analysis Period (Source: DOE 2021)**

## 4.5 ENVIRONMENTAL JUSTICE IMPACTS

The analysis of environmental justice impacts considers whether impacts from the proposal to establish energy conservation standards for manufactured housing are likely to fall disproportionately on minority and/or low-income populations. Impacts might be adverse or beneficial, and what is considered a beneficial impact to some population groups may be considered an adverse impact to others (IWG 2016).

This EIS has identified minority and low-income populations for five representative locations in Section 3.5, described the demographic and economic conditions in Section 3.4, and characterized indoor air quality conditions and health implications in Sections 3.2.3 and 3.3 to frame the baseline environment and an understanding of the character and degree of potential impacts. Section 3.5 also includes public health data from applying EPA's Environmental Justice Mapping and Screening (EJCSREEN) tool to evaluate the potential for cumulative exposures and health impacts in the affected population. Populations affected by DOE's proposed energy conservation standards for manufactured housing would extend across the United States and would include all people seeking to purchase manufactured homes under the new standard. The majority of manufactured homes are located in the south and southeastern United States. In order to evaluate location-specific impacts, the DOE identified five metropolitan areas to serve as illustrative locations for the affected environment, considering multiple factors for this selection (including manufactured housing, climate, ambient air quality, and demographics).

Federal environmental justice policies stress that early and ongoing public outreach is a vital component of the environmental justice process. DOE has consulted with HUD and sought input from the manufactured housing industry and the public throughout this process. DOE established the Manufactured Housing Working Group to reach consensus on energy-efficiency standards in manufactured housing and provide its recommendations to DOE to develop the proposed rule. In addition, DOE sought stakeholder comments during multiple comment periods and consultations during the process. The tiered standards and relaxed exterior insulation standards were developed in response to concerns related to potential adverse impacts of proposed energy conservation standards on price-sensitive, low-income purchasers of manufactured housing.

For each alternative, DOE considered whether there are any adverse impacts to minority and low-income populations that would appreciably exceed impacts to the general population or the larger metropolitan areas within the five locations that represent the affected environments for this assessment. DOE acknowledges that manufactured home purchasers and residents are disproportionately from lower income and minority populations (see Section 3.4). Environmental justice impacts can include positive and negative economic impacts, and this EIS has identified certain potentially adverse impacts on indoor air quality and health, as well as on socioeconomic conditions. Energy conservation standards could impact indoor air quality with implications for human health if homes are not adequately ventilated. Increased purchase price and up-front costs might reduce access to affordable homeownership for some low-income consumers. Alternatively, positive economic impacts are expected through increased energy efficiency that would lower energy bills for low-income households, easing the financial burden on owners and other occupants of manufactured homes in meeting monthly utility expenses. Under each alternative, the DOE considered indoor air quality impacts from new energy conservation standards for manufactured housing and economic impacts that might amplify the effects for low-income and minority populations.

### 4.5.1 Potential Environmental Justice Impacts of Alternative A1

Alternative A1 would follow a tiered approach in which a subset of manufactured homes below a $63,000 retail price cap would require less stringent energy conservation standards that would correspond to a $750 increase in approximate incremental purchase price while still improving the overall energy efficiency of the manufactured home. Homes above the $63,000 price threshold would align with the energy conservation standards based on the 2021 IEC. The evaluation of environmental justice impacts limits the consideration to Tier 1 homes because low-income populations are expected to purchase the lowest-priced homes.

#### 4.5.1.1 Access to Affordable Home Ownership

Under this alternative, the purchase price for Tier 1 homes is estimated to increase 1.2 percent. Any increase in purchase price could potentially price low-income consumers out of new home ownership, but a 1.2 percent increase is not expected to impact many consumers. Section 3.4.4 describes financing considerations for manufactured homes, particularly that chattel loans tend to have higher interest rates and are more likely to be denied than site-built home loans. Chattel loan borrowers have lower median incomes and a higher percentage of Hispanic, Blacks and African Americans, American Indians and Alaskan Natives, and elderly borrowers than do borrowers of site-built home loans. Because the increase in purchase price would be small, it is not anticipated to substantially impact the ability of a low-income or minority population group to secure a chattel loan under Alternative A1.

#### 4.5.1.2 Indoor Air Quality and Health

Air quality impacts were not analyzed under the Tier 1 standard, but impacts are expected to be similar for all homes because each action alternative includes improved air-sealing of the envelopes and ducts. Section 4.3 discusses indoor air quality impacts. Reducing air leakage through required improvements in envelope and duct airtightness will lead to lower indoor concentrations of some outdoor air pollutants including ozone, $NO_2$, and $PM_{2.5}$, and improves the ability to control exposure to wildfire smoke.

DOE's proposed energy conservation standards for manufactured homes would lower the average air exchange rate and substantially reduce uncontrolled airflows throughout the year, with an expected improvement in comfort and ventilation control and thus better protection from outdoor air pollution when needed. Under closed-house conditions, with ventilation systems temporarily turned off as recommended during outdoor air pollutant events, homes built to DOE's proposed airtightness standards would have indoor concentrations of outdoor $NO_2$ and $PM_{2.5}$ that are about 25−30 percent lower (safer) than in a HUD Code home.

The impacts of energy conservation standards for manufactured homes could result in higher concentrations of pollutants emitted from indoor sources, in particular when ventilation is inadequate. Sections 3.3 and 4.3 discuss indoor air pollutants that may be present in manufactured homes at concentrations that exceed reference concentrations or exposure guidelines, or that present a potential health risk, and which could potentially increase as a result of DOE's proposed energy conservation standards. Median acrolein levels might exceed the reference level by seven to eight times in summer and winter, respectively. Formaldehyde levels could exceed by four to five times the reference level, although the cancer risk might be just above the target range for incremental cancer incidence (1 in 10,000). It is also possible that homes could exceed the NAAQS reference levels. The impacts will be more constrained in homes using continuous exhaust ventilation. Concentrations of indoor air pollutants might increase 30–44 percent for VOCs emitted from indoor materials, 16–21 percent for $PM_{2.5}$ emitted by occupant activities, 35–40 percent for acrolein and other gases from cooking, 20–28 percent for $PM_{2.5}$ from cooking, and 16–24 percent for $NO_2$ from gas cooking burners.

In homes that do not use mechanical ventilation, pollutant concentrations in indoor air are higher than under ventilated conditions and the absolute increases are higher. Increases in indoor air pollutant concentrations that would otherwise result from the proposed rule could be mitigated by increasing the use of mechanical ventilation, including both whole-house ventilation and kitchen exhaust ventilation. Formaldehyde concentrations would range from 6 percent lower to 16 percent higher with a home meeting DOE's proposed standards. A home that uses a range hood during all cooking would have cooking-related acrolein concentrations that are 43–48 percent lower compared with a HUD Code home. The reduction would be 54–57 percent lower for $NO_2$ from gas cooking burners and 53–55 percent lower for $PM_{2.5}$ from cooking than in a HUD Code home.

These estimates are provided as general ranges because concentrations of pollutants in indoor air will vary with house-specific emission rates and location-specific outdoor pollutant levels. For example, Section 3.5 illustrates applications of EPA's EJSCREEN tool that contains EPA 2014 National Air Toxics Assessment data to estimate ambient air quality conditions in Fresno, California. Every census block group in Fresno containing manufactured housing communities exceeded the health-based standard for ambient $PM_{2.5}$. For the communities in Fresno, DOE's proposed energy conservation standards could lower indoor concentrations of some outdoor air pollutants, which would be a benefit over a HUD Code home. However, the increase in indoor air pollutants could potentially exacerbate exposure conditions for population groups already experiencing poor air quality. Fresno was also selected for the evaluation of wildfire impacts because of its proximity to recent wildfire events; Section 3.2.4 discusses wildfire impacts on air quality under existing conditions. Both envelope and duct airtightness help reduce indoor concentration of outdoor particles, improving the protective quality of homes under wildfire conditions and reducing potential indoor air quality impacts on low-income and minority populations.

Because all manufactured homes under this alternative are expected to have similar envelope and duct airtightness, air quality and health impacts are also expected to be similar. The benefits from lower indoor concentrations of some outdoor air pollutants and the potential adverse impact on indoor air quality of pollutants generated indoors would be the same for all homes and would impact minority and low-income populations equally regardless of the price or size of the home.

#### 4.5.1.3 Energy Poverty/Insecurity

Under Alternative A1, the annual energy cost savings for Tier 1 single-section manufactured homes are estimated to be $176, which would come from reduced energy bills. It would take approximately 3.7 years for the consumer to recover the increased purchase price through lower operating costs from a more-efficient manufactured home.

The simple payback period varies widely for the metropolitan areas for Tier 1 single-section manufactured homes. Estimated simple payback periods range from 3.0 years in Chicago and 3.7 years in Memphis to 5.1 years in Houston, 6.5 years in Phoenix, and 7.4 years in Miami. Alternative A1 could have differing impacts on low-income and minority populations in each of these cities.

Section 3.4.5 described energy insecurity issues for manufactured housing residents. More than half (56 percent) of households living in manufactured homes[23] reported experiencing challenges in paying their energy bills or sustaining adequate heating and cooling, which is substantially higher than for all U.S. households (31 percent). Energy burden, the measure of energy costs as a percentage of household income, varies by location and population. Section 3.4.5 presents the median energy burden for Chicago, Houston, Miami, and Phoenix.

The median energy burden for low-income populations in those areas ranges from 6.9 to 8 percent, 4 percentage points higher than the U.S. median. An energy burden of 6 percent is considered high. Energy conservation standards of Tier 1 homes result in positive energy cost savings, although Tier 1 homes would not receive the full benefit of energy conservation standards as Tier 2 homes. This disparity could potentially widen the inequity between Tier 1 and Tier 2 homes, decreasing the potential benefits of energy savings for low-income communities who already experience much higher energy burdens compared with the national average.

### 4.5.2 Potential Environmental Justice Impacts of Alternative A2

Alternative A2 would follow the tiered approach identified in Alternative A1. In addition, there would be a less stringent requirement for Tier 2 homes, using an R-21 exterior wall insulation instead of the R-20+5 wall insulation for climate zones 2 and 3. The evaluation of environmental justice impacts limits the consideration to Tier 1 homes because low-income populations are expected to purchase the lowest-priced homes. Because the exterior wall insulation applies only to Tier 2 homes, this alternative is not evaluated for environmental justice impacts.

### 4.5.3 Potential Environmental Justice Impacts of Alternative B1

Alternative B1 would follow a tiered approach where all single-section homes (Tier 1) would require less stringent energy conservation standards that correspond to a $750 increase in approximate incremental purchase price while still improving the overall energy efficiency of manufactured homes. All multi-section homes (Tier 2) would align with the proposed energy conservation standards. The evaluation of environmental justice impacts limits the consideration

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[23] These data are for all households living in manufactured homes, including older manufactured homes; characteristics might differ in newer homes.

to Tier 1 homes because low-income populations are expected to purchase the lowest-priced homes.

### 4.5.3.1 Access to Affordable Home Ownership

Under this alternative, the purchase price for Tier 1 homes would increase 1.2 percent, corresponding to a $66 increase in down payment. Any increase in purchase price could price out low-income consumers, but a 1.2 percent increase is not expected to impact many consumers. Section 3.4.4 described financing considerations for manufactured homes, particularly that chattel loans tend to have higher interest rates and are more likely to be denied than site-built home loans. Chattel loans borrowers have lower median incomes and have a higher percentage of Hispanic, Blacks and African Americans, American Indians and Alaskan Natives, and elderly borrowers than borrowers of site-built home loans. Because the increase in purchase price is so small, it is unlikely to impact low-income or minority populations' ability to secure a chattel loan under Alternative B1.

### 4.5.3.2 Indoor Air Quality and Health

Air quality impacts were not analyzed under the Tier 1 standard, but impacts are expected to be lower in Tier 1 homes. Section 4.3 discusses indoor air quality impacts. Reducing air leakage through required improvements in envelope and duct airtightness would lead to lower indoor concentrations of some outdoor air pollutants, including ozone, $NO_2$ and $PM_{2.5}$, and would improve the ability to control exposure to wildfire smoke.

DOE's proposed energy conservation standards for manufactured homes would lower the average air exchange rate and substantially reduce uncontrolled airflows throughout the year, with an expected improvement to comfort and ventilation control, and thus better protection from outdoor air pollution when needed. Under closed-house conditions, with ventilation systems temporarily turned off as recommended during outdoor air pollutant events, homes built to DOE's proposed airtightness standards would have indoor concentrations of outdoor $NO_2$ and $PM_{2.}$that are about 25−30 percent lower (safer) than in a HUD Code home.

The impacts of energy conservation standards for manufactured homes could result in higher indoor air concentrations of pollutants emitted from indoor sources, in particular when ventilation is inadequate, as described for Alternative A1. The impacts illustrated by the Fresno EJSCREEN application and the wildfire impact analysis described for Alternative A1 also apply to Alternative B1. Likewise, because all manufactured homes under this alternative are expected to have similar envelope and duct airtightness, air quality and health impacts are also expected to be similar. The benefits from lower indoor concentrations of some outdoor air pollutants and the potential adverse impact on indoor air quality of pollutants generated indoors would be the same for all homes and would impact minority and low-income populations equally regardless of the price or size of the home.

#### 4.5.3.3 Energy Poverty/Insecurity

Under Alternative B1, the lifecycle cost savings over 10 years for a Tier 1 single-section manufactured home are estimated to be $726, and over 30 years it would be $1,606. Annual energy cost savings are estimated to be $176, which would come from reduced energy bills. It would take an estimated 3.7 years for the consumers to recover the increased purchase price through lower operating costs from a more-efficient manufactured home.

The simple payback period varies widely across the example the metropolitan areas assessed, the same as described for Alternative A1. Also like Alternative A1, Alternative B1 could have differing impacts on low-income and minority populations in each of the metropolitan areas. The energy burden implications for this alternative are also as described for Alternative A1, with the potential to widen the inequity between Tier 1 and Tier 2 homes and decrease the potential benefits of energy savings for low-income communities, who already experience much higher energy burdens compared with the national average.

### 4.5.4 Potential Environmental Justice Impacts of Alternative B2

Alternative B2 follows the same tiered approach as Alternative B1, with the additional consideration that the insulation requirement would be less stringent for Tier 2 homes, for which R-21 insulation would be used on the exterior wall (instead of the R-20+5 insulation) in climate zones 2 and 3. The evaluation of environmental justice impacts limits the consideration to Tier 1 homes because low-income populations are expected to purchase the lowest-priced homes. Because the exterior wall insulation applies only to Tier 2 homes, this alternative is not evaluated for environmental justice impacts.

### 4.5.5 Potential Environmental Justice Impacts of Alternative C1

Alternative C1 would follow an untiered approach, which proposes that energy conservation standards for all manufactured homes (single-section and multi-section) would align with the energy conservation standard elements reflected in the DOE rule.

#### 4.5.5.1 Access to Affordable Home Ownership

Under this alternative, the purchase price for single-section manufactured homes is estimated to increase 7.3 percent. Any increase in purchase price might price out low-income consumers from the new home market, and a 7.3 percent increase could impact those striving for affordable ownership of a new home. Section 3.4.4 describes financing considerations for manufactured homes, particularly that chattel loans tend to have higher interest rates and are more likely to be denied than site-built home loans. Chattel loan borrowers have lower median incomes and have a higher percentage of Hispanic, Blacks and African Americans, American Indians and Alaskan Natives, and elderly borrowers than borrowers of site-built home loans. The increase in purchase price might impact a low-income or minority population group’s ability to secure a chattel loan under Alternative C1.

#### 4.5.5.2 Indoor Air Quality and Health

Section 4.3 discusses indoor air quality impacts. Reducing air leakage through required improvements in envelope and duct airtightness will lead to lower indoor concentrations of some outdoor air pollutants, including ozone, $NO_2$ and $PM_{2.5}$, and improves the ability to control exposure to wildfire smoke.

DOE's proposed energy conservation standards for manufactured homes would lower the average air exchange rate and substantially reduce uncontrolled airflows throughout the year, with an expected improvement to comfort and ventilation control and thus better protection from outdoor air pollution when needed. Under closed-house conditions, with ventilation systems temporarily turned off as recommended during outdoor air pollutant events, homes built to DOE's proposed airtightness standards would have indoor concentrations of outdoor $NO_2$ and $PM_{2.}$that are about 25−30 percent lower (safer) than in a HUD Code home.

The impacts of energy conservation standards for manufactured homes could result in higher indoor air concentrations of pollutants emitted from indoor sources, in particular when ventilation is inadequate, as described for Alternative A1. The impacts illustrated by the Fresno EJSCREEN application and the wildfire impact analysis described for Alternative A1 also apply to Alternative C1. Because all manufactured homes under this alternative have the same energy conservation standards, the benefits from lower indoor concentrations of some outdoor air pollutants and the potential adverse impact on indoor air quality would be the same for all homes and would impact minority and low-income populations equally regardless of the price or size of the home.

#### 4.5.5.3 Energy Poverty/Insecurity

Annual energy cost savings are estimated to be $354, which would come from reduced energy bills. It would take approximately 11 years for the consumers to recover the increased purchase price through lower operating costs from a more-efficient manufactured home.

The simple payback period varies widely for the metropolitan areas for single-section manufactured homes; the estimated period ranges from 8.8 years in Houston and 10.8 years in Miami, to 12.1 years in Chicago, 12.6 years in Memphis, and 14.5 years in Phoenix. The simple payback period is longer for homes under this alternative than under the tiered alternatives (Alternatives A and B); and the impact on low-income and minority populations would differ in each of these metropolitan areas. The current energy burdens for Chicago, Houston, Miami, and Phoenix are described for Alternative A in Section 3.4.5.

Energy conservation standards under Alternative C1 result in positive energy cost savings, although the 10-year LCC analysis results in a negative LCC for single-section homes. In addition, all manufactured homes would receive the same energy conservation standards under this alternative, providing the same energy savings and reducing energy insecurity concerns, and therefore reducing potential impacts to low-income communities who already experience much higher energy burdens compared with the national average.

### 4.5.6 Potential Environmental Justice Impacts of Alternative C2

Alternative C2 would follow an untiered approach, which proposes that energy conservation standards for all manufactured homes (single-section and multi-section) would align with the energy conservation standard elements reflected in the DOE rule. In addition, there would be a less stringent requirement for all homes in climate zones 2 and 3, using an R-21 exterior wall insulation instead of the R-20+5 wall insulation.

#### 4.5.6.1 Access to Affordable Home Ownership

Under this alternative, the purchase price for single-section manufactured homes is estimated to increase 5.3 percent. Any increase in purchase price might price low-income consumers out of the market for a new manufactured home, and a 5.3 percent increase could have an impact on those striving for affordable home ownership, but it is more affordable than Alternative C1. Section 3.4.4 described financing considerations for manufactured homes, particularly that chattel loans tend to have higher interest rates and are more likely to be denied than site-built home loans. Chattel loans borrowers have lower median incomes and have a higher percentage of Hispanic, Blacks and African Americans, American Indians and Alaskan Natives, and elderly borrowers than borrowers of site-built home loans. A 5.3 percent increase in purchase price might impact a low-income or minority population group's ability to secure a chattel loan under Alternative C2.

#### 4.5.6.2 Indoor Air Quality and Health

Section 4.3 discusses indoor air quality impacts. Reducing air leakage through required improvements in envelope and duct airtightness will lead to lower indoor concentrations of some outdoor air pollutants, including ozone, $NO_2$ and $PM_{2.5}$, and improves the ability to control exposure to wildfire smoke.

DOE's proposed energy conservation standards for manufactured homes would lower the average air exchange rate and substantially reduce uncontrolled airflows throughout the year, with an expected improvement to comfort and ventilation control, and thus better protection from outdoor air pollution when needed. Under closed-house conditions, with ventilation systems temporarily turned off as recommended during outdoor air pollutant events, homes built to DOE's proposed airtightness standards would have indoor concentrations of outdoor $NO_2$ and $PM_{2.5}$ that are about 25−30 percent lower (safer) than in a HUD Code home.

The impacts of energy conservation standards for manufactured homes could result in higher indoor air concentrations of pollutants emitted from indoor sources, in particular when ventilation is inadequate, as described for Alternative A1. The impacts illustrated by the Fresno EJSCREEN application and the wildfire impact analysis described for Alternative A1 also apply to Alternative C2. Because all manufactured homes under this alternative have the same energy conservation standards, the benefits from lower indoor concentrations of some outdoor air pollutants and the potential adverse impact on indoor air quality would be the same for all homes and would impact minority and low-income populations equally regardless of the price or size of the home.

#### 4.5.6.3 Energy Poverty/Insecurity

Under Alternative C2, the lifecycle cost savings over 10 years for single-section manufactured homes are estimated to be $518, and the estimated savings over 30 years are $2,432. Annual energy cost savings are estimated to be $331, which would come from reduced energy bills. It would take approximately 8.5 years for the consumers to recover the increased purchase price through lower operating costs from a more-efficient manufactured home.

The simple payback period varies widely for the metropolitan areas for single-section manufactured homes. The estimates range from 8.5 years in Chicago and 8.8 years in Memphis and Houston to 10.1 years in Phoenix and 10.8 years in Miami. The simple payback period for homes under this alternative is longer than in the tiered alternatives (Alternatives A and B), but shorter than under Alternative C1. The impact on low-income and minority populations would differ in each of these metropolitan areas.

Alternative A1 describes the current energy burden for Chicago, Houston, Miami and Phoenix, as presented in Section 3.4.5 Energy conservation standards under Alternative C2 are estimated to result in positive energy cost savings under the 10-year and 30-year lifecycle cost savings analysis. In addition, all manufactured homes would receive the same energy conservation standards under Alternative C2, providing the same energy savings and reducing energy insecurity concerns, therefore reducing potential impacts to low-income communities that already experience much higher energy burdens compared with the national average.

### 4.5.7 Potential Environmental Justice Impacts of Alternative D

Alternative D is the no-action alternative where DOE would not establish energy conservation standards for manufactured housing, and energy conservation requirements would remain as they are in the existing HUD Code.

#### 4.5.7.1 Access to Affordable Home Ownership

Under this alternative, there would be no increase in purchase price from energy conservation standards.

#### 4.5.7.2 Indoor Air Quality and Health

Under this alternative, there would be no increase in protection from outdoor pollutants. If adequate ventilation were not used, the potential for adverse health effects from exposures to pollutants generated indoors would continue (including noncancer effects of acrolein and formaldehyde and the potential for incremental cancer risk from formaldehyde.

#### 4.5.7.3 Energy Poverty/Insecurity

Under this alternative, there would be no lifecycle cost savings and energy bills would not be reduced through energy-efficient manufactured homes that would result from energy conservation standards.

## 4.6 UNAVOIDABLE ADVERSE IMPACTS

In accordance with NEPA and the Council on Environmental Quality (CEQ) implementing regulations (see Chapter 1), this section addresses any adverse environmental impacts that cannot be avoided should the proposal be implemented (40 CFR 1502.16). As discussed in Chapter 4, the proposed action (Alternative A) and action alternatives (Alternatives B and C) could result in a decrease in indoor air quality compared with the no-action alternative (Alternative D). The DOE proposal could incrementally increase the potential for adverse health impacts from exposures to increased concentrations of indoor air pollutants that are generated indoors.

In addition, the proposed action and action alternatives could exclude some individuals from the market for new manufactured housing by pricing them out of the market, primarily through the increased purchase price of the home. For example, the incremental increase in purchase price associated with the proposed standards might make price-sensitive prospective buyers of new manufactured homes ineligible for financing.

However, these potential adverse impacts to human health and purchase power could be mitigated. Potential incremental health impacts from exposures to indoor pollutants could be offset by changes in ventilation requirements and changes in consumer behavior (e.g., increasing the use of ventilation). Potential impacts to prospective manufactured homeowners could be mitigated through financial mechanisms that enable prospective buyers to secure financing, or other similar enabling activities. (See the discussion of proposed mitigation measures in Section 4.11.)

## 4.7 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

In accordance with NEPA and the CEQ implementing regulations, this section addresses any irreversible and irretrievable commitments of resources that would be involved in the proposal should it be implemented (40 CFR 1502.16). An irreversible commitment of resources represents a loss of future options. It applies primarily to nonrenewable resources, such as minerals or cultural resources, and to those factors that are renewable only over longtime spans, such as soil productivity. An irretrievable commitment of resources represents opportunities that are foregone for the period of the proposed action. Examples include the loss of production, harvest, or use of renewable resources. The decision to commit resources is reversible, but the utilization of opportunities foregone is irretrievable.

Some manufacturers might commit to an increase in the use of certain building materials, or might commit additional resources to existing, redeveloped, or new production facilities to meet the proposed standards. In some cases, this could potentially represent an irreversible and irretrievable commitment of resources. The specific amounts and types of irretrievable resources (such as building materials, electricity, or other forms of energy) that manufacturers would expend in meeting the proposed standards would depend on the technologies and materials manufacturers select. Potential impacts would be anticipated to be within the current range of variability for the production of manufactured homes.

## 4.8 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

In accordance with NEPA and the CEQ implementing regulations, this section addresses the relationship between short-term uses of man’s environment and the maintenance and enhancement of long-term productivity (40 CFR 1502.16). This includes using “all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generation of Americans.”[24]

The proposed action and action alternatives could potentially result in an increase in the use of certain building materials (e.g., insulation) compared with the no-action alternative. To meet the proposed standards, manufacturers might apply various technologies during the production of manufactured homes. DOE cannot predict with certainty which materials or technologies manufacturers would apply or in what order. Some manufacturers might commit additional resources to existing, redeveloped, or new production facilities to meet the standards, although DOE cannot predict with certainty what actions manufacturers may take.

## 4.9 OTHER POTENTIAL ENVIRONMENTAL IMPACTS

In accordance with NEPA, this section addresses four additional categories of potential environmental impacts identified in the CEQ implementing regulations (40 CFR 1502.16). The first category is possible conflicts between the proposed action and the objectives of federal, regional, state, tribal, and local land use plans, policies, and controls for the area concerned. This category is not applicable because the DOE proposal to establish energy conservation standards for manufactured homes does not impact any particular land area.

The second category is energy requirements and conservation potential of various alternatives and mitigation measures. Energy conservation is at the heart of DOE’s proposal to establish energy conservation standards for manufactured housing. Implementing the proposed action or any of the action alternatives would improve the energy conservation potential of new manufactured homes.

The third category is natural or depletable resource requirements and conservation potential of various alternatives and mitigation measures. The proposal to establish energy conservation standards for manufactured housing would improve energy conservation and reduce the consumption of fossil fuels through more energy-efficient manufactured homes.

The fourth category is urban quality, historic and cultural resources, and the design of the built environment, including the reuse and conservation potential of various alternatives and mitigation measures. Promoting energy conservation is at the heart of DOE’s proposal to establish national energy conservation standards for manufactured housing. There would be no impacts to urban quality, historical resources, or the design of the built environment.

## 4.10 CUMULATIVE IMPACTS

In accordance with NEPA, this section considers cumulative effects, which are effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions regardless of what agency (federal or nonfederal) or person undertaking such other actions. Cumulative effects can result from

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[24] NEPA, Section 101, 42 U.S.C. 4331.

individually minor but collectively significant actions taking place over a period of time. DOE is not aware of any past, present, or reasonably foreseeable actions that when combined with the proposed energy conservation standards for manufactured housing would result in any incremental effects beyond the cumulative effects already identified in the analyses presented in this EIS.

## 4.11 MITIGATION MEASURES

The analyses presented in this EIS identify impacts to indoor air quality, health, socioeconomic conditions, environmental justice, and cumulative effects of DOE's proposed action and action alternatives (see Sections 4.2–4.6). This section describes measures that could mitigate potential adverse impacts.[25] The proposed mitigation measures are summarized in Table 4.11-1, along with the environmental resource areas they address. The development of these measures has benefited from public inputs provided in comments on the scope of the EIS and during the rulemaking process.

### 4.11.1 Promote Installation of Energy-Efficient Fans for Ventilation

The analyses of impacts to indoor air quality and health in Sections 4.2 and 4.3 found that air-sealing measures would increase the concentrations of several pollutants in indoor air that already exceed health-based levels in many homes in absence of the standard, and the impacts would be largest in homes that are not well ventilated due in large part to lack of consumer use of ventilation fans. In addition, the analyses of socioeconomic and environmental justice impacts associated with energy costs and energy insecurity in Sections 4.4 and 4.5 identified the higher cost of operating continuous, whole-house mechanical ventilation (as recommended in the HUD Code). In a manufactured home that uses the fan integral to the heating and cooling system to provide ventilation, the cost to provide that ventilation would translate to higher energy costs compared with the use of a separate, more energy-efficient exhaust ventilation fan.[26]

Many existing manufactured homes already have energy-efficient ventilation fans. Manufacturers can expand their installation of whole-house ventilation fans that meet the efficacy requirements in IECC 2021 in new manufactured homes. DOE could encourage this practice, such as through the mitigation steps described below. Installation of efficient whole-house mechanical ventilation would reduce the cost of ventilation, which could lead to more frequent consumer use of ventilation fans. Additionally, more frequent use of ventilation fans would reduce concentrations of indoor air pollutants. Increasing the use of energy-efficient whole-house mechanical ventilation could thus mitigate two potential adverse impacts associated with the proposed rule.

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[25] The mitigation measures described here are not already included in the proposed action and alternatives because they are not within the prescriptive requirements of EIS. These measures could apply to each proposed alternative. Many of these proposed mitigation measures would be beneficial even in the absence of a DOE rule.

[26] For example, operating a base-model, single-speed central fan to provide ventilation in a typical double-wide manufactured home — during all the times when the heating and cooling system is not operating to provide heating or cooling — could translate to estimated annual energy costs for the homeowner of $120 to $270. If, instead, a continuous exhaust or supply ventilation fan that meets the proposed fan efficacy requirements were operated in the same home, that would translate to an estimated annual energy cost of $23.

A further mitigation measure would be to promote the installation of a range hood instead of a simple exhaust fan to meet the HUD Code requirement for kitchen exhaust, and to provide a range hood that meets the sound-level limits specified in ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Standard 62.2.[27] Several surveys have found noise to be a top reason that respondents report as limiting their use of kitchen exhaust ventilation. This suggests that quieter equipment could lead to more frequent use, with the benefits of reducing indoor levels of air pollutants released during cooking and jointly reducing the potential for adverse health effects from related exposures. A further benefit would be an improved auditory environment within the manufactured home.

### 4.11.2 Advance Research and Stakeholder Engagement to Increase Implementation of Efficient Ventilation in Manufactured Housing

DOE could advance research and stakeholder engagement to increase the incorporation and use of efficient ventilation equipment in manufactured homes. Key stakeholders include manufacturers of manufactured homes, suppliers of ventilation equipment, and homeowners.

The research and coordinated outreach could focus on the following activities: (1) documenting how mechanical ventilation is being provided currently and determining air flows;[28] (2) identifying existing options for efficient ventilation, and conducting field studies to assess their performance as installed; (3) identifying emerging efficient technologies and assessing their performance in controlled laboratory homes and occupied homes; (4) understanding how manufactured home residents use ventilation and the potential barriers to increasing deployment and use of efficient ventilation equipment; and (5) understanding the associations between whole-house ventilation system type and usage patterns and concentrations of indoor air pollutants that pose potential health concerns.

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[27] ASHRAE Standard 62.2 addresses ventilation and acceptable indoor air quality in residential buildings (https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2).

[28] The 2012 GAO report on manufactured housing encouraged documenting airflows to better ensure safe indoor air quality (https://www.gao.gov/assets/gao-13-52.pdf).

### 4.11.3 Provide Training and Technical Assistance to Manufacturers

DOE could provide training and technical assistance to manufacturers on design and production modifications to meet the energy-efficiency standards. Training could also include information regarding rating systems, labeling, and software used for residential code compliance. Providing necessary training and assistance to manufacturers would aid all manufacturers, especially small manufacturers, to achieve the energy-efficiency standards in the most cost-efficient manner.

### 4.11.4 Promote Improved Indoor Air Quality and Environmental Justice through Informational Resources and Labeling

DOE could develop and implement informational campaigns to promote improved indoor air quality and environmental justice. Collaborating with HUD, EPA, the manufactured housing industry, nonprofit organizations, and other organizations on such campaigns could result in reaching a wider audience of homeowners and homebuyers. Two mitigation activities are described in Sections 4.11.4.1 and 4.11.4.2.

#### 4.11.4.1 Promote Healthy Homes Principles

DOE could encourage manufactured homebuyers and homeowners to practice Healthy Homes Principles.[29] An informational campaign on this topic could be coordinated and conducted in partnership with other agencies (including HUD and EPA), industry (e.g., manufacturers of manufactured housing), and nonprofit organizations. Information could be shared through mechanisms such as signage or labels to be applied in the home, links to online resources, and print materials (e.g., homebuyer packets), as well as agency social media programs. Healthy Homes Principles are intended to promote safe, decent, and sanitary housing as a means for preventing disease and injury. The eight principles for a healthy home are:

1. Keep it dry (check for leaks and keep water from entering the home).

2. Keep it clean (e.g., control sources of dust and contaminants).

3. Keep it safe (e.g., install smoke and carbon monoxide detectors).

4. Keep it well-ventilated (e.g., via kitchen, bathroom, and whole-house ventilation).

5. Keep it pest-free (including by sealing cracks and openings).

6. Keep it contaminant-free (including wet-cleaning floors and windows).

7. Keep it maintained (via routine inspections, cleaning, and repairs).

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[29] Healthy Homes Principles are summarized here from descriptions by HUD (https://www.hud.gov/program_offices/healthy_homes/healthyhomes) and the National Center for Health. Housing (https://nchh.org/information-and-evidence/learn-about-healthy-housing/healthy-homes-principles/).

8. Maintain thermal controls (keep temperatures at safe levels, not too hot or cold).

DOE and partner agencies could also encourage homeowners to invest in higher-performance filters for their forced-air heating and cooling systems, as already recommended by EPA[30]. These filters are typically replaced on a quarterly or semiannual basis, and filters that have particle-removal performance that is substantially better than a base filter can be obtained for an incremental cost of a few dollars per filter.

#### 4.11.4.2 Promote Efficiency Labeling

DOE could encourage labeling that shows the energy efficiency and energy features of each manufactured home, similar in concept to the Energy Guide label for appliances and the fuel economy window sticker on cars, as well as two voluntary home ratings, the DOE Home Energy Score and the Home Energy Rating System (HERS) Index. Efficiency labels could aid potential homebuyers in identifying and comparing energy efficiency between homes. These labels might also encourage manufacturers to build homes that can achieve better than the minimum required efficiency standards.

### 4.11.5 Promote Financial Mechanisms to Offset First Costs Through Incentives, Assistance, and Informational Resources

The proposed action and alternative actions would reduce overall costs for manufactured homeowners, i.e., the combined purchase expense and operating (energy) costs through the simple payback period. However, the first cost of buying a manufactured home could increase. The analyses of socioeconomic and environmental justice impacts in Sections 4.4 and 4.5 show that the incremental upfront cost that could result from the proposed energy conservation standards could impact manufactured homebuyers. A mitigation measure to address the incremental purchase expense is already incorporated into Alternatives A and B by tiering the standards based on price and size (which influences price), respectively. A further mitigation measure would be to promote financial mechanisms that would mitigate adverse impacts on consumers, as described in the following three subsections.

#### 4.11.5.1 Financial Incentives

DOE could develop a program or partnership to establish or promote financial incentives (such as rebates and/or tax credits) for manufacturers to offset the costs associated with manufacturing homes that meet the energy conservation standards. Likewise, DOE could encourage a program or partnership to establish or promote financial incentives (such as rebates and/or tax credits) for consumers who purchase manufactured homes that meet the energy conservation standards.

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[30] See https://www.epa.gov/indoor-air-quality-iaq/air-cleaners-and-air-filters-home.

#### 4.11.5.2 Financial Assistance

DOE could develop a program, leverage an existing program, or develop a collaboration or partnership with another organization (e.g., other agency, industry, or nonprofit) to offer financial assistance to certain manufactured homebuyers to offset the initial incremental cost to purchase a manufactured home that would result from the proposed energy conservation standards. Such assistance would reduce the adverse impacts of an incremental purchase expense and corresponding environmental justice impacts that could affect the ability of members of disadvantaged communities to purchase and retain a manufactured home, such as due to the denial of a loan application or the challenge of monthly payments associated with high-priced chattel loans. The need for such assistance has been identified by the Government Accountability Office.[31]

#### 4.11.5.3 Increase Awareness of Financing Options

DOE could develop an informational campaign to increase awareness of financing options for buyers of manufactured homes, including coordination with other agencies and organizations. Increasing consumer awareness and understanding of differences among financing options, including cost implications of chattel loans compared with mortgages, might help reduce the use of these high-cost loans. Increased awareness could help reduce overall costs associated with financing and could aid prospective manufactured home borrowers in attaining more energy-efficient, better homes. This measure and others within this section could be implemented in combination with the research and engagement measure described in Section 4.11.2, to collectively highlight opportunities for improving indoor air quality, avoiding incremental costs associated with operating energy-inefficient systems, and securing more cost-effective financing.

### 4.11.6 Promote Awareness of DOE's Energy Justice Initiatives

DOE could develop an informational campaign to promote awareness of the Justice40 Initiative, which was established by Executive Order 14008[32] and requires that 40 percent of the overall benefits of certain federal investments — including investments in clean energy and energy efficiency, affordable and sustainable housing, and training and workforce development — flow to disadvantaged communities. DOE's Office of Economic Impact and Diversity (OEID)[33] defines energy justice as the goal of achieving equity in social and economic participation in the energy system, while also remediating social, economic, and health burdens on those disproportionately harmed by the energy system. The DOE program could coordinate with OEID and/or other related DOE offices to promote partnerships that enhance community awareness of and engagement in advancing energy justice concepts within the manufactured housing sector.

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[31] GAO (2014) describes the need to enhance program effectiveness (https://www.gao.gov/assets/gao-14-410.pdf).

[32] *Executive Order on Tackling the Climate Crisis at Home and Abroad*. Section 223. Justice40 Initiative. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/. January 27, 2021.

[33] DOE Office of Economic Impact and Diversity (https://www.energy.gov/diversity/office-economic-impact-and-diversity).

**TABLE 4.11-1 Summary of Proposed Mitigation Measures**

| Mitigation Measure | Resource Areas Addressed |
|---|---|
| Promote installation of energy-efficient fans for ventilation | Indoor air quality and health, socioeconomics, and environmental justice |
| Advance research and stakeholder engagement to increase implementation of energy-efficient ventilation | |
| Provide training and technical assistance to manufacturers | |
| Promote improved indoor air quality and environmental justice through efficiency labeling and informational resources about healthy homes and financing options:<br>Promote Healthy Homes Principles<br>Promote efficiency labeling | Indoor air quality and health, socioeconomics, and environmental justice |
| Promote financial mechanisms to offset first costs through incentives, assistance, and informational resources:<br>Promote financial incentives<br>Promote financial assistance<br>Increase awareness of financing options | Socioeconomics and environmental justice |
| Promote awareness of DOE's energy justice initiative | Environmental justice |

# 5 CONSULTATIONS AND COORDINATION

The NEPA process requires appropriate consultation and coordination with Native American tribes, as well as appropriate federal and state agencies. DOE encourages tribal and agency participation throughout the NEPA process. DOE has reached out to tribes and agencies to fulfill these requirements and will continue to do so.

## 5.1 CONSULTATION AND COORDINATION WITH TRIBAL GOVERNMENTS

DOE encourages participation and meaningful consultation with Native American tribes at all stages of the NEPA process. On July 7, 2021, DOE sent information via email and U.S. mail to the 574 federally recognized tribes. That information included a description of the proposed rule, notice of DOE's intent to complete an EIS, an invitation to answer any questions a tribe may have regarding the proposed rule, an invitation for tribes to provide comments on the scope of the EIS, and an invitation to engage in consultation, including government-to-government consultation (see Appendix A). On August 24, 2021, DOE received questions about the proposed rule from one tribe, the Southern Ute Indian Tribe. On September 2, 2021, DOE provided the requested information to the tribe. No tribe has requested further consultation. DOE continues to encourage all tribes to participate in the NEPA process, including providing comments on the draft EIS and engaging in consultation.

## 5.2 CONSULTATION UNDER THE ENDANGERED SPECIES ACT

The Endangered Species Act requires federal agencies to ensure that agency actions are not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species. 16 U.S.C. § 1536(a)(2). DOE has determined that the proposed rule, which would require that new manufactured homes be built to a specific energy conservation standard and would occur within the footprint of existing manufacturing facilities, would have no effect on listed species or their critical habitats. As such, DOE has not engaged in consultation under the Endangered Species Act.

## 5.3 CONSULTATION UNDER THE NATIONAL HISTORIC PRESERVATION ACT

Section 106 of the National Historic Preservation Act of 1966 (NHPA) (54 U.S.C. §306108; 36 CFR Part 800) requires federal agencies to consider the effects of their activities on historic properties and give the Advisory Council on Historic Preservation an opportunity to comment. If a federal activity has the potential to affect historic properties, a Section 106 review will take place and consultation will occur with the appropriate state or tribal agencies, generally a State Historic Preservation Office and/or Tribal Historic Preservation Office. DOE has determined that the proposed rule, which would require energy conservation standards for manufactured housing, does not have the potential to cause effects to historic properties because it would not apply to existing manufacture homes (including homes older than 50 years); would only change the applicable energy conservation standards for new manufactured housing; and manufacturing would occur within the footprint of existing factories. Thus, DOE has not engaged in consultation under Section 106.

## 5.4 COORDINATION WITH HUD

DOE determined, pursuant to 40 CFR 1501.8, that HUD may have expertise with respect to environmental impacts and mitigation measures related to manufactured homes to be evaluated in the EIS. On October 4, 2021, DOE invited HUD to become a cooperating agency on the preparation of the EIS or to engage more informally. HUD responded on November 1, 2021, with a preference to engage with DOE more informally than as a cooperating agency.

## 5.5 COORDINATION WITH OTHER FEDERAL AGENCIES AND STATE GOVERNMENTS

DOE is committed to incorporating comments and input from multiple sources. DOE reached out to multiple federal agencies and each state government. DOE provided notice of DOE’s intent to complete an EIS, a summary of the proposed rulemaking, and invited comments on the scope of the EIS. State comments received to date relate to the rulemaking process rather than specific comments informing the EIS scope. Comments received from state and federal agencies are incorporated in Appendix A.

DOE will continue outreach to States and federal agencies in seeking comments on this draft EIS.

# 6 LIST OF PREPARERS

| Name | Education/Expertise | Contribution |
|---|---|---|
| ***Argonne National Laboratory*** | | |
| Georgia Anast | B.A., Mathematics and Biology; 30 years of experience in environmental analyses | Public comments |
| Young-Soo Chang | Ph.D., Chemical Engineering; 34 years of experience in air quality, noise, health risk, and engineering system analyses | Air resources, energy resources, health and safety, alternatives, assessment methods |
| Patrick Cuscaden | M.S., Economics and Policy Analysis; B.S., Business Administration; 4 years of experience in financial and economic analyses | Socioeconomic resources |
| Laura Fox | B.S., Biology; 10 years of experience in environmental analyses and impact assessments | Assessment methods, document integration and compliance |
| David LePoire | Ph.D., Computer Science; B.S., Physics; 18 years of experience in systems modeling and environmental risk analyses | Energy resources |
| Margaret MacDonell | Ph.D., Civil/Environmental Health Engineering; B.S., Biology; 35 years of experience in technology, health risk, and cumulative impact analyses | EIS project manager; health and safety, environmental justice, mitigation measures, alternatives |
| Braeton Smith | Ph.D., Mineral and Energy Economics; M.S., Applied Economics; B.A., Economics; 12 years of experience in economic and energy analyses | Socioeconomic resources |
| Ellen White | M.P.P., Public Policy; B.A., Environmental Studies; 17 years of experience in environmental and socioeconomic analyses | Socioeconomic resources, environmental justice, cumulative impacts, alternatives |
| Emily Zvolanek | M.S., Geographic Information Systems; B.S., Environmental Science; 15 years of experience in geographic information systems (GIS) and environmental analyses | Environmental justice, GIS mapping and analyses |
| ***Lawrence Berkeley National Laboratory*** | | |
| Wanyu Chan | Ph.D., Civil and Environmental Engineering; 20 years of experience in indoor air quality, modeling, and air infiltration analyses | Air resources |
| William Delp | Ph.D., Mechanical Engineering; 33 years of experience in indoor air quality simulations and analyses of building airflow and heating, ventilation, and air conditioning system impacts | Air resources |

| Name | Education/Expertise | Contribution |
|---|---|---|
| Spencer Dutton | Ph.D., Building Energy and Air Quality Modeling (Engineering Department); 17 years of experience in building energy and indoor air quality modeling | Air resources |
| Brett Singer | Ph.D., Civil and Environmental Engineering; 23 years of experience in indoor air quality, sources, controls, and residential exposures | Co-EIS project manager; air resources, health and safety, mitigation measures |
| Iain Walker | Ph.D., Mechanical Engineering; 35 years of experience in building science, air infiltration, and indoor air quality | Air resources |
| Haoran Zhao | Ph.D., Civil, Architectural and Environmental Engineering; 6 years of experience in indoor air quality research and analyses | Air resources |
| ***DOE Office of Energy Efficiency and Renewable Energy, Golden Field Office*** | | |
| Kristin Kerwin | M.P.S., Environmental Science; M.P.A., Public Administration; B.S., Environmental Studies; 17 years of experience in energy efficiency, environmental impact analyses, and agency coordination | DOE NEPA Compliance Officer |
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## 7.5 CHAPTER 5 REFERENCES

None

## 7.6 CHAPTER 6 REFERENCES

None

# APPENDIX A:

# PUBLIC COMMENTS

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# APPENDIX A: PUBLIC COMMENTS

The EIS scoping process, public involvement, and comments received regarding alternatives, information, and analyses for DOE's consideration in developing the EIS are summarized in Section A.1.[1] In addition, public involvement and comments received on the preceding NEPA review, the 2016 draft EA and RFI,[2] are summarized in Section A.2. Furthermore, public comments submitted on the 2021 supplemental notice of proposed rulemaking (SNOPR)[3] and the follow-on analysis presented in the Notice of Data Availability (NODA)[4] that help inform considerations for the EIS scope are summarized in Section A.3.

## A.1 EIS

The EIS scoping process and public involvement are described in Section A.1.1, and comments received during the comment period for this process are summarized by topic in Section A.1.2.

### A.1.1 EIS Scoping Process and Public Involvement

On July 7, 2021, DOE EERE published a notice of intent (NOI) to prepare an EIS for energy conservation standards for manufactured housing, request public comments on its scope, and conduct public scoping meetings.[5] In the NOI, DOE announced two online EIS scoping meetings (July 21 and 22, 2021), and invited stakeholders to submit oral comments at these meetings and written comments via the project's public website at https://ecs-mh.evs.anl.gov or by mail to the DOE Golden Field Office. Details on how to join the online scoping meetings and how to register to provide oral comments were posted on the EIS website. The public scoping period for this EIS continued from July 7 to August 6, 2021.

In addition to publishing the NOI in the Federal Register, DOE mailed and emailed the notice and request for comments to the 574 federally recognized tribes. DOE also emailed the notice to identified NEPA stakeholders, individuals, and organizations who commented on the draft EA and RFI in 2016, members of the Manufactured Housing Working Group, and approximately 25,000 stakeholders who have expressed interest in standards and rulemaking processes. The contents of these communications are presented as Attachments 1-3 of this appendix.

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[1] For purpose of this discussion, by "public involvement, and comments" we mean the comment process and all comments received from stakeholders, interested individuals, organizations, state or federal agencies, and tribes.

[2] *Draft Environmental Assessment for Notice of Proposed Rulemaking, "Energy Conservation Standards for Manufactured Housing" With Request for Information on Impacts to Indoor Air Quality.* Notice of availability request for public comment, and request for information. 81 FR 42576 (June 30, 2016).

[3] *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing: Availability of Provisional Analysis*. Supplemental notice of proposed rulemaking and request for comment. 86 FR 47744 (August 26, 2021).

[4] *Energy Conservation Program: Energy Conservation Standards for Manufactured Housing*. Notice of supplemental notice of proposed rulemaking; reopening of public comment period and notification of data availability (NODA). 86 FR 59042 (October 26, 2021).

[5] *Notice of Intent to Prepare an Environmental Impact Statement for Energy Conservation Standards for Manufactured Housing.* Notice of intent to prepare an environmental impact statement, to request public comments on its scope, and to conduct public scoping meetings. 86 FR 35773 (July 7, 2021).

At the EIS scoping meetings on July 21 and 22, 2021, DOE presented information about the EIS process and planned EIS scope and invited public comments. Oral comments were invited during the meetings and written comments were invited for submittal through the close of the comment period. More than forty people attended the virtual scoping meetings from industry and trade organizations, utility companies, tribes, federal and state agencies, nongovernmental organizations (NGOs), and academia. Slides presented at the meetings and recordings of the meetings are available on the EIS website.

Altogether, DOE received oral and written comments on the scope of the EIS from 17 organizations and two individuals. Six people submitted oral comments at the EIS scoping meetings; three of these individuals also submitted written comments. DOE received written comment documents from tribes, state agencies, industry and trade associations, NGOs, and individuals. Most comments (11) were submitted via the EIS website; others were submitted by email, postal mail, via the online docket (regulations.gov), and through the Nevada (NV) Clearinghouse (see Table A.1). Comments were received from three tribes and four states. Two tribes and one state agency responded that they had no comments, one tribe sought additional information, and two state agencies provided information that was not specific to the EIS.

**TABLE A.1 Organizations Submitting EIS Scoping Comments**

| Organization | Submittal Type(s) |
|---|---|
| American Council for an Energy-Efficient Economy *(DC)* | Oral |
| Clayton Homes, Inc *(IN)* | Oral, website |
| Dakotaland Homes *(SD)* | Oral |
| Earthjustice (also submitted on behalf of Sierra Club) *(DC)* | Website |
| Institute for Policy Integrity *(NY)* | Docket |
| Manufactured Housing Assoc for Regulatory Reform (MHARR) *(DC)* | Oral, website, mail |
| Manufactured Housing Institute *(VA)* | Oral, website |
| Missouri Department of Natural Resources *(MO)* | Website |
| Moapa Band of Paiutes[a] *(NV)* | Email |
| National Association of State Energy Officials (NASEO) *(VA)* | Website |
| Nevada Division of Environmental Protection[a] *(VA)* | NV Clearinghouse |
| Northwest Energy Efficiency Alliance *(OR)* | Oral |
| Pennsylvania Department of Community and Economic Development *(PA)* | Website |
| Redwood Energy *(CA)* | Docket |
| Southern Ute Indian Tribe *(CO)* | Email |
| United Auburn Indian Community[a] *(CO)* | Email |
| Virginia Department of Environmental Quality (DEQ)[b] *(VA)* | Website |

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[a] Stated they had no comments

[b] No comments specific to this EIS

## A.1.2 EIS Scoping Comments Organized by Theme

Comments on the EIS scope presented during the virtual scoping meetings for the EIS on July 21 and 22, 2021, and comments submitted in writing through August 6, 2021, are organized by theme in the following sections. The five main themes are: (1) proposed action and alternatives, (2) socioeconomic impacts, (3) indoor air quality and human health impacts, (4) environmental justice, and (5) climate change.

### A.1.2.1 Proposed Action and Alternatives

#### *A.1.2.1.1 Proposed Action*

Several commenters expressed general support for DOE updating its code with energy conservation standards for manufactured housing. They stated that these standards are long overdue and that the 2021 IECC should be a starting point for a new manufactured housing standard. Some commenters stated that energy inefficiency in manufactured homes has resulted in increased energy costs for residents and increased air pollution in the environment from the combustion of fossil fuels.

#### *A.1.2.1.2 No-Action Alternative*

Some commenters stated that instead of DOE proposing energy conservation standards based on the 2021 IECC, the HUD Code should be used to update energy standards for manufactured housing. They stated that the IECC code was developed for site-built residential homes and commercial buildings and does not recognize the unique aspects and construction techniques used by manufactured housing. They asserted that working with the Manufactured Housing Consensus Committee to modify the existing Manufactured Home Construction and Safety Standards would be more appropriate than adopting the 2021 IECC. The commenters noted that HUD standards are established and modified using a process where all stakeholders are represented and permitted to vote at all levels of standard development, whereas the IECC standard was developed with no input from the manufactured housing industry.

#### *A.1.2.1.3 Action Alternatives*

***Tiered Approach, Price Threshold***. One commenter expressed concern that the tiered approach (with more limited improvements in energy efficiency for the Tier 1 standards) could deny energy bill savings and other benefits to people who need them the most. Another commenter thought the two-tiered approach made sense but wanted DOE to take affordability into account for both tiers. An additional commenter expressed concern about a tiered approach to energy conservation standards based on retail price, because a price-based threshold for determining differences in the code is not typically used in the industry and would not necessarily be cost effective or result in lower operating costs. Noting that the retail price thresholds used to determine the Tier 2 and Tier 2 levels could easily be manipulated, they stated that some energy codes use size as a threshold.

***Household Energy Use Basis***. Two commenters argued that the energy standards should be based on total energy use per household rather than energy use per square foot of living space. They felt that larger homes should be targeted for tighter energy standards because they use more total energy.

***Zone-Specific Requirements***. One commenter felt that retaining the current three thermal zones in the Manufactured Home Construction and Safety Standards made sense, as did providing a prescriptive insulation path and a total building U-value path (with the U-value being used to assess the rate of heat loss/gain through a structure). The commenter suggested increasing the proposed zone 2 total $U_o$ to 0.076 for single-section and 0.073 for multi-section manufactured housing, with a zone 3 total $U_o$ of 0.067 for single-section and 0.064 for multi-section housing, to better align with ENERGY STAR requirements.

***Clean Energy and Circuit Upgrades***. One commenter wanted the EIS to evaluate the impacts of (1) adding photovoltaic (PV) solar power to manufactured homes, (2) upgrading circuits from 50 to 100 amps, and (3) a clean energy code that disallows gas piping for methane or propane in manufactured houses. The commenter also noted that the proposed DOE code should show a pathway to all-electric 50-amp and 100-amp manufactured homes.

***Testing and Inspection.*** Some commenters stated that the 2021 IECC contained several requirements that were costly and added little value to homeowners. For example, one commenter suggested that onsite field tests for whole house and heating, ventilation and air conditioning (HVAC) duct tightness could be replaced with visual onsite inspections and factory testing.

### A.1.2.2 Socioeconomic Impacts

This section summarizes comments within three general themes – impacts on consumers, on the manufactured housing industry, and on state and local governments. Some overlaps exist across these themes (for example, one commenter stated that applying the 2021 IECC without proper evaluation of the cost impact to home buyers would potentially penalize consumers and industry). Overlaps also exist with comments that emphasize environmental justice (see next section).

#### *A.1.2.2.1 Impacts on Consumers*

Commenters stressed that it was important for the new energy conservation standards to maintain affordability at the time of purchase and throughout the lifetime of the home. They stated that DOE should evaluate the cost effectiveness of any proposed changes to the energy conservation standards to assure they did not include unnecessary, costly requirements that would raise the purchase price but add little value to homeowners, noting the quality-of-life implications for people who would be priced out of the manufactured housing market.

One commenter stated that, particularly for the lower-income population, non-energy quality-of-life benefits such as health, safety, or comfort can be more important than energy savings and must be included in the cost-benefit analysis. Another commenter expressed the concern that owners of manufactured homes are the least economically able to afford the costs of making their homes carbon neutral. The commenter asked that DOE consider subsidies for solar panels, improved insulation, and heat pump installation tor owners of manufactured homes.

One commenter referred to a June 2021 analysis (by Home Innovation Research Labs/National Association of Home Builders [NAHB] that indicated payback periods would be excessive, unrealistic, and would not produce a net benefit over the typical ownership tenure. The commenter stated that the NAHB analysis of the impacts of the 2021 IECC on a 2,500 square foot site-built house showed a national simple payback period of 32 to 67 years. This commenter, extrapolating from NAHB 2014 data, determined that price increases associated with the 2021 IECC would exclude at least 2,750,000 households from the single-section manufactured housing market and 4,070,000 households from the double-section market. According to the commenter, the 2014 data had concluded that for every $1,000 increase in the purchase price over 300,000 people (on average) would be excluded from the manufacturing housing market.

#### *A.1.2.2.2 Impacts to the Manufactured Housing Industry*

Commenters expressed concerns about the potential impact of DOE's proposal on industry's ability to produce enough manufactured houses to meet the strong demand for affordable housing and about the effects of applying 2021 IECC standards, which were initially developed for site-build residential homes and commercial buildings, to the manufactured housing industry. They maintained that the IECC does not take into account unique construction techniques utilized by manufactured housing and could potentially lead to factory closures and loss of jobs. They stated that the new standards would affect the design, transport, and cost of manufactured houses, as well as the industry's ability to produce enough homes to meet the demand. For example, thicker IECC insulation requirements would require redesign and a review of how homes will be transported from the factory to the home site. One commenter noted that this will increase the demand for insulation, which is already a stressed commodity, and that HVAC systems may have to be redesigned to meet the new requirements.

#### *A.1.2.2.3 Impacts on State and Local Governments*

Several commenters stated that the EIS should consider the socioeconomic impacts to state and/or local governments resulting from increased costs associated with conducting, overseeing, and/or enforcing onsite IECC required testing, inspections, or verifications. Commenters further stated that if DOE requires enforcement at the local or state levels, the EIS should consider the cost associated with providing technical assistance and additional funding and staffing to states and/or localities. One commenter noted that many States remove (by State amendments) cost-prohibitive sections of the IECC before adopting it for use in their State.

Commenters gave examples of how the 2021 IECC could potentially conflict with existing building codes:

- No state has yet adopted the 2021 IECC standards. The proposed energy standards would exceed those required for site-built and industrialized (modular) houses in states that are using earlier versions of the IECC.
- Different jurisdictions in a state may have different enforcement rules for building codes.
- There are conflicts between the proposed rule and other aspects of federal law relating to manufactured housing.

### A.1.2.3 Indoor Air Quality and Human Health Impacts

Several commenters wanted the EIS to consider how the proposed energy conservation standards would affect indoor air quality which, in turn, would impact the health of manufactured housing residents. They expressed concerns about how standards that aim to increase the efficiency of the thermal envelope (create a tighter home) would affect air exchange rates and indoor pollutant levels. One commenter stated that the standards need to address building materials, with the goal of limiting exposure to off-gassing pollutants.

Commenters also wanted the EIS to consider mitigation measures, such as increasing mechanical ventilation, to assure proper air exchange. One commenter suggested consulting ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings,* for ways to mitigate the effects of decreased air exchange.

#### A.1.2.4 Environmental Justice

Some commenters expressed concern that the revised standards would result in higher purchase prices for manufactured homes, which would affect their affordability and would disproportionately exclude racial and ethnic minorities, and lower-income populations from the manufactured home market. Commenters felt this outcome would be contrary to President Biden’s Executive Memorandum of January 26, 2021, *Redressing Our Nation’s and the Federal Government's History of Discriminatory Housing Practices and Policies.*

One commenter noted that manufactured housing serves primarily lower and moderate-income consumers and constitutes the nation’s largest source of unsubsidized affordable housing. Another commenter expressed concerns about the environmental justice and socioeconomic impacts of a tiered approach, asserting that would deny energy bill savings and other benefits to people who need them the most.

Commenters' concerns also included the extent and severity of market exclusion resulting from regulatory-driven price increases; the particular impact of such exclusion on racial equity and economic justice; downstream socioeconomic impacts that would inevitably follow from such market exclusions; impacts on smaller industry businesses and the competitiveness of the manufactured housing market resulting from a contraction of the HUD Code market due to price, purchase price exclusion; and the impact of collateral purchase price increases that would result from a regulatory-driven contraction of the overall HUD Code market.

#### A.1.2.5 Climate Change

One commenter called on DOE to consider health and climate impacts from energy use and associated air pollution in a cost-effectiveness analysis in the EIS. Another asked DOE to consider applying the Social Cost of Carbon (SCC) tool developed by an interagency working group to assess the potential climate impacts of each alternative.

## A.2 DRAFT EA AND RFI

The public involvement process for the 2016 draft EA and RFI is described in Section A.2.1, and public comments submitted during the comment period are summarized by theme in Section A.2.2.

### A.2.1 Public Involvement in the Draft EA and RFI

DOE publicly announced the availability of draft EA and RFI in the Federal Register on June 30, 2016, and invited the public to submit written comments by mail (to the DOE document manager in Golden, Colorado) or by email (to RulemakingEAs@ee.doe.gov). By email, DOE also notified an extensive number of parties who had expressed interest in energy conservation standards for manufactured housing. The comment period for the EA-RFI continued from June 30 to August 15, 2016.

DOE received written comments on the draft EA from 6 organizations and 5 members of the public. The organizations are:

- California Department of Housing and Community Development
- U.S. Environmental Protection Agency, Indoor Environments Division
- Manufactured Housing Consensus Committee
- Manufactured Housing Association for Regulatory Reform
- National Association of Home Builders
- Northwest Energy Works

Of the individual public commenters, one submitted an email expressing support for the comments submitted by the California Department of Housing and Community Development but offered no comments of their own. Another person submitted a comment on total leakage testing that more directly related to the proposed rule and was forwarded to the DOE Program Office responsible for the proposed rulemaking. The other three comments were not related to the EA (these consisted of a personal resume, a business plan, and a mass email request not applicable to DOE NEPA).

Meanwhile, three organizations separately provided comments on the 2016 proposed rule that included context for the NEPA review:

- Arkansas Manufactured Housing Association
- North Carolina Justice Center
- The George Washington University

These inputs are included in the comment synthesis in Section A.2.

### A.2.2 COMMENTS ON THE DRAFT EA AND RFI ORGANIZED BY THEME

Comments received on the EA-RFI, plus input on the proposed rule relevant to the scope of the EA, are organized by theme in the following sections. The four main themes are: (1) proposed action and alternatives, (2) socioeconomic impacts, (3) indoor air quality and human health impacts, and (4) environmental justice.

### A.2.2.1 Proposed Action and Alternatives

#### *A.2.2.1.1 Proposed Action*

One organization endorsed DOE's adoption of strong, enforceable rules that result in significant improvements to building quality, energy conservation, and energy efficiency of manufactured homes and in turn lower energy bills; create safer and healthier living spaces; and lower harmful environmental impacts.

One organization objected to DOE's standards development process claiming that the proposed rule was developed without adequate data on potential impacts to indoor air quality and health for manufactured housing residents and related cost implications. The organization stated that DOE should withdraw its proposal and restart the process as originally directed by the Office of Management and Budget (OMB) Office of Information and Regulatory Affairs (OIRA) in 2011.

#### *A.2.2.1.2 No-Action Alternative*

One organization stated that the existing HUD Code was carefully balanced, having considered thermal envelope requirements and the potential negative impacts on indoor air quality and health of manufactured housing residents (while DOE's proposal fell short in this regard).

#### *A.2.2.1.3 Action Alternative*

*(Different from the current DOE proposal, the 2016 proposal to establish energy conservation standards for manufactured housing did not include any requirements for air sealing of the thermal envelope.)*

***Ventilation.*** One organization recommended that DOE use the mechanical ventilation rates referenced in the 2015 IECC[6] for manufactured housing, for consistency with the most widely adopted mechanical ventilation requirements in the United States. The organization recommended that DOE adopt whole-house mechanical ventilation language per the 2015 IECC and otherwise keep current HUD Code ventilation requirements as they are.

Another organization argued that unnecessarily high ventilation rates consume more energy in all climates and contribute to difficulties in controlling indoor moisture levels in humid climates. It maintained that there is no health science- or medical-based evidence supporting the need for higher ventilation rates for improved occupant health outcomes in residential buildings, and that whole house filtration of respirable particles appears to be more important than air exchange for dilution of air contaminants.

An additional organization pointed out that current HUD standards successfully balance tighter thermal envelope standards with the concerns related to air exchange and condensation within the

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[6] 2015 IECC Section 403.6, which references the 2015 International Residential Code except for the fan efficacy requirements given in the IECC Table R403.6.1.

home living space. A third organization commented that ASHRAE Standard 62.2-2016, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings* is the industry standard for ventilation in residential buildings.

***Glazing.*** One organization stated the EA should discuss the proposed limit on glazing fenestration, which may further reduce openable areas for ventilation purposes. Another organization recommended removing the requirement for a maximum glazing area of 12 percent of the floor area, pointing out that there is no glazing area restriction in the 2015 IECC [See draft EA Table 2, 460.102(b)(7)].

***Insulation.*** One organization noted that the requirement for ceiling insulation to have a uniform thickness or density would not generally be possible and recommended eliminating the requirement. (See draft EA Table 2, 460.103(b)(3).) It also recommended removing the requirement that required floor insulation to be installed with the underside of the floor decking. This requirement had been removed for the 2015 IECC and would be difficult to accomplish in a factory [See draft EA Table 2, 460.103(b)(4)]. Another organization commented that the draft EA had not discussed the potential cumulative impacts of requiring more insulation that may contain formaldehyde or other volatile organic chemicals.

***Testing Costs.*** One commenter opposed onsite “leakage to outside” or “net leakage” tests of completed homes because it would increase the costs of the testing procedure and make it harder to correct any detected faults. The commenter noted that a total duct leakage test protocol in the plants can produce a tight duct system in the field and asked DOE to allow for total leakage testing of each home section that contains a trunk duct (in section 460.201 of the proposed rule).

### A.2.2.2 Socioeconomic Impacts

#### *A.2.2.2.1 Impacts on Consumers*

One organization asked for more information about how increases in the retail cost of manufactured homes associated with implementing the updated standards would affect the ability of low-income and minority populations to afford a down payment or qualify for home financing. Information was also requested on whether sections of the 2015 IECC code proposed for adoption for manufactured homes are adopted for site-built U.S. residential structures, which are usually owned by those in higher income brackets.

Considering formaldehyde standards that were being developed by EPA at that time, one organization pointed out that the EA lacked (1) a timeframe in which noncompliant composite wood products would be prohibited from installation and (2) a discussion of potential cumulative impacts from required use of increased quantities of insulation that might add formaldehyde or other volatile organic compounds.

Another organization maintained that based on more recent industry production growth rates and shipment data, and potential underestimates of retail costs by DOE, both DOE’s projected loss in production of over 40,000 homes over a 30-year period (based on 2014 shipment data and an elasticity factor of -0.48) and HUD’s projected loss of over 200,000 homes (elasticity factor of -2.40) appear to underestimate future losses in production and availably of manufactured houses.

This organization also asked for the retail cost impact analysis to reflect the past industry projected retail cost markup factor of 2.30 rather than the factor of 1.67 used by DOE.

Information was also requested on potential increases in purchase price based on current data, including any changes resulting from public input on the proposed project, and socioeconomic impact on affordability for potential low-income and minority populations. (See the environmental justice theme for related comments.)

One organization stated any regulation change that results in price increases for manufactured homes, even modest increases, will likely result in pricing many potential consumers out of homeownership.

##### *A.2.2.2.2 Impacts on Industry*

In addition to the preceding comment regarding production loss reflected in the consumer impacts section, another organization thought the EA should discuss the impacts of the proposed rule on small manufacturers who may not be able to compete with large manufacturers who are able to purchase material in large volume at discounted rates.

As noted in the comment synthesis related to alternatives, one organization stated that DOE did not conduct a valid cost-benefit analysis as required under the cost-benefit provision of EISA Section 413 (and thus, they felt the proposed rule should be withdrawn and the process restarted).

#### A.2.2.3 Indoor Air Quality and Human Health Impacts

Several organizations noted that measures designed to increase the tightness of the thermal envelope would negatively impact indoor air quality by reducing natural air infiltration, with no proposed increase in mechanical ventilation. One organization stated that implementation of these measures should be deferred pending further study.

One organization stated that the EA should discuss whether the increase in air pollutants generated by building occupants' activities and building materials could have significant adverse health effects, and whether the potential reduction in indoor air quality would be a significant, mitigatable, or unmitigated environmental impact as related to indoor air quality. In addition, the organization asked that the EA discuss measures, such as increased ventilation requirements, to mitigate the impacts of reduced air exchange.

Another organization agreed with DOE's assessment that specific data and consensus standards for occupant exposure levels in residential buildings are lacking. It stated that absent accurate and unbiased field data there is no health-science or medical-based evidence supporting any need for higher ventilation rates for improved occupant health outcomes in residential buildings.

A different organization recommended that DOE consider Indoor airPLUS specifications and EPA's guidance on *Healthy Indoor Environmental Protocols for Home Energy Upgrades* to ensure good indoor air quality when developing new requirements for energy-efficient manufactured housing. Considering that a substantial portion of risk from exposure to some pollutants comes from indoor exposures, and that many of those exposures occur in homes, the organization offered several examples of scientific studies of indoor pollutants in residential settings. This organization also cautioned that if proper consideration were not given to indoor air quality, then energy retrofit activities for homes might negatively affect indoor air quality.

#### A.2.2.4 Environmental Justice

One commenter stated that the proposed standards would overwhelmingly affect low-income households and elderly households, and they called on DOE to take special care to evaluate the distributive impacts of its rule and any potential regressive effects. They stated that DOE may be overestimating the benefits of its proposal by disregarding resale market obstacles that prevent manufactured housing owners from recouping higher upfront costs from increased efficiency.

The commenter further stated that these obstacles greatly reduce the lifetime to manufactured homes for some occupants and suggest that a significant portion of the purchasers of single-section and multi-section manufactured homes will bear net costs instead of benefits. They also stated that many of those who bear net costs are low-income households who are likely borrowing at higher rates to finance the purchase of their manufactured home.

## A.3 SNOPR and NODA

This section summarizes public comments on the SNOPR and the NODA that helps inform the NEPA review. These comments were submitted during the SNOPR and NODA comment periods, which extended from August 26 through November 26, 2021.

Comments received on the SNOPR and NODA are organized by theme in the following sections. The four main themes are (1) implementation of standards; (2) the basis for the standards, (3) structure of standards, and (4) efficiency requirements.

### A.3.1 Implementation of the Standards

Several commenters suggested that the standards should be implemented by HUD and not DOE. Further, some recommended that the avenue to update standards is by amending the HUD code to include new energy efficiency standards for manufactured homes. Finally, other commenters suggested that the standards process is more appropriate to modify through submissions to the Manufactured Housing Consensus Committee for possible revisions rather than a separate agency implementing a totally new standard.

### A.3.2 Basis for the Standards

Multiple stakeholders provided alternate recommendations to the SNOPR primary tiered proposal, including: (1) a single-tier standard based on the 2021 IECC standard; (2) a standard based on previous iterations of the IECC; (3) a standard based on the current HUD code; (4) a standard based on the Tier 1 SNOPR proposal; and (5) no change compared to the current HUD code. Further, stakeholders commented that the 2021 IECC is not appropriate to be used in updating standards as the 2021 IECC was not developed or intended for manufactured housing. Finally, a couple of commenters suggested evaluating ASHRAE Standard 90.2-2018 in place of the 2021 IECC.

### A.3.3 Structure of the Standards

Regarding the tiered proposal, multiple stakeholders suggested that basing the tiers on manufacturer's retail list price is not appropriate and the retail price threshold may be discriminatory for low-income purchasers. Therefore, stakeholders suggested that if DOE wants to finalize a tiered approach, to base the tiers on the following alternatives: (1) actual sales price of the home to the ultimate customer; (2) manufactured home size (single-section or multi-section; square footage); and (3) a significantly increased retail list price threshold, closer to $110,000 to $111,000. Some stakeholders also suggested that the threshold be location based.

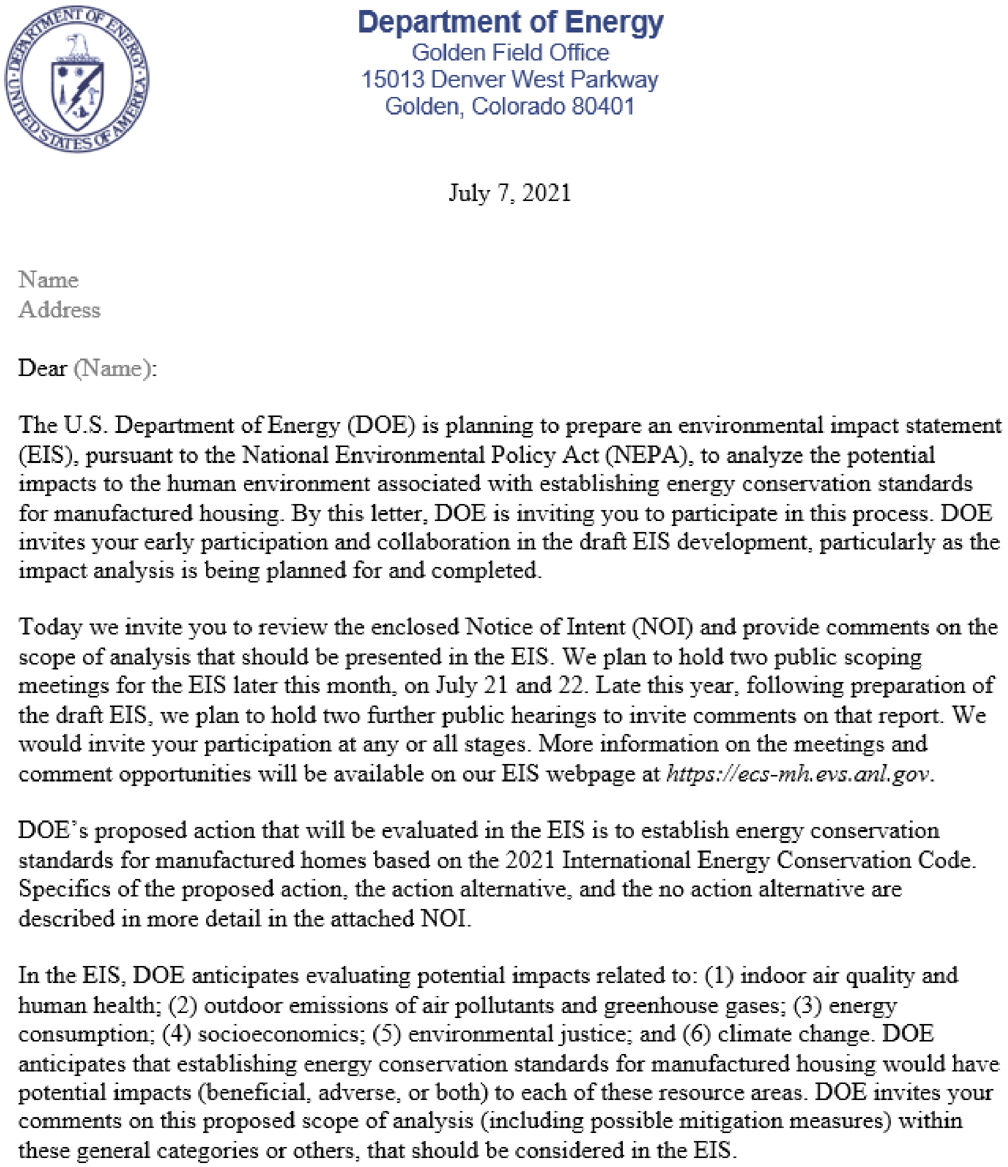
### A.3.4 Efficiency Requirements

Numerous stakeholders stated that the proposed efficiency requirements, specifically for the Tier 2 standards, are not cost-effective because the increased costs will never be recouped by the homeowner and therefore would eliminate a significant source of affordable housing. Further, at least one stakeholder suggested that certain homebuyers will no longer be able to buy a manufactured home because of the impact of increased mortgage payments on debt-to-income ratios. Accordingly, at least one stakeholder suggested that the best first step would be to improve the minimum standards currently in place that are workable in the current market environment, and then continue to evaluate additional improvements to the standards over time. Another stakeholder, on the other hand, suggested that the incremental costs for energy-efficiency upgrades do not price out manufactured housing homebuyers or residents.

As such, several stakeholders suggested relaxed efficiency requirements for both Tier 1 and Tier 2 standards. Most stakeholders strongly recommended relaxing efficiency requirements for Tier 2 standards specifically because of the increased costs, including recommended lower performance requirements (lower Uo requirements) and/or removing the requirement for continuous wall insulation for climate zones 2 and 3. Several commenters suggested that they would not be able to satisfy the proposed Tier 2 requirements using current home construction options available. Further, several stakeholders suggested that increased insulation could require truss and joist redesigns and could cause the demand for fiberglass insulation to overwhelm a market that is already under substantial stress from the current insulation shortage.

On the other hand, at least one stakeholder suggested that more than half of manufactured homes in the northwest are built with a $U_o$ equal to Tier 2. Furthermore, certain stakeholders recommended that DOE increase the maximum window SHGC for Tier 2 standard to 0.25 for climate zone 1. In addition, several stakeholders recommended that DOE consider requirements more stringent than those proposed in the SNOPR and requirements beyond the manufactured home thermal envelope requirements. These recommended additional efficiency requirements including efficient heating and cooling equipment, water heating, appliances, lighting, and consideration of the 2021 IECC optional packages provided in Section R408 of the 2021 IECC. Further, one stakeholder recommended that if DOE keeps Tier 1 standards, to set it at least 20 to 25 percent more stringent than the proposed requirement, including a recommendation to increase the floor insulation requirement for climate zone 2 to be consistent with climate zones 1 and 3.

# ATTACHMENT 1: TRIBAL COORDINATION AND SCOPING NOTICE LETTER



**Department of Energy**
Golden Field Office
15013 Denver West Parkway
Golden, Colorado 80401

July 7, 2021

Name
Address

Dear (Name):

The U.S. Department of Energy (DOE) is planning to prepare an environmental impact statement (EIS), pursuant to the National Environmental Policy Act (NEPA), to analyze the potential impacts to the human environment associated with establishing energy conservation standards for manufactured housing. By this letter, DOE is inviting you to participate in this process. DOE invites your early participation and collaboration in the draft EIS development, particularly as the impact analysis is being planned for and completed.

Today we invite you to review the enclosed Notice of Intent (NOI) and provide comments on the scope of analysis that should be presented in the EIS. We plan to hold two public scoping meetings for the EIS later this month, on July 21 and 22. Late this year, following preparation of the draft EIS, we plan to hold two further public hearings to invite comments on that report. We would invite your participation at any or all stages. More information on the meetings and comment opportunities will be available on our EIS webpage at *https://ecs-mh.evs.anl.gov*.

DOE's proposed action that will be evaluated in the EIS is to establish energy conservation standards for manufactured homes based on the 2021 International Energy Conservation Code. Specifics of the proposed action, the action alternative, and the no action alternative are described in more detail in the attached NOI.

In the EIS, DOE anticipates evaluating potential impacts related to: (1) indoor air quality and human health; (2) outdoor emissions of air pollutants and greenhouse gases; (3) energy consumption; (4) socioeconomics; (5) environmental justice; and (6) climate change. DOE anticipates that establishing energy conservation standards for manufactured housing would have potential impacts (beneficial, adverse, or both) to each of these resource areas. DOE invites your comments on this proposed scope of analysis (including possible mitigation measures) within these general categories or others, that should be considered in the EIS.

# ATTACHMENT 2: EMAIL NOTIFICATION TO NEPA STAKEHOLDERS

Subject: Notice of Intent to Prepare an Environmental Impact Statement (DOE/EIS-0550)

**The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) is preparing an environmental impact statement (EIS) for proposed energy conservation standards for manufactured housing. The Notice of Intent (NOI), as published in the Federal Register on July 7, 2021, is attached to this email.**

The Energy Independence and Security Act of 2007 (EISA) directs DOE to establish energy conservation standards for manufactured housing based on the most recent version of the International Energy Conservation Code (IECC). EERE is currently planning to issue a Supplemental Notice of Proposed Rulemaking (SNOPR) (on or before August 16, 2021) for publication in the *Federal Register* that will propose energy conservation standards for manufactured housing based on the 2021 IECC.

DOE will be proposing energy efficiency standards for manufactured homes that relate to the building thermal envelope; air sealing; installation of insulation; duct sealing; HVAC; service hot water systems; mechanical ventilation fan efficacy; and heating and cooling equipment sizing. DOE is also considering an action alternative that uses a tiered approach to address affordability and cost-effectiveness concerns with respect to energy cost savings and the cost of efficiency improvements relative to the retail price of manufactured housing.

DOE will prepare an environmental impact statement (DOE/EIS-0550) to evaluate the potential impacts to the human environment associated with this proposed action (energy conservation standards for manufactured housing) and alternatives, including a no action alternative. DOE anticipates evaluating potential impacts related to: (1) indoor air quality and human health; (2) outdoor emissions of air pollutants and greenhouse gases; (3) energy consumption; (4) socioeconomics; (5) environmental justice; and (6) climate change.

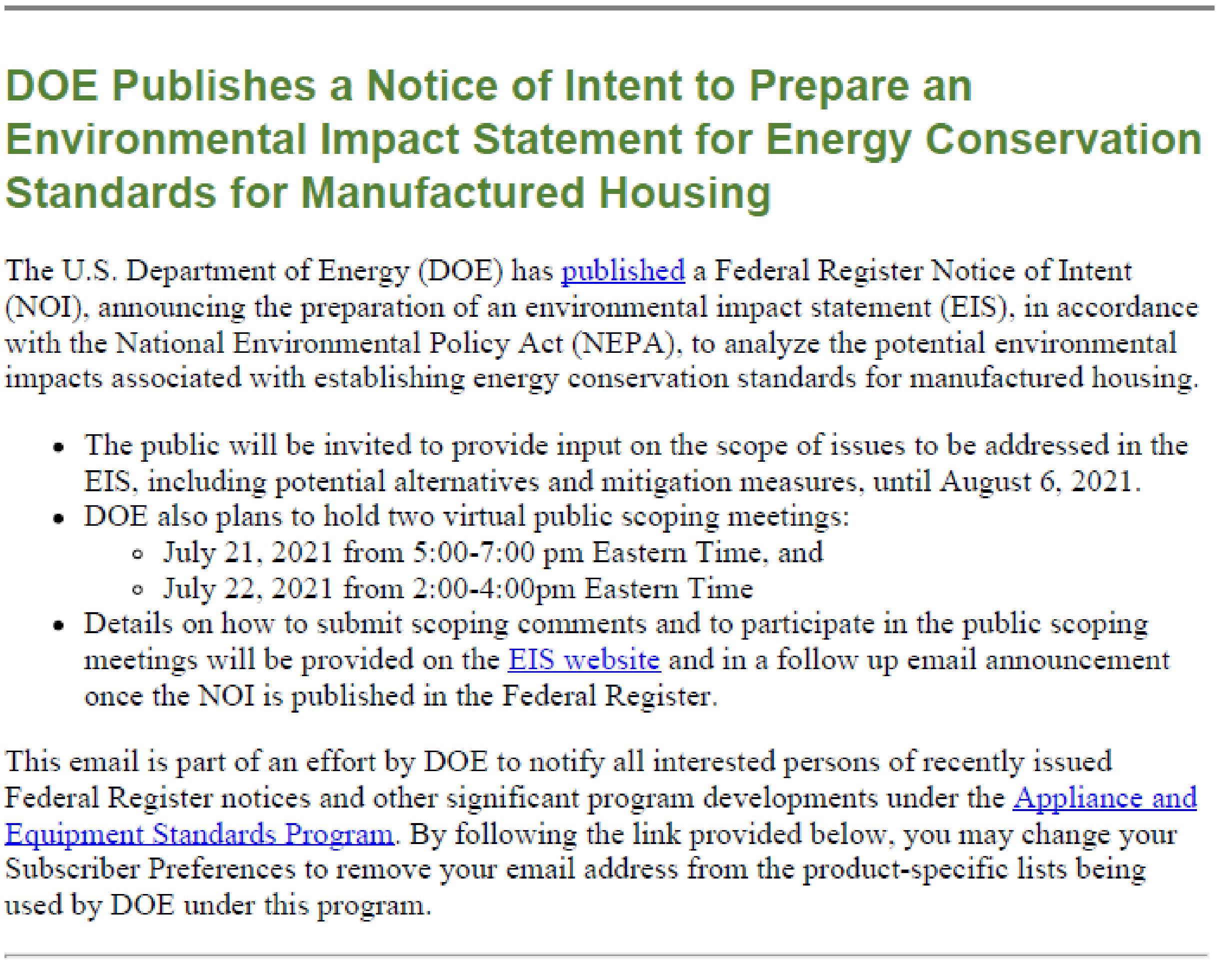
**The public scoping period** for the EIS started with the publication of the attached Notice of Intent in the *Federal Register*. DOE is seeking input from stakeholders on the appropriate scope of the EIS, including potential areas of impact, reasonable action alternatives, and mitigation measures. In defining the scope of the EIS, DOE will consider all scoping comments received or postmarked by August 6, 2021.

**Written comments** may be submitted online, through the EIS webpage at: *https://ecs-mh.evs.anl.gov,* or by mail at: NEPA Document Manager, U.S. Department of Energy – Golden Field Office, 15013 Denver West Parkway, Golden, CO 80401. **Oral comments** will be accepted by DOE during two virtual public scoping meetings: (1) Wednesday, July 21, 2021 at 5:00 p.m. – 7:00 p.m. Eastern Time and (2) Thursday July 22, 2021 at 2:00 p.m. – 4:00 p.m. Eastern Time. Details on how to participate in the virtual public meetings will be posted on the EIS webpage at: *https://ecs-mh.evs.anl.gov*.

**For additional information** on the scoping meetings and/or the EIS process, contact the DOE via email at: *DOE_EIS_MANUFACTURED_HOUSING@ee.doe.gov* or via mail at: NEPA Document Manager, U.S. Department of Energy – Golden Field Office, 15013 Denver West Parkway, Golden, CO 80401. For general information on DOE's NEPA review process, contact Brian Costner, Director, Office of NEPA Policy and Compliance, GC–54, U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585–0119, email *AskNEPA@hq.doe.gov*, telephone (202) 586-4600 or (800) 472-2756.

The attached NOI, the draft EIS, and other documents, as they are available, will be posted on the EIS webpage: *https://ecs-mh.evs.anl.gov*.

# ATTACHMENT 3:
# EMAIL NOTIFICATION TO APPLIANCE STANDARDS RULEMAKING STAKEHOLDERS



## DOE Publishes a Notice of Intent to Prepare an Environmental Impact Statement for Energy Conservation Standards for Manufactured Housing

The U.S. Department of Energy (DOE) has published a Federal Register Notice of Intent (NOI), announcing the preparation of an environmental impact statement (EIS), in accordance with the National Environmental Policy Act (NEPA), to analyze the potential environmental impacts associated with establishing energy conservation standards for manufactured housing.

- The public will be invited to provide input on the scope of issues to be addressed in the EIS, including potential alternatives and mitigation measures, until August 6, 2021.
- DOE also plans to hold two virtual public scoping meetings:
  - July 21, 2021 from 5:00-7:00 pm Eastern Time, and
  - July 22, 2021 from 2:00-4:00pm Eastern Time
- Details on how to submit scoping comments and to participate in the public scoping meetings will be provided on the EIS website and in a follow up email announcement once the NOI is published in the Federal Register.

This email is part of an effort by DOE to notify all interested persons of recently issued Federal Register notices and other significant program developments under the Appliance and Equipment Standards Program. By following the link provided below, you may change your Subscriber Preferences to remove your email address from the product-specific lists being used by DOE under this program.

# APPENDIX B:

# ASSESSMENT METHODS AND SUPPORTING DETAILS

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## B.1 INTRODUCTION

This appendix summarizes the assessment methods underlying the analyses of environmental consequences in this draft environmental impact statement (EIS).

As described in Chapter 1, in accordance with the Energy Independence and Security Act (EISA), the U.S. Department of Energy (DOE) proposes to establish energy conservation standards for manufactured housing (MH) that are based on the 2021 International Energy Conservation Code (IECC). DOE's dual purpose for the proposed action is to satisfy its EISA obligations and to help achieve the following national goals:

- Reduce national energy consumption;
- Reduce energy costs for owners of manufactured homes;
- Reduce emissions of outdoor pollutants associated with electricity production;
- Reduce emissions of greenhouse gases associated with electricity production that may lead to climate change; and
- Protect public health and safety related to energy efficiency.

## B.2 ENVIRONMENTAL RESOURCE AREAS

### B.2.1 Energy Resources

All detailed methodologies and data are available in the supplemental notice of proposed rulemaking (SNOPR), its technical support document (TSD), and the notice of data availability (NODA) (DOE 2021a, 2021b, 2021c).

### B.2.2 Air Quality, Meteorology, and Climate Change

#### B.2.2.1 Description of Affected Resource

#### *B.2.2.1.1 Meteorology and Climate Change*

This section provides a brief overview of meteorology for the six illustrative locations that illustrate different climate, ambient air quality, socioeconomic, and environmental justice conditions and also represent various conditions regarding the presence of manufactured housing. Next, the general features and modeled future conditions of climate change are presented.

*Meteorology.* Meteorology influences ambient air quality, which can affect indoor air quality. Meteorological variables include temperature, wind speed, wind direction, relative humidity, and precipitation, including snowfall. Summary meteorological data spanning a period of at least 30 years from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NCEI) collected at the six airports representing the study locations are summarized in Table B-1 (NCEI 2021). The data for temperature, relative humidity, precipitation, and snowfall in this table are based on climate normals, which are defined as 30-

year averages (1991 through 2020). The data for mean wind speed are from 1984 through 2020, and those for prevailing wind direction span 45 to 52 years, beginning in 1969 to 1976 and extending through 2020.

**TABLE B-1 Overview of Meteorological Data for Illustrative Locations**[a]

| **Location** | **Climate Zone** | **Temperature** *(°F)* | | | **Relative Humidity** *(%)* | **Mean Wind Speed** *(mph)* | **Prevailing Wind Direction** | **Precipitation** *(in.)* | **Snowfall** *(in.)* |
|---|---|---|---|---|---|---|---|---|---|
| | | **Daily Min** | **Daily Max** | **Mean** | | | | | |
| Chicago, IL | 3 | 40.7 | 59.0 | 49.8 | 71, 60-81 | 9.9 | W | 36.89 | 36.3 |
| Fresno, CA | 2 | 51.9 | 76.7 | 64.3 | 61, 41-79 | 6.0 | NW | 11.50 | 0.0 |
| Houston, TX | 1 | 60.0 | 79.7 | 69.8 | 75, 60-90 | 7.5 | S | 49.77 | 0.1 |
| Memphis, TN | 2 | 53.6 | 72.4 | 63.0 | 67, 58-80 | 8.0 | SSW | 53.68 | 3.8 |
| Miami, FL | 1 | 70.0 | 84.3 | 77.2 | 73, 61-83 | 8.4 | ESE | 61.90 | 0.0 |
| Phoenix, AZ | 2 | 63.4 | 86.6 | 75.0 | 36, 23-49 | 6.1 | ESE | 8.03 | 0.0 |

[a] The locations span all three climate zones identified in DOE's proposed rule. As described in Chapter 2, these climate zones are the same as those in the U.S. Department of Housing and Urban Development (HUD) Code. All data are based on 1991 through 2020 climate normals, except mean wind speed (1984 through 2020) and prevailing wind direction (1969/1976 through 2020); these data are summarized from NCEI (2021). For relative humidity, the first value is the climate normal (1991-2020), and the second values are lower and higher values averaged at four measurements per day, which typically occur in morning and afternoon, respectively.

Chicago is in climate zone 3, in a region with frequent weather changes. Although partly moderated by Lake Michigan, the climate is predominantly continental and ranges from relatively warm in the summer to relatively cold in the winter. The annual average temperature is about 50°F, with an average daily minimum of nearly 41°F and maximum of 59°F. The average wind speed is almost 10 mph, with a relatively weak prevailing wind direction from the west. Precipitation falls mostly from air that passes over the Gulf of Mexico and is relatively higher during warm months. In winter, lake-effect snow is sometimes locally heavy when colder air moves from the north with a long trajectory over Lake Michigan and along the Chicago lakeshore. Annual precipitation averages about 37 inches (in.), with an annual average snowfall of about 3 feet (ft).

Fresno is in zone 2, with a semi-arid climate characterized by dry, mild winters and hot summers. The annual average temperature is about 64°F, with an average daily minimum of about 52°F and maximum of almost 77°F. The average wind speed is about 6 mph. Winds flow with the major axis of the San Joaquin Valley, generally from the northwest, except southeast during the winter. Nearly 90 percent of the annual precipitation of 11.5 in. falls from November to April, and any rainfall during the summer is usually very light. It rarely snows in Fresno.

Memphis is also in zone 2 and has a humid subtropical climate with four distinct seasons. Extremely high or low temperatures are relatively rare. The summer months are persistently hot and humid due to moisture encroaching from the Gulf of Mexico. The annual average temperature is 63°F, with an average daily minimum of nearly 54°F and maximum of about 72°F. The average wind speed is about 8 mph, mostly blowing from the south and southwest, except during

September when it comes from northeast. Rainfall is relatively frequent because of humid air from the Gulf of Mexico colliding with colder air from the north. Annual precipitation averages just under 54 in. and is fairly well distributed, although it is relatively higher in winter and spring and relatively lower in summer and fall. The average annual snowfall is just under 4 in., and it occurs from December through March.

Phoenix is located in both the Salt River Valley and the Sonoran Desert, in zone 2. It has a desert climate with low annual rainfall, low relative humidity, very hot summers, and mild winters. The annual average temperature is 75°F, with an average daily minimum of about 63°F and maximum of nearly 87°F. The valley is characterized by light winds at an average wind speed of about 6 mph; prevailing winds blow from the east except during May through July when they blow from the west. The annual precipitation is about 8 in. and falls throughout the year, with the highest monthly average being around 1 in. High winds associated with thunderstorms that occur periodically in the summer occasionally generate dust storms (called "haboob") that can move long distances across the deserts. Light snowfall without accumulation has been infrequently observed.

Houston is in zone 1 and has a predominantly marine climate. Temperatures are moderated by the influence of winds from the Gulf, producing mild winters. The annual average temperature is almost 70°F, with an average daily minimum of 60°F and maximum of about 80°F. The average wind speed is about 7.5 mph, with prevailing winds from the south and southeast, except during November to January when they blow from the north with the frequent passages of high-pressure areas bringing in polar air. Another effect of the proximity to the Gulf of Mexico is abundant rainfall. Annual precipitation averages nearly 50 in. and is relatively evenly distributed. Extended dry periods are rare in Houston, as is snow. Although destructive windstorms are fairly infrequent, both thundersqualls and tropical storms occasionally pass through the area.

Also, in zone 1, Miami's climate is essentially subtropical marine, with long, warm summers marked by abundant rainfall followed by a mild, dry winter. The annual average temperature is about 77°F, with an average daily minimum of 70°F and maximum of about 84°F. The average wind speed is about 8.4 mph, and it blows from the east or southeast about half the time. Due to the marine influence from the east, the annual average precipitation is nearly 62 in., with higher rainfall in warmer months and lower in colder months. Although it rarely snows in Miami, hurricanes occasionally affect the area, most frequently in September and October.

*Climate Change*. Climate is defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities, such as temperature, precipitation, and wind, over a period of time ranging from months to thousands or millions of years. Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the objective of the Intergovernmental Panel on Climate Change (IPCC) is to provide governments at all levels with scientific information that they can use to develop climate policies. According to the IPCC Fifth Assessment Report (IPCC Report), climate change is consistent with observed changes to the world's natural systems (IPCC 2014).[1] The recently released sixth IPCC report reiterates the findings of the fifth report, with growing concerns about increasing greenhouse gas (GHG) emissions and climate change impacts.[2]

Climate changes in the United States and across the globe are projected to increase over the next several decades unless concerted measures are taken to reverse this trend. Climate-related changes include rising temperatures and sea levels; increased frequency and intensity of extreme weather (e.g., heavy downpours, floods, and droughts); frequent wildfires; earlier snowmelts; and reduced snow cover, glaciers, permafrost, and sea ice. The "greenhouse effect" is a natural phenomenon occurring when GHGs absorb much of the long-wave thermal radiation emitted by the land and ocean and reradiate it back to earth, keeping the atmosphere warmer than it otherwise would be. Without the greenhouse effect, the earth would not be warm enough to support life.

However, if the greenhouse effect becomes stronger due to increases in GHG emissions, the earth's average temperature will rise, resulting in global warming, which is only one aspect of climate change. Since the onset of the industrial revolution in the mid-1700s, human activities have contributed to the production of GHGs, primarily through the combustion of fossil fuels (such as coal, oil, and natural gas) and deforestation. The principal GHGs that enter the atmosphere because of human activities include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), and fluorinated gases (F-gases), such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$). Some GHGs such as $CO_2$, $CH_4$, and $N_2O$ are emitted to the atmosphere through natural processes, whereas F-gases are created and are present in the atmosphere exclusively due to human activities.

The global average combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 (0.65–1.06)°C from 1880 to 2012 (IPCC 2014). Additionally, the IPCC report found that most of the temperature increase since the mid-20th century was very likely caused by the increase in anthropogenic concentrations of $CO_2$ and other GHGs such as $CH_4$ and $N_2O$ in the atmosphere, rather than from natural causes. Global surface temperature was projected to rise over the 21st century under all assessed emission scenarios[3] (IPCC 2014). Future climate depends on committed warming caused by both past and future anthropogenic emissions along with natural climate variability. The global mean surface temperature change for the period 20162035 relative to 1986–2005 is similar for the four representative concentration pathways (RCPs) assessed and will likely be in the range 0.3 to 0.7°C, assuming no major volcanic eruptions or changes in some natural sources (e.g., $CH_4$ and $N_2O$), or unexpected changes in total solar

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[1] Although the Working Group I study, *The Physical Science Basis*, of the IPCC Sixth Assessment Report (AR6) was published in 2021, all other reports will be published in 2022.

[2] IPCC Sixth Assessment Report; Working Group1 report, Climate Change 2021: The Physical Science Basis. https://www.ipcc.ch/assessment-report/ar6/, accessed January 8, 2022.

[3] Anthropogenic GHG emissions are mainly driven by population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy. The representative concentration pathways (RCPs), which are used for making projections based on these factors, describe four different 21st-century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions, and land use. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario with very high GHG emissions (RCP8.5), considered as a worst-case scenario. Scenarios without additional efforts to constrain emissions ("baseline scenarios") lead to pathways ranging between RCP6.0 and RCP8.5. RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.

irradiance. By the mid-21st century (2046–2065), the magnitude of the projected climate change would be substantially affected by the choice of emissions scenarios, ranging from 1.0 (0.4 to 1.6)°C for RCP2.6 to 2.0 (1.4 to 2.6)°C for RCP8.5, relative to the 1986–2005 period.

It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean surface temperature increases. It is very likely that heat waves will occur with a higher frequency and longer duration. Occasional cold winter extremes will continue to occur (IPCC 2014). In the United States, changes in projected annual average temperature between the mid-century (2036–2065) and the near-present (1976-2005) under RCP4.5 and RCP8.5 are in the range of 3.4–4.2°F (1.9–2.3°C) and 4.3-5.3°F (2.4–2.9°C), respectively, by region (USGCRP 2017). These U.S. values are somewhat higher than global temperatures because the former are only for the continental United States while the latter are for land and sea combined. These projected warming and associated precipitation pattern changes in the future could trigger changes in energy use, air quality, and frequency and magnitude of wildfires, which can significantly affect efforts in balancing between energy conservation and indoor air quality for manufactured homes.

The annual average temperature has increased by 1.2°F over the contiguous United States for 1986-2016 relative to 1901–1960, and by 1.8°F relative to the beginning of the last century (USGCRP 2018). Monitoring data indicate accelerated warming from 1979 to 2016, notably in the western half of the country and least in the Southeast, as shown Figure B-1. Over the next few decades, annual average temperatures are projected to increase by about 2.2°F relative to 1986-2015, regardless of the future scenario. Much larger increases are projected by late century, 2.3-6.7°F under a lower scenario (RCP4.5) and 5.4–11.0°F under a higher scenario (RCP8.5) relative to 1986–2015.

Since 1901, annual average precipitation has increased by 4 percent across the entire United States, with strong regional differences that range from increases over the Northeast, Midwest, and Great Plains and decreases over parts of the Southwest and Southeast (Figure B-2), consistent with the human-induced expansion of the tropics (USGCRP 2018). In the late 21st century, the greatest precipitation changes are projected to occur in winter and spring, with similar geographic patterns: increases across the northern Great Plains, Midwest, and Northeast, and decreases in the Southwest and Texas. Surface soil moisture over most of the United States is likely to decrease, accompanied by large declines in snowpack in the western United States and shifts to more winter precipitation falling as rain rather than snow, which is conducive to more wildfires.

Climate change can impact air quality and, conversely, air quality can impact climate change, mutually compounding their effects. In general, daily ozone concentrations and temperature are nonlinearly related, that is, there is no dependence on temperature below 70–80°F, but strong dependence on temperature above 90°F (NRC 1991). Thus, global warming with increasing frequency of heat waves and the northward migration of storm tracks associated with climate change have the potential to increase ground-level ozone in many regions, which may present challenges for compliance with ozone standards in the future (EPA 2021a). The impact of climate change on particulate matter (PM), is less certain, and research is ongoing to address these uncertainties.

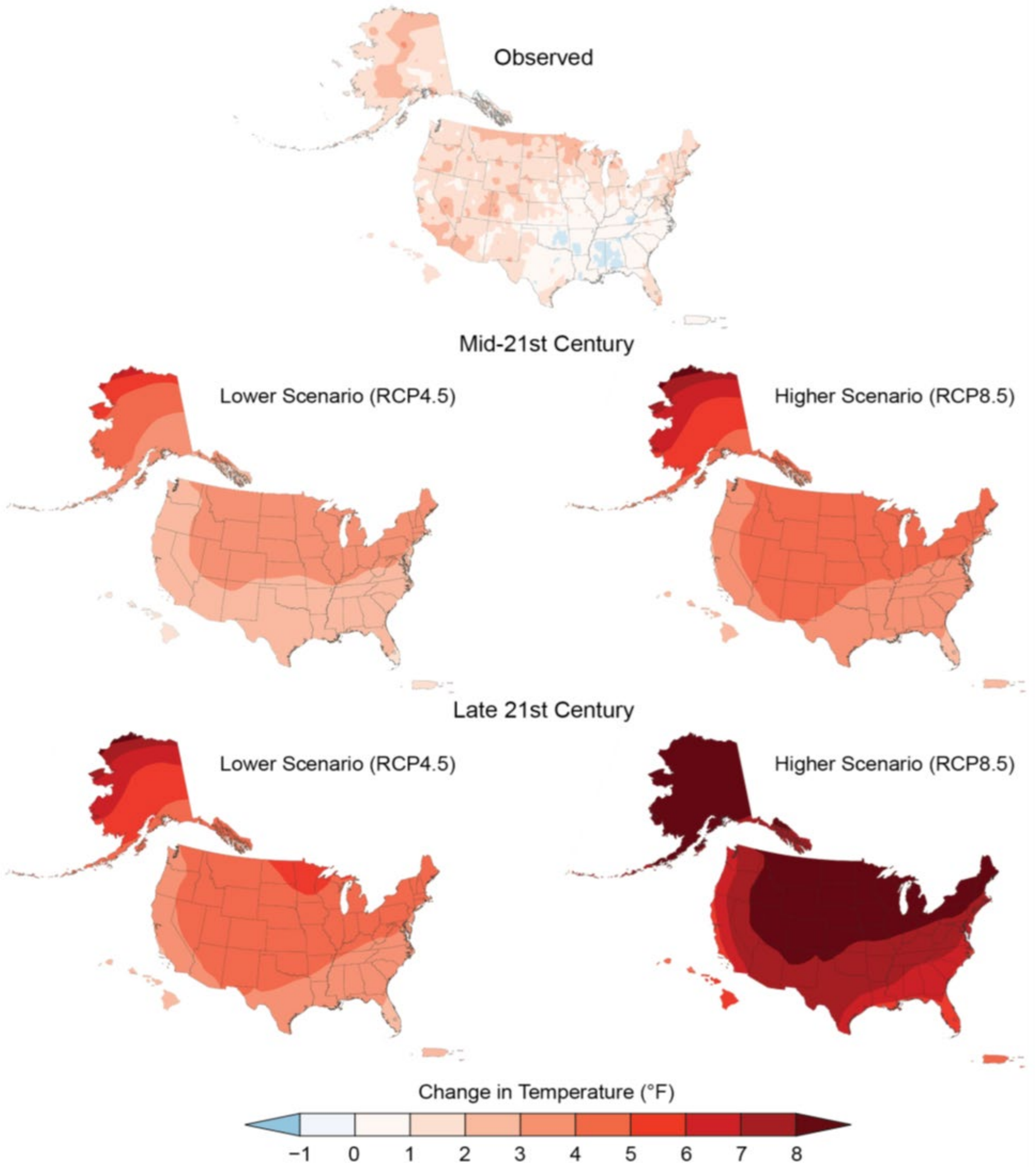


**FIGURE B-1 Observed and Projected Changes in Annual Average Temperature under a Very High Emissions Scenario (RCP8.5, right) as Compared to an Intermediate Emissions Scenario (RCP4.5, left)** ***(Source: USGCRP 2018).***

Notes: This figure compares (top) observed changes for 1986-2016 (relative to 1901-1960 for the contiguous United States and 1925-1960 for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands), with projected differences in annual average temperature for mid-century (2036-2065, middle) and end of-century (2070–2099, bottom) relative to the near-present (1986-2015).

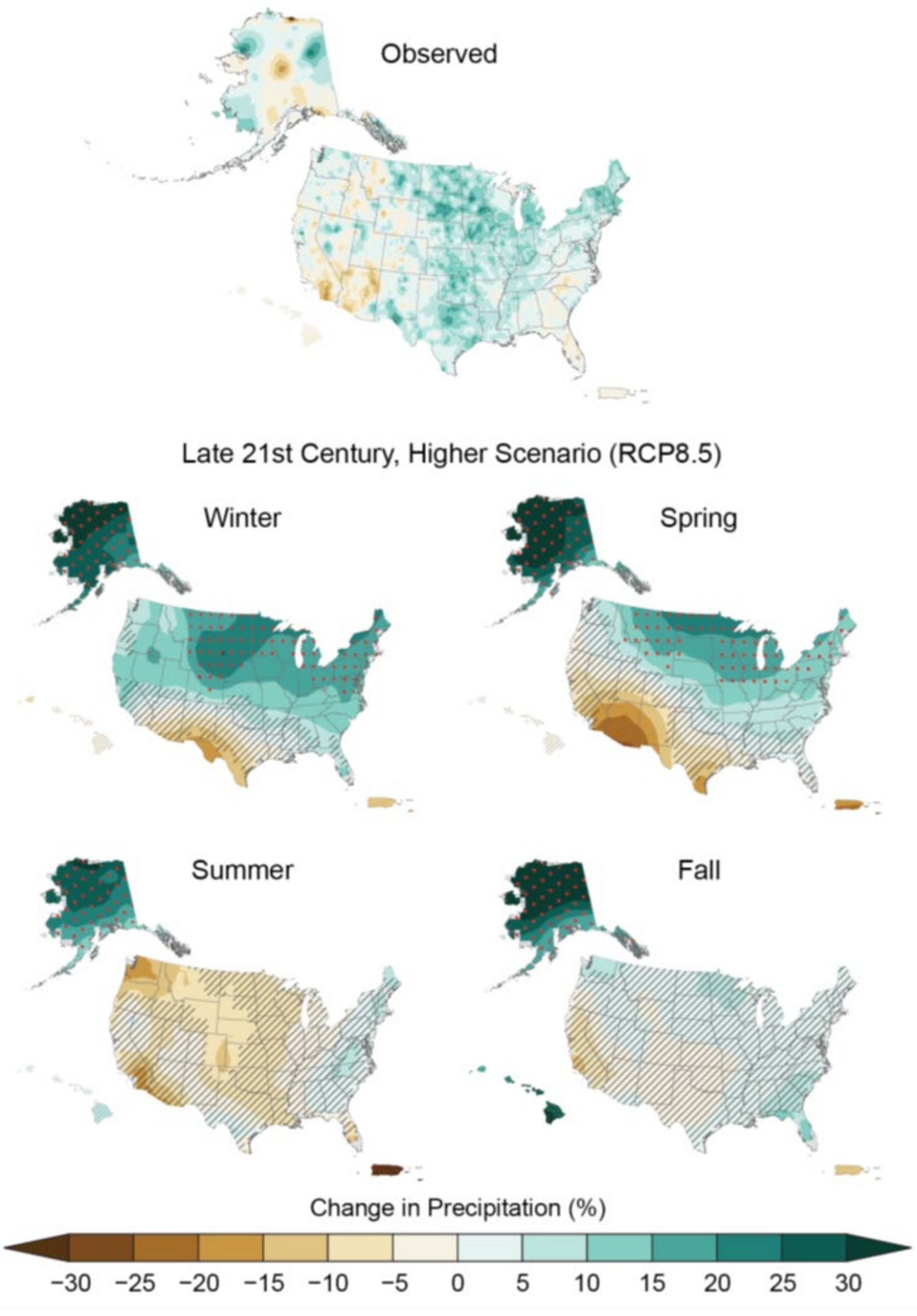


**FIGURE B-2 Observed and Projected Changes in Seasonal Precipitation under a Very High Emissions Scenario (RCP8.5)** *(Source: USGCRP 2018).*
*Notes: This figure compares (top) observed changes for 1986-2015 (relative to 1901-1960 for the contiguous United States and 1925-1960 for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands), with projected differences in precipitation for end-of-century (2070-2099, middle and bottom) relative to the near-present (1986-2015).*

Emissions of air pollutants can influence changes to the climate. Ozone in the atmosphere warms the climate, whereas PM can have either warming or cooling effects on the climate. For example, black carbon, a particulate pollutant from combustion, contributes to the warming of the Earth, whereas particulate sulfates cool the earth's atmosphere (EPA 2021a).

Also associated with global warming is the frequency of large wildfires, fire duration, and fire season length, which have increased substantially in the western United States in recent decades. Continued increases are projected, especially in the Southwest (USGCRP 2018). This effect primarily results from earlier spring snowmelt and warmer temperatures that increase evaporation rates, thus reducing the moisture availability and drying out the vegetation that provides the fuel for fires. The increasing temperatures, increasing frequency of heat waves, and northward migration of storm tracks due to climate change are expected to contribute to accelerating the reactions that form key pollutants, notably ground-level ozone pollution and secondary PM. In addition, it is very likely that rising temperature and earlier spring snowmelt will result in lengthening the wildfire season in portions of the country, leading to an increased frequency of wildfires and associated smoke, mostly $PM_{2.5}$. Thus, climate change is anticipated to adversely impact indoor air quality.

#### *B.2.2.1.2 Indoor Air Quality*

***Building Thermal Envelope Requirements in SNOPR.*** Tables B-2 and B-3 show the prescriptive requirements for the building thermal envelope proposed for Tiers 1 and 2 of Alternative A1. Tables B-4 and B-5 show the performance requirements for the building thermal envelope proposed for Tiers 1 and 2 of Alternative A1. (The figures corresponding to these tables are in Section 2, Figures 2-2 through 2-5.)

**TABLE B-2 Prescriptive Requirements for Thermal Envelope: Tier 1**

| **Climate Zone** | **R-value** *(thermal resistance)* | | | **U-factor** *(thermal transmittance)* | | | **Glazed Fenestration SHGC** |
|---|---|---|---|---|---|---|---|
| | **Exterior Wall Insulation** | **Exterior Ceiling Insulation** | **Exterior Floor Insulation** | **Window** | **Skylight** | **Door** | |
| 1 | 13 | 22 | 22 | 1.08 | 0.75 | 0.40 | 0.7 |
| 2 | 13 | 22 | 19 | 0.5 | 0.55 | 0.40 | 0.6 |
| 3 | 19 | 22 | 22 | 0.35 | 0.55 | 0.40 | *Not applicable* |

**TABLE B-3 Prescriptive Requirements for Thermal Envelope: Tier 2**

| **Climate Zone** | **R-value** *(thermal resistance)* | | | **U-factor** *(thermal transmittance)* | | | **Glazed Fenestration SHGC** |
|---|---|---|---|---|---|---|---|
| | **Exterior Wall Insulation** | **Exterior Ceiling Insulation** | **Exterior Floor Insulation** | **Window** | **Skylight** | **Door** | |
| 1 | 13 | 30 | 13 | 0.32 | 0.75 | 0.40 | 0.33 |
| 2 | 20+5 | 30 | 19 | 0.30 | 0.55 | 0.40 | 0.25 |
| 3 | 20+5 | 38 | 30 | 0.30 | 0.55 | 0.40 | *Not applicable* |

**TABLE B-4 Performance Requirements for Thermal Envelope: Tier 1**

| Climate Zone | $U_o$ *(overall thermal transmittance)* | |
|---|---|---|
| | **Single Section** | **Multi Section** |
| 1 | 0.110 | 0.109 |
| 2 | 0.091 | 0.087 |
| 3 | 0.074 | 0.072 |

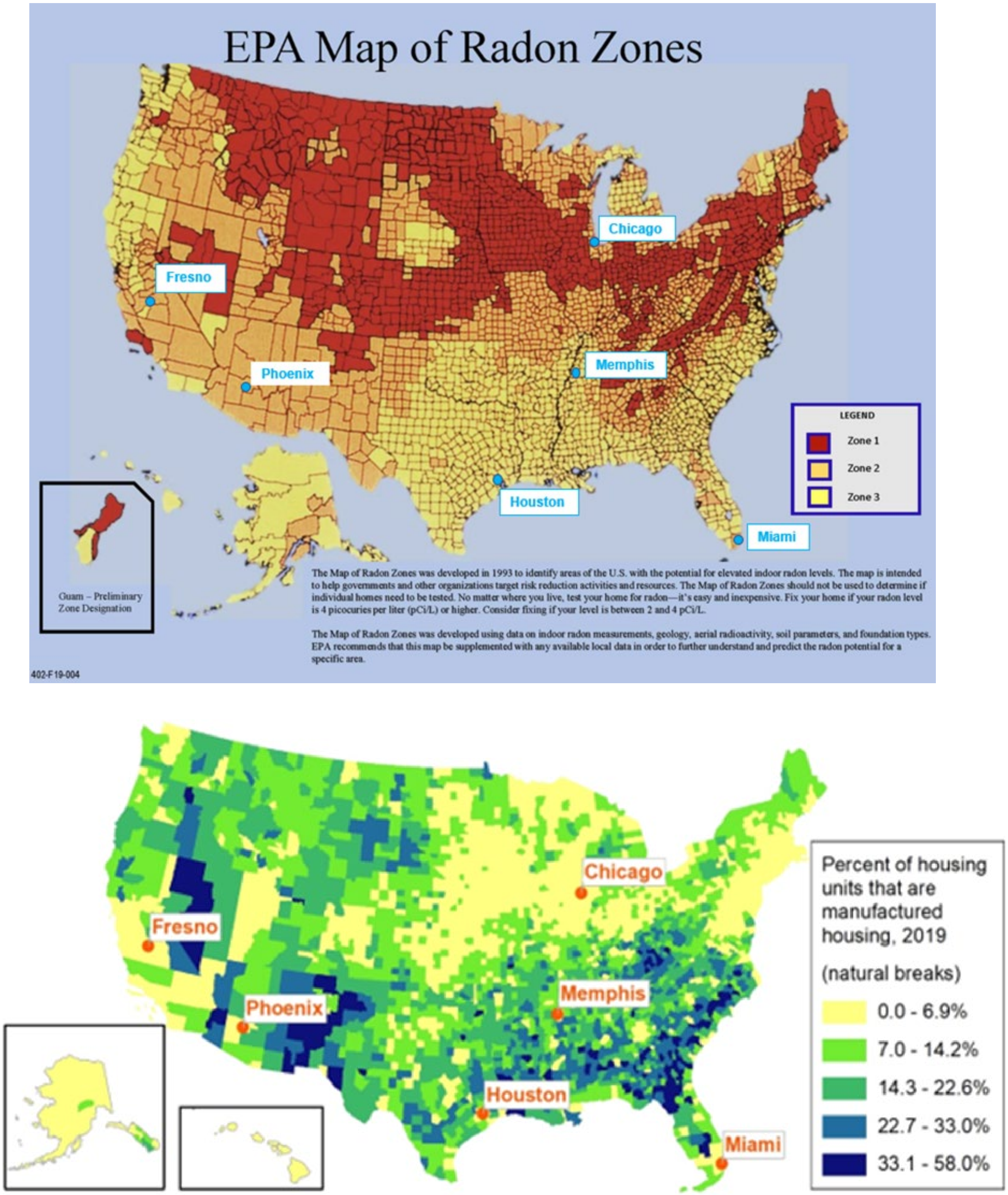
**TABLE B-5 Performance Requirements for Thermal Envelope: Tier 2**

| Climate Zone | $U_o$ *(overall thermal transmittance)* | |
|---|---|---|
| | **Single Section** | **Multi Section** |
| 1 | 0.086 | 0.082 |
| 2 | 0.062 | 0.063 |
| 3 | 0.053 | 0.052 |

*Radon.* Average radon levels vary substantially from home to home depending on underlying geology and soil permeability, foundation type (e.g., basement, crawl space, concrete slab), housing type (e.g., free-standing houses, apartments, multi-story homes), construction materials (e.g., tiles, countertops), year of construction (e.g., older homes have more cracks in flooring and foundation), seasonality and heating/cooling systems (e.g., basements have lower pressure due to heating in winter and higher pressure due to air conditioning in summer), and occupant behaviors that influence building dynamics (e.g., opening windows). A recent Canadian study indicated that radon levels have steadily risen in North American homes (Stanley et al. 2019). For most manufactured homes, the absence of a connected foundation tends to reduce radon issues. For those homes with a basement, the basement construction is governed by local building codes that have radon provisions, especially in areas of high radon concentration.

A nationwide study of indoor air quality in homes treated under the Weatherization Assistance Program found substantially lower radon concentrations in manufactured homes compared to site-built homes (Pigg et al. 2014, 2018). The pre-weatherization mean and geometric mean (GM) radon levels for MH were 0.7 and 0.5 pCi/L, respectively, and the comparable values for site-built homes were 2.3 and 1.3 pCi/L, respectively. The study also reported a decrease of 0.3 pCi/L in radon concentrations among the manufactured homes post-weatherization. One plausible explanation for this decrease in radon levels post-weatherization is an overall reduction in radon-bearing soil gas entering into the home as a result of air sealing. Another explanation could be that the net increase in ventilation resulting from the addition of mechanical ventilation (MV) led to more dilution and a decrease in radon concentrations.

To help national, state, and local organizations target their resources and implement radon-resistant building codes, the U.S. Environmental Agency (EPA) identified three radon zones across the United States to indicate the potential for elevated levels, based on indoor radon measurements, geology, aerial radioactivity, soil parameters, and foundation types, as shown in Figure B-3. Radon zones 1 through 3 delineate counties with predicted average indoor radon screening levels above 4 pCi/L, from 2–4 pCi/L, and below 2 pCi/L, respectively. EPA recommends that homes be outfitted with mitigation if the indoor radon level is at or above 4 pCi/L (EPA 2021b). Note that the average indoor and outdoor radon concentrations in U.S. homes are about 0.4 and 1.3 pCi/L, respectively.



The Map of Radon Zones was developed in 1993 to identify areas of the U.S. with the potential for elevated indoor radon levels. The map is intended to help governments and other organizations target risk reduction activities and resources. The Map of Radon Zones should not be used to determine if individual homes need to be tested. No matter where you live, test your home for radon—it's easy and inexpensive. Fix your home if your radon level is 4 picocuries per liter (pCi/L) or higher. Consider fixing if your level is between 2 and 4 pCi/L.

The Map of Radon Zones was developed using data on indoor radon measurements, geology, aerial radioactivity, soil parameters, and foundation types. EPA recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential for a specific area.

**FIGURE B-3 Radon Zones 1–3 and Manufactured Homes by County as a Percent of All Occupied Housing Units** ***(Source: EPA 2021b)***

***Study Pollutants and Role of Air Exchange Rate***. The potential impacts of the proposed action and alternatives on residential indoor air pollutant exposures in manufactured housing are evaluated in this EIS through four pollutants that often exceed health-based target concentrations in homes (Logue et al. 2011) and are also among the top causes of potential adverse health effects from residential exposures to indoor air (Logue et al. 2012). These four study pollutants represent the main types of air pollutant sources and also the variability in deposition loss rates.

Formaldehyde is the simplest, as it is dominated by continuous emissions from indoor materials and is thus directly reduced with increasing air exchange. Acrolein is emitted both by materials and also by heating of oils during cooking; it is thus mitigated both by the whole-house ventilation and kitchen exhaust ventilation equipment that are required in the U.S. Department of Housing and Urban Development (HUD) Code.

$PM_{2.5}$ and nitrogen dioxide ($NO_2$) enter with outdoor air and have deposition rates that are as high or higher than air exchange rates. This means that a change to their entry rate with outdoor air will impact the ratio of their indoor-to-outdoor concentration when there are no indoor sources. They are also both introduced substantially by cooking, and thus substantially mitigated by the use of kitchen exhaust ventilation. $PM_{2.5}$ is also emitted through miscellaneous indoor activities that can occur at any time throughout the day, an emission pattern that is directly impacted by outdoor air exchange, i.e., by infiltration and the use of the whole house mechanical ventilation.

An analysis was conducted to evaluate examples of each of these types of pollutants, focusing on contaminants known to be present at concentrations exceeding health-based exposure levels relevant to residential exposures. This analysis considered two pollutants that have substantial indoor loss mechanisms (PM and $NO_2$) and two that do not (formaldehyde and acrolein). The analysis excludes contaminants from sources that are already widely known to be harmful and related to lifestyle choices (such as tobacco smoking); highly unusual sources, such as those associated with home businesses; those that are widely understood to require special controls, such as interior saunas; and semivolatile chemicals, which are not substantially impacted by the relatively small changes in infiltration air exchange that would result from the proposed action or alternatives. The impact of air sealing on pets is not discussed; pets are widely recognized as sources of odors and dander that require active management via intentional ventilation and cleaning.

For $NO_2$, there are substantial differences across sites that derive from the outdoor pollutant levels (see Table B-6). Within each study location, there are relatively small variations in the average and 95th percentile daily $NO_2$ for each airtightness level evaluated in the indoor air quality (IAQ) assessment. The conditions that provide higher air exchange rates (AERs) generally have higher indoor $NO_2$, but the variations are not proportional, as explained in Singer et al. (2020). Similar context is presented in Table B-7 for $PM_{2.5}$.

**TABLE B-6 Statistics of Daily Average $NO_2$ (ppb) Used in Simulations to Determine IAQ Impacts.** ***Note: Data obtained from regulatory ambient air quality monitoring sites.***

| Area | Mean | Median | 75th Percentile | 90th Percentile | 95th Percentile | 98th Percentile |
|---|---|---|---|---|---|---|
| Chicago | 13.32 | 12.47 | 15.65 | 18.05 | 19.30 | 20.83 |
| Fresno | 8.26 | 7.39 | 11.11 | 12.68 | 13.36 | 14.24 |
| Houston | 5.56 | 5.33 | 6.70 | 8.02 | 8.73 | 9.46 |

**TABLE B-7 Statistics of Daily Average $PM_{2.5}$ (µg/$m^3$) Used in Simulations to Determine IAQ Impacts.** ***Note: Data obtained from regulatory ambient air quality monitoring sites.***

| Area | Mean | Median | 75th Percentile | 90th Percentile | 95th Percentile | 98th Percentile |
|---|---|---|---|---|---|---|
| Chicago | 9.03 | 8.85 | 10.21 | 11.68 | 13.22 | 14.18 |
| Fresno | 10.99 | 9.91 | 13.61 | 17.12 | 19.14 | 22.90 |
| Houston | 8.43 | 8.22 | 9.37 | 10.63 | 11.95 | 13.20 |

To answer the question, *Why do indoor concentrations of $NO_2$ not vary proportionally to AER?* – the first reason is that the ratio of indoor to outdoor for outdoor pollutants (called the infiltration factor) is impacted non-proportionally to AER, because it depends on the following equation, where the deposition rate for $NO_2$ is estimated to be 0.75/h:

Infiltration Factor = AER/(AER + deposition rate)

The second reason is that outdoor $NO_2$ varies over time, and there are differences between sites in how outdoor $NO_2$ varies with air exchange. In particular, $NO_2$ is lower in Chicago during the high AERs when windows are open than during the times when windows are closed. A HUD Code home with exhaust ventilation operating continuously but no other intentional ventilation would have an average AER of 0.47/h in Fresno and 0.51/h in Houston.

A home meeting the minimum air tightness requirements of DOE's proposed standards and ventilated continuously with an exhaust fan would have an average air exchange rate of 0.32/h in Fresno and 0.35/h in Houston. When protection from outdoor air is desired (e.g., from intense wildfires or high ozone days), the ability to achieve lower air exchange is desired. The average AER for a home with no intentional ventilation ("-MN" scenarios) would be 0.37/h for Fresno or 0.41/h for Houston. With minimally compliant proposed air sealing, homes in those two areas would have AERs of 0.21/h or 0.25/h, providing much better protection from outdoor pollutants. An example summary of air exchange rates across the three study locations under different mechanical ventilation approaches is presented in Table B-8.

**TABLE B-8 Air Exchange Rates Estimated for a 1568-ft$^2$ Manufactured Home Having Air Tightness Minimally Compliant with Current HUD-Code or DOE Proposed Standards**

| Type and Operation of Mechanical Ventilation | HUD Code | | | DOE Proposed Standards | | |
|---|---|---|---|---|---|---|
| | Chicago | Fresno | Houston | Chicago | Fresno | Houston |
| By central fan integral system only when heating/cooling | 0.52 | 0.37 | 0.41 | 0.32 | 0.21 | 0.25 |
| By central fan integral system operating all hours | 0.80 | 0.72 | 0.69 | 0.50 | 0.42 | 0.43 |
| By continuous exhaust fan | 0.61 | 0.47 | 0.51 | 0.42 | 0.33 | 0.35 |

Modeled concentrations of $NO_2$ and $PM_{2.5}$ from cooking under varied equipment and ventilation assumptions are illustrated in Figures B-4 and B-5, respectively.

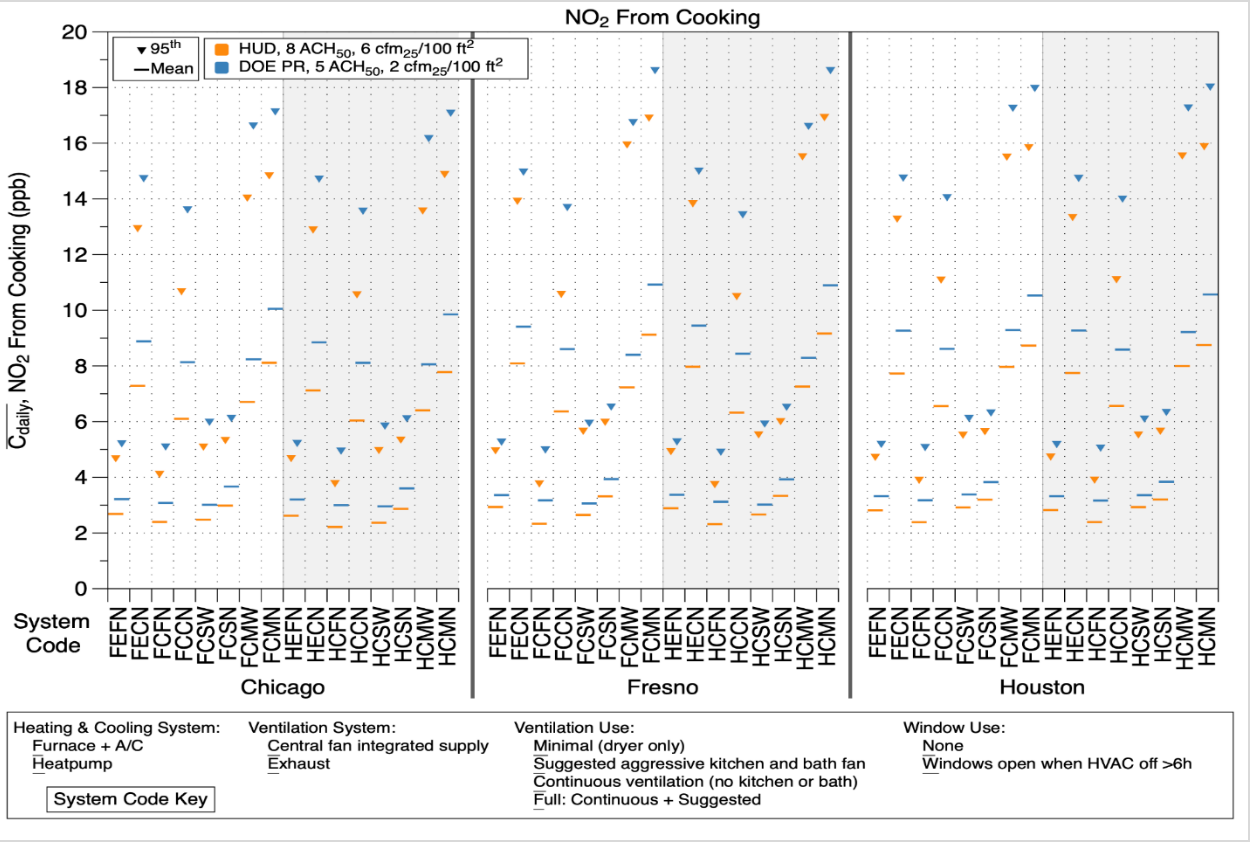


**FIGURE B-4 Modeled Daily Mean $NO_2$ from Frequent Cooking with Gas Burners in a 1568-ft$^2$ Home Meeting HUD Code or DOE Proposed Standards with Varied Equipment and Ventilation**

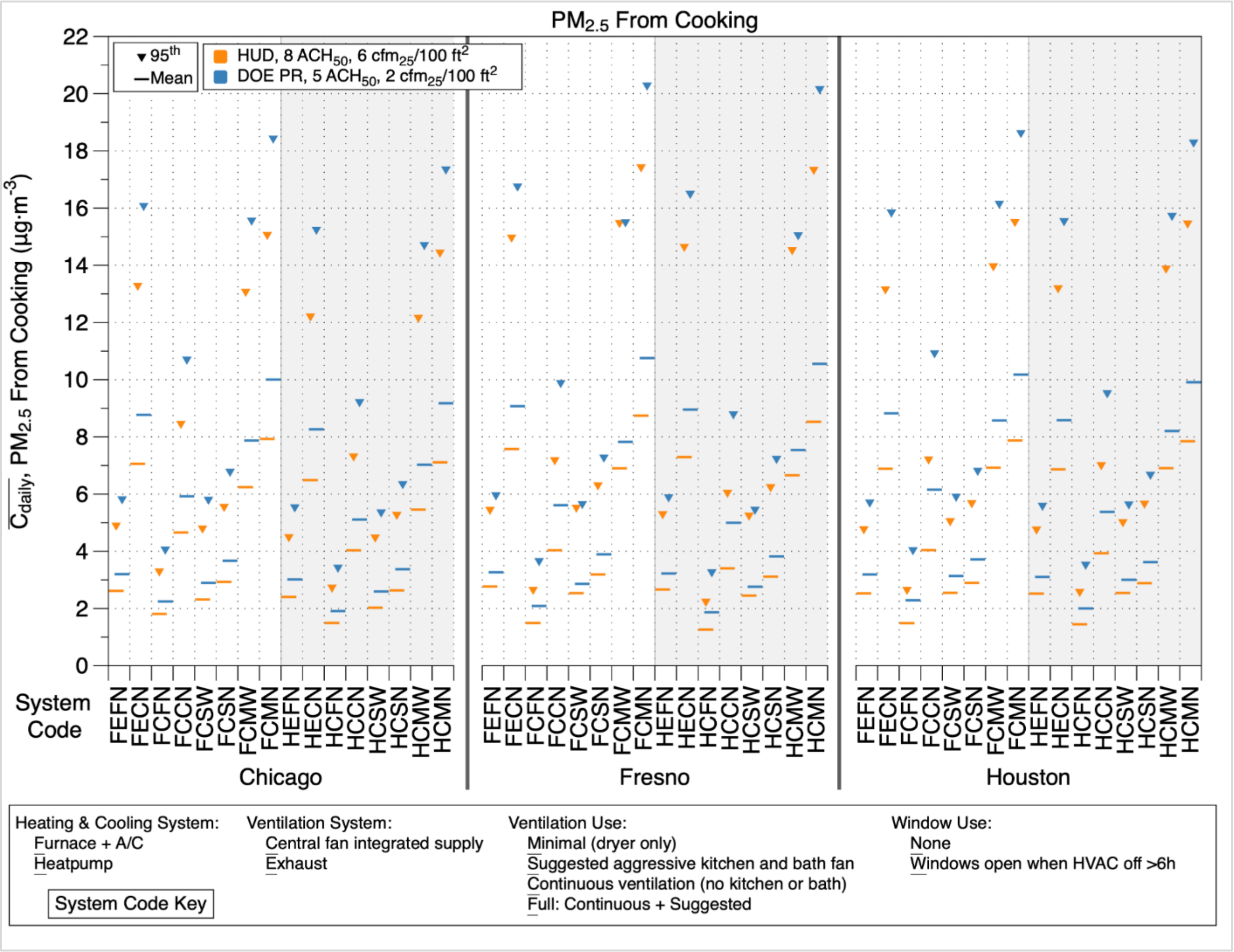


**FIGURE B-5 Modeled Daily Mean PM$_{2.5}$ from Frequent Cooking in a 1568-ft$^2$ Home Meeting HUD Code or DOE Proposed Standards with Varied Equipment and Ventilation**

### B.2.2.2 Resource Characteristics and Impact Assessment Methods

#### *B.2.2.2.1 Social Cost of Greenhouse Gas Emissions*

The social cost of greenhouse gas emissions represents the monetary value of the net harm to society associated with a marginal increase in emissions of these pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services (OMB 2021).

### B.2.2.3 Sources and Types of Data

Table B-9 presents summary information about studies used to assess indoor pollutant concentrations for manufactured housing.

## TABLE B-9 Summary of Studies Used to Assess Indoor Pollutant Concentrations for Manufactured Housing

| Study | Study Description and Locations | Description of Sample Homes | Measurement Information |
|---|---|---|---|
| Doll, 2016 | Study of weatherization with pre/post measurements in 69 homes, 13 controls.<br>Three (3) sites with varied climate in North Carolina: Wilmington (warm-humid coastal), Raleigh (warm-mixed central), Boone (cool-humid mountain).<br>138 samples (69 pre/post): 37 had smoking.<br>54-home subsample; 36 in heating season, 18 in cooling season. Data collected 2012–2015. | 69 homes statistics: median (5th–95th)<br>Area (ft$^2$): 1064 (672–1606);<br>Air-tightness (ach50): 9 (6–25);<br>54-home subsample (Table 1):<br>27 site-built, 27 manufactured; 51 with crawl space; 45 forced air; 19 with combustion appliances; 14 with smokers; 24 with pets; 24 single, 20 with 2 occupants, 10 with >2 occupants | 5–6 days per pre/post sample<br>$PM_{2.5}$ by GrayWolf / Lighthouse Real-Time Particle Meter.<br>Also sampled $NO_2$ and formaldehyde but not reporting since most homes had no combustion appliances and homes were old. |

## TABLE B-9 Summary of Studies Used to Assess Indoor Pollutant Concentrations for Manufactured Housing (Cont.)

| Study | Study Description and Locations | Description of Sample Homes | Measurement Information |
|---|---|---|---|
| Health Canada, cities | Sampling campaigns in 5 cities; each during summer and winter to measure volatile organic compounds (VOCs) in homes from the general population, 2005–2010. | Aimed to collect a sample broadly representative of population; details provided in reports for each campaign. | 24h integrated samples collected using canisters, with analysis by gas chromatography/mass spectrometry (GC/MS). |
| Kang, 2022 | Study of impacts of ventilation system type on indoor air quality and health of adult subjects with asthma. 40 homes completed 4 quarterly sampling periods before and four after a ventilation system (exhaust, supply, balanced energy recovery ventilator [ERV]) was installed. Data collected 2019–2020. | Statistics: median (10th–90th)<br>Area (ft$^2$): 2378 (1345–3229)<br>Air-tightness (ach50): 10.5 (6.0–17.3)<br>Year: 1923 (1913–1931)<br>Occupants: 3.0 (1.0–5.1) | Particles from 0.3–10 um in 6 size channels with MetOne GT-526. $PM_{2.5}$ calculated from particle counts and calibration adjusted to filter samples. |
| Logue, 2014 | Simulations of $NO_2$ resulting from use of gas cooktop and oven for 6634 Southern California homes that provided data to the 2003 Residential Appliance Saturation Survey (RASS). | The RASS survey sample was weighted to reflect the population of Southern California. | Simulations used measured $NO_2$ emission rates (measured ca. 2008), air exchange rates, and deposition rates from prior literature. |
| Singer et al. | Study of ventilation and IAQ in new California homes with | Statistics: median (10th–90th)<br>Area (ft$^2$): 2615 (1571–3649) | ~1 week of sampling;<br>HCHO by UMEx passive; |

| | | | |
|---|---|---|---|
| 2020 (Zhao, et al. 2021) | gas cooking and code-required MV. Participants asked to keep windows closed. Selected for formaldehyde because homes were built with materials complying with federal standard. Zhao et al. (2021) presents results for PM$_{2.5}$ and NO$_2$ in homes that cooked; all had gas cooking. Data collected 2016–2018. | Air-tightness (ach50): 4.4 (3.6–6.0) | NO$_2$ by Ogawa;<br>PM$_{2.5}$ by MetOne ES-642 photometer |

## TABLE B-9 Summary of Studies Used to Assess Indoor Pollutant Concentrations for Manufactured Housing (Cont.)

| Study | Study Description and Locations | Description of Sample Homes | Measurement Information |
|---|---|---|---|
| Williams, 2003; Wallace, 2006 | Study of PM exposure of 29 low socioeconomic status (SES), age >50y, African Americans with controlled hypertension (Raleigh, North Carolina); 8 subjects age >50y with implanted defibrillators (Chapel Hill, North Carolina). Recruited for non-smokers; but 6 reported some smoking. Data collected 2000–2001. | Statistics: mean (range)<br>Floor area (ft$^2$): 1345 (721–2454)<br>70% central air conditioning (AC). 76% electric ranges | Filter-based PM$_{2.5}$ samples each day for up to 1 week in 4 seasons; 831 d of data; study percentiles for averages calculated for each home. |
| Wallace, 2003 | Study of particle exposures in 294 homes with asthmatic children living in inner-city, low-income census tracts in 7 cities (Boston, Bronx, Chicago, Dallas, Manhattan, Seattle, and Tucson). 101 homes with at least one smoker. Data collection: August 1998 through August 2001. | No data on sizes/ages of homes. 49% apartments.<br>Self-reports: % of homes and mean amount:<br>29% used AC (13h/d); 36% used high-efficiency particulate absorbing (HEPA) air cleaner (19h/d); 78% kept at least one window open (12 h/d); 34% with smoker (9 cigs/d); 6% used stove to heat home (6 h/d); 29% burned candles and 15% incense (35 h and 4 h over 2 weeks). | At least 14 d of measurements in each home using Thermo pDR-1000 integrating nephelometer zeroed and calibrated to PM$_{2.5}$ filter samples for outdoor air. |
| Weisel et al., 2005 | Study aimed to understand the impacts of outdoor and residential indoor air exposures to total exposure for PM$_{2.5}$ and components and a suite of VOCs. Data collected 1999–2001: 105 in Los Angeles, 106 homes in Houston and 95 homes in Elizabeth, New Jersey. PM samples from 60% of homes. | PM$_{2.5}$ collected in 60% of homes. Statistics provided only for the full sample. See Weisel et al. (2005) for details. | Samples collected over 48 h. PM$_{2.5}$ mass from filter-based samples. |

| | | | |
|---|---|---|---|
| Zhao et al. 2021 | Study of IAQ in 23 low-income apartments with gas cooking and California code-required mechanical ventilation; built or renovated 2013–2016.<br>Selection criteria was cooking with gas burners on most days.<br>Data collected in 2019. | Statistics: median (10th–90th)<br>Area (ft$^2$): 915 (377–1141)<br>Air-tightness (ach50): 8.6 (2.0–14.3) | ~1 week samples;<br>Integrated $NO_2$ by Ogawa;<br>$PM_{2.5}$ by TSI DustTrak-II-8530 or Thermo pDR-1500 photometer and filters. |

**TABLE B-9 Summary of Studies Used to Assess Indoor Pollutant Concentrations for Manufactured Housing (Cont.)**

| Study | Study Description and Locations | Description of Sample Homes | Measurement Information |
|---|---|---|---|
| Zhu, 2013 | Nationally representative sample for Canada.<br>3218 houses, 546 apartments, 93 other (hotel lodging house, camp, mobile home).<br>Data collected 2009–2010. | Sample weighted to reflect national housing stock by type (house/apt), age, smoking status. | 7-day passive sample on Carbopack B sorbent, analysis by thermal desorption, GC/MS detection. |

***Additional Notes on Study Selection***. For $PM_{2.5}$, the most significant factor is whether there are smokers or no smokers. The collection includes several studies that sampled both in homes with smokers and with no smokers, enabling direct comparisons. A seminal paper in this literature was Wallace et al. (2003), which reported a mean increment of about 37 μg/m$^3$ based on 101 homes with smokers and 193 homes without smokers. The studies reported in Williams et al. 2003 (Wallace et al. 2006) and Doll 2016 were modest in size but conducted in homes and communities that are relevant to manufactured housing by construction type and region; and both had some homes with smoking. And Doll was focused on weatherization-eligible homes. The Kang et al. (2022) study was in Chicago but focused on weatherization, and it provided data about benefits of mechanical ventilation. Zhao et al. (2021) featured a substantial amount of cooking in a collection of low-income apartments. The study of recently constructed California homes was reported by Singer et al. (2020). The *Relationship of Indoor Outdoor and Personal Air* study reported by Weisel et al. (2005) had a diverse range of housing types and subpopulations, and its large size makes it a valuable set of data.

For $NO_2$, the focus was on studies conducted in homes with gas cooking burners. Mullen et al. (2016) oversampled homes with higher risk factors including smaller size. Logue et al. (2014) was a simulation study; but it used measured data for all relevant parameters, including an actual sample of home sizes and self-reported cooking frequencies. Zhao et al. (2021) reported $NO_2$ concentrations in low-income apartments with gas and also a 40-home subset of the homes from Singer et al. (2020) that had verified cooking activity.

For acrolein, the most extensive available data by far are measurements made by Health Canada in hundreds of homes in Canadian cities in 2005–2010. They also provide a limited subsample of from homes with smokers. Reports of these studies and summary data are provided on the Health Canada public website. Helpfully, chloroform, p-dichlorobenzene, and naphthalene were included in the Canadian national study reported by Zhu et al. (2013), providing very broadly representative data from thousands of homes.

Data on formaldehyde was the most challenging to obtain because: (a) formaldehyde concentrations decrease over the first few years after a home is built and continue to decrease over time, so older homes cannot be used to represent newer homes; and (b) the homes had to be built after the regulations limiting formaldehyde emissions from manufactured wood products took effect. Only one published study was found to fit both criteria, Singer et al. (2020). Additional, previously unpublished data from a study that used similar methods to sample homes in Colorado and Oregon were obtained from the study team at Pacific Northwest National Laboratory.

Table B-10 provides the studies' results for certain critical measures.

**TABLE B-10 Illustrative Concentrations of Selected Indoor Air Pollutants[a]**

| Pollutant and Qualifier | Homes | GM (GSD) | AM (SD) | 5th | 25th | 50th | 75th | 95th | Study |
|---|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$, non-smoking | 51 | 7 (2) | 9 | 3 | 4 | 6 | 11 | 25 | Doll, 2016 |
| $PM_{2.5}$, non-smoking, no MV | 40 | 11 (2) | 14 | 5 | 7 | 9 | 14 | 56 | Kang, 2022 |
| $PM_{2.5}$, non-smoking, MV | 40 | 5 (2) | 7 | 1 | 3 | 4 | 7 | 30 | Kang, 2022 |
| $PM_{2.5}$, large homes, non-smoking, MV | 67 | 4.9 (2.6) | 7.5 | 1.3 | 2.9 | 4.8 | 9.5 | 24.3 | Singer, 2020 |
| $PM_{2.5}$, non-smoking | 193 | - | 17.8 | 5 | 11 | 15 | 23 | 50 | Wallace, 2003[b] |
| $PM_{2.5}$, non-smoking | 31 | 22 (2) | 25 | 10 | 15 | 22 | 28 | 52 | Wallace, 2006 |
| $PM_{2.5}$, non-smoking | 280 | NR | 36.3 | 12.7 | - | 30.6 | - | 87.4 | Weisel, 2005 |
| $PM_{2.5}$, non-smoking, MV | *21* | 5.0 (2.5) | 7.7 | 1.5 | 3.4 | 3.9 | 9.2 | 15.7 | *Zhao et al. 2021* |
| $PM_{2.5}$, smoking | 18 | 50 (2) | 69 | 12 | 31 | 53 | 82 | 235 | Doll, 2016 |
| $PM_{2.5}$, smoking | 101 | NR | 47.5 | 13 | 22 | 30 | 62 | 168 | Wallace, 2003[b] |
| $PM_{2.5}$, smoking | 6 | 43 (2) | 56 | 13 | 23 | 50 | 66 | 133 | Wallace, 2006 |
| $NO_2$, gas cooking without range hood, no smoking, simulated[c] | 6634 | 10.1 (0.8)-16.2 (1.6) | - | 4-9 | 6-12 | 9-16 | 12-21 | 17-28 | Logue, 2014 |
| $NO_2$, 82% with gas cooking, no smoking | 338 | 13.4 (2.1) | 17.7 | 4 | 8.2 | 13.2 | 23.1 | 41 | Mullen, 2016 |
| $NO_2$, large homes with gas cooking ≥5x in the sample week, non-smokers, MV | 40 | 5.7 (2.4) | 7.1 | -1.2 | 3.7 | 5.5 | 10.2 | 22.7 | Singer, et al. 2020 / Zhao |

| Pollutant and Qualifier | Homes | GM (GSD) | AM (SD) | 5th | 25th | 50th | 75th | 95th | Study |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | et al. 2021 |
| $NO_2$, large homes with gas cooking, ≥1x in the sample week, non-smokers, MV | 53 | 4.8 (2.5) | 6.4 | 0.3 | 3 | 4.9 | 8 | 22.7 | Singer et al. 2020 / Zhao et al. 2021 |

### TABLE B-10 Illustrative Concentrations of Selected Indoor Air Pollutants[a] (Cont.)

| Pollutant and Qualifier | Homes | GM (GSD) | AM (SD) | 5th | 25th | 50th | 75th | 95th | Study |
|---|---|---|---|---|---|---|---|---|---|
| $NO_2$, apartments with gas cooking, non-smokers, MV | 22 | 17.3 (1.5) | 18.8 | 9.6 | 12.2 | 16.6 | 21.7 | 35.5 | Zhao et al. 2021 |
| Acrolein, summer, non-smokers[d] | 282 | - | - | - | - | 4.1–8.1 | - | 10.2–21 | Health Canada[e] |
| Acrolein, winter, non-smokers[f] | 278 | - | - | - | - | 1.3–6.2 | - | 3.5–15.6 | Health Canada[e] |
| Acrolein, summer, smokers[g] | 13 | - | - | - | - | 7.0 | - | 16.0 | Health Canada[e] |
| Acrolein, winter, smokers[g] | 21 | - | - | - | - | 2.5 | - | 10.1 | Health Canada[e] |
| Formaldehyde, large homes, no smoke, MV | 68 | 18.7 (1.4) | 19.8 | 11.5 | 15.1 | 18.2 | 23.3 | 31.2 | Singer, 2020 |
| Formaldehyde, no smoke, most MV | 55 | 20.3 (1.4) | 21.7 | 10.6 | 15.6 | 19.7 | 25.1 | 37.5 | PNNL, 2020 |
| Chloroform | 3857 | 0.62, 0.47–0.78 | 0.29, 0.22–0.40 | 0.05 | 0.15 | 0.37 | 0.73 | 2.02 | Zhu, 2013[h] |
| p-Dichlorobenzene | 3857 | 0.21, 0.15–0.28 | 5.5, 41–7.0 | 0.01 | 0.06 | 0.14 | 0.42 | 12.30 | Zhu, 2013[h] |
| Naphthalene | 3857 | 0.85, 0.73–1.0 | 2.6, 1.5–3.7 | 0.18 | 0.40 | 0.72 | 1.50 | 7.74 | Zhu, 2013[h] |

[a] Units are $\mu g/m^3$ for $PM_{2.5}$, acrolein, and other VOCs, and ppb for $NO_2$ and formaldehyde. MV = mechanical ventilation; since MV has been uncommon, it is assumed that very few of the homes in studies where this is not indicated had MV. GM = geometric mean; GSD = geometric standard deviation; AM = arithmetic mean; SD = standard deviation; NR = not reported. Short dash indicates data not provided in publication and not readily accessible. [b] Estimated data from Figure 3 by using a web tool to extract data from plots: https://apps.automeris.io/wpd/.

[c] Range reflects simulations for winter and summer and with first-order deposition rates of 0.5 or 1.05/h.

[d] Results of studies conducted during summer sampling campaigns in Windsor, Ontario (45 homes in 2005, 46 homes in 2006); Regina, Saskatchewan (91 homes, 2007); Halifax, Nova Scotia (50 homes, 2009), and Edmonton, Alberta (50 homes, 2010). Statistics are ranges across the 5 campaigns.

[e] https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guidelines-acrolein.html#a3.

[f] Results of studies conducted during summer sampling campaigns in Windsor, Ontario (48 homes in 2005, 47 homes in 2006); Regina, Saskatchewan (83 homes, 2007); Halifax, Nova Scotia (50 homes, 2009), and Edmonton, Alberta (50 homes, 2010). Statistics are ranges across the 5 campaigns.

[g] Same data as in preceding notes. These limited data in homes with smokers are from Edmonton, Alberta, which had the highest outdoor concentrations and also the highest values for non-smoking homes.

[h] Values after the comma for GM and AM for Zhu are 95% confidence intervals.

Air Tightness Data. Table B-11 provides air leakage data from 95 manufactured homes in Minnesota. Figures B-9 and B-10 show air leakage data findings from two studies (NEEA 2019, Pigg et al. 2016) that focus on homes built in Minnesota in 2000 or later.

Two studies conducted in the past decade provide data on air tightness in manufactured homes produced to meet the HUD Code but not additional standards such as Energy Star. These studies suggest envelope air leakage of approximately 8 ACH50 [4]for a minimally compliant HUD Code home, with only about 10 percent of the homes with higher air leakage (the unit of ACH50 is explained in Section 3.2.3.3). The data also show that many homes produced since 2000 have tighter envelopes with mean values of 5-6 ACH50.

The first study is the Residential Building Stock Assessment (RBSA), conducted in Idaho, Montana, Oregon, and Washington, that aimed to characterize the building stock including manufactured homes. A 2019 report (NEEA 2019) presents results from the second RBSA, which collected data from 411 site visits to manufactured homes in 2016-2017. Blower door data were available from approximately half of the homes, of which 25 were built in 2000 or newer. Among these 25 homes, 20 were identified as HUD Code homes, one was built to the Northwest Energy Efficient Manufactured Housing Program standard, and four were of unknown construction standard. The majority of the homes (N=18) were double-wide but included five triple-wide and two single-wide homes. Supporting information in Appendix B (Section B.3.2.3) shows that approximately 60 percent of the homes had envelope air tightness of 5 ACH50 or lower. The mean and median ACH50 were 6.3 and 4.9, respectively, and 8 ACH50 roughly corresponded to the 90th percentile highest air leakage.

The second study, in Minnesota, assessed manufactured homes for a utility program (Pigg et al. 2016). It included a telephone survey of 633 residents of manufactured homes, and data collected on site from a subsample of 99 homes. Air leakage was measured using blower-door tests for 95 of the 99 homes. The results, summarized in Appendix B (Section B.3.2.3) show that air tightness has improved over time, with substantially tighter homes built after 2000, after the 1994 HUD Code was in effect. Authors of the study provided detailed results of the 17 homes built since 2000 (Section B.3.2.3). Among these, the measured ACH50 ranged from 3.7 to 11.0. The mean and median ACH50 were 6.6 and 6.1, respectively. Most of the manufactured homes were between 1,000–1,500 $ft^2$ (N=8) and 1,500–2,000 $ft^2$ (N=5). The two most leaky homes were the largest (2,356 $ft^2$) at 10.9 ACH50 and the smallest (728 $ft^2$), at 11.0 ACH50.

McIlvaine et al. (2003) reported measurements made during 1996 and 2003 at 24 plants of six manufacturers of HUD Code-compliant manufactured homes that were interested in improving

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their energy efficiency. They noted the challenge of characterizing duct leakage to the outside for a home at the factory because outside leakage is impacted by the installation of the forced air system and also connections between sections that are not typically done at the factory. The authors noted a target of 0.06 cfm25/sf and a goal of half that leakage to the outside. Measurements were made for 190 floors (sections), including 132 with mastic sealing and 58 with taped connections. Ducting sealed with mastic had a mean total leakage of 0.05 cfm25/sf with 68 percent meeting the target of 0.06 (for 124 tests), and mean leakage to outside of 0.024 cfm25/sf with 85 percent meeting the target of 0.03 (based on 86 tests).

Taped systems had a mean total leakage of 0.082 percent (based on 56 tests) and mean leakage to outside of 0.057 (based on 30 tests). Taped systems met the targets of 0.06 cfm25/sf total and 0.03 cfm25/sf to outside in only 34 percent and 17 percent of the systems tested, respectively. Hales et al. (2007) also reported measured data to verify the improvements in duct tightness that result from sealing with mastic. Several experts who are knowledgeable about manufactured home production confirmed that it is already common practice for manufacturers to use mastic to seal ductwork.[5]

Limited data are available to estimate the duct leakage of minimum HUD Code homes today. As discussed in McIlvaine et al. (2003), duct leakage measurements can report total air leakage from the ducts or air leakage to the outside. For the most common configuration of a forced air system located in a closet with a louvered return directly connecting the unit to the living space, all or almost all of the ducting will be on the supply side and leakage will be out via the supply ducts. Ducts are most commonly in the enclosed belly, beneath the floor of the unit, and sometimes in the attic. Some of the air that leaks from ducts into the belly space will return into the conditioned space as air infiltrates from the belly up through the floor.

Pigg et al. (2016) reported results of onsite measurements of duct leakage for homes in Minnesota. They also noted the common architecture of a down-flow furnace/AC unit located in a utility closet with distribution ducts in an underfloor plenum and a non-ducted return through louvers in the utility closet door. Each section had a central supply duct running along the length and multiple branches to the rooms, with the systems in multi-section homes connected by crossover junctions that are outside of the enclosed belly. They noted that leaks are common at the joints connecting the furnace through the floor, at the boots for supply registers and at the junctions. They measured leakage using duct pressurization or a pressure pan technique at 88 sites and using the “Delta Q” test that seeks to measure air leakage under natural equipment operating conditions in 42 homes. These combined tests found that leakage to outside was about 72 percent of the total cfm25 value, and homes built since 2000 leaked about 6 percent of the air handler flow to the outside. The lead author of the report provided additional details about the data by personal communication. Duct leakage data were obtained for 15 of the 17 homes built since 2000. For this sample, the mean and median total leakage (by duct pressurization test) were 0.06 and 0.05 cfm25/sf.

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[5] These experts include Brady Peeks of the Northwest Energy Works, Michael Lubliner of Washington State University, Jordan Dentz of the Systems Building Research Alliance, and Scott Pigg of Slipstream.

**TABLE B-11 Air Leakage Data from 95 Manufactured Homes in Minnesota**

| Year Built | Mean ACH50 |
|---|---|
| Pre 1976 | 20.6 |
| 1976–1989 | 12.2 |
| 1990–1999 | 9.7 |
| 2000 and Newer | 6.3 |

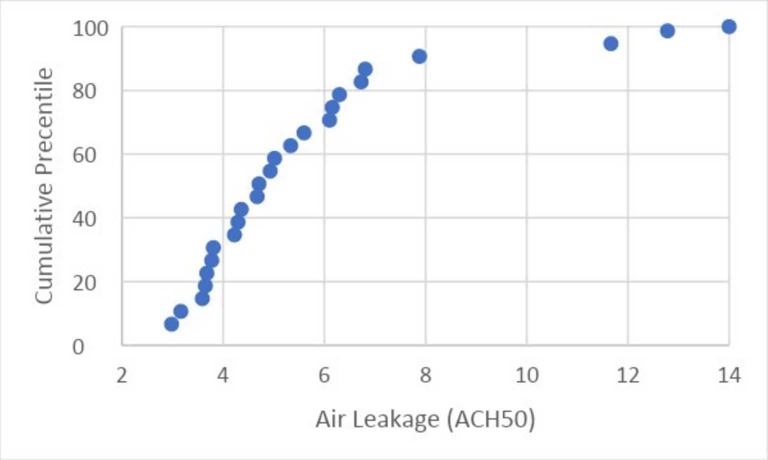

**FIGURE B-9 Air Leakage Data for 25 Homes Built in 2000 and Later from 2016–2017 Residential Building Stock Assessment** ***(Source: NEEA 2019; one home with an ACH50 of 26 is not shown on this plot.)***

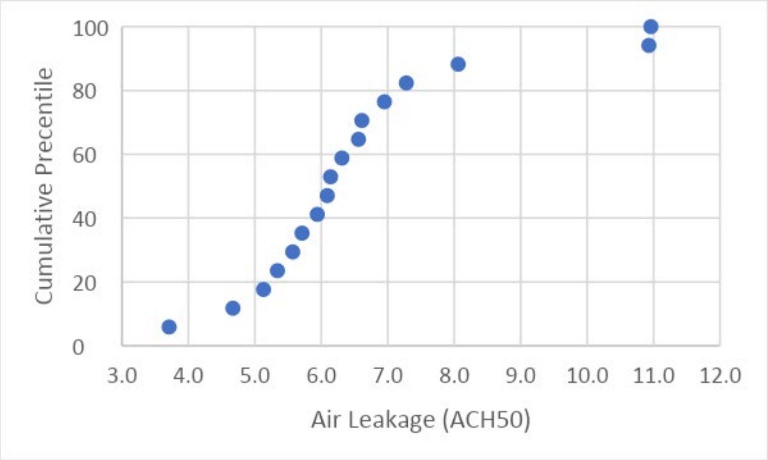

**FIGURE B-10 Air Leakage Data for 17 Minnesota Homes Built in 2000 and Later** ***(Source: Pigg et al. 2016.)***

***Core Requirements of Mechanical Ventilation Systems***. Table B-12 presents MV provisions of the HUD Code, ASHRAE 62.2-2019, and IECC-2021.

### TABLE B-12. Mechanical Ventilation Provisions of the HUD Code, ASHRAE 62.2-2019, and IECC-2021

| | HUD Code (1994) | ASHRAE 62.2-2019 | IECC / IRC 2021[a] |
|---|---|---|---|
| Kitchen exhaust | Minimum 100 cfm fan located as close as possible to the range or cooktop, but in no case farther than 10 ft horizontally from the range or cooktop. | Intermittent 100 cfm range hood or 300 cfm fan in kitchen (Table 5-1) OR continuous fan with flow providing 5 ACH for kitchen (Table 5-2). | Recirculating range hood allowed. If kitchen fan is vented to outside, requires 100 cfm intermittent or 25 cfm continuous (IRC Table M1505.4.4). |
| Bathroom exhaust | 50 cfm intermittent | 50 cfm intermittent (Table 5-1) or 20 cfm continuous (Table 5-2). | 50 cfm intermittent or 20 cfm continuous (IRC Table M1505.4.4). |
| Whole house mechanical ventilation[b] | 0.035 cfm/ft$^2$ but not less than 50 cfm or greater than 90 cfm | 0.03 cfm/ft$^2$ + 15 cfm for the first bedroom + 7.5 cfm for each other bedroom (Section 4.1.1). Required fan airflow can be lowered by taking credit for infiltration, based on measured envelope air leakage (Section 4.1.2), or with enhanced filtration (Section 4.1.4). | 0.01 cfm/ft$^2$ + 15 cfm for the first bedroom + 7.5 cfm for each other bedroom (IRC Section M1505.4.3, Equation 15-1). 30% reduction allowed for balanced systems that provide ducted outside air to bedrooms and to at least one common room. |
| Sound limits | None | Intermittent: 3 sone (Section 7.2.2)<br>Continuous: 1 sone (Section 7.2.1) | None |
| Duct leakage | Static pressure with all registers sealed and furnace air circulator at high speed must be at least 80 percent of static pressure measured in the furnace casing, with its outlets sealed and furnace air circulator operating at high speed. | HVAC systems that include air handlers or ducts outside the pressure boundary shall have total air leakage of no more than 6% of total fan flow when measured at 25 Pa (Section 6.5.2). | Total duct leakage must be <0.04 cfm25/sf or <0.03 cfm25/sf, if air handler is not installed at rough-in. Ducts entirely within the thermal envelope must be tested to be <0.08 cfm25/sf. |
| Efficiency | Central fan integrated supply (CFIS) allowed. | CFIS allowed. | Heat recovery ventilation required in climate zones 7-8. Fan efficacy requirements in Table R403.6.2. CFIS allowed with an efficacy of 1.2 total cfm/W. |
| Airflow verification | No requirement for 3rd-party performance verification. | Airflows must be rated and installed as prescribed, or verified on site (Sections 4.3 and 5.4). Sound must be rated. | Airflows must be verified (Section R403.6.3). Exception for 6" ducted kitchen exhaust with one or no 90º elbows. Gravity dampers required in ventilation ducts (Section R403.6). |

[a] Ventilation requirements of the IECC are adopted by reference to the International Residential Code (IRC).

[b] All of the standards require manual override (i.e., a switch) and allow intermittent operation to achieve equivalent rates on an hourly basis.

#### B.2.2.4 Interfaces with Other Resource Categories

Several aspects of the air quality, meteorology, and climate change assessment are relevant to other topics addressed elsewhere in this report. Table B-13 identifies and describes the resource areas that should be considered alongside air resources for a consistent and comprehensive assessment of potential environmental impacts.

**TABLE B-13 Air Quality, Meteorology, and Climate Change Interfaces with Other Resource Areas and Sections of this Report**

| Item/Description | Related Topics |
|---|---|
| Indoor air quality impacts on low-income and minority populations | Environmental Justice, Section B.2.5 |
| Net present value of total consumer costs and savings | Socioeconomics, Section B.2.4 |

### B.2.3 Health and Safety

#### B.2.3.1 Description of Affected Resource

Human health and safety addresses potential exposures and effects of radiological, chemical (nonradiological), and industrial (physical) hazards for illustrative residents, here for residents of manufactured housing. These risks are estimated under baseline conditions (no action) and proposed action alternatives.

#### B.2.3.2 Resource Characteristics and Impact Assessment Methods

The hazard identification draws on prior studies and measurement campaigns that can be compared to reference values. The exposure assessment considers how long people reside in manufactured homes over the course of their lifetimes and how much time they spend in the homes each day, on average. The exposures are compared against reference or guideline exposure levels or toxicity estimators that were developed using established methodologies, had peer-review, and were compiled into databases by government agencies and other organizations for use in health risk assessments. Updates based on new data or re-analysis of existing data with improved methods often appear first in peer-reviewed scientific papers, as the processes for changing the databases take time.

To aid in the assessment of whether an air toxin is at a level that potentially warrants concern, the EPA determines inhalation reference concentrations, RfCs, which are levels that are likely to be without appreciable risk of deleterious effects. The Office of Health Hazard Assessment (OEHHA)of the California EPA has a similar approach of setting reference exposure levels (RELs) for chronic and/or acute exposure as appropriate to the health endpoint. These RfCs and RELs are established to assess noncancer endpoints (see Tables B-14 and also B-15 for acrolein . For cancer, there is a different approach that is described in Section 3.3.

**TABLE B-14 Duration-Specific Inhalation Reference Values for Noncancer Endpoints**[a]

| **Organization / Database** | **Inhalation Reference Value** | **Duration** | | | |
|---|---|---|---|---|---|
| EPA ORD: Integrated Risk Information System (IRIS) | **Reference Concentration** *(RfC)* | | | | **Chronic:**<br>>7 yr (~10% life) to lifetime; 24-hr, continuous |
| EPA ORD: Provisional Peer-Reviewed Toxicity Value (PPRTV) *(screening)* | **p-RfC** | | | **Subchronic:**<br>Up to 10% of lifetime, 2-7 yr | **Chronic:**<br>>7 yr to lifetime; 24-hr, continuous |
| ATSDR: Minimal Risk Level *(screening vs. action level)* | **MRL** | **Acute:**<br>1-14 d | **Intermediate**:<br>>2 wk up to 1 yr | | **Chronic:**<br>≥1 yr |
| CalEPA OEHHA: Reference Exposure Level | **REL** | **Acute**:<br>1-hr (Infrequent) | **8-hr**:<br>Repeat exposures (e.g., 8 hr/d, 5 d/wk) | | **Chronic**:<br>Long-term; 24-hr, continuous |
| TX CEQ (TCEQ): Reference Value and Effect Screening Level | **ReV**<br>**ESL** | **Acute**:<br>Short-term | **24-hr**:<br>Short-term | | **Chronic**:<br>Long-term, months to years |
| MN DOH: Health Based Value | **HBV**$_{\textbf{chronic}}$ | **Acute**:<br>≤24 hr | **Short-term**:<br>Repeat exposures, >1-30 d | **Subchronic:**<br>Repeat, >30 d-8 yr | **Chronic**:<br>>8 yr (~10% life) to lifetime |
| *National Research Council, Acute Exposure Guideline Level* | *AEGL* | *Acute:*<br>*10, 30 min*<br>*1, 4, 8 hr* | | | |
| *EPA NHSRC, Provisional Advisory Level* | *PAL* | *Acute:*<br>*Up to 24 hr* | *Short term:*<br>*From 1-30 days* | *Intermediate to subchronic:*<br>*1-24 mo to 2-7 yr* | |

[a] Gray shading indicates that the duration does not generally apply to that reference value. Green, blue, and yellow shading indicate Tiers 1, 2, and 3, respectively, per the "hierarchy of human health toxicity values generally recommended for use in risk assessments" (EPA 2003, 2017). Unshaded entries in the last two rows illustrate durations for other reference values; these inform response and recovery from acute releases (whether from a natural disaster or accident, or intentional). As defined in the OSWER Directive: "Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most

current, the basis for which is transparent and publicly available, and which have been peer reviewed." For acrolein (Table B-15), Blessinger et al. (2020) represents the most current source, the bases of the reference value are transparent and publicly available, and they have been peer-reviewed as part of the journal's publication process.

**TABLE B-15 Inhalation Reference Values (IRVs) for Acrolein**

| Source | Date | IRV | Concentration *(µg/m3)* | Basis |
|---|---|---|---|---|
| EPA IRIS | June 2003 | RfC<br>*(Chronic)* | 0.03 | Based on the lowest observed adverse effect (LOAEL) from Feron et al. (1978), total uncertainty factor (UF) of 1000 (this derivation preceded Dorman 2008). |
| ATSDR | Aug. 2007 | Intermediate MRL *(1-14 d)* | 0.09 | Same study basis as above; converted from 0.04 ppb; total UF of 300. |
| CalEPA OEHHA | Dec. 2008 | Chronic REL | 0.35 | Based on the no observed adverse effect level (NOAEL) from Dorman 2008; supported by a derivation of 0.1 µg/m$^3$ from two other studies; total UF of 200. |
| TCEQ | March 2014 | Chronic ReV | 2.7 | Same study basis as above (Dorman 2008); no adjustment for using a subchronic study to derive a chronic value; total UF of 30. |
| | | Chronic ESL | 0.82 | ESL is 0.3*ReV (hazard quotient 0.3) to account for exposures to additional pollutants in air (to not exceed an HI of 1). |
| MN DOH | Oct. 2012 | $\text{HBV}_{\text{chronic}}$ | 0.4 | Same study basis as above (Dorman 2008); rounded from 0.383; total UF of 180. |
| Peer-reviewed literature, Blessinger et al. 2020 (EPA authors) | Dec. 2020 | Deterministic IRV<br>*(Chronic)* | 0.82 | Same study basis as above (Dorman); derivation includes a factor of 3 ($10^{1/2}$) to adjust for deriving a chronic value from a subchronic study; total UF of 100.<br>*Note: Not applying this adjustment (like TCEQ) results in an IRV of 2.6 µg/m$^3$.* |
| | | Probabilistic IRV<br>*(Chronic)* | 0.63 | Same study basis as above (Dorman); IRV represents 5th percentile of the probability distribution calculated for the risk-specific dose – at which 1% of population is estimated to experience minimal lesions. |
| | | | 0.9-2 | Range per the sensitivity analysis with alternative assumptions for the point of departure type and exposure duration. |

The Clean Air Act of 1970 designated a set of "criteria air pollutants," which were known at the time to cause harm at levels that were present in air at some or many locations in the United States. The initial set of criteria pollutants were carbon monoxide (CO), lead, sulfur dioxide ($SO_2$), $NO_2$, ozone, and PM. The EPA was required to set national ambient air quality standards (NAAQS) for these pollutants at levels that protect public health with an adequate margin of safety. This effort is carried out through a process that involves the compilation and review of all of the available scientific evidence, leading to the publication of an integrated scientific assessment. Through this process, the EPA decided in 1987 that particulate matter regulations should focus on those particles that pass through the nasal cavity when inhaled (set as those with aerodynamic diameters of 10 micrometers [µm] or smaller, abbreviated as $PM_{10}$) and in 1997 started to set thresholds for particles with aerodynamic diameters of 2.5 µm or less ($PM_{2.5}$), as these particles more readily reach the lower respiratory system. While the EPA's ambient air standards are only enforced for outdoor air, the identified threshold concentrations are often used as benchmarks for indoor air quality hazard assessment. This is because these criteria pollutants sometimes or commonly reach potential hazardous levels in U.S. homes, as discussed in Section 3.2.3, and several were specifically suggested to be considered in response to the request for information in 2016.

#### B.2.3.3 Source and Types of Data

Several standard sources of peer-reviewed toxicity values exist, including the EPA IRIS to CalEPA OEHHA databases, ATSDR online resources, and more. They types of data (toxicity values and their bases) data are illustrated in Tables B-14 and B-15

#### B.2.3.4 Interfaces with Other Resource Categories

Several aspects of the human health and safety assessment are relevant to other topics addressed elsewhere in this report. Table B-16 identifies and describes the resource areas that are considered alongside human health and safety for a consistent and comprehensive assessment of potential environmental impacts.

**TABLE B-16 Health and Safety Interfaces with Other Resource Areas and Sections of this Report**

| Item/Description | Related Topics |
|---|---|
| Health impacts on low-income and minority populations | Indoor air quality, Section B2.2.<br>Environmental justice, Section B.2.5 |

## B.2.4 Socioeconomics

### B.2.4.1 Description of Affected Resources

Demographic data relevant to proposed energy conservation standards for manufactured housing include geographic characteristics, income, employment status, home ownership, housing prices and availability, and race/ethnicity.

Socioeconomic impacts are defined in terms of changes to the demographic and economic characteristics and social conditions from an action. Because energy conservation standards could affect consumers nationwide, the DOE selected six illustrative metropolitan areas (Chicago, Fresno, Houston, Memphis, Miami, and Phoenix) to comprise its affected environment. The DOE also evaluated the socioeconomic environment at the national and regional levels.

### B.2.4.2 Resource Characteristics and Impact Assessment Methods

The analysis characterized the socioeconomic and demographic environment by (1) geographic characteristics, (2) income and employment characteristics, (3) housing characteristics, (4) financing considerations, and (5) energy insecurity. The DOE analyzed the consumer impacts of the conservation standards for each alternative. Consumer impacts included life cycle cost (LCC) savings for 10-year and 30-year home lifetimes, increase in the purchase price of a new manufactured home, annual energy cost savings after implementing the conservation standard, and a national average simple payback period to recoup the costs of the standards. All detailed methodologies and data are available in the August 2021 Supplemental Notice of Proposed Rulemaking Proposing Energy Conservation Standards for Manufactured Housing (SNOPR) and associated Technical Support Document (TSD) and the October 2021 Notice of Data Availability (NODA) (NODA) (DOE 2021a, 2021b, 2021c).

DOE estimated the potential financial impact of energy conservation standards on the manufacturers of manufactured homes through manufacturer impact analysis (MIA). DOE estimated the potential financial impact of energy conservation standards on manufacturers using the Government Regulatory Impact Model (GRIM). GRIM is an industry cash-flow model that estimates changes in industry value as a result of energy conservation standards using industry financial metrics, manufacturer production cost estimates, shipments forecasts, conversion costs, and manufacturer markups. The primary output of the GRIM is the industry net present value (INPV), which is the sum of industry annual cash flows over the analysis period (2021-2052), and discounted using the industry average discount rate.  All detailed methodologies and data are available in the SNOPR and associated TSD and the NODA (DOE 2021a, 2021b, 2021c).

For the national impact analysis, DOE assessed national energy savings (NES) and national net present value (NPV) of total consumer costs and savings associated with the conservation standards. Both of these were calculated based on projected annual shipments together with projected annual energy consumption and total incremental cost data from the LCC analyses. All detailed methodologies and data are available in the SNOPR and associated TSD and the NODA (DOE 2021a, 2021b, 2021c).

### *B.2.4.2.1 Geographic Characteristics*

An important consideration in the assessment of impacts from energy conservation standards for manufactured housing is to assess where existing manufactured homes are located and where new manufactured homes have been shipped. DOE depicted occupied manufactured homes across the United States by county and by Census Division and illustrated manufactured home shipments in 2021 by Census Division and by state. Occupied housing data was obtained through the U.S. Census American Community Survey. Shipment data were obtained through the U.S. Census Manufactured Housing Survey. DOE also presented manufactured housing as a percentage of all occupied housing for each of the six illustrative metropolitan areas, using U.S. Census American Community Survey data.

### *B.2.4.2.2 Income and Employment Characteristics*

Manufactured housing provides affordable, non-subsidized housing for low-income Americans. Therefore, an evaluation of income and unemployment conditions is central to the assessment of impacts of energy conservation standards on manufactured housing homeowners. DOE assessed income for people living in manufactured homes across the United States through median household income and percent of manufactured homeowners living at the federal poverty level. Table B-17 contains the household income data of U.S. homeowners in 2019. The federal poverty level threshold was defined by the U.S. Department of Health and Human Services (HHS) based on household size and assumed an average household size of two (HHS 2021). Median household income was presented using U.S. Census American Community Survey data.

DOE evaluated median household income, unemployment rate, and housing vacancy within the six illustrative metropolitan areas using the U.S. Census American Community Survey 2015-2019 five-year estimates. To define the areas where people may purchase manufactured homes, each metropolitan area was divided into smaller, non-contiguous areas that contain census blocks with manufactured housing communities. The Ameri7can Community Survey data is the appropriate data source to measure income employment conditions in metropolitan areas because it is the most recent data available at the census block level.

### *B.2.4.2.3 Housing Characteristics*

DOE described housing characteristics in terms of historical and forecasted prices. Historical prices were collected from the United States Census Bureau Manufactured Housing Survey Public Use Files (MHS PUF). Average prices were aggregated by manufactured housing with one section (single-section) or by those that had two or more sections (multi-section). Forecasted prices were calculated utilizing an exponential triple smoothing method based on monthly 2017 through 2020 historical average prices from the MHS PUF. Forecasted data accounts for seasonality. DOE compared prices of site-built homes to manufactured homes, as well as single-section homes to multi-section homes. The Manufactured Housing Survey, which is conducted by the U.S. Census and sponsored by HUD, was used to characterize manufactured housing prices. Table B-18 contains 2020 manufactured housing price data by census region.

**TABLE B-17 Household Incomes of U.S. Homeowners in 2019[a]**

| **Household Income** | **All Homeowners** *(all housing types)* | | **Manufactured Homeowners** | |
|---|---|---|---|---|
| | **Number of Units** *(in thousands)* | **Percentage of Units** | **Number of Units** *(in thousands)* | **Percentage of Units** |
| Less than $5,000 | 3,010 | 3.8 | 400 | 7.8 |
| $5,000 to $9,999 | 1,210 | 1.5 | 220 | 4.3 |
| $10,000 to $14,999 | 2,230 | 2.8 | 350 | 6.9 |
| $15,000 to $19,999 | 2,470 | 3.1 | 390 | 7.7 |
| $20,000 to $24,999 | 2,640 | 3.3 | 360 | 7.2 |
| $25,000 to $29,999 | 2,620 | 3.3 | 360 | 7.1 |
| $30,000 to $34,999 | 3,100 | 3.9 | 360 | 7.1 |
| $35,000 to $39,999 | 2,980 | 3.8 | 350 | 6.9 |
| $40,000 to $49,999 | 5,540 | 7.0 | 620 | 12.2 |
| $50,000 to $59,999 | 5,720 | 7.2 | 420 | 8.3 |
| $60,000 to $79,999 | 10,430 | 13.1 | 500 | 9.8 |
| $80,000 to $99,999 | 8,340 | 10.5 | 300 | 6.0 |
| $100,000 to $119,999 | 7,130 | 9.0 | 160 | 3.2 |
| $120,000 or more | 22,060 | 27.8 | 280 | 5.6 |
| *Total* | *79,475* | | *5,060* | |
| **Household Income Relative to Poverty Level** | | | | |
| Less than half the poverty level | 3,600 | 4.5 | 470 | 9.2 |
| From half the poverty level up to the poverty level | 3,400 | 4.2 | 640 | 12.6 |
| From the poverty level up to 1.5 times the poverty level | 4,600 | 5.8 | 750 | 14.8 |
| From 1.5 times the poverty level up to twice the poverty level | 5,800 | 7.3 | 700 | 13.8 |
| Twice the poverty level | 62,100 | 78.1 | 2,500 | 49.6 |

[a] Household income is the sum of the income of all people 16 years and older living in the household. Numbers are rounded to simplify this presentation. (Source: Census 2020.)

**TABLE B-18 Sales Prices of Manufactured Housing in 2020 by Census Region**[a]

| Census Region | Single-Section Sales Price | | | Two-Section Sales Price | | |
|---|---|---|---|---|---|---|
| | **Average** | **Minimum** | **Maximum** | **Average** | **Minimum** | **Maximum** |
| Northeast | $57,916 | $35,600 | $95,000 | $107,951 | $56,000 | $233,000 |
| Midwest | $56,983 | $33,200 | $79,000 | $104,987 | $54,000 | $184,000 |
| South | $56,798 | $31,400 | $79,000 | $106,942 | $58,000 | $170,000 |
| West | $61,748 | $34,100 | $117,000 | $118,282 | $64,000 | $236,000 |
| *All* | *$57,233* | *$31,400* | *$117,000* | *$108,583* | *$54,000* | *$236,000* |

[a] Sales prices are in 2020 dollars. *(Source: DOE 2021a.)*

#### *B.2.4.2.4 Financing Considerations*

Financing options can affect an individual's ability to purchase a manufactured home. DOE relied on a 2021 report published by the Consumer Financial Protection Bureau to characterize financing considerations for manufactured housing. One of the most significant factors includes loan type (chattel vs. real estate loans) because financing costs, length of loan, and consumer protections differ between the two loan types. The DOE also presented borrower demographics to provide baseline data for people who finance manufactured homes through chattel or real estate loans, including the ethnicity and race of borrowers.

#### *B.2.4.2.5 Energy Insecurity*

The ability of a household to be able to afford utility bills is an important factor when considering energy efficiency standards for manufactured homes. DOE relied on the Energy Information Administration's 2015 Residential Energy Consumption Survey to characterize energy insecurity concerns for households living in manufactured housing compared to all occupied homes. Table B-19 contains this energy insecurity data. To illustrate the ownership cost effects on low-income homeowners, DOE analyzed the utilities cost and total ownership cost of manufactured homes as a percentage of median income. The utilities cost is the sum of the average monthly gas cost plus the average monthly electric cost for manufactured homes. Ownership cost is the sum of the average monthly gas cost plus the average monthly electric cost plus the average first mortgage payment for manufactured homes. Data for these ownership costs came from the American Community Survey, 2015–2019 ACS 1-Year Estimates Data Profiles. Average household income is adjusted to be in constant yearly dollars.

### B.2.4.3 Source and Types of Data

Data were compiled on current socioeconomic conditions, including manufactured housing by location, income and unemployment rate, vacant housing, and housing prices. Table B-20 lists the data and data sources used to describe the affected environment. Table B-21 lists the input parameters used to determine the potential impacts of the alternatives.

**TABLE B-19 Household Energy Insecurity**[a]

| | **Number of U.S. Manufactured Homes** *(million)* | **Percent of Total U.S. Manufactured Homes** | **Number of Total U.S. Homes** *(million)* | **Percent of Total U.S. Homes** |
|---|---|---|---|---|
| Number of homes *(million)* | 6.8 | *(100)* | 118.2 | *(100)* |
| Any household energy insecurity | 3.8 | 55.9 | 37.0 | 31.3 |
| Reducing or foregoing food or medicine to pay energy costs | 2.8 | 41.2 | 25.3 | 21.4 |
| Leaving home at unhealthy temperature | 1.6 | 23.5 | 12.8 | 10.8 |
| Receiving disconnect or delivery stop notice | 2.1 | 30.9 | 17.2 | 14.6 |
| Unable to use heating equipment | 1.1 | 16.2 | 6.1 | 5.2 |
| Unable to use cooling equipment | 1.1 | 16.2 | 6.9 | 5.8 |

[a] Source: EIA (2018).

**TABLE B-20 Socioeconomics-Affected Environment Sources of Data**

| **Resource Characteristics** | **Required Data and Information** | **Data Source** |
|---|---|---|
| *Geographic Characteristics* | | |
| Manufactured home occupancy | Percent of housing units that are manufactured homes by county | 2015–2019 U.S. Census American Community Survey |
| Manufactured home occupancy | Percent of occupied homes that are manufactured homes by Census Division | 2015–2019 U.S. Census American Housing Survey |
| Manufactured home occupancy | Percent of occupied homes that are manufactured homes by Metropolitan area | 2015–2019 U.S. Census American Community Survey, using census block data |
| Manufactured home shipments | Percent of manufactured home shipments by Census Division, 2021 | 2021 U.S. Census Manufactured Housing Survey |
| Manufactured home shipments | Percent of manufactured home shipments by state, 2021 | 2021 U.S. Census Manufactured Housing Survey |
| Manufactured home shipments | Number of manufactured home shipments, 1980–2020 | Consumer Financial Protection Bureau, 2021 |
| *Income and Employment Characteristics* | | |
| Household income | Median household income for all occupied manufactured homes, 2019 | 2015–2019 U.S. Census American Community Survey |
| Household income | Median household income for all occupied homes, 2019 | Census, Income and Poverty Report, 2020 |
| Household income | Median household income for metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |
| Household income | Median household income for census block groups that contain manufactured housing within metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |
| Unemployment | Unemployment rate for metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |
| Unemployment | Unemployment rate for census block groups that contain manufactured housing within metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |

**TABLE B-20 Socioeconomics-Affected Environment Sources of Data (Cont.)**

| Resource Characteristics | Required Data and Information | Data Source |
|---|---|---|
| *Housing* | | |
| Vacant housing | Vacant housing units for metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |
| Vacant housing | Vacant housing units for census block groups that contain manufactured housing within metropolitan areas, 2019 | 2015–2019 U.S. Census American Community Survey |
| Housing Prices | Sales price for new manufactured housing, 2017–2020 | 2021 U.S. Census Manufactured Housing Survey Public Use File |
| Housing Prices | Average price for all new housing, 2017–2020 | 2021 Federal Reserve Economic Data (Federal Reserve 2021) |
| Housing Prices | Forecasts of Average Prices for manufactured home | 2021 U.S. Census Manufactured Housing Survey Public Use File |
| Housing Prices | Average sales prices of manufactured homes by Census Region, 2020 | 2021 U.S. Census Manufactured Housing Survey |
| *Energy Insecurity* | | |
| Manufactured Home Energy Insecurity | Percent of manufactured homes with home energy insecurity characteristics | 2018 Energy Information Administration Residential Energy Consumption Survey |
| Ownership Costs | Average monthly gas cost; average monthly electric cost; average first mortgage payment for manufactured homes | 2015–2019 ACS 1-Year Estimates Public Use Microdata Sample |
| Household Income | Average household income past 12 months for mobile home or trailer | 2015–2019 ACS 5-Year Estimates Public Use Microdata Sample |

**TABLE B-21 Socioeconomics Impact Data Inputs**

| **Input Parameter** | **Description** |
|---|---|
| *Life-cycle Cost and Payback Period Analyses* | |
| Mortgage interest | Includes real estate and personal property (chattel) |
| Loan term | Period over which the loan is repaid |
| Down payment | Percentage of purchase price paid upfront |
| Loan fees and points | Fees paid upfront in addition to down payment |
| Discount rate | Time value of money; alternative investment rate |
| Analysis period | Duration of analyzed operating expenses |
| Residual value of energy efficiency measures | Assumption that monetary value of energy efficiency measures depreciated linearly over time for duration of analysis period |
| Property and sales tax rate | Taxes paid based on value and price of home |
| Fuel prices and escalation rate | Price of electricity, gas, etc., and expected annual increases |
| *National Energy Savings* | |
| Unit energy consumption | Annual energy consumption per square foot of floor space (HUD Code and SNOPR) |
| Primary energy and full fuel cycle factors | Factors to account for losses associated with the generation, transmission, and distribution of electricity |
| Housing stock | Cumulative number of shipments up to that year less the number of homes that have exceeded their 30-year lifetime |
| *Net Present Value* | |
| Incremental installed costs and equipment price trend | Weighted average across three different methods of payment: personal property loans, real estate loans, and outright purchases |
| Unit energy consumption | Annual energy consumption per square foot of floor space (HUD Code and SNOPR) |
| Energy prices | Energy price forecasts from the Annual Energy Outlook 2021 (EIA 2021) |
| Equipment stock | Cumulative number of shipments up to that year less the number of homes that have exceeded their 30-year lifetime |
| Discount rates | Time value of money; alternative investment rate |
| *Manufacturer Impact Analysis* | |
| Financial parameters | Tax rate; working capital; net property, plant and equipment; standard selling, general and administrative expenses (SG&A); research and development; depreciation; capital expenditures |
| Conversion costs | One-time conversion costs for manufacturers to bring their product designs and production facilities into compliance with new regulations |
| Manufacturer production costs and markups | Derived from retail price information and the markup factor, which is the product of the manufacturer markup, the retail markup, and sales tax |

**TABLE B-21 Socioeconomics Impact Data Inputs (Cont.)**

| Input Parameter | Description |
|---|---|
| Shipments | Shipment projections using historical data from the Manufactured Housing Institute (MHI), ENERGY STAR® certified manufactured homes, and projections for growth in new housing from the AEO 2020 |
| Manufacturer markup scenarios | Modeled to capture the uncertainty regarding potential impacts on prices and profitability following implementation of energy conservation standards |

(Data Source: DOE 2021a, 2021b, 2021c)

#### B.2.4.4 Interfaces with Other Resource Categories

Some characteristics related to defining socioeconomics and assessing potential impacts are relevant to other topics addressed elsewhere in this report. Table B-22 identifies and describes the resource areas that should be considered alongside socioeconomics for a consistent and comprehensive assessment of potential environmental impacts.

**TABLE B-22 Socioeconomics Interfaces with Other Resource Areas and Sections of this Report**

| Item/Description | Related Topics |
|---|---|
| Low-income households | Environmental Justice, Section B.2.5 |
| Emission reductions | Air Quality Resources, Section B.2.2 |

### B.2.5 Environmental Justice

#### B.2.5.1 Description of Affected Resource

Environmental justice (EJ) refers to the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (IWG 2016). To focus federal agency attention on human health and environmental conditions in minority and low-income communities, Executive Order 121898, *Federal Action to Address Environmental Justice in Minority and Low-Income Populations*, was issued in 1994.

The Executive Order (EO) calls on agency NEPA reviews to consider the environmental effects of proposed actions, including human health, economic, and social effects on minority and low-income populations. With a shared goal to eliminate discrimination in the form of disproportionately high and adverse health and environmental impacts on members of communities of color and/or low income, the Order suggested four ways to advance EJ under NEPA:

- Assess environmental effects of federal actions on minority and low-income populations and American Indian tribes;
- Mitigate high and adverse impacts on these populations;

- Meaningfully engage communities and citizens in the NEPA process and improve the accessibility of meetings, documents, and notices; and
- Conduct interagency reviews on NEPA compliance and prepared EISs.

A federal EJ Interagency Working Group (IWG) was formed by representatives of 17 federal agencies and White House offices after the EO was issued. The IWG Promising Practices report (IWG 2016) called for: meaningful engagement, a scoping process, defining the affected environment, developing and selecting alternatives, identifying minority populations, identifying low-income populations, impacts, disproportionately high and adverse impacts, and mitigation and monitoring.

In consultation with the IWG, the Council on Environmental Quality (CEQ) developed guidance (CEQ 1997) that states that

> multiple or cumulative exposure to human health or environmental hazards in the affected population, as well as historical patterns of exposure to environmental hazards, must be considered to the extent such information is reasonably available. These multiple, or cumulative effects, even if certain effects are not within the control or subject to the discretion of the agency proposing the action need to be considered.

Factors considered in identifying unique pathways and other vulnerabilities include (1) exposure pathways; (2) direct, indirect, and cumulative economic, social, or health impacts; and (3) distribution of any potential beneficial or adverse impacts.

#### B.2.5.2 Resource Characteristics and Impact Assessment Methods

EO 12898 (1994) defined “low-income population,” “minority,” and “minority population” for purposes of implementing its requirements. According to the Order:

> Low-income populations in an affected area should be identified with the annual statistical poverty thresholds from the Bureau of the Census’ Current Population Reports, Series P-60 on Income and Poverty. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another, or a set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect.

The Order defines the term “minority” as “Individual(s) who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic.” The Order further states:

> Minority populations should be identified where either: (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. In identifying minority communities, agencies may consider as a community either a

> group of individuals living in geographic proximity to one another, or a geographically dispersed/transient set of individuals (such as migrant workers or Native American), where either type of group experiences common conditions of environmental exposure or effect. The selection of the appropriate unit of geographic analysis may be a governing body's jurisdiction, a neighborhood, census tract, or other similar unit that is to be chosen so as to not artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds.

The Promising Practices Report supplements this definition with the following consideration: "Minority populations may consist of groups of culturally different subpopulations with potentially different impacts and outreach needs" and that "minority populations may be dispersed throughout the study area, but have significant numbers." Common terms and definitions used in environmental justice analyses are listed in Table B-23.

The Promising Practices Report recommends the following three options for identifying minority populations:

- ***Fifty-Percent Analysis***—An agency determines whether the "percentage of minorities residing within the geographic unit of analysis meets or exceeds 50%." This initial screen can identify areas with majority minority populations. A Fifty-Percent analysis may be followed by a Meaningfully Greater Analysis (described below). However, a Meaningfully Greater Analysis may be conducted regardless of the results from the Fifty-Percent Analysis.
- ***Meaningfully Greater Analysis***—Compares the percentage of minority population in the affected area to a reference community population, using a reasonable subjective threshold to define "meaningfully greater." The choice of affected area (e.g., census block), reference population, and definition of "meaningfully greater" varies by agency and proposed action. The Promising Practices Report advises agencies to present a written rationale that explains the selection of the geographic unit of analysis, the reference community, and the meaningfully greater threshold. When a large percentage of residents are minority individuals, a larger-scale reference community (e.g., municipal, state, or region) may be required to obtain findings that accurately reflect the existence of minority populations within the geographic unit of analysis. One example of a "meaningfully greater" approach that has been used in a number of NEPA documents, including some past DOE EISs, is defined by the National Research Council's (NRC's) *Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions* (NRC 2004). It states that "a minority or low-income community is identified by comparing the percentage of the minority or low-income population in the impacted area to the percentage of the minority or low-income population in the County (or Parish) and the State" and that "if the percentage in the impacted area significantly exceeds that of the State or the County percentage for either the minority or low-income population then EJ will be considered in greater detail. 'Significantly' is defined by staff guidance to be 20 percentage points." The Promising Practices Report notes that some agencies define the "meaningfully greater"

threshold as a percentage of the absolute number, a decision that can be "especially important when the percent of the minority population is small."

- ***No Threshold***—Reports the "percent minority for each geographic unit of analysis within the affected environment," thus attempting "to identify all minority populations regardless of population size."

The Promising Practices Report urges the consideration of all three approaches and provides specific steps for conducting each type of analysis. The Promising Practices Report recommends that a Meaningfully Greater Analysis should follow a Fifty Percent Analysis.

DOE considered six metropolitan areas to illustrate existing conditions and provide a baseline for evaluating potential consequences of the proposed action and alternatives (Chicago, Fresno, Houston, Memphis, Miami, and Phoenix). The Promising Practices report suggests that the affected environment should be a unit of geographic analysis chosen so as to not "artificially dilute or inflate the affected minority population." DOE recognizes that most manufactured homes are located in suburban and rural areas rather than in cities. To more accurately represent the populations of future manufactured homeowners in this assessment, the affected environment included all of the census block groups that contain manufactured home communities within each of these metropolitan areas. Using only the larger metropolitan or urban areas as the affected environment would skew the data away from the disadvantaged communities because it would incorporate dense urban areas and populations where location-specific zoning rules exclude manufactured housing.

DOE defined a population as a minority population if the minority population within each metropolitan area containing manufactured homes exceeds fifty percent or if the minority population exceeds the minority population in the reference community (metropolitan area) by 20 percent or more.

DOE defined low-income populations as populations whose income is less than 200 percent of the poverty level (twice the federal poverty level), using poverty data from the Census Bureau's poverty thresholds. This is the same threshold as defined by EPA (2021a) for EJSCREEN.

An EJ impact assessment should include early communication and participation from the EJ communities regarding their situations and concerns, identification of potential unique pathways of exposure and special vulnerabilities, potential mitigation strategies to avoid or lessen impacts, and consideration of other resource areas to determine whether any impacts are cumulative or disproportionately high and adverse.

Factors to be considered in identifying unique exposure pathways and other special vulnerabilities include (1) exposure pathways; (2) direct, indirect, and cumulative ecological, aesthetic, historic, cultural, economic, social, or health impacts; and (3) distribution of any potential beneficial or adverse impacts.

Terms used in Environmental justice analyses are presented in Table B-23.

**TABLE B-23 Terms Used in Environmental Justice Analyses**[a]

| Term | Description |
|---|---|
| ***Definitions*** | |
| Low-Income Population | Identified with the annual statistical poverty thresholds from Census Bureau Current Population Reports on Income and Poverty (Series P-60). May be considered as a community, either a group of individuals living in geographic proximity to one another, or a set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect. |
| Minority | Members of these population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic; and either:<br>(a) The minority population of the affected area exceeds 50 percent, or<br>(b) The minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis.<br>Selection of the appropriate unit of geographic analysis may be a jurisdiction, neighborhood, census tract, or other similar unit chosen so as to not artificially dilute or inflate the affected minority population. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds.<br>Minority populations may be dispersed throughout the study area yet have significant numbers. They may consist of groups of culturally different subpopulations with potentially different impacts and outreach needs. |
| ***Grouping for Analysis*** | |
| Fifty-Percent Analysis | Determines whether the percentage of minorities residing within the geographic unit of analysis meets or exceeds 50%. This initial screen can identify areas with a majority of minority populations. (This analysis can be used together with the Meaningfully Greater Analysis to identify minority populations.) |
| Meaningfully Greater Analysis | Compares the percentage of minority population in the affected area to a reference community population, using a reasonable subjective threshold to define meaningfully greater. The choice of affected area (e.g., census block), reference population, and definition of "meaningfully greater" has varied across projects. When a large percentage of residents are minority individuals, a larger reference community (e.g., municipality) may be needed. When determining whether the percentage in an area of interest significantly exceeds that of the reference group for either the minority or low-income population, some have used 20 percentage points to indicate a "significant" percentage. |
| ***Analysis Approaches for Identifying Low-Income Populations*** | |
| Alternative criteria | Establishes a population percentage at or above the selected poverty threshold within the geographic unit of analysis. |

Federal environmental justice policies stress that early and ongoing public outreach is a vital component of the environmental justice process. DOE consulted with HUD and provided multiple opportunities for public comment. Unlike projects with a specific geographic location, energy conservation standards for manufactured housing can affect low-income and minority populations across the United States. Solicitation of public input was sought from industry groups, nongovernmental organizations, and other interested stakeholders to gain a better understanding of concerns, including environmental justice concerns. DOE mailed and emailed the notice of intent and request for comments to the 574 federally recognized tribes. DOE also emailed notice to approximately 25,000 stakeholders who have expressed interest in standards and rulemakings processes, individuals and organizations who commented on the draft environmental assessment (EA) and previous rulemaking processes, and members of the Manufactured Housing Working Group, as well as identified NEPA stakeholders. Table B-24 lists the public comment opportunities offered to obtain information about the DOE rule.

**TABLE B-24 Solicitation of Public Participation for DOE Rule and EIS**

| Date | Outreach |
|---|---|
| February 22, 2010 | Advance notice of proposed rulemaking (ANOPR) to develop and publish energy standards for manufactured housing, with a request for comment |
| June 25, 2013 | Request for information (RFI) |
| June 13, 2014 | Notice of intent to establish a negotiated rulemaking Manufactured Housing Working Group |
| February 11, 2015 | RFI to address Working Group recommendation that DOE conduct an additional analysis to inform the selection of solar heat gain coefficient (SHGC) requirements in certain climate zones |
| June 17, 2016 | Notice of proposed rulemaking (NOPR) that proposed to establish energy conservation standards for manufactured housing based on the consensus recommendations of the Manufactured Housing Working Group and technical support document that presented the analyses underlying the proposed standards |
| June 30, 2016 | Issued draft EA for public review to evaluate the environmental impacts of the proposed standards |
| August 3, 2018 | Notice of data availability (NODA) and RFI to further inform certain aspects of the proposed energy conservation standards |
| July 7, 2021 | Notice of intent (NOI) to prepare an environmental impact statement for energy conservation standards for manufactured housing, to invite public comments on the EIS scope, and to conduct public scoping meetings |

**TABLE B-24 Solicitation of Public Participation for DOE Rule and EIS (Cont.)**

| Date | Outreach |
|---|---|
| July 21–22, 2021 | Conducted online meetings July 21 and July 22 and invited oral comments on the scope of the EIS, with written comments invited through August 6 |
| August 26, 2021 | Supplemental notice of proposed rulemaking (SNOPR) to establish energy conservation standards for manufactured housing |
| October 26, 2021 | NODA issued regarding updated inputs and results of corresponding analyses and invited interested parties to comment on these analyses |
| October 26, 2021 | DOE reopened the public comment period on the SNOPR through November 26, 2021 |

#### B.2.5.3 Source and Types of Data

Table B-25 lists the data and data sources used to describe the affected environment. DOE used the EPA's EJSCREEN (EPA 2021c), which is an environmental justice mapping and screening tool that combines environmental and demographic indicators into a national dataset to help frame environmental justice evaluations.

**TABLE B-25 Environmental Justice Data and Information Needs**

| Resource Characteristics | Required Data and Information | Data Source |
|---|---|---|
| Affected environment area | Metropolitan area boundaries | U.S. Census Bureau 2021 |
| Affected environment area | Communities within metropolitan area boundaries that contain manufactured housing communities | DHS 2018 |
| Low income population | 200% of the federal poverty threshold using census block data | EPA, EJSCREEN census block data for low-income populations |
| Minority population | Minority populations using census block data | EPA, EJSCREEN census block data for minority populations |
| Environmental indicator | Concentration of $PM_{2.5}$ (annual) in ambient air | EPA, EJSCREEN, 2014 National Air Toxics Assessment |
| Environmental indicator | NATA respiratory hazard index | EPA, EJSCREEN, 2014 National Air Toxics Assessment |

**TABLE B-25 Environmental Justice Data and Information Needs (Cont.)**

| **Resource Characteristics** | **Required Data and Information** | **Data Source** |
|---|---|---|
| Environmental indicator | National Air Toxics Assessment (NATA) air toxics cancer risk | EPA, EJSCREEN, 2014 National Air Toxics Assessment |
| Environmental indicator | Ambient and exposure concentrations of acrolein | EPA, EJSCREEN, 2014 National Air Toxics Assessment |
| Environmental indicator | Ambient and exposure concentrations of formaldehyde | EPA, EJSCREEN, 2014 NATA |

### B.2.5.4 Interfaces with Other Resource Categories

Some characteristics related to defining environmental justice and assessing potential impacts are relevant to other topics addressed elsewhere in this report. Table B-26 identifies and describes the resource areas that should be considered alongside environmental justice for a consistent and comprehensive assessment of potential environmental impacts.

**TABLE B-26 Environmental Justice Interfaces with Other Resource Areas**

| **Item/Description** | **Related Topics** |
|---|---|
| Potential for socioeconomics impact on minority or low-income populations | Socioeconomics, Section B.2.4 |
| Potential for indoor air quality impacts on minority or low-income populations | Air Quality Resources, Section B.2.2 |

## B.3 CUMULATIVE IMPACTS

Table B-27 presents potential energy savings under Alternatives A, B, and C by tiers and type (size) of home.

**TABLE B-27 Cumulative Full-Fuel-Cycle National Energy Savings of Manufactured Homes under the Alternatives Considered**

| Alternative | Energy Savings in Quads | | |
|---|---|---|---|
| | Single-Section Home | Multi-Section Home | Total |
| A1: Tiered standards based on purchase price, exterior wall insulation per IECC 2021 | 0.58 | 1.44 | 2.01 |
| A2: Tiered standards based on purchase price, alternate exterior wall insulation | 0.56 | 1.38 | 1.94 |
| B1: Tiered standards based on home size, exterior wall insulation per IECC 2021 | 0.46 | 1.47 | 1.93 |
| B2: Tiered standards based on home size, alternate exterior wall insulation | 0.46 | 1.41 | 1.88 |
| C1: Untiered standards, exterior wall insulation per IECC 2021 | 0.89 | 1.47 | 2.36 |
| C2: Untiered standards, alternate exterior wall insulation | 0.84 | 1.41 | 2.26 |

Source: DOE (2021c); numbers are rounded to two decimal places to simplify this presentation.

Notes: Savings are based on manufactured homes purchased during 2023 through 2052, assuming a 30-year lifetime. The exterior wall insulation options apply for homes in climate zones 2 and 3.

Earlier analyses presented in the TSD (DOE 2021b) provided estimates of the cumulative full-fuel-cycle national energy savings under proposed energy conservation standards (e.g., homes in 19 cities, including five of the six evaluated in this EIS). These estimates cannot be compared with the updated analyses in the NODA (2021c) because modeling inputs have changed. Nevertheless, they provide insights into potential energy savings across different climate zones (Table B-28).

**TABLE B-28 Cumulative Full-Fuel-Cycle National Energy Savings of Manufactured Homes for Locations that Span Multiple Climate Zones**

| Climate Zone | City | Primary National Energy Savings in Quads | | | | | |
|---|---|---|---|---|---|---|---|
| | | Tiered Standards (Alternative A) | | | Untiered Standards (Alternative C) | | |
| | | Single-Section Home | Multi-Section Home | Total | Single-Section Home | Multi-Section Home | Total |
| 1 | Miami | 0.029 | 0.154 | 0.183 | 0.044 | 0.154 | 0.198 |
| 1 | Houston | 0.075 | 0.172 | 0.247 | 0.107 | 0.172 | 0.279 |
| 1 | Atlanta | 0.021 | 0.056 | 0.077 | 0.029 | 0.056 | 0.085 |
| 1 | Charleston | 0.021 | 0.075 | 0.096 | 0.029 | 0.075 | 0.104 |
| 1 | Jackson | 0.041 | 0.078 | 0.119 | 0.058 | 0.078 | 0.136 |
| 1 | Birmingham | 0.035 | 0.082 | 0.117 | 0.048 | 0.082 | 0.130 |
| 2 | Phoenix | 0.004 | 0.028 | 0.032 | 0.006 | 0.028 | 0.034 |
| 2 | Memphis | 0.062 | 0.160 | 0.222 | 0.088 | 0.160 | 0.248 |
| 2 | El Paso | 0.086 | 0.173 | 0.259 | 0.131 | 0.173 | 0.304 |
| 2 | San Francisco | 0.006 | 0.078 | 0.084 | 0.008 | 0.078 | 0.086 |
| 2 | Albuquerque | 0.014 | 0.052 | 0.066 | 0.021 | 0.052 | 0.073 |
| 3 | Baltimore | 0.072 | 0.134 | 0.206 | 0.089 | 0.134 | 0.223 |
| 3 | Salem | 0.003 | 0.032 | 0.035 | 0.004 | 0.032 | 0.036 |
| 3 | Chicago | 0.137 | 0.137 | 0.274 | 0.172 | 0.137 | 0.309 |
| 3 | Boise | 0.006 | 0.026 | 0.032 | 0.008 | 0.026 | 0.034 |
| 3 | Burlington | 0.049 | 0.089 | 0.138 | 0.062 | 0.089 | 0.151 |
| 3 | Helena | 0.016 | 0.021 | 0.037 | 0.020 | 0.021 | 0.041 |
| 3 | Duluth | 0.040 | 0.057 | 0.097 | 0.049 | 0.057 | 0.106 |
| 3 | Fairbanks | 0.002 | 0.002 | 0.004 | 0.002 | 0.002 | 0.004 |
| | ***U.S. Total*** | ***0.718*** | ***1.606*** | ***2.324*** | ***0.976*** | ***1.606*** | ***2.582*** |

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