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Lawrence Berkeley National Laboratory

A Survey of Households with Direct Heating Equipment in California

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Acronyms and Abbreviations

AHS	American Housing Survey
CEC	California Energy Commission
DHE	Direct Heating Equipment
DOE	United States Department of Energy
DV	Console Wall Furnace
FF	Floor Furnace DHE
GHG	Greenhouse Gases
RASS	California Residential Appliance Saturation Study
RECS	Residential Energy Consumption Survey
RH	Room Heater DHE
WF	Upright Wall Furnace DHE

Executive Summary

Direct Heating Equipment (DHE) is a category of ductless, space heating appliance that supplies heat directly to the space where it is installed. It is estimated that 36% of the DHE in use in the United States is installed in California (Blum et al, 2023), where it is the primary and/or secondary source of space heating in 16% of households and is estimated to use 15% of the gas consumed for space heating in the state.[1] Figure ES-1 shows examples of the different types of DHE available on the market.[2]

Figure ES - 1. Examples of DHE

Source: Williams Comfort Products (www.williamscomfortprod.com)

We surveyed 1,200 households with DHE in California to learn about their DHE technical, installation, and operation characteristics, as well as household demographics and occupants' perspectives towards energy-efficient DHE.

Figure ES-2 shows the saturation of DHE in households in California, and the distribution of households with DHE across regions of the state. Most of the DHE in the state (86%) is in Southern California and in the San Francisco Bay Area, where it is the primary source of heating in approximately 70% of the households where it is installed. DHE in households in California's North Coast, despite representing only 1% of the DHE fleet in the state, is the secondary source of heating in 65% of the households in that region.

[1] Estimate based on 2019 RASS.[15]

[2] The images represent only a small sample of DHE models available on the market. Reference to these DHE specific models and brand does not constitute or imply their endorsement, recommendation, or favoring by the U.S. Department of Energy, the Regents of the University of California, or the California Energy Commission.

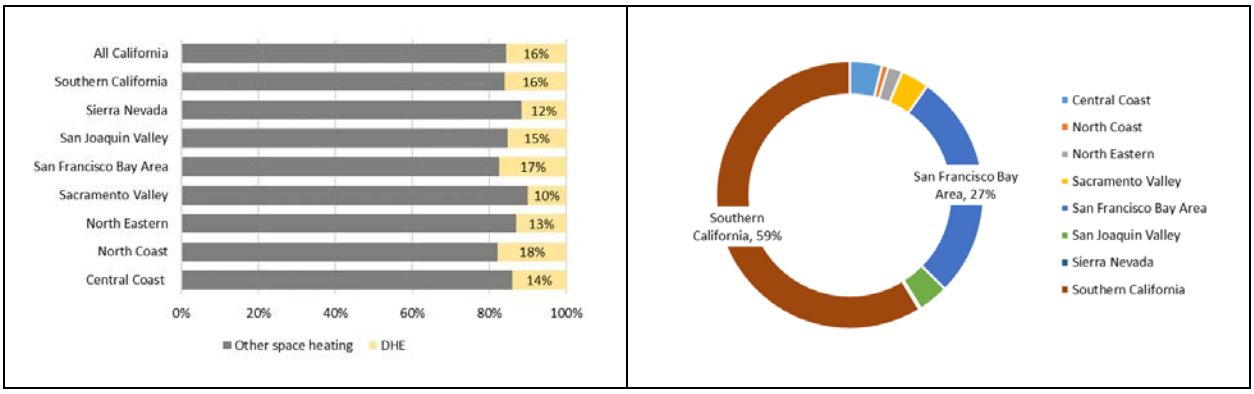


Figure ES - 2. Regional saturation and distribution of DHE in California

DHE is installed in 14% of households in single-family buildings in California and 17% of households in multi-family buildings.[1] These correspond, respectively, to 61% and 38% of households with DHE.[3] Approximately half of the households with DHE were built before 1960, and 90% before 1990. Overall, the share of households with DHE that are owner-occupied or rented is approximately the same. However, households with DHE in single-family detached buildings are mostly owner-occupied, and households with DHE in single-family attached and multi-family buildings are mostly rented.[4]

The typical annual income in households with DHE in the state is lower than $100,000. Owner-occupied households have an average annual income of approximately $80,000; households rented from private owners, $60,000; and households rented from a housing authority, $53,000. Owner-occupied households with DHE are, on average, slightly larger in size than rented homes.[4] In half of all households, the occupant pays for gas, with no subsidies. Contrastingly, in approximately 65% of homes with DHE rented from private owners, the occupant either pays for gas with subsidies or does not pay for gas at all; in homes with DHE rented from a housing authority that percentage increases to 87%.

Most households with DHE in California have only one DHE unit installed (70%). Of the remaining households, approximately two thirds (20%) have one additional unit and one third (10%) have three or more units installed. Approximately 50% of the most frequently used DHE units in homes were installed within the 10 years before the survey was conducted (2011-2020). Considering the typical age of households with DHE in the state, this indicates that the DHE market in California is mainly a replacement market.[5]

The majority of the most frequently used DHE units in homes are installed in the living- or family room; they also heat the dining room or kitchen, and sometimes a bedroom. They are mostly ignited by a pilot light and do not include a circulation fan. In general, DHE users

[3] The remaining 1% of households refers to mobile homes.
[4] This may not be a characteristic specific to households with DHE, but a characteristic of all households in the state.
[5] This has also been pointed by Blum et al (2023), based on interviews conducted with DHE manufacturers, and with DHE distributors and installers in California.

indicated they are satisfied with their units, despite mentioning that the units do not heat enough of the space and are expensive to use. Additional concerns include the indoor air quality (gas smell, dust) and malfunctioning of the unit. A large fraction of users also indicated that the space is initially warmer near the equipment, and it takes time to heat the space farther from the unit.

Almost half of households with DHE have never had any routine maintenance work done on their most-frequently used DHE unit, and 40% indicated that, although their most-frequently used DHE does require some repair, they have never repaired it. The households that did repair their units, fixed or replaced the thermostat (33%) or the pilot light (28%). Almost half of households indicated that the repair was triggered because the system started to malfunction or because the unit was not heating well. Most of the households that repaired their most frequently used DHE expected an additional lifetime of more than one year (87%), and approximately half of the households expected an additional lifetime of at least three years. Some households preferred to repair the unit, rather than replace it, because (a) other necessary expenses with the residence took priority (37%), (b) repairing was the best short-term solution given their financial situation at the time (21%), and (c) they were not planning to be in that residence long enough to justify the replacement. However, 38% of households indicated that if they need to repair their most frequently used DHE in the future, they would rather replace it. For the remaining 62% of households, the repair cost would have to be, on average, greater than $450 to lead to the replacement of the unit.[6]

Some households have recently replaced their most frequently used DHE. The main reasons for replacing – rather than repairing – the unit were that it broke down (40%) and it was not turning on or off (36%). Other interesting reasons mentioned were that the unit was “80 years old and was leaking gas,” and that the unit “kept setting the smoke alarm off.” Replacement units were purchased approximately half of the time by a contractor and half by the households themselves; in the latter case, typically from a large home improvement store. In the majority of households, the new unit was installed by a contractor or certified technician (88%); in the remaining households, the unit was installed by the household occupant with the help of a friend, relative, or neighbor.

Around 23% of households planned to replace their most frequently used DHE in the two years following the survey. The main reasons for replacing the unit are to improve the heating comfort (45%), lower energy bills (37%), and the age of the unit (36%). Two-thirds of the households that know who will buy the new unit and where it will be purchased from indicated they will buy the unit themselves, most likely from a large home improvement store; the other third of households will have a contractor purchase the new unit. The majority of households will have the unit installed by a contractor or certified technician (85%).

In addition to purchasing a new DHE unit to replace their most frequently used one, 30% of households indicated they had recently purchased or were planning to purchase an additional DHE unit for their home. The main reason for the purchase was/is to improve the heating in a

[6] The median value of the repair cost that would trigger the replacement of the unit is $300.

space already heated by another heater, either a DHE or any other type of heating system (60%); another reason was to add the unit to a space not yet being heated (33%).

When buying a new DHE unit, households are concerned about their thermal comfort, indoor air quality, fuel costs, and the environment; and they indicated what they are willing to spend on a new DHE that would improve one or more of those four areas. The majority of households (80%) would spend, on average, $410 to have more control of the temperature and better-distributed heat in the spaces heated by their most frequently used DHE; and 7% of households would spend more than $1,000 for the same goal.[7] The willingness to spend more than $500 monotonically increases as annual income increases; and, while fewer owner-occupied households would spend to improve thermal comfort when compared with rented households, the former are willing to spend more than the latter. Similar results are observed when it comes to investing in a new DHE unit to improve the cleanliness of the air inside the home (e.g., reduce pollutants, dust particles, etc.).

Most households would also spend money on a new DHE unit that would reduce their annual gas bill. The amount they would spend depends on their annual gas cost and the savings the new unit would provide. Some households, however, do not spend enough on their most frequently used DHE gas bill to justify the investment. Almost three quarters (74%) of households would spend, on average, $339 on a new DHE to reduce their annual energy bill by $50; 62% of households would spend, on average, $417 to reduce the bill by $100; 54% would spend, on average, $488 to reduce it by $250; and 44%, an average of $560 to reduce their annual bill by $500. These average values refer to households that would spend between $50 and $1,000. Some households would spend more than $1,000. Five percent of households would spend more than $1,000 to reduce their most frequently used DHE's annual gas bill by $50; 8% to reduce it by $100; 12% to reduce it by $250; and 22% to reduce it by $500. Figure ES-3 shows how households' willingness to spend on a new DHE that would reduce their gas bill increases with the reduction in their annual gas bill.

Results show that the higher the fuel cost reduction, the larger the share of households that would spend more than $1,000 to achieve a reduction greater than or equal to the amount they spend annually for fuel. In addition, while the share of households that would spend between $50 and $1,000 decreases as the fuel cost reduction increases, the average amount those households would spend significantly increases. The shares of owner-occupied households and rented households that would spend a certain amount to reduce the annual fuel cost of their most frequently used DHE are approximately the same; but, overall, owners would spend more than renters would.

[7] These values refer to what households are willing to spend above what they would spend with a new DHE unit that is similar to their current most-frequently used one.

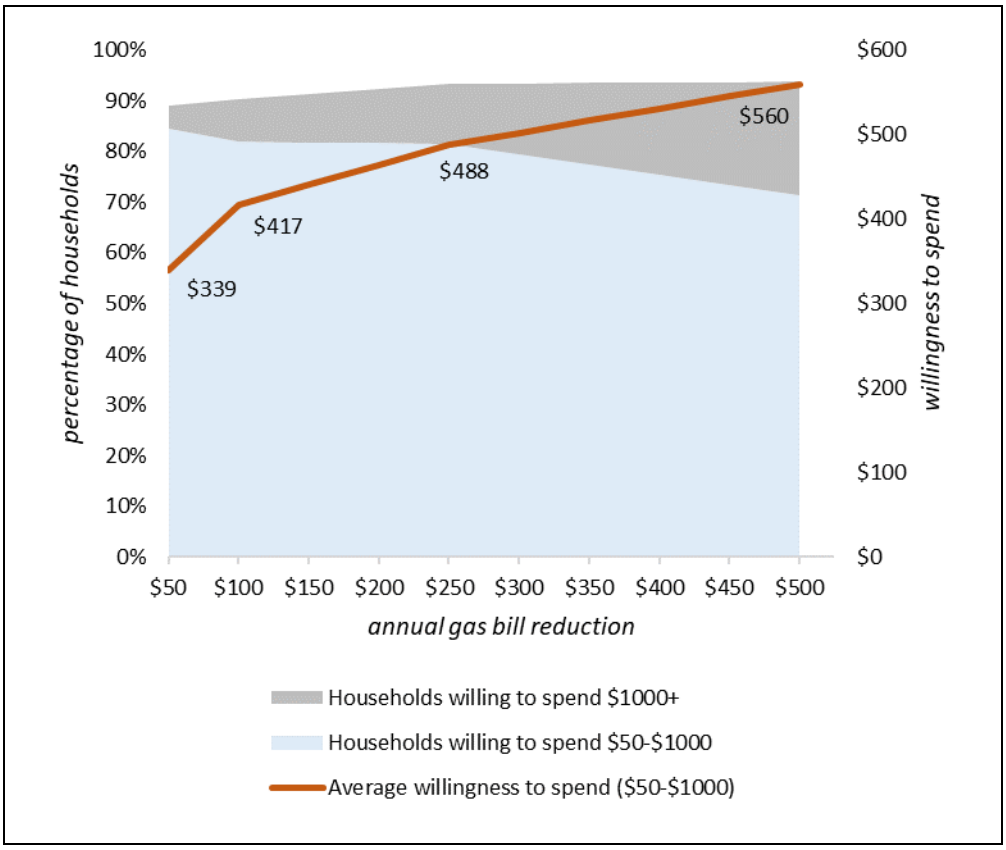


Figure ES - 3. Increase in willingness to spend on a new DHE to reduce annual gas bill

A large share of households would also be willing to spend on a new DHE unit that would reduce the environmental impact or carbon footprint of the household by reducing their energy use. They would spend an average of $326 to reduce their carbon footprint by 10% (80%); an average of $365 to reduce it by 20% (81%); and an average of $421 to reduce it by 50% (82%). For the three levels of environmental impact reductions, the fraction of households that would spend more than $1,000 monotonically increases with annual income.

When it comes to purchasing a new DHE, households' purchase decision is driven mainly by the purchase- and installation costs of the unit. Concerns about the energy bill come next, followed by maintenance costs. Additional aspects suggested by respondents include the efficiency of the new unit, how long it will last, and whether it is programmable. There are no significant differences between the responses from owner-occupied and rented households, except that the latter seem less concerned about maintenance costs. Households would rely mostly on three sources of information to inform their purchase of a new DHE unit: credible expert evaluations of the energy, economic, environmental, and health benefits; reviews from other purchasers; and State of California recommendations and guidelines.

Overall, households' opinion on high-efficiency DHE is unanimously positive. They believe that a new, high-efficiency DHE unit will provide better indoor air quality (95%), improve

the comfort in their home (93%), and lower their energy bill (92%). However, when it comes to the maintenance costs and the significance of the home retrofit required to install a high-efficiency DHE, households have mixed, yet balanced opinions: some believe a high-efficiency unit will be more expensive to maintain, some do not; some believe a significant home retrofit will be needed, while some do not.

The recent COVID-19 pandemic had some effect on households' perspectives of their major appliances. Most households (68%) indicated that the pandemic affected their interest in and willingness to upgrade their major appliances, including their DHE. The shares of households that are willing to upgrade their major appliances to enhance comfort and promote a healthier environment grow with annual income. Overall, the households' perspectives about efficient appliances, including high-efficiency DHE, are positive, with approximately half of them believing their health is impacted by their ability to control the temperature and air quality of their homes and that a high-efficiency DHE would enhance their family's comfort. Also, more than half of households describe themselves as committed to behaving in an environmentally friendly manner.

1. Introduction

Direct Heating Equipment (DHE) is a category of space heating products that do not use ducts to move warm air through a home. Rather, it supplies heat directly to the space where the heater is installed. Three types of space heaters comprise the DHE space-heating category: wall furnaces, floor furnaces, and room heaters. Wall furnaces can be upright (WF) or have a console-like shape (DV); they are installed attached to the wall.[8] Room heaters (RH), despite looking like console wall furnaces, are installed detached from the wall. Floor furnaces (FF) are installed under the floor, in a basement or in a crawl space. Figure 1 shows examples of DHE.[9]

Figure 1. Examples of DHE
Source: Williams Comfort Products (www.williamscomfortprod.com)

Blum et al (2023) estimate that DHE uses 3.7% of the total energy used for space heating in the United States, and that 36% of the DHE in use in the United States is installed in

[8] Although upright wall furnaces are usually vented vertically and console wall furnaces are typically vented through the wall (direct vent), the former can also be direct vented and the latter, under certain conditions, vented vertically.
[9] The images represent only a small sample of DHE models available on the market. Reference to these DHE specific models and brand does not constitute or imply their endorsement, recommendation, or favoring by the U.S. Department of Energy, the Regents of the University of California, or the California Energy Commission.

California.[10] They further estimate that DHE is the primary or secondary source of space heating in 12.1% of households in California,[11] yet little is known about the technical and usage characteristics of this equipment and the homes where they are used in the state.

The lack of knowledge about the current fleet of DHE in California raises concerns. One particular concern refers to the energy efficiency of the models. Less efficient and inadequately operated DHE contributes to increasing household energy costs and greenhouse gas (GHG) emissions in the state. Another concern refers to the age of the heaters. Older DHE still in use may not only be low efficiency and lead to the abovementioned issues, but also inadequately installed, insufficiently maintained, and negligently repaired. Inadequate installation, insufficient maintenance, and negligent repair of DHE may pose safety and health risks to users. In addition, we estimate that 72% of households with DHE in the state are low-income households,[12] which adds the dimension of energy justice for disadvantaged communities to the concerns. Finally, it is not clear what the market barriers to modern, more efficient DHE are. The availability of targeted information about DHE in California is therefore paramount to inform the design of state programs, which could mitigate the adverse energy, economic, environmental, and health effects of the old, low-efficiency DHE currently in use in households in the state.

Other surveys have addressed DHE in the United States and California. The *2019 American Housing Survey* (AHS),[13] the most comprehensive national housing survey in the United States, provides relevant information about household characteristics and demographics. This information can be obtained for households with a DHE in two ways. One, when the main heating equipment in the house is either a "floor, wall, other pipeless furnace" or a "vented room heater;" two, when the first or second source of supplemental heating is a "floor, wall or other pipeless furnace built into the structure" or a "room heater vented to the outside through a chimney, flue, or pipes." The *2020 Residential Energy Consumption Survey* (RECS),[14] an energy survey conducted with a nationally representative sample of housing units in the United States, collects energy-related data for housing units occupied as a primary residence and the households that live in them. This information is available for households with a DHE, which are identified when the main space heating equipment is a "built-in room heater burning gas or oil," or when the secondary space heating equipment is "other." The *2019 California Residential*

[10] Estimates based, respectively, on the *2015* and *2020 Residential Energy Consumption Surveys*[14] considering all types of DHE fueled by natural gas or propane. If only natural gas DHE is considered, the fraction of the stock of DHE in the U.S. that is installed in California increases to 40.6%.

[11] Estimate based on the *2019 California Residential Appliance Saturation Study*[15] considering both natural gas and propane DHE. If only natural gas DHE is considered, the fraction of the households in California with a DHE drops to 11.2%.

[12] Estimate based on the *2019 California Residential Appliance Saturation Study*[15] and the *2019 State Income Limits Briefing Materials* (https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits/docs/Income-Limits-2019.pdf).

[13] AHS is sponsored by the United States Department of Housing and Urban Development and conducted by the United States Census Bureau. For more information about AHS, please refer to https://www.census.gov/programs-surveys/ahs.html.

[14] RECS is conducted by the United States Department of Energy's Energy Information Administration. For more information about the 2020 RECS, please refer to https://www.eia.gov/consumption/residential/data/2020/.

Appliance Saturation Study (RASS),[15] a comprehensive energy survey of households in California, estimates energy consumption for electric- and natural gas residential end uses, as well as household appliance saturations in the state. Data from households with a DHE can be obtained when the household has a primary or secondary "floor or wall gas furnace" and "floor or wall bottled gas heater." While these surveys provide valuable information about households with a DHE, with estimates of their energy use, the data does not discriminate between the four types of DHE. Further, these surveys do not specifically address DHE installation, usage, maintenance, repair, and replacement, nor DHE users' behavior towards energy-efficient DHE.

This report describes a survey conducted with 1,201 households in California that rely on DHE as their primary or secondary space heating needs.[16] Therefore, all results presented in the report refer – solely – to households in California with at least one DHE unit in operation. The survey targeted specific information that will bridge the knowledge gaps about the DHE currently in use in California, including their type, installation, usage, maintenance, and repair. It also covers aspects related to the quality of the air and the heat provided, as well as household demographics and their willingness to spend for improved thermal comfort, environmental footprint, and energy efficiency. The survey was designed to inform future research on cost-effective strategies to reduce the natural gas use of DHE in California.

The survey was conducted online. Online survey results may be misleading when the distribution of respondents is biased and does not represent the target population. We believe that this is the case in this survey. To address the issue, we calibrated (post-stratified) the survey sample to meet the distribution of households in the state based on the *2019 RASS*.[17] In this report, we describe and discuss survey results based on our post-stratified sample of households. In some cases, we provide additional context based on the number or share of respondents in the sample. Chapters 2 and 3 describe households and DHE characteristics. Chapter 4 describes how DHE is used and how satisfied users are with their existing DHE. Chapter 5 describes DHE maintenance and repair frequency as well as the main reasons and household plans for replacing DHE. Chapter 6 describes households' willingness to spend on a new, efficient DHE model. Chapter 7 concludes with our main findings and their limitations. In addition to the main chapters, Appendices A and B describe, respectively, the survey methodology and sample, and the approach used to calibrate the initial, raw sample.

[15] RASS is funded by the California Energy Commission and conducted by DNV GL Energy Insights (formerly KEMA, Inc.). For more information about the 2019 RASS, please refer to https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.
[16] Appendix A describes the survey methodology and sample.
[17] Appendix B describes the post-stratification data sources and methodological approach.

2. Household Characteristics

DHE is the primary and/or secondary source of space heating in a non-negligible share of households in California, and some households with a DHE in the state have more than one DHE unit. According to our survey, of all households with a DHE in the state, 30.1% have one or more additional units installed. Of those, 68.1% have two DHE units, and the remaining 31.9% have three or more DHE units. In this report, unless explicitly stated (like in Section 3.2), all results refer to the most frequently used DHE in the household.

In California, households with DHE are in all regions of the state, with the majority of installations where DHE is the primary source of space heating found in Southern California and the San Francisco Bay Area. Table 1 presents the regional saturation of DHE for households where DHE is the primary (only), secondary (only), or both the primary and secondary source of space heating.[18] In the table, the columns under "All DHE" represent households with a DHE that is fueled either by natural gas or propane; the columns under "Natural Gas DHE" represent only the households with a DHE that is fueled by natural gas. Figure 2 shows how households with DHE are distributed throughout California. The locations where DHE is more commonly used are consistent with the limited heating capacity offered by these heaters, which are typically designed for houses with smaller heating loads and, therefore, may not be able to provide sufficient heat to support space heating in cooler regions of the state.

Table 1. Saturation of households with DHE

Region*	**All DHE**			**Natural Gas DHE**		
	DHE is the … source of space heating					
	Primary (only)	Secondary (only)	Primary and Secondary	Primary (only)	Secondary (only)	Primary and Secondary
Central Coast	9.3%	5.0%	0.4%	8.5%	4.6%	0.1%
North Coast	7.8%	11.7%	1.6%	3.9%	2.1%	0%
Northeastern	4.1%	8.9%	0.05%	2.0%	5.3%	0.03%
Sacramento Valley	6.8%	3.6%	0.3%	6.7%	2.8%	0%
San Francisco Bay Area	11.6%	6.2%	0.3%	11.5%	5.9%	0.3%
San Joaquin Valley	6.8%	8.5%	0.1%	6.0%	6.9%	0.02%
Sierra Nevada	4.4%	7.4%	0.3%	0.3%	0.5%	0%
Southern California	11.1%	5.3%	0.4%	10.9%	4.8%	0.1%
All Regions	10.2%	5.9%	0.4%	9.8%	5.0%	0.2%

* See Figure 2 for a spatial view of the regions.

[18] Estimates based on RASS.[15]

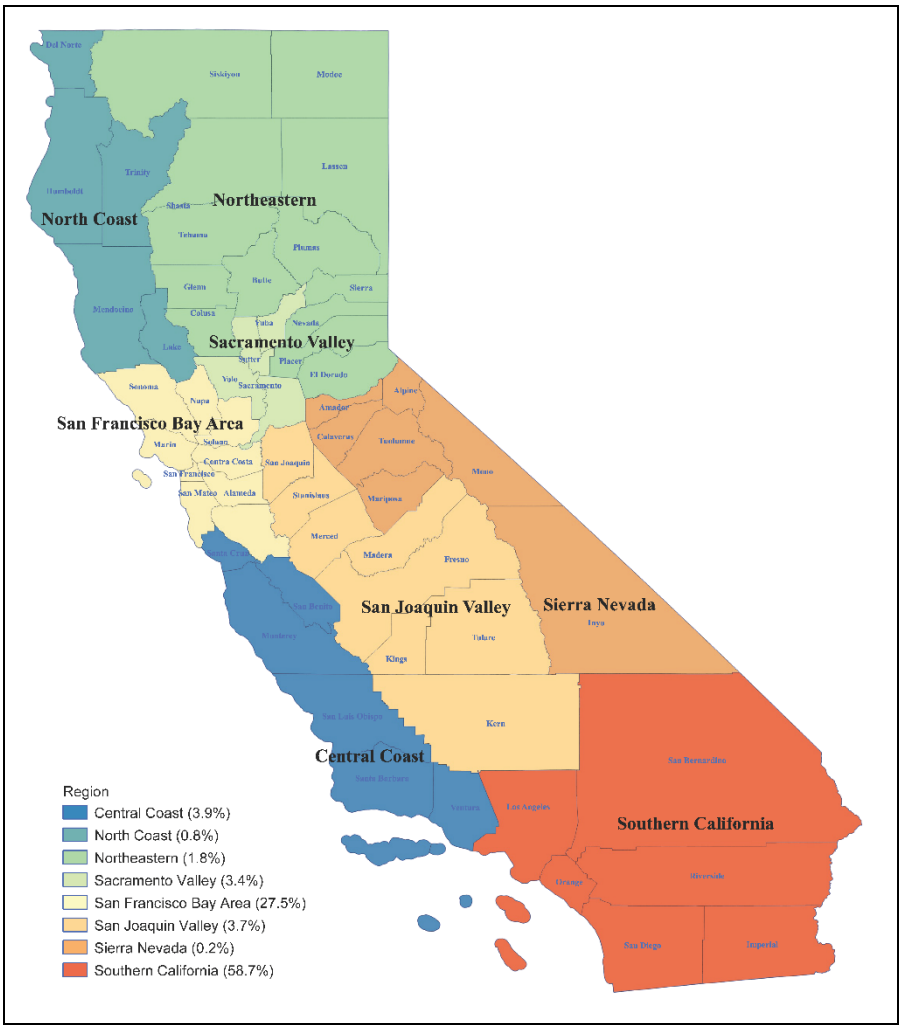


Figure 2. Spatial distribution of households with DHE in California

Households in all types of buildings use DHE. Households in single-family buildings represent 60.7% of households with a DHE in the state, and households in multi-family buildings represent 37.8%. The remaining 1.5% of households with a DHE are in mobile (or similar) homes. Table 2 provides more details on the shares of households with DHE by building type. Table 3 shows distributions of the DHE types used by households in each type of building. When considering households in all types of buildings, the most used type of DHE is upright wall furnaces, and the second most is console wall furnaces.

Table 2. Distribution of households with DHE by building type

Building Type	Households with DHE
Single-family (detached)	53.2%
Single-family (attached)	7.5%

Building Type	Households with DHE
Multi-family (2-4 units)	14.2%
Multi-family (5+ units)	23.6%
Mobile home	1.5%
All Building Types	**100.0%**

Table 3. Distribution of DHE type by building type

Building Type	DHE Type				Sum
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Single-family (detached)	67.2%	20.1%	6.1%	6.6%	100.0%
Single-family (attached)	67.8%	16.9%	11.7%	3.5%	100.0%
Multi-family (2-4 units)	72.5%	19.5%	5.4%	2.5%	100.0%
Multi-family (5+ units)	70.9%	26.0%	3.1%	-	100.0%
Mobile home	82.9%	14.9%	2.2%	-	100.0%
All Building Types	69.1%	21.1%	5.7%	4.1%	100.0%

Almost half (49.2%) of households with DHE were built before 1960. Households built since 1990 represent less than 10% of the stock of DHE currently installed in the state. The primary reason for the decrease in adoption of DHE in the last 30 years is the rapid increase of central heating systems. Those easily suit a variety of heating loads, including larger heating loads, and are capable of providing a uniform temperature throughout the house, resulting in better comfort conditions for their occupants. In addition, the average size of houses built in the last 20 years has significantly increased, resulting in larger heating loads and making DHE less suitable as a space heating solution. Table 4 shows distributions of households with DHE by household vintage for each type of building. The table shows a concentration of single-family (attached) homes and small (2-4) multi-family buildings with DHE built in the 1970-1989 period. The table also shows a consistent decline of households with DHE since 1970 in single-family (attached) homes and dwellings in multi-family buildings. Table 5 shows distributions of the DHE types used by households of each category of household vintage. The table shows that upright wall furnaces are the type of DHE that has been the most installed over all vintages, which is consistent with the overall distribution of DHE types installed in the state. The table also shows that room heaters, which are the type of DHE that, overall, is the least installed in the state, have (approximately) the second largest level of adoption since 2000. The growth in adoption of room heaters is primarily because they are easier to install, portable, present a more modern look and aesthetic, and often offer better controls, all for lower prices compared

with other types of DHE. In addition, room heaters tend to be the secondary source of space heating in a particular room of a household that is primarily heated by a central furnace. Table 6 shows distributions of the household vintage categories by DHE type. Overall, DHE is more ubiquitous in older households. This is particularly noticeable for floor furnaces, which are the oldest DHE technology on the market.

Table 4. Distribution of households by household vintage for each building type

Year Building Was Built	Building Type*					All Building Vintages
	SF Det	SF Att	MF 2-4	MF 5+	MH	
2010-2020: Less than 11 years old	1.9%	0.8%	1.1%	0.4%	0.4%	1.3%
2000-2009: 11 to 20 years old	4.9%	2.5%	2.3%	1.4%	5.6%	3.6%
1990-1999: 21 to 30 years old	3.6%	4.2%	4.2%	5.5%	3.8%	4.2%
1980-1989: 31 to 40 years old	12.0%	17.0%	12.8%	13.3%	21.0%	12.9%
1970-1979: 41 to 50 years old	11.0%	19.7%	23.5%	14.2%	20.7%	14.3%
1960-1969: 51 to 60 years old	12.9%	7.7%	9.0%	22.9%	28.1%	14.5%
1950-1959: 61 to 70 years old	21.6%	13.7%	17.1%	20.3%	20.3%	20.1%
Before 1950: More than 70 years old	32.0%	34.4%	30.1%	22.1%	-	29.1%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 5. Distribution of DHE type by building vintage

Year Building Was Built*	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
2010-2020: Less than 11 years old	50.0%	14.7%	35.3%	-	100.0%
2000-2009: 11 to 20 years old	42.5%	28.8%	28.6%	0.1%	100.0%
1990-1999: 21 to 30 years old	65.1%	24.8%	10.1%	-	100.0%
1980-1989: 31 to 40 years old	63.7%	22.9%	13.0%	0.3%	100.0%
1970-1979: 41 to 50 years old	65.5%	28.1%	5.4%	1.1%	100.0%
1960-1969: 51 to 60 years old	75.9%	19.8%	1.7%	2.6%	100.0%
1950-1959: 61 to 70 years old	82.5%	14.8%	0.8%	1.9%	100.0%
Before 1950: More than 70 years old	65.4%	20.7%	3.1%	10.9%	100.0%
All Building Vintages	69.1%	21.1%	5.7%	4.1%	100.0%

* Building ages are calculated from 2021, when the survey was conducted.

Table 6. Distribution of building vintages by DHE type

Year Building Was Built*	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
2010-2020: Less than 11 years old	1.0%	0.9%	8.3%	-	1.3%
2000-2009: 11 to 20 years old	2.2%	4.9%	18.0%	0.1%	3.6%
1990-1999: 21 to 30 years old	3.9%	4.9%	7.5%	-	4.2%
1980-1989: 31 to 40 years old	11.9%	14.0%	29.8%	1.0%	12.9%
1970-1979: 41 to 50 years old	13.6%	19.1%	13.6%	3.8%	14.3%
1960-1969: 51 to 60 years old	16.0%	13.7%	4.3%	9.1%	14.5%
1950-1959: 61 to 70 years old	24.0%	14.1%	2.9%	9.1%	20.1%
Before 1950: More than 70 years old	27.5%	28.5%	15.7%	76.9%	29.1%
All Building Vintages	100.0%	100.0%	100.0%	100.0%	100.0%

* Building ages are calculated from 2021, when the survey was conducted.

The size of the households with DHE ranges from small to large dwellings, with most DHE (69.0%) installed in households with square footage ranging from 501 to 1500 square feet. Table 7 shows distributions of households with DHE by household size for each type of building. In general, the concentration of existing DHE in households with square footage ranging from 501 to 1500 square feet seems homogeneous across building types. Considering the mid-points of the household size ranges shown in Table 7, and with 500 square feet and 3000 square feet, respectively, as the lower and higher ranges, the average size of a household with a DHE in California is approximately 1,200 square feet. Table 8 shows distributions of the DHE types used by households of each category of household size. The distributions of DHE types by household size are consistent with the overall distribution of DHE types in the state, with upright wall furnaces being the most used DHE and floor furnaces the least. Console wall furnaces are the second most used type of DHE in households of all sizes.

Table 7. Distribution of households by household size for each building type

Household Size	Building Type*					All Building Types
	SF Det	SF Att	MF 2-4	MF 5+	MH	
Less than or equal to 500 sq ft	1.8%	1.3%	16.8%	13.6%	15.5%	6.9%
From 501 to 1000 sq ft	29.5%	48.0%	36.9%	57.2%	41.3%	38.6%
From 1001 to 1500 sq ft	36.8%	28.1%	28.9%	17.6%	30.4%	30.4%
From 1501 to 2000 sq ft	21.9%	10.2%	9.6%	3.1%	10.1%	14.7%

Household Size	Building Type*					All Building Types
	SF Det	SF Att	MF 2-4	MF 5+	MH	
From 2001 to 2500 sq ft	6.6%	8.1%	3.3%	1.3%	2.6%	5.0%
From 2501 to 3000 sq ft	2.3%	2.9%	1.6%	2.1%	-	2.2%
More than 3000 sq ft	1.1%	1.3%	2.9%	5.2%	-	2.3%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 8. Distribution of DHE type by household size

Household Size	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Less than or equal to 500 sq ft	63.0%	32.9%	4.1%	-	100.0%
From 501 to 1000 sq ft	70.6%	19.6%	6.5%	3.2%	100.0%
From 1001 to 1500 sq ft	72.6%	15.1%	5.6%	6.8%	100.0%
From 1501 to 2000 sq ft	62.8%	30.7%	4.3%	2.2%	100.0%
From 2001 to 2500 sq ft	74.7%	13.5%	6.9%	4.9%	100.0%
From 2501 to 3000 sq ft	50.3%	37.1%	5.8%	6.9%	100.0%
More than 3000 sq ft	61.3%	31.0%	3.1%	4.6%	100.0%
All Household Sizes	69.1%	21.1%	5.7%	4.1%	100.0%

The vast majority of DHE in the state (87.0%) are installed in households with one to three bedrooms. Table 9 shows the distributions of households by number of bedrooms for each type of building. The most frequent number of bedrooms in households with DHE varies by building type. Single-family detached homes with DHE more often have two or three bedrooms. The remaining types of buildings, except mobile homes, most often have one or two bedrooms. Mobile homes with DHE mostly have two bedrooms. Table 10 presents the distribution of households with DHE across DHE types based on the number of bedrooms in the household. The distributions follow the same trend for all households.

Table 9. Distribution of households by number of bedrooms in the house for each building type

Number of Bedrooms	Building Type*					All Building Vintages
	SF Det	SF Att	MF 2-4	MF 5+	MH	
Studio	1.4%	0.0%	1.8%	17.8%	13.4%	5.4%
1 bedroom	5.1%	31.4%	42.5%	43.7%	6.9%	21.6%
2 bedrooms	32.9%	52.0%	42.0%	32.2%	65.4%	36.0%
3 bedrooms	47.7%	10.0%	12.6%	5.6%	10.0%	29.4%
4 or more bedrooms	11.4%	6.7%	1.1%	0.7%	2.6%	6.9%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 10. Distribution of DHE type by number of bedrooms in the household

Number of Bedrooms	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Studio	52.0%	46.6%	1.4%	-	100.0%
1 bedroom	70.1%	25.5%	3.3%	1.1%	100.0%
2 bedrooms	73.8%	14.1%	7.4%	4.8%	100.0%
3 bedrooms	68.6%	19.0%	6.3%	6.1%	100.0%
4 or more bedrooms	65.1%	27.1%	5.0%	2.9%	100.0%
All Households	69.1%	21.1%	5.7%	4.1%	100.0%

Households with DHE typically house four or fewer people, but the number of occupants can range from one to more than 10 people.[19] Table 11 shows the distributions of households by number of occupants for each type of building. In general, the largest shares of DHE are installed in households with 1-2 occupants, although for single-family detached homes that share is closer to the share of households with 3-4 occupants than in other types of buildings. The same applies when comparing the shares of households with 3-4 occupants with the shares of households with 5-6 occupants. Table 12 presents the distribution of households with DHE across DHE types for each level of household occupancy. For most levels of occupancy, the distributions follow the same trend as when considering all households, except for households with 1-2 occupants where room heaters present a slightly lower penetration than floor furnaces.

[19] A few respondents (n=4), corresponding to 0.61% of the total households, preferred not to say the total number of household occupants.

Table 11. Distribution of households by number of household occupants for each building type

Number of Occupants	Building Type*					All Building Types
	SF Det	SF Att	MF 2-4	MF 5+	MH	
1-2	44.9%	74.7%	77.0%	81.8%	94.6%	61.3%
3-4	38.4%	20.4%	18.3%	16.8%	5.0%	28.5%
5-6	15.5%	4.9%	3.9%	0.7%	0.4%	9.3%
7 or more	1.2%	-	0.7%	0.7%	-	0.9%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 12. Distribution of DHE type by number of household occupants

Number of Occupants	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
1-2	75.3%	17.4%	3.3%	4.0%	100.0%
3-4	58.1%	27.8%	9.0%	5.1%	100.0%
5-6	60.9%	28.3%	9.4%	1.4%	100.0%
7 or more	75.5%	22.0%	2.4%	-	100.0%
All Households	69.1%	21.1%	5.7%	4.1%	100.0%

The typical annual income of a household with DHE in California is less than $100,000.[20] Table 13 shows the distribution of annual income in households with DHE for each type of building. While in most types of buildings approximately 85% or more of the households have an annual income lower than $100,000, in single-family detached homes this level of annual income comprises only 68% of households. Consequently, households with an annual income at or above $100,000 are ubiquitous in single-family detached homes. In the other types of buildings, except mobile homes, the percentage of households with that level of annual income is around 13% to 16% of households of each type of building. Mobile homes have the lowest share of households (approximately 2%) with an annual income equal to or greater than $100,000. Table 14 presents the distribution of households with DHE across DHE types for each level of household annual income. The table shows that the penetration of upright wall furnaces decreases as household annual income increases. Contrastingly, the highest penetration of

[20] Some respondents (n=37), corresponding to 0.40% of the total households, either did not know or preferred not to say the total household annual income.

room heaters is in households with a total annual income between $100,000 and $139,999, and of floor furnaces is in households with a total annual income equal to or greater than $140,000.

Table 13. Distribution of households by household total annual income for each building type

Household Annual Income	Building Type*					All Building Types
	SF Det	SF Att	MF 2-4	MF 5+	MH	
Less than $30,000	17.4%	11.7%	37.7%	37.6%	62.3%	25.3%
$30,000 to $59,999	24.6%	43.1%	27.8%	29.7%	18.4%	27.6%
$60,000 to $99,999	25.7%	28.8%	21.0%	19.6%	17.4%	23.7%
$100,000 to $139,999	15.9%	8.4%	7.9%	5.9%	1.9%	11.6%
Equal or greater than $140,000	16.3%	8.0%	5.6%	7.2%	-	11.8%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 14. Distribution of DHE type by household total annual income

Household Annual Income	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Less than $30,000	74.9%	19.6%	1.8%	3.6%	100.0%
$30,000 to $59,999	71.4%	20.8%	3.9%	4.0%	100.0%
$60,000 to $99,999	68.8%	21.3%	8.1%	1.9%	100.0%
$100,000 to $139,999	65.5%	17.4%	12.6%	4.6%	100.0%
Greater than $140,000	62.6%	18.5%	5.5%	13.3%	100.0%
All Households	69.1%	21.1%	5.7%	4.1%	100.0%

The type of household occupancy varies significantly across types of buildings.[21] Table 15 shows the distribution of the type of occupancy of households with DHE for each type of building. Single-family detached homes and mobile homes with DHE are mostly occupied by their owners. In the other three types of buildings, households with DHE are mostly rented from a private owner. Multi-family buildings are the building type with the most households that are

[21] A few respondents (n=9), corresponding to approximately 1.5% of the total households, either did not know or preferred not to say if the household is owned or rented.

rented from a housing authority,[22] followed by single-family attached homes and mobile homes. Mobile homes present the highest share of households that are occupied with no payment of rent. Table 16 presents the distributions of households with DHE across DHE types for each type of household occupancy. The table shows that owner-occupied households, as well as households rented from private owners or from a housing authority present distributions similar to the same distribution when all households are considered. Households occupied with no payment of rent have mostly console wall furnaces. None of the respondents who rent the house from a housing authority or occupy the house with no payment indicated they have a floor furnace installed in their home.

The distribution of type of household occupancy also changes with income level and size. Table 17 shows the distributions of household occupancy by income level when considering only households that are owner-occupied or rented. While most of the households rented from a private owner (86.1%) and from a housing authority (91.3%) have a total annual income of less than $100,000, only 61.9% of the owner-occupied households have a total annual income of less than $100,000. Table 18 shows the distributions of household occupancy by household size when considering only households that are owner-occupied or rented. While most of the owner-occupied households (86.2%) and the households rented from private owners (85.8%) are in the range of 501 to 2,000 square feet, most of the households rented from a housing authority (89.6%) are 1,500 square feet or less.

Table 15. Distribution of households by type of household occupancy for each building type

Household Occupancy	**Building Type***					**All Building Types**
	SF Det	SF Att	MF 2-4	MF 5+	MH	
Owner occupied	64.5%	26.2%	17.0%	12.2%	50.2%	42.5%
Rented (private owner)	33.8%	66.6%	63.7%	63.3%	43.1%	47.5%
Rented (housing authority)	1.3%	7.2%	19.3%	24.0%	5.1%	9.6%
Occupied with no payment	0.4%	-	-	0.5%	1.6%	0.4%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

[22] A Public Housing Authority, referred as a *housing authority* in this report, is a governmental entity or public body or agency or instrumentality of these entities that is authorized to engage or assist in the development or operation of low-income housing under the United States Housing Act of 1937, in accordance with 24 CFR §5.100.

Table 16. Distribution of DHE type by type of household occupancy

Household Ownership	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Owner occupied	64.0%	19.3%	9.9%	6.8%	100.0%
Rented (private owner)	73.6%	21.0%	2.6%	2.8%	100.0%
Rented (housing authority)	70.1%	27.2%	2.7%	-	100.0%
Occupied with no payment	14.5%	79.0%	6.5%	-	100.0%
All Households	69.1%	21.1%	5.7%	4.1%	100.0%

Table 17. Distribution of households by household total annual income and type of occupancy

Household Annual Income	Owner Occupied	Rented (private owner)	Rented (housing authority)
Less than $30,000	16.5%	29.5%	40.9%
$30,000 to $59,999	19.0%	33.9%	34.8%
$60,000 to $99,999	26.4%	22.7%	15.7%
$100,000 to $139,999	17.7%	7.9%	4.3%
Greater than $140,000	20.4%	6.0%	4.4%
All Income Levels	100.0%	100.0%	100.0%

Table 18. Distribution of households by household size and type of occupancy

Household Size	Owner Occupied	Rented (private owner)	Rented (housing authority)
Less than or equal to 500 sq ft	1.0%	8.2%	25.6%
From 501 to 1000 sq ft	27.6%	47.5%	45.6%
From 1001 to 1500 sq ft	34.8%	29.3%	18.4%
From 1501 to 2000 sq ft	23.7%	9.1%	0.2%
From 2001 to 2500 sq ft	8.9%	1.6%	4.1%
From 2501 to 3000 sq ft	2.4%	1.5%	3.9%
More than 3000 sq ft	1.6%	2.8%	2.2%
All Sizes	100.0%	100.0%	100.0%

In general, occupants of households with DHE pay for the gas used.[23] Table 19 shows the distributions of the three categories of 'who pays for gas' in households with DHE for each type of building. The table shows that households in mobile homes, unlike households in all other types of buildings, mostly do not pay for gas or have gas subsidies from a government or utility program.[24] Table 20 presents the distributions of households with DHE across DHE types, for each of the three categories of who pays for gas. Overall, the distribution of DHE types for the three categories of 'who pays for gas' is similar to the distribution when all households are considered. Table 21 shows the distributions of who pays for gas for each type of household occupancy. Most of the owner-occupied households (93.9%) pay for gas, and 54.2% of them are not subsidized. Similarly, 83.5% of rented households pay for gas, yet only 34.8% are not subsidized. Households rented from a housing authority are those with the largest share of households where the gas is partially subsidized (71.0%), compared with households rented from a private owner (47.8%) and owner-occupied households (43.0%).

Table 19. Distribution of households by who pays for gas for each building type

Who pays for gas	Building Type*					All Building Types
	SF Det	SF Att	MF 2-4	MF 5+	MH	
Occupant pays (no subsidies)	66.3%	61.8%	55.0%	53.5%	30.2%	60.6%
Occupant pays (subsidized)	26.1%	25.0%	38.7%	25.5%	45.5%	28.0%
Occupant does not pay	7.7%	13.3%	6.3%	21.0%	24.3%	11.4%
Sum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Legend: SF Det: Single-family (detached) SF Att: Single-family (attached)
MF 2-4: Multi-family (2-4 units) MF 5+: Multi-family (5+ units) MH: Mobile homes

Table 20. Distribution of DHE type by who pays for gas

Who pays for gas	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Occupant pays (no subsidies)	66.2%	21.5%	6.5%	5.8%	100.0%
Occupant pays (subsidized)	77.0%	15.4%	4.9%	2.7%	100.0%
Occupant does not pay	69.3%	27.1%	3.2%	0.4%	100.0%
All Households	69.1%	21.1%	5.7%	4.1%	100.0%

[23] Some respondents (n=45), corresponding to 5.4% of the total households, either did not know or preferred not to say who pays for the gas fuel.
[24] This is consistent with results presented in Table 13, which show that 62.3% of mobile home households have an annual income lower than $30,000.

Table 21. Distribution of who pays for gas by type of occupancy

Household Annual Income	**Owner Occupied**	**Rented** (private owner)	**Rented** (housing authority)
Occupant pays (no subsidies)	50.9%	35.4%	13.0%
Occupant pays (subsidized)	43.0%	47.8%	71.0%
Occupant does not pay	6.1%	16.8%	16.0%
All Income Levels	100.0%	100.0%	100.0%

3. Equipment Characteristics

Most households in California have only one DHE unit installed. Some, according to respondents, may have up to three or more units. We asked participants about the main characteristics of their DHE. When participants had more than one DHE unit installed in their household, we asked them about the main characteristics of their most frequently used DHE unit (*primary DHE*) and their second most frequently used unit (*secondary DHE*). When a household had only one DHE unit installed, that unit was considered their primary DHE. Below we describe the characteristics of the primary and secondary DHE used in California.

3.1 Primary DHE

The most used type of DHE, which is the primary DHE in a home, is upright wall furnaces (69.1%), followed by console wall furnaces (21.1%), room heaters (5.7%), and floor furnaces (4.1%). About 46% of respondents did not identify the make or brand of their unit. Of the remaining respondents, Williams is the brand that makes up most of the existing fleet of DHE in the state (59.8%), followed by Cozy (16.3%), Empire (14.0%), Rinnai (5.3%) and other brands (4.6%). The same ranking applies when considering only wall furnaces. However, when considering only room heaters, Empire is the second most frequent brand, and Cozy is the third. When it comes to floor furnaces only, Empire has the largest market share, closely followed by Williams.

Overall, most DHE units in California were installed either in the 10 years before the survey was conducted (48.8%) or more than 20 years before it (33.3%).[25] Table 22 presents, for each DHE type, the approximate periods when the primary DHE was installed. The vast majority of room heaters were installed in the 10 years before the survey, which is consistent with both the time this type of equipment has been on the market and its typically shorter lifetime. On the other hand, most of the floor furnaces have been installed for more than 20 years, which is consistent with the fact that this technology was introduced to the market more than 70 years ago and with its longer lifetime. In addition, 44.1% of the existing floor furnaces were installed in the 20 years before the survey, which may indicate that these furnaces continue to be replaced on a like-for-like basis. This is likely due to the additional retrofit costs homeowners would incur to replace them with a different type of DHE.

[25] Some respondents (n=172) did not know when their primary DHE was installed.

Table 22. Distribution of DHE vintage by DHE type

Installation Period*	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Less than 2 years ago	11.5%	16.0%	18.6%	6.1%
2 to 5 years ago	17.4%	20.3%	45.8%	3.6%
6 to 10 years	14.8%	19.3%	22.2%	13.0%
11 to 20 years ago	18.5%	19.8%	5.8%	21.4%
More than 20 years ago	37.9%	24.6%	7.5%	55.9%
All Vintages	100.0%	100.0%	100.0%	100.0%

* Relative to 2021.

Most of the primary DHE in use in California is installed in the living- or family room (61.2%). Other spaces where the primary DHE is installed include hallways, bedrooms, dining rooms, and kitchens. Figure 3 shows the distribution of where DHE is typically installed, including the main living space and other spaces[26] in a home. When accounting for all DHE types, hallways are the second-most likely space in a home to have DHE installed; however, this is not the case when it comes to console wall furnaces, which are more often installed in a bedroom than in the hallway. This is consistent with hallways usually being located in an internal area of the home, with no external walls – which is a requirement for typical direct-vent installations of console wall furnaces. When disaggregating the fraction of DHE installed in a living room or family room, room heaters, when compared with the other types of DHE, are more often installed in a family room than in a living room.

[26] The other spaces include the office or study, attic, basement, garage, and any other non-living space in the home.

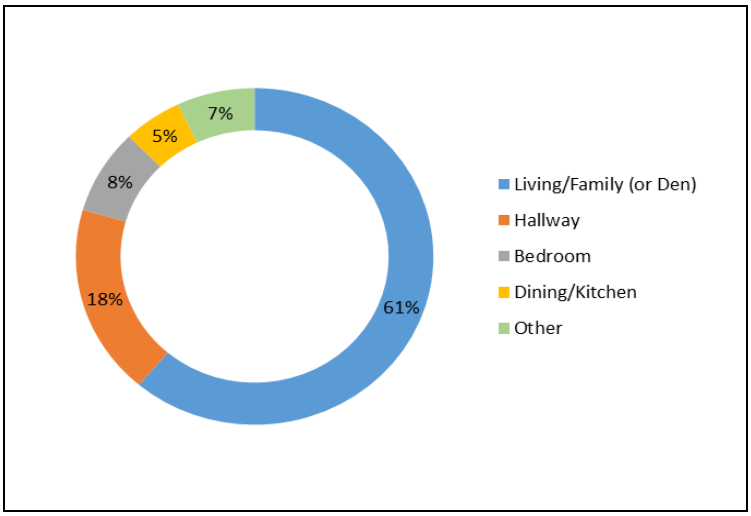


Figure 3. Distribution of spaces where the primary DHE is installed

The distribution of the additional spaces heated by the primary DHE is consistent with a floorplan where the living/family room, dining room, and kitchen are part of the same open space, which may or may not be separated from the bedrooms by a hallway. It further highlights the role of the primary DHE as the heating source not only to the space where it is installed – which would be expected, given the very definition of this class of appliance – but also to additional spaces in the home. Overall, 69.5% of all primary DHE also heat other spaces in the home, with an average of 1.7 additional spaces heated. Table 23 shows the main additional spaces heated by the primary DHE according to where in the home it is installed. DHE installed in the living room or family room, most often also heats the dining room and kitchen, and sometimes heats one or more bedrooms and/or a hallway. When installed in a bedroom, it most often also heats the living room or family room and the dining room and kitchen. When DHE is installed in the dining room or the kitchen, it most often also heats the living room or family room, and when installed in the hallway, the primary DHE most often also heats the living room or family room.

Table 23. Distribution of other spaces heated by the primary DHE

Installed in the…	**Also heats…**				
	Living/Family	Hallway	Bedroom	Dining/Kitchen	Other
Living/Family	-	18.3%	25.4%	42.4%	13.9%
Hallway	38.1%	-	29.9%	26.0%	6.0%
Bedroom	30.7%	12.4%	-	31.2%	25.8%
Dining/Kitchen	39.7%	17.0%	33.1%	-	10.2%

In addition to heating other areas in the home, because either they are all part of the same open space or through open doors, some types of wall heaters can blow warm air to other spaces that are separated from the main DHE space by a wall. Upright wall furnaces can be single- or double-sided. Double-sided upright wall furnaces are installed through a wall and heat the two adjacent spaces. In addition, some single-sided upright wall furnaces can also heat two spaces separated by a wall by installing a circulation fan through the wall that blows the warm air from the primary space where the DHE is installed to the space on the other side of the wall. Of all upright wall furnaces in California, 46.4% provide warm air to two separate spaces; of those, 81.3% are double-sided upright wall furnaces and 18.7% are single-sided upright wall furnaces installed with a through-the-wall circulation fan.

DHE can be installed in an internal or external wall. An external wall is a wall that separates the inside of a home from the outside. When installed in an internal wall, DHE is vented vertically; when installed on an external wall, it is typically vented horizontally, through the wall.[27] Overall, 28.5% of the primary DHE is installed in an external wall. In the particular case of room heaters, this fraction increases to 35.5% of units. This is a relevant characteristic, as it allows these units to be replaced, in the future, with console wall furnaces, which are more energy efficient than room heaters. Note that these percentages exclude double-sided upright wall furnaces, upright wall furnaces with through-the-wall fans, and floor furnaces, as it would not make sense for the first two to be installed in an external wall, and the latter are not installed in a wall but under the floor.

Most of the floor furnaces that are the primary DHE of the home are installed in a crawl space under the house (80.1%); the remaining are installed in the basement (19.9%).[28] Additionally, in the particular case of single-sided upright wall furnaces – which can be installed fully or partially inside the wall, or attached to the wall – 57.5% of the single-sided upright wall furnaces that are the primary DHE are installed fully or partially inside the wall. The remaining units, which correspond to 42.5% of households where the primary DHE is a single-sided upright wall furnace, are attached to – not embedded into – the wall.[28]

Some DHE models require electricity to power fan(s) and/or an electronic ignition. A large fraction of respondents (46.6%) could not identify whether their DHE unit is connected or not to a power source. Those who could correspond to 46.1% of households, of which 35.2% of the primary DHE do use electricity and 64.8% do not. The latter refers to gravity DHE.[29] Table 24 shows two sets of distributions of households according to whether their primary DHE is connected to a power source or not. The first set accounts separately for the respondents who were unsure about their primary DHE being connected to a power source or not. The second set assumes that, in those cases, since the respondent cannot confirm that the unit "has an electric plug that attaches to a wall outlet or has an electrical connection," those units are not

[27] This is how most of console wall furnaces are installed.
[28] This is important information for estimating replacement costs.
[29] Gravity DHE rely on the principle of heat rising to circulate warm air in a room and to vent the burned fuel. Note that part of the upright wall furnaces for which respondents indicated the unit is connected to a power source could also be gravity DHE, since it is possible that those units have an external accessory circulation fan.

connected to a power source. When normalizing the second set of distributions to the overall distribution of primary DHE across DHE type, results show that all floor furnaces and the majority of upright wall furnaces are gravity units.

Table 24. Distributions of households regarding electricity use by the primary DHE

Connected to a power source?	DHE Type				All DHE Types
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Unsure	73.5%	16.4%	3.5%	6.7%	100.0%
Not connected	75.6%	18.8%	3.8%	1.8%	100.0%
Connected	42.7%	41.0%	16.4%	0.0%	100.0%
Assuming 'unsure' as not connected					
Not connected	90.0%	68.6%	53.2%	100.0%	-
Connected	10.0%	31.4%	46.8%	0.0%	-
All households	100.0%	100.0%	100.0%	100.0%	-

DHE can be ignited by either a pilot light or an electronic ignition. Approximately half of the respondents (50.3%) could not identify whether their DHE unit has a pilot light or an electronic ignition. Those respondents who provided this information correspond to 67.4% of the households, of which the majority (88.5%) rely on a pilot light to ignite their primary DHE unit. The primary DHE in the remaining 11.5% of the households is ignited by an electronic ignition. When comparing the ignition method used by the two types of wall furnaces – upright and direct-vent – most of the former rely on a pilot light (93.4%), while only 64.0% of the latter do.

The room temperature of spaces heated by a DHE can be controlled automatically by a thermostat or manually by the user, typically by turning the unit on and off. Almost half of respondents (43.3%) did not respond to whether their DHE unit has a thermostat, a manual knob to control temperature, or an on/off switch. Those who did, correspond to 65.1% of households, of which 81.9% use a thermostat to control their primary DHE. The remaining 18.1% control the unit with a manual knob or an on/off switch. The shares of DHE units with and without a thermostat are relatively homogeneous across DHE types and follow the overall distribution of DHE with and without a thermostat; except for room heaters, in which case only 58.2% have a thermostat. Overall, in 88.0% of the households where the DHE has a thermostat, the thermostat is attached to the wall. Of those, 71.1% are within five feet of the unit, and the remaining 28.9% are installed more than five feet from the unit. Console wall furnaces and room heaters are the two DHE types where a larger fraction of units have a thermostat that is either attached to or is part of the unit, rather than installed on the wall. This is likely related to the console-like shape of these two DHE types, which may be more prone to

accommodate controls on the unit's case.

Approximately 88% of the primary DHE does not have a fan (gravity DHE).[30] Of the remaining primary DHE, which participants reported that do include a fan, in 94.6% of the households the fan is part of the model, while in the remaining 5.4% the fan is an accessory to the unit. Almost half of the primary DHE (49.7%), including those with and without a fan, blow the warm air straight out of the unit, while 40.3% of them blow the warm air mostly upwards and 8.2% mostly towards the floor. The direction in which the warm air is blown varies considerably across DHE types and whether the fan is part of the model or is an accessory. Table 25 shows the breakdown of units based on the DHE type, whether the fan is part of the model or not, and the direction the unit blows the warm air.

Table 25. Distribution of warm air direction by DHE type

Warm Air Direction	DHE Type		
	Upright Wall Furnace	Console Wall Furnace	Overall
Fan is part of the model			
Mostly upwards toward the ceiling[31]	66.6%	46.9%	57.7%
Out straight from the front or side of the equipment	22.0%	30.3%	25.8%
Mostly towards the floor	11.4%	22.7%	16.5%
Fan is an accessory			
Mostly upwards toward the ceiling	18.8%	-	18.8%
Out straight from the front or side of the equipment	29.3%	-	29.3%
Mostly towards the floor[32]	52.0%	-	52.0%

3.2 Secondary DHE

The presence of a secondary DHE in a household in California cannot be overlooked. More than half of respondents (55.4%), corresponding to 30.1% of all households, reported having a secondary DHE. Figure 4 shows the regional distribution of households with a secondary DHE. The distribution is similar to the general distribution of households with DHE.

[30] A small fraction of participants (0.9%) did not know whether the unit has a fan or not.
[31] In most cases, the fan is located at the bottom of the unit.
[32] In most cases, the accessory is installed on top of the unit.

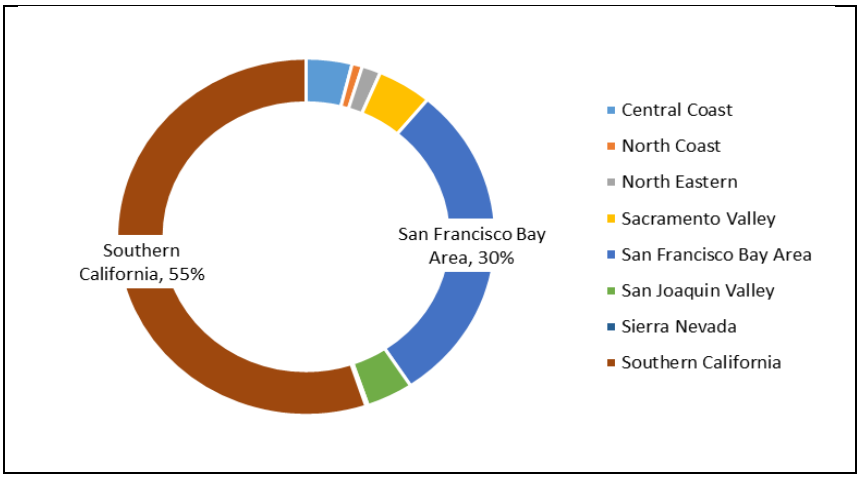


Figure 4. Regional distribution of households with a secondary DHE

The second most used DHE unit in households with more than one DHE unit is most commonly the upright wall furnaces (66.5%), followed by room heaters (25.0%). About 48.2% of the upright wall furnaces that are the secondary DHE are double-sided, and 18.2% are single-sided units that use a through-the-wall blower to warm a second space in the home.

Almost half of the secondary DHE in use in California is installed in the living room or family room (49.5%). Other spaces where the secondary DHE is installed include bedrooms (24.5%), hallways (8.9%), and dining rooms and kitchens (7.3%). Figure 5 shows the distribution of spaces where secondary DHE is typically installed, including the main living space and other spaces[26] in a home.

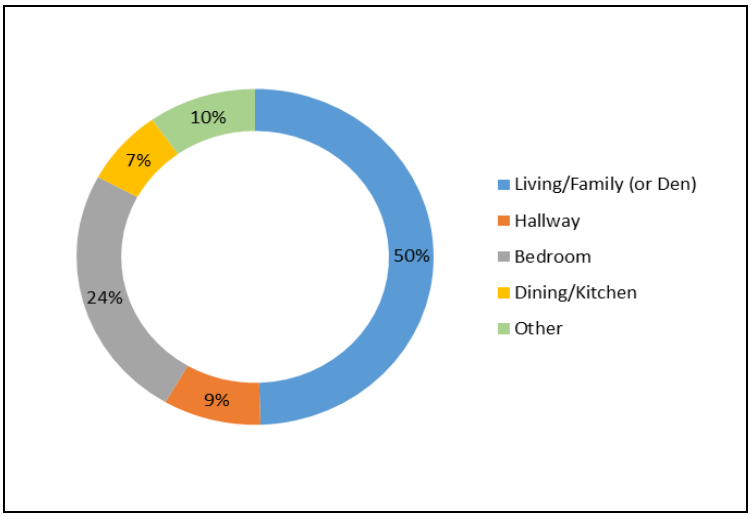


Figure 5. Distribution of spaces where the secondary DHE is installed

Overall, 16.2% of all secondary DHE also heat other spaces in the home. Table 26 shows the main additional spaces heated by the secondary DHE according to where in the home it is

installed. Secondary DHE installed in the living room or family room, most often also heats the dining room and the kitchen, as well as bedrooms and other spaces[26] in the home. When installed in a hallway, it mostly heats also the living room or family room and the bedrooms. When they are installed in the dining room or the kitchen, they most often also heat other spaces[26] in the home, as well as the living room or family room and a hallway. When the secondary DHE is installed in a bedroom it may also heat all other spaces in the home. The distribution of the additional spaces heated by the secondary DHE highlights its role as the heating source not only to the space where it is installed but also to additional spaces in the home. The secondary DHE is also a relevant source of heating for spaces not served by the primary DHE. Table 27 shows where in the house the secondary DHE supplements the heating provided by the primary DHE.

Table 26. Distribution of other spaces heated by the secondary DHE

Installed in the…	**Also heats…**				
	Living/Family	Hallway	Bedroom	Dining/Kitchen	Other
Living/Family	-	13.1%	23.8%	34.7%	28.3%
Hallway	33.3%	-	31.5%	18.9%	16.3%
Bedroom	24.7%	21.8%	-	27.4%	26.0%
Dining/Kitchen	28.2%	27.5%	6.3%	-	38.1%

Table 27. Location of the primary DHE relative to where the secondary DHE is installed

Location of the Secondary DHE	**Location of the primary DHE**				
	Living/Family	Hallway	Bedroom	Dining/Kitchen	Other
Living/Family	-	34.1%	43.6%	15.3%	7.0%
Hallway	90.7%	-	5.7%	0.0%	3.6%
Bedroom	67.1%	4.3%	20.5%	3.6%	4.4%
Dining/Kitchen	75.4%	1.5%	14.9%	-	8.2%
Other	66.6%	5.1%	18.0%	7.9%	2.4%

Overall, 35.2% of the upright wall furnaces and room heaters that are the secondary DHE in a home are installed in an external wall.[33] This is more common with room heaters (44.0% are installed in an external wall) than with upright wall furnaces (only 7.3% are installed in an external wall).[34] Concerning the floor furnaces that are the secondary DHE in a home, 71.2% are installed in crawl space under the house, while 28.8% are installed in a basement.[35]

[33] Approximately 4.0% of the households with a secondary DHE did not know whether that unit is installed on an external wall or not.

[34] Note that all console wall furnaces are installed in an external wall, and floor furnaces are not installed in a wall.

[35] Approximately 6.7% of the households where the secondary DHE is a floor furnace did not know whether that unit is installed in the basement or in a crawl space under the house.

4. Equipment Usage and User Satisfaction

The main aspects related to equipment usage that were addressed in the survey refer to when the primary DHE unit is used and how their users operate the unit's pilot light and thermostat. The season when DHE is used most is, as expected, the winter, followed by the fall. Almost all households (98.1%) use their primary DHE during the winter, while 38.0% use it during the fall. Concerning the other two seasons, 18.2% of the households use their primary DHE during the spring, and 7.6% during the summer.

Approximately 38.6% of respondents, corresponding to 59.6% of households, indicated that their primary DHE has a pilot light. In 52.6% of the households where the primary DHE has a pilot light, the pilot is on all year long; in 40.3%, the pilot is on only during the heating season; and in 7.2%, the pilot is off whenever the heater is off. Table 28 shows the breakdown of these fractions for each DHE type. It is consistent that room heater users mostly turn the pilot light off when the heater is off, and that floor furnace users mostly keep the pilot light on all year given that room heaters can easily have the pilot light turned on/off, while it is harder to turn a floor furnace pilot light on/off as the unit is installed under the floor and offers very simplified and limited controls.

Table 28. Distribution of pilot light operation by DHE type

Pilot Light Operation	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Pilot is on all year	52.1%	52.6%	27.0%	71.2%
Pilot is on only in the heating season	40.3%	43.8%	46.9%	28.6%
Pilot is off whenever the heater is off	7.6%	3.6%	26.1%*	0.2%

* When considering only propane room heaters, this percentage goes up to 48.7%.

Roughly half of the households (50.3%) who indicated that their primary DHE has a thermostat use the thermostat to turn the unit on and off as needed. The other households either set the thermostat at one temperature and leave it there most of the time (19.3%), manually adjust the temperature at night or when no one is at home (16.9%), or program the thermostat to automatically adjust the temperature during the day and night at certain times (13.5%). Table 29 presents descriptive statistics of the typical temperature at which the thermostat is set at different periods of the day.[36]

[36] Out of the 403 respondents who indicated that their primary DHE has a thermostat, 387 (corresponding to 51.1% of households) provided typical thermostat set points.

Table 29. Descriptive statistics of typical thermostat temperature (°F) set points

Typical thermostat temperature when…*	Min	Percentiles			Max	Mean	St Dev
		25%	50%	75%			
Someone is home during the day (winter)	40.0	68.0	70.0	73.3	100.0	69.5	9.1
No one is home during the day	40.0	60.0	65.0	70.0	86.0	64.4	9.7
Someone is home at night	40.0	65.0	70.0	74.8	100.0	68.5	9.6

* Responses were limited to the 40F-100F range.

DHE users are either satisfied (49.0%), dissatisfied (35.0%), or neither satisfied nor dissatisfied with their primary DHE (16.0%) with their primary DHE. The share of users that are neither satisfied nor dissatisfied with their primary DHE is relatively homogenous across DHE types. For some DHE types, however, a larger fraction of users are satisfied – rather than dissatisfied – with their primary DHE. Table 30 shows the breakdown of the level of satisfaction of DHE users with their primary DHE by DHE type. A larger fraction of owner-occupied households (56.2%) are satisfied with their primary DHE when compared with rented households (43.3%). Similarly, a larger fraction of rented households are more dissatisfied (41.6%) than the owner-occupied ones (26.8%). Of those households that are dissatisfied with their primary DHE, 51.9% indicated that their dissatisfaction comes from the unit not heating enough of the space. Additionally, of those households that are dissatisfied with their primary DHE only 47.7% had the unit installed more than 20 years before the survey, which shows that equipment age is not necessarily a driver of user satisfaction. Table 31 and Table 32[37] show the reasons why households are dissatisfied with their primary DHE.

Table 30. Level of satisfaction with the primary DHE

Levels of Satisfaction	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Dissatisfied	39.4%	25.5%	14.4%	39.2%
Neither satisfied nor dissatisfied	16.7%	14.5%	12.7%	16.0%
Satisfied	43.9%	60.0%	72.9%	44.8%

[37] Non-categorized, open-ended 'Other' reasons provided by 38 respondents.

Table 31. Reasons for dissatisfaction with the primary DHE

Reasons for Dissatisfaction	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Does not get the space warm enough	32.2%	35.3%	6.7%	37.5%	31.3%
Does not heat enough of the space	51.0%	50.0%	26.7%	87.5%	51.9%
I don't like the look of the unit	38.3%	44.1%	6.7%	31.3%	36.4%
It is too noisy	14.8%	32.4%	46.7%	12.5%	19.6%
I don't like the location of the unit in the home	30.9%	35.3%	6.7%	37.5%	30.4%
It is expensive to use it	30.9%	32.4%	13.3%	56.3%	31.8%

Table 32. Other reasons for dissatisfaction with the primary DHE

Reasons		DHE Type*
Age	It’s ancient	WF
	It’s old and not eco-friendly	DV
Air Quality	Afraid of carbon monoxide	WF
	Give me allergies	WF
	It creates a lot of dust	WF
	Smells awful when on	WF
	Smelly	WF
	Sometimes I think I can smell the gas	WF
	Too much dust comes out	DV
Comfort	Doesn't have a thermostat	DV
	Gets too hot	DV
	I have very little control over temp and it's not digital	WF
	It’s inefficient to heat the whole house	WF
	It does not circulate the air	WF
	It does not heat the back bedrooms	WF
	It does not heat the bedroom well only the living room	WF
	It doesn't have the on/off thermostat on the wall	WF
	It gets too hot, difficult to control temp	WF
	it is complicated to program thermostat	WF
	Larger vents would be better	DV
	No thermostat / temps swing wildly	WF
	All the heat goes toward the ceiling	WF
	The heat flow out is not stable	WF
	The thermostat is too close to the unit, and will only allow it to stay on if you crank the thermostat all the way up, if you try to set it to a lower temp it shuts off immediately. So you can choose no heat or too hot, and control by turning on/off. And the heat doesn't reach the master bedroom at all.	DV

Reasons		DHE Type*
	Very uneven heating, either too hot or too cold	WF
	Want to control with my smartphone	WF
Energy	Uses a lot of gas	FF
	Inefficient	WF
Malfunction	Doesn't work	WF
	Doesn't turn on and have to get maintenance to reheat the propane	WF
	Pilot goes out frequently	WF
	Pilot light does not stay on, so not working	WF
	Thermostat is broken, have to play with it to turn it on	WF
Safety	Feels unsafe; in the middle of floor and grate gets too hot to touch	FF
	I like the unit but lighting the pilot light is scary	WF
	It caught the house on fire	WF
	I've had safety issues with it before	DV

* WF: Upright wall furnace, DV: Console wall furnace, RH: Room heater, FF: Floor furnace.

More than half of households (58.6%) consider the home to be warm during the cold season or winter. The remaining households consider their home to be cold (33.5%) or neither cold nor warm (7.9%). Upright wall furnaces are the DHE type with the highest fraction (60.3%) of households that consider the house warm during the winter, while floor furnaces are the ones with the lowest fraction (48.9%).

Considering the heat distribution over the space heated by their primary DHE during the winter, only 24.0% of households indicated that the warm air is evenly distributed throughout the space. Most of the remaining households (45.6%) reported that it is initially warmer near the equipment, and it takes time to heat the space farther from the unit. The other 30.4% of the households consider that either: it is initially warmer near the upper part of the space, and it takes time to heat the bottom of the space, by their feet (23.2%); or it is initially warmer near their feet and it takes time to heat the upper part of the space (7.2%). Table 33 shows how this sentiment varies across users of different types of DHE. Results are consistent with the fact that floor furnaces tend to initially heat the lower part of the space, while upright wall furnaces tend to blow the warm air upwards.

Table 33. Characteristics of the heat distribution in the space heated by the primary DHE

Heat Distribution	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Evenly distributed throughout the space	25.6%	19.5%	29.1%	13.4%
Initially warmer near the upper part of the space It takes time to heat the bottom of the space	22.8%	27.8%	20.1%	10.8%

Heat Distribution	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Initially warmer near the bottom of the space It takes time to heat the upper part of the space	4.8%	9.8%	17.0%	20.7%
Initially warmer near the equipment It takes time to heat the space farther from the unit	46.8%	42.9%	33.9%	55.1%

Around two thirds of the households (65.3%) consider the quality of the air when their primary DHE is on about the same as when the unit is off; the remaining households consider it either better (19.3%) or worse (15.4%). Table 34 shows the breakdown of these fractions of households by DHE type. Room heater users are the largest fraction of households who indicated that the air quality when their primary DHE is on is better than when the unit is off. Users of the other three types of DHE have a relatively balanced opinion about the quality of the air being better or worse when their primary DHE unit is on, compared with when it is off. Most of the respondents who indicated the quality of the air is worse when their primary DHE is on complained about the dryness of the air (40.8%). Other reasons include dustier (37.8%) and stuffy (31.6%) air, as well as smell (typically burnt) and other odors that come off the unit when it is running (35.7%).[38] Table 35[39] presents additional comments from some respondents who feel that the quality of the air is worse when their primary DHE is on, compared with when it is off.

Table 34. Quality of the air when the primary DHE is on compared with when it is off

Air Quality	DHE Type			
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace
Better	15.7%	24.8%	45.4%	15.8%
About the same	68.7%	57.9%	49.6%	69.5%
Worse	15.6%	17.4%	4.9%	14.8%

[38] DHE, unlike central furnaces, do not include filters. Therefore, they are not able to remove dust from the warm air provided. In addition, because dust can accumulate on the unit, as the unit heats it burns the dust and creates a burning smell in the heated space.

[39] Non-categorized, open-ended 'Other' reasons provided by 32 respondents.

Table 35. Reasons the quality of the air is worse when the primary DHE is on than when it is off

Comments	DHE Type*
Air quality decreased with the increase of air temperature	RH
Allergy symptoms sometimes so probably dust	DV
Because the grate is on the floor dust and pet hair is constantly getting into it and it smells like burning every time I turn it on	FF
Eyes itch, sore throat in the morning	WF
I'm sure that the heater is old and blows dust through broken ducts	WF
It feels like there are particles in the air	WF
It gives off a burnt smell sometimes that can't be good for the air	WF
It puts out a lot of dust in the air and makes it dry. Dries out my nose.	RH
it seems not to be clear and has an odor	WF
It seems to always be dusty and attract dust and the heat is very dry	WF
Lowers the oxygen level and you can tell! Makes small apt dustier as well	WF
Much more particulates	FF
Odor, stuffy, and dust even though I clean the vents often	WF
Smell and weight of the heated air	WF
Smells awful. We hardly use it because of that. We only turn it on when it gets too cold.	WF
Smells of burnt fuel. Air gets dryer and a little stuffy.	WF
Sometimes there is an odor, but it feels stuffy when it is on too long	FF
Stirs up stuff from the carpet, etc.	WF
Stuffy and heavy feeling, sometimes I open a window on opposite side of room to encourage air flow	WF
Sucks all of the humidity out of the air, definitely has an impact on some of our house plants	WF
The air becomes heavy and dry	DV
The air becomes very dry if the heater is on for a prolonged period of time	WF
The air feels thicker, not comfortable. We usually turn the heater on and off often due to it's not making the air comfortable to breath.	WF
The air gets dry. Rust odor. Feels like an oven.	WF
The air is very dry and dusty. The unit is difficult to clean, and blows hot dust out. Also, because it seems to blast heat, it creates a stuffy environment.	WF
The system came with the house and it blows out a lot of dust while on. Too expensive to replace at the moment	DV
There is a very light smell of gas. My husband can't feel it, but I can. Also the air is super dry after we use the heater.	WF

There is an old musty odor and stale air	WF
There is definitely an odor after having it shut off for a season, and the air is much drier. Sometimes I need to compensate for this dryness by using a humidifier.	DV
There is more dust and my air purifier comes on regularly. It is dry and stuffy.	WF
Too hot in one spot and breathing is bad.	WF
Too much dust comes out. Therefore, I feel some dust even in my throat. …[40]	DV

* WF: Upright wall furnace, DV: Console wall furnace, RH: Room heater, FF: Floor furnace.

Overall, only 28.9% of households have no problems or issues with their primary DHE and have been able to use it as much as they wanted. Of the remaining households, those that have problems with their primary DHE unit, 36.2% stated that the unit is expensive to operate and they wanted to lower their heating bills. In addition, 35.2% mentioned that the temperature is inconsistent, with some areas being too hot while other areas remain cold, and 19.3% have concerns about the quality of the air indoors when the DHE is on. Further, 16.9% indicated that the unit is too old and they are concerned it will break down with frequent use. Table 36 presents the main reasons households do not use their primary DHE to improve comfort, as an aggregate and broken down by DHE type. Table 37[41] provides additional comments from respondents who indicated an "Other reason" for not using their primary DHE to improve comfort.

Table 36. Main reasons for not using the primary DHE to improve comfort

Reasons	**DHE Type**				**All DHE**
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
It is expensive to operate and I wanted to lower my heating bills	25.8%	6.9%	2.0%	1.5%	36.2%
Temperature is inconsistent, some areas are too hot while other areas remain cold	23.6%	9.2%	1.3%	1.1%	35.2%
Concern about the quality of the air indoors when the DHE is on	13.3%	4.5%	1.1%	0.4%	19.3%
The equipment is too old and I am concerned it will break with frequent use	11.3%	4.2%	0.6%	0.9%	16.9%

[40] "*… Thus, I had to put water in the bottle and spay it on the air in the room. Also, I had to buy air purifier and then, I operated the air purifier for several hours while I was out of home. Sometimes I had to give up operating the DHE due to the air problem (dust) and, instead of using DHE I put water in slow cooker and made the vapor from the slow cooker heat my room while I am sleeping at night. Then, in the morning after I got up, I operate the DHE. I moved in this apt in 2014. But this building was built in 1927 (about 100 year old building). I guess the DHE was installed long, long time ago. This DHE uses gas. I pay for gas. I would like to suggest you make Gas company replace old DHE for free since it contaminates air and makes residents' health (especially lung) risky*."

[41] Non-categorized, open-ended 'Other' reasons provided by 20 respondents.

Reasons	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
The unit breaks down very often	3.0%	0.6%	0.4%	-	4.0%
It does not improve the home's comfort	6.9%	1.8%	0.3%	0.2%	9.3%
Other reason	3.8%	1.7%	0.03%	0.1%	5.6%
I have no problems or issues, and I have been able to use the DHE as much as I wanted	21.1%	4.3%	1.8%	1.7%	28.9%

Table 37. Other reasons for not using the primary DHE to improve comfort

Reasons	DHE Type*
Afraid of intoxication if pilot goes off and gas comes out at night	WF
DHE is not well placed in the apartment	WF
Doesn't heat the spaces I want heated	WF
It can be loud, when working from home	WF
It caught the house on fire	WF
It doesn't heat the back rooms	WF
Lost thermostat remote controller	RH
Makes too much noise	RH
My spouse and I don't agree on a comfortable temperature	WF
Never really know temperature because the thermostat is broken, have to tap it to turn on	WF
Noise	WF
Pilot light has gone out several times	WF
Safety concerns (landlord never checks anything in the house, also grate gets very hot)	FF
The apartment isn’t well insulated so basically we’re wasting energy & money when we use it	DV
The space is too large	DV
The thermostat goes out all of the time, causing us to have to call the Gas Company out to repair. It broke just before winter this year. We left it off all winter due to the whole COVID outbreak and lockdown. Thankfully it didn't get as cold as normal this past winter. Our house has no insulation, so it gets cold.	WF
Too noisy	DV
Trying to conserve energy	WF
We have warm to hot days in winter also	DV

5. Equipment Maintenance, Repair and Replacement

DHE needs maintenance and sometimes repairs. Nevertheless, almost half of households (49.0%) have never had any routine maintenance work done on their primary DHE unit. Of those households that did have routine maintenance work done on their primary DHE, 73.3% had one or more maintenance services performed every two years. Contrastingly, 17.2% of households had only one maintenance service done every three to four years, and 9.5% every five years or more.[42] When considering the frequency of maintenance services by DHE type, room heaters are the type of DHE that receive maintenance most frequently, with 54.7% of households reporting one or more maintenance services per year, while 40.3% of floor furnaces report having maintenance service once every two years.

Concerning the need for repairs, 8.7% of households stated that their primary DHE has never required any repair, while 40.5% indicated that, although their primary DHE does require some repairs, they have never repaired it. Of the remaining households, that did do some repairs to their primary DHE, 83.1% had it repaired in the five years before the survey, and 16.9% had it repaired more than five years before the survey.[43] Of the primary DHE that was repaired in the five years before the survey, 39.0% had only one repair event, 38.4% had two repair events, and 22.6% were repaired three or more times. The most frequent reasons for repairing the primary DHE were fixing or replacing the thermostat (32.7%) and the pilot light (28.5%). The vast majority of those two types of repairs refer to upright wall furnaces, which comprise 82.9% of the repairs done on the pilot light and 70.6% of the repairs related to the thermostat. Table 38 shows the types of repairs performed on the primary DHE with their corresponding frequency. The table also shows, for each type of repair, the distribution of the repair events considering how often the unit was repaired.[44]

Table 38. Main types of repair performed on the DHE[44]

Type of Repair	Repair Frequency*			Repaired >5 years**	Any time
	1x	2x	3x		
Pilot repair or replacement	7.5%	12.1%	5.4%	3.5%	28.5%
Thermostat repair or replacement	10.2%	11.1%	7.5%	3.9%	32.7%
Electrical, circuit, or amperage repair or adjustment	2.2%	6.9%	5.1%	0.1%	14.3%
Fan repair or replacement	2.8%	7.1%	4.5%	0.5%	14.8%
Fan Sensor repair or replacement	3.7%	5.4%	2.0%	0.3%	11.4%
Heat exchanger repair or replacement	1.9%	7.8%	1.7%	0.6%	12.0%
Flue vent repair or replacement	2.3%	4.5%	2.0%	2.0%	10.9%

[42] Approximately 10.3% of respondents, corresponding to 15.6% of households, did not remember when they had a routine maintenance work done on their primary DHE unit.

[43] Approximately 6.8% of respondents, corresponding to 9.1% of households, did have their primary DHE repaired but did not remember when.

[44] The percentages under the columns 'Repair Frequency' and 'Repaired >5 years' do not imply that the corresponding type of repair happened with that frequency. Rather, it shows – in general – how often households that had that type of repair on their primary DHE do repair the unit (regardless of the type of repair).

Type of Repair	Repair Frequency*			Repaired >5 years**	Any time
	1x	2x	3x		
Gas piping	1.5%	5.6%	4.5%	0.05%	11.6%

* Frequency of repairs in the five years before the survey.

** The unit was repaired more than 5 years before the survey.

Most households learned that they needed to repair their primary DHE because the unit malfunctioned (28.6%) or it was not heating well (20.6%). Table 39 shows a list of factors that triggered the repair of the primary DHE, with the fractions of households that learned they needed to repair it due to these factors. Other factors mentioned by some individual respondents include the smell of gas and being informed by the gas utility that the unit needed to be repaired. Some households were not sure of how long the unit would continue to work, after being repaired, before it would have to be replaced (26.9%). Of those who did expect the extended life of the unit once it was repaired, 55.1% thought the unit would continue to work for at least three more years. Table 40 shows additional lifetime expectations from households that had their primary DHE repaired. Depending on the severity of the required repair and the age of the unit, households may choose to replace the unit rather than repair it. Among the reasons for which those households did not replace the unit, 36.8% mentioned that other necessary expenses in the residence took priority, and therefore repair was the best decision, while 21.4% cited their financial situation at the time to justify that repairing was the best short-term solution. In addition, 20.0% stated they were not planning to be in the house long enough to justify the replacement. Table 41 shows other reasons for which households preferred to repair their primary DHE instead of replacing it. Concerning future repairs, 38.1% of households indicated that if they need to repair their primary DHE in the future, they would rather replace it. For the remaining households, the repair cost would be a determinant of whether the unit would be repaired or replaced. The repair costs expressed by households range from $10 to $1,500 (the maximum allowed in the survey questionnaire), with an average of $451.54. Figure 6 presents the cumulative distribution of the repair costs and the values of selected percentiles.

Table 39. Main factors that triggered the repair of the primary DHE

Factors that Triggered a Repair	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
System started to malfunction	22.2%	5.1%	0.4%	0.6%	28.3%
Equipment was not heating well	14.6%	3.8%	1.7%	0.5%	20.6%
System broke down completely	8.9%	5.7%	3.1%	0.2%	17.9%
System was making strange noises	7.7%	4.5%	1.5%	0.2%	13.9%
Equipment was old, and I was concerned that it would break down at any minute	6.8%	3.8%	1.5%	0.1%	12.2%

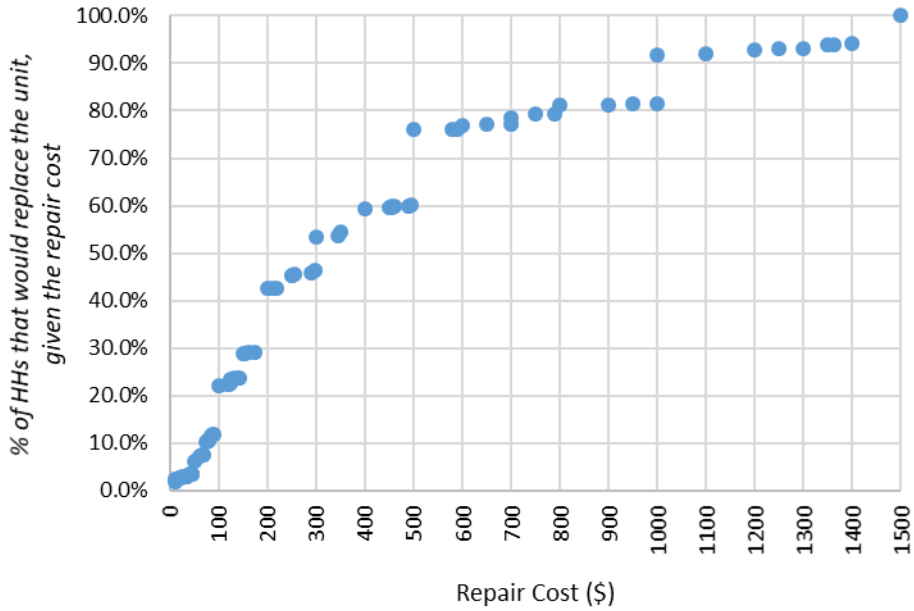
Factors that Triggered a Repair	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Problem found during routine maintenance or a "clean and check" service call	8.9%	1.3%	1.0%	0.0%	11.2%
Was not sure the equipment was safe	4.0%	1.5%	0.0%	0.1%	5.7%

Table 40. Expected extended lifetime of the primary DHE after being repaired

Additional Lifetime Expected	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Less than a year	9.7%	17.7%	21.7%	-	12.7%
1 to 2 years	27.8%	42.0%	41.0%	7.2%	32.2%
3 to 5 years	30.5%	22.1%	20.4%	32.5%	27.5%
6 or more years	31.9%	18.2%	16.9%	60.3%	27.6%

Table 41. Main reasons for repairing the primary DHE rather than replacing it

Reasons for Repairing	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Other necessary expenses with my residence took priority, so repair was the best decision	25.8%	7.3%	3.1%	0.6%	36.8%
This was the best short-term solution given our financial situation at the time	12.4%	6.3%	2.3%	0.3%	21.4%
I was not planning to be in this residence long enough to justify the replacement	14.1%	5.8%	-	-	20.0%
Wanted to start with a repair as a first step before deciding to replace the equipment	10.3%	2.8%	1.5%	0.1%	14.7%
The suggested repair was minor, and it was more cost-efficient to repair the equipment rather than replace it	7.9%	3.0%	2.4%	0.2%	13.5%
Decided to go ahead with this repair and then consider purchasing the new equipment closer to the next winter	6.6%	1.9%	0.9%	0.9%	10.3%



Min	Percentile					Max
	5%	25%	50%	75%	95%	
$10	$50	$150	$300	$500	$1,500	$1,500

Figure 6. Cumulative distribution of households that would replace their primary DHE unit given a repair cost

Although some households had their primary DHE unit repaired in the five years before the survey, some had it replaced during that period.[45] The main reasons for replacing, rather than repairing their primary DHE, were that they had a problem with unit breaking down (39.5%) and that the unit was not turning on and/or off (36.5%). Table 42 shows reasons that led households to replace their primary DHE rather than repair it, with the corresponding fractions of households.[46] Other reasons mentioned were that the unit was "80-year old and was leaking gas," and that the unit "kept setting the smoke alarm off."

Some households did not know who purchased the new unit or from where it was purchased (25.9%). Of those who did, more than half (51.2%) indicated that the new unit was purchased by a contractor; the remaining households purchased the unit themselves. Table 43 shows who purchased the new replacement unit and from where it was purchased. In some cases, the

[45] Results about replaced units assume that the primary DHE installed in the last five years was a replacement unit, rather than a unit that was installed in a space where there was not previously heated by another DHE unit.
[46] Note that 7.3% of the households where the primary DHE was replaced did not know the reason for replacing it.

purchase could have been made either in person or online. Results show that households who did not have the new unit purchased by a contractor preferred to purchase it in person when they purchased it directly from a large home improvement store (62.5%), a hardware store, or a similar retail store (74.1%), or a distributor or dealer (57.5%). In addition, most of the households (81.3%) where the new unit was purchased directly from a physical or online store are owner-occupied. The remaining purchases made directly by the household were made by households rented from a private entity (18.0%) or a housing authority (0.7%).

Most households (94.8%) know who installed the new primary DHE and indicated the unit was installed most often (88.3%) by a contractor or a certified technician. This holds even for the replacement units that were purchased directly by the household, of which 78.8% were installed by a contractor or a certified technician. Table 44 provides more details regarding who installed the replacement primary DHE. Results are consistent with the fact that room heaters tend to be easier to install, in contrast with the other types of DHE, especially floor furnaces. In addition, room heaters purchased directly by the household were installed by the household (27.2%) more often than upright wall furnaces (19.3%) and console wall furnaces DHE (18.6%) units.

Table 42. Main reasons for replacing the primary DHE rather than repairing it

Reasons for Replacing	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Problem with unit breaking down	23.5%	11.0%	4.3%	0.7%	39.5%
The unit was too old	15.4%	5.8%	1.1%	-	22.4%
The unit did not turn on and/or not turn off	25.9%	4.5%	5.2%	0.8%	36.5%
The pilot went off on its own regularly	4.5%	2.4%	0.5%	0.1%	7.5%
The unit was too expensive to repair	7.2%	3.1%	0.1%	-	10.4%
To improve heating comfort	1.8%	3.7%	1.5%	-	6.9%
To improve indoor air quality	9.5%	4.0%	4.7%	0.2%	18.3%
To lower energy bill	13.6%	2.8%	4.6%	-	21.1%
Replaced as part of a house remodeling	11.1%	4.6%	2.4%	-	18.0%

Table 43. Who purchased the new primary DHE and from where it was purchased

Purchased by	Purchased from	DHE Type				All DHE
		Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Contractor	-	62.0%	45.6%	23.9%	98.4%	51.2%
Household	Large home improvement store	23.4%	17.7%	32.0%	-	22.9%
	Hardware or similar retail store	4.8%	14.3%	9.8%	-	8.3%
	Distributor or dealer	6.1%	13.8%	5.2%	-	8.1%
	Online-only retailer	3.7%	8.6%	29.1%	1.6%	9.4%

Table 44. Who installed the new primary DHE

Installed by	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Contractor or certified technician	94.1%	87.1%	67.0%	100.0%	88.3%
Household occupant with the help of a friend, relative, or neighbor	5.9%	12.9%	33.0%	-	11.7%

Some households planned to replace their primary DHE in the two years following the survey (22.7%). The type of DHE most likely to be replaced is room heaters (48.8%), followed by console wall furnaces (22.7%), upright wall furnaces (21.3%), and floor furnaces (10.6%). This is consistent with lower equipment and installation costs of room heaters when compared with the other DHE types, especially floor furnaces. The main reasons for making the change are to improve the heating comfort (44.8%), lower energy bills (37.3%), and the age of the unit (36.0%). Table 45 shows other reasons for replacing the primary DHE in the near future, with their corresponding fractions of households. Some households (16.8%) did not know, at the time of the survey, who would buy the new unit and from where. Most of those who did know indicated that the new unit would be purchased directly by the household (66.4%). Floor furnaces would be most likely purchased by a contractor (40.3%), while room heaters would be most likely purchased by the household (86.9%). Of the units that would be purchased by the household, most would be purchased from a home improvement store (35.6%), followed by a hardware or retail store (11.5%), an online-only store (11.2%), and a distributor or dealer (8.1%). The largest fraction of households that would buy the new unit from an online-only store is from room heater users (32.5%). Table 46 shows who is likely to purchase the new replacement unit and from where, and Table 47 shows who will install it. Overall, the majority of the new units will be installed by a contractor or certified technician (84.7%). However, a larger percentage of households whose primary DHE is a room heater, when compared with other

types of DHE, indicated that the new unit would be installed by the household occupant with the help of a friend, relative, or neighbor (29.0%). This is consistent with the results above that show that room heaters are also most likely to be purchased directly by the household.

Table 45. Reasons for replacing the primary DHE in the near future

Reasons for Replacing	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Improve heating comfort	28.2%	12.2%	2.8%	0.2%	44.8%
Lower the energy bill	26.5%	7.4%	1.9%	2.2%	37.3%
Unit is too old	25.3%	9.0%	1.0%	2.4%	36.0%
Improve indoor air quality	10.3%	10.2%	2.4%	0.3%	25.2%
Unit replaced as part of a house remodeling	18.6%	4.4%	0.7%	0.4%	23.4%
Unit is too expensive to repair	10.9%	4.5%	0.3%	0.3%	15.4%
Unit replaced with another piece of equipment	8.4%	4.4%	0.2%	1.2%	13.4%
Problem with the unit breaking down	6.9%	2.7%	0.4%	-	10.1%
Pilot goes off on its own regularly	6.8%	1.4%	0.5%	-	8.8%
Unit is not turning on and/or not turning off	5.8%	1.1%	0.1%	-	6.9%

Table 46. Who will purchase the new primary DHE and from where it will be purchased

Purchased by	Purchased from	DHE Type				All DHE
		Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Contractor	-	36.4%	36.3%	13.1%	40.3%	33.6%
Household	Large home improvement store	35.3%	34.9%	38.0%	38.6%	35.6%
	Hardware or similar retail store	12.0%	9.7%	12.2%	10.1%	11.5%
	Distributor or dealer	7.6%	11.6%	4.2%	10.9%	8.1%
	Online-only retailer	8.7%	7.6%	32.5%	-	11.2%

Table 47. Who will install the new primary DHE

Installed by	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Contractor or certified technician	85.4%	89.6%	71.0%	94.8%	84.7%
Household occupant with the help of a friend, relative, or neighbor	14.6%	10.4%	29.0%	5.2%	15.3%

In addition to purchasing a new DHE unit to replace the existing primary DHE, 29.9% of households indicated they had recently purchased or were planning to purchase an additional DHE unit for their home. The main reason for purchasing an additional DHE was to improve the heating in a space already heated by another heater, either a DHE or any other type of heating system (59.3%); another reason was to add the unit to a space not yet being heated (32.6%).

6. Investing in a New DHE Unit

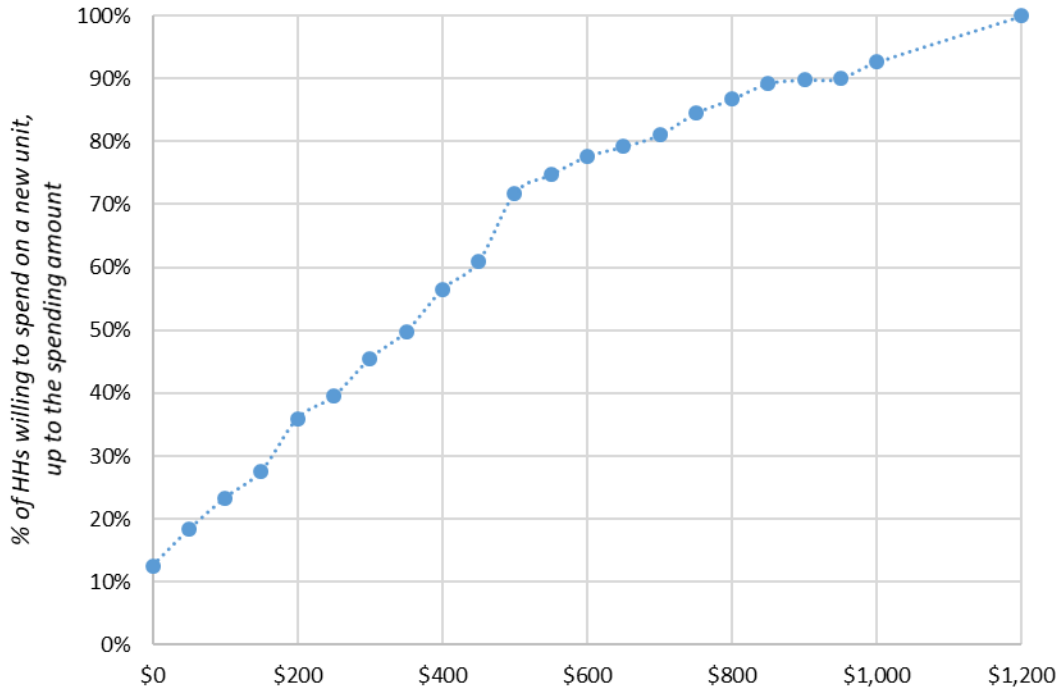
Households with DHE have concerns regarding their thermal comfort, indoor air quality, fuel costs, and the environment, and they indicated they are willing to spend money on a new DHE that would improve those four areas of concern. The majority of households (80.1%) would spend an average of $410.58, and 7.4% would spend more than $1,000 to have more control of the temperature and better-distributed heat to improve the comfort in the spaces heated by their primary DHE.[47] Fewer owner-occupied households (47.0%) would spend to improve the comfort provided by their primary DHE than rented households would spend (53.0%). However, homeowners who are willing to spend between $50 and $1,000 would spend an average of $512.97, compared with the average of $332.24 that renters would spend; and a larger fraction of owner-occupied households (12.7%) would spend more than $1,000, when compared with rented households (3.9%). This is consistent with previous results that show that owner-occupied households are more satisfied with their primary DHE than rented households are and suggests that homeowners are willing to make larger investments in their own houses. There is no relevant association between the willingness to spend to improve thermal comfort and the age of the unit; yet, some relationship can be observed between the willingness to spend and annual household income. In the latter case, the household's willingness to spend any amount below $200 (including a $0 willingness to spend) monotonically decreases as annual income increases, while the household's willingness to spend more than $500 monotonically increases as annual income increases. This is consistent with the idea that households with a higher income can – and would – spend more to improve the comfort provided by their primary DHE unit than households with lower levels of income would spend.

Table 48 shows the fractions of households according to what they are willing to spend to improve the comfort provided by their primary DHE, as well as the corresponding average dollar amount. When compared with other DHE types, a higher share of households where the primary DHE is a floor furnace would spend more than $1,000, and a lower share would not spend any amount. They would also spend a higher average dollar value when considering spending within the range of $50 to $1,000. This indicates that floor furnace DHE users are the least satisfied DHE users when it comes to the thermal comfort the unit provides. It is also consistent with previous results that show that floor furnace users comprise the lowest fraction of users, across DHE types, who consider their home to be warm during the winter, as well as those users representing the highest fraction of households that indicated the DHE does not heat enough of the heated space. Figure 7 presents the cumulative distribution of the dollar amount that households are willing to spend to increase thermal comfort in the spaces heated by their primary DHE, and those values for selected percentiles. In the figure, the $1,200 value symbolically represents a willingness to spend more than $1,000.

[47] These values refer to the dollar amount households are willing to spend on top of the cost of a new DHE unit that is similar to their current primary DHE.

Table 48. Willingness to spend to improve thermal comfort provided by the primary DHE

Value	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
$0	14.6%	6.5%	14.1%	6.3%	12.5%
$50 - $200	26.5%	20.7%	5.2%	12.9%	23.5%
$250 - $500	32.8%	47.3%	41.2%	20.9%	35.8%
$550 - $1,000	19.5%	20.0%	25.5%	39.4%	20.8%
Average value ($50 - $1,000)	$392.69	$425.05	$478.07	$552.88	$410.58
$1,000+	6.7%	5.4%	13.9%	20.5%	7.4%



Min	Percentile					Max
	5%	25%	50%	75%	95%	
$0	$0	$150	$350	$550	$1,000+	$1,000+

Figure 7. Cumulative distribution of households' willingness to spend to increase thermal comfort

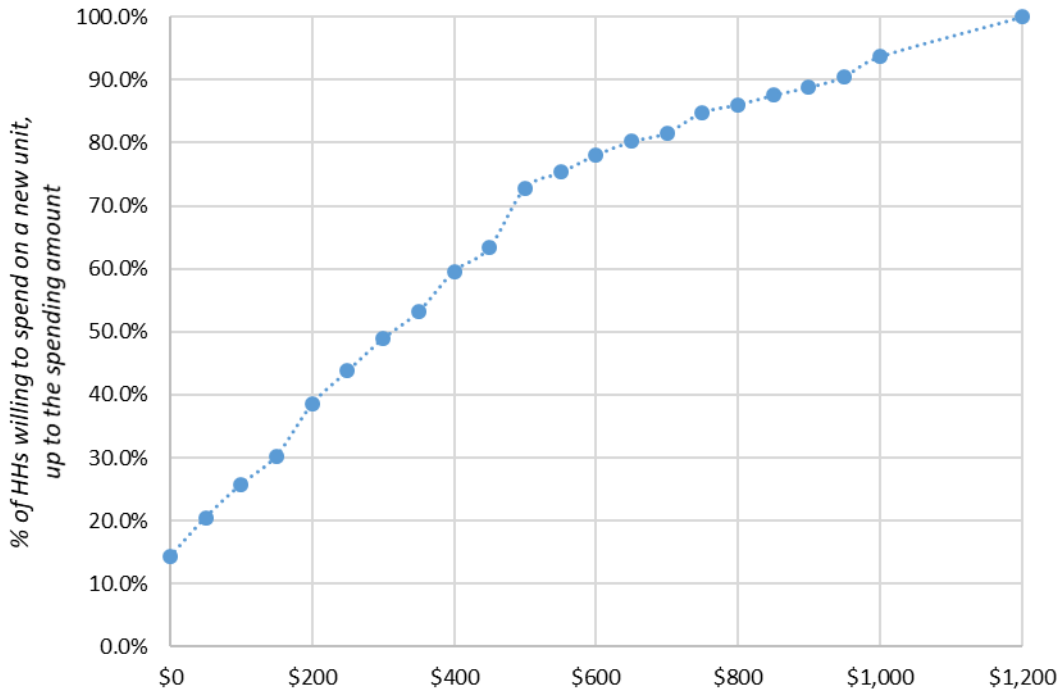
Most households are also willing to spend on a new DHE to improve the cleanliness of the air inside their home (e.g., reduce pollutants, dust particles, etc.), with 79.5% willing to spend between $50 and $1,000, and 6.3% above $1,000.[47] The average amount that the households, which are willing to spend between $50 and $1,000, would spend is $408.99. Floor furnace users would spend a higher average value ($472.12) when compared with users of the other types of DHE. Similar to their willingness to spend to improve comfort, fewer owner-occupied households (46.0%) would spend to improve the indoor air quality associated with their primary DHE than rented households (54.0%). However, homeowners who are willing to spend between $50 and $1,000 would spend an average of $487.30, compared with the average of $347.09 that renters would be willing to spend, and a larger fraction of owner-occupied households (9.3%) would spend more than $1,000 when compared with rented households (4.8%). This also suggests that homeowners are willing to make larger investments in their own house, and is consistent with previous results that show that owner-occupied households are more satisfied with their primary DHE than rented households are. There is no relevant association between the willingness to spend to improve the indoor air quality in the spaces heated by the primary DHE and the age of the unit, or between willingness to spend and the household annual income. In the latter case, however, the average dollar value of those households that reported they would spend between $500 and $1,000 grows with household annual income. This is consistent with the idea that households with higher income can – and would – spend more to improve the indoor air quality of the spaces heated by their primary DHE unit than households with lower income would spend.

Table 49 shows the fractions of households according to what they are willing to spend to improve the indoor air quality associated with their primary DHE, as well as the corresponding average dollar amount. Similar to their willingness to spend to improve comfort, when compared with other DHE types, a higher share of households where the primary DHE is a floor furnace would spend more than $1,000, and a lower share would not spend any amount of dollars. They would also spend a higher average dollar value, when considering the range of $50 to $1,000. This indicates that floor furnace DHE users are the least satisfied with the indoor air quality associated with the DHE unit. Figure 8 presents the cumulative distribution of the dollar amount that households are willing to spend to improve indoor air quality in the spaces heated by their primary DHE, and those values for selected percentiles. In the figure, the $1,200 value symbolically represents a willingness to spend more than $1,000.

Table 49. Willingness to spend to improve indoor air quality associated with the primary DHE

Value	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
$0	16.8%	8.6%	9.3%	7.2%	14.2%
$50 - $200	27.0%	18.3%	15.1%	20.5%	24.2%
$250 - $500	31.9%	42.1%	40.0%	27.6%	34.3%

Value	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
$550 - $1,000	19.2%	24.0%	25.3%	26.9%	20.9%
Average value ($50 - $1,000)	$394.35	$437.14	$429.48	$472.12	$408.99
$1,000+	5.1%	6.9%	10.2%	17.9%	6.3%



Min	Percentile					Max
	5%	25%	50%	75%	95%	
$0	$0	$100	$350	$550	$1,000+	$1,000+

Figure 8. Cumulative distribution of households' willingness to spend to improve indoor air quality

Concerning fuel costs, most households are willing to spend on a new DHE that would reduce the annual gas bill from their primary DHE. The amount they are willing to spend depends on their annual gas cost and the savings the new unit would provide. Households would spend $50 to more than $1,000 on a new DHE to reduce their annual energy bill by $50 (74.0%), by

$100 (62.4%), by $250 (53.8%), and by $500 (44.0%).[47,48] Some households, however, do not spend enough on their primary DHE's gas bill to justify those fuel cost reductions. Table 50 shows the shares of those households by DHE type and annual fuel cost reduction amounts. Other households (5.4%) responded they would not spend any amount on a new DHE to reduce their fuel cost by any value, mostly because they are renters, but also because their current primary DHE is either new or working fine, or because they believe the investment would not be cost-effective.

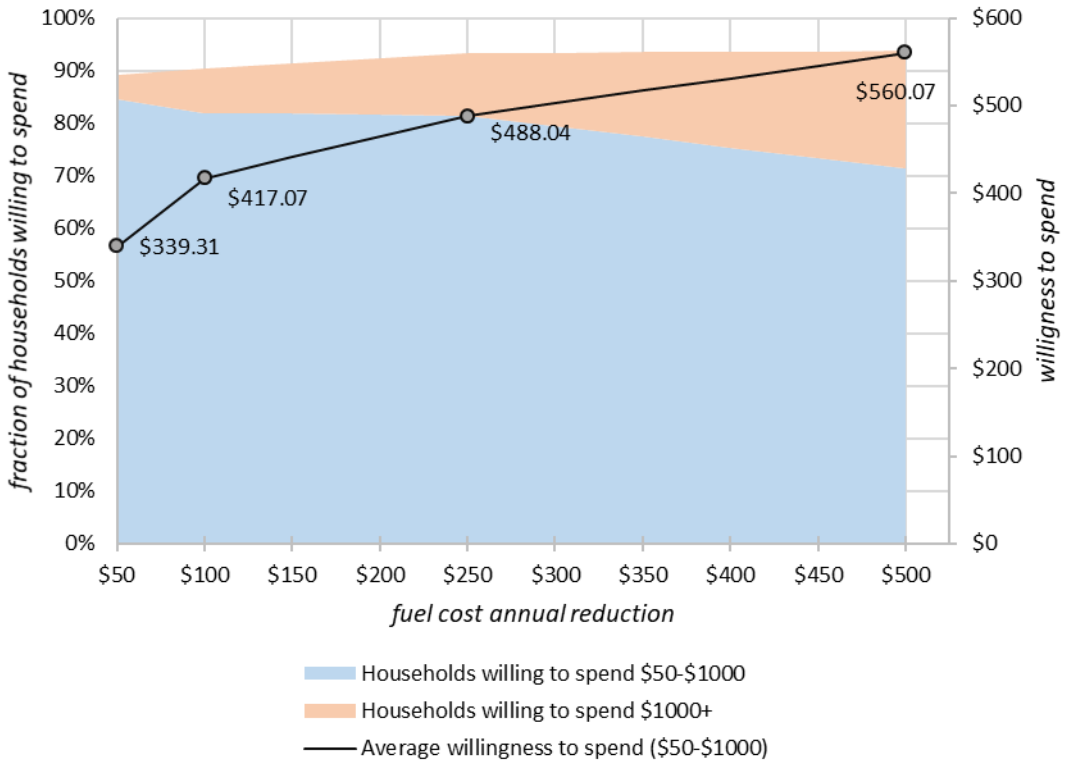
Table 50. Shares of households that would not spend on a new DHE to reduce fuel cost

Annual Fuel Cost Reduction	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
$50	15.4%	23.5%	11.8%	15.2%	16.9%
$100	24.2%	32.5%	33.0%	27.7%	26.6%
$250	33.0%	43.9%	44.3%	29.0%	35.8%
$500	43.9%	47.9%	49.5%	41.3%	44.9%

The majority of households (83.1%) spend $50 or more annually on fuel for their primary DHE. Of those, 84.4% would spend between $50 and $1,000 to reduce the annual gas bill of their primary DHE by $50, with an average willingness to spend $339.31, while 4.7% would spend more than $1,000 for the same reduction. A smaller fraction of households (73.4%) spend $100 or more annually on fuel for their primary DHE, while 64.2% spend $250 or more, and 55.1% spend $500 or more. Of those whose annual gas bill is $100 or more, 82.0% would spend between $50 and $1,000 to reduce the annual gas bill of their primary DHE by $100, with an average willingness to spend $417.07, and 8.3% would spend more than $1,000 for the same reduction. Of those with an annual gas bill equal to or greater than $250, 81.4% would spend between $50 and $1,000 to reduce the bill by $250, with an average willingness to spend $488.04, and 11.9% would spend more than $1,000 for the same reduction. Of those who spend $500 or more, 71.3% would spend between $50 and $1,000 to reduce their gas bill by $500, with an average willingness to spend $560.07, and 22.4% would spend more than $1,000 for the same reduction. Figure 9 shows the shares of households willing to spend between $50 and $1,000, with the corresponding average amount they are willing to spend, for each value of annual fuel cost reduction. The figure also shows, for each value of annual fuel cost reduction, the share of households that would spend more than $1,000. The figure also includes a table with the 25th and 75th percentiles of the amount households are willing to spend for each level of annual fuel cost reduction. Results indicate that the higher the fuel cost reduction, the larger the share of households – which annually spend at least the same amount

[48] The percentage of households decreases as the willingness to spend increases. This is because fewer households have higher gas costs.

as the reduction – willing to spend more than $1,000 to achieve that reduction. In addition, while the share of households that would spend between $50 and $1,000 decreases as the fuel cost reduction increases, the average amount those households would spend significantly increases. This is consistent with previous results that show that 36.2% of households do not use their primary DHE to improve comfort because it is expensive to operate and because they want to lower their heating bills. It is also consistent with previous results that show that 37.3% of households that were planning to replace their primary DHE soon after the survey would replace the unit to lower their energy bill.



Annual Fuel Cost Reduction	25% percentile	Median	75% percentile
$50	$150	$300	$450
$100	$200	$375	$550
$250	$250	$450	$650
$500	$350	$550	700

Figure 9. Willingness to spend to reduce the annual fuel cost of the primary DHE

Note: The average values of willingness to spend in the chart were estimated for households that would spend between $50 and $1,000 to reduce the annual fuel cost, and does not include households that would not spend any amount or would spend more than $1,000.

The shares of owner-occupied households and rented households that would spend a certain amount to reduce the annual fuel cost of their primary DHE are approximately the same for the four amounts of annual fuel cost reduction ($50, $100, $250, and $500). Table 51 shows the average amount that those owners and renters, who indicated they would spend between $50 and $1,000 to reduce the annual fuel cost of their primary DHE, would spend. Overall, owners would spend more than renters would, which is consistent with the idea that the former are more likely to make higher investments in their own house than the latter.

Table 51. Average willingness to spend (between $50 and $1,000) to reduce DHE annual fuel cost

Annual Fuel Cost Reduction	Owners	Renters
$50	$412.85	$268.14
$100	$492.15	$346.14
$250	$555.47	$420.77
$500	$621.55	$494.98

When accounting for who pays for gas, the shares of owner-occupied and rented households that would spend $50 or more on a new DHE to reduce the fuel cost of their primary DHE are approximately the same, regardless of the amount of annual fuel cost reduction and whether their gas bill is subsidized or not. However, for those households with a subsidized gas bill, the share of owners willing to spend $50 or more on a new DHE slightly increases with the amount of annual fuel cost reduction, while the share of renters slightly decreases. This is likely because the subsidies may cover only a small part of the fuel cost. It is also consistent with previous results that show that rented households with a subsidized gas bill tend to be smaller than owner-occupied households and likely have lower fuel costs. It is further consistent with previous results that show that rented households with subsidized gas have an income that is lower than owner-occupied households, which – besides being a renter – would prevent them from making larger investments in the house. Figure 10 shows these shares for owner-occupied households and rented households, and for households that fully or partially pay for gas, separately and combined.

Households that pay for gas and would spend between $50 and $1,000 on a new DHE to reduce their annual fuel cost would spend more on a DHE that would provide them with higher annual fuel cost reductions, regardless of whether their gas bill is subsidized or not. Of those, rented households would consistently spend less than owner-occupied households would, which is consistent with previous results showing that the former tend to exhibit lower annual income than the latter. However, the willingness to spend of renters with subsidized gas bill increases with the amount of fuel cost reduction, proportionally more than the willingness to spend of owners with a subsidized gas bill and renters without a subsidized gas bill. Figure 11 shows how the willingness to spend compares between owner-occupied households and rented households, with and without gas bill subsidies.

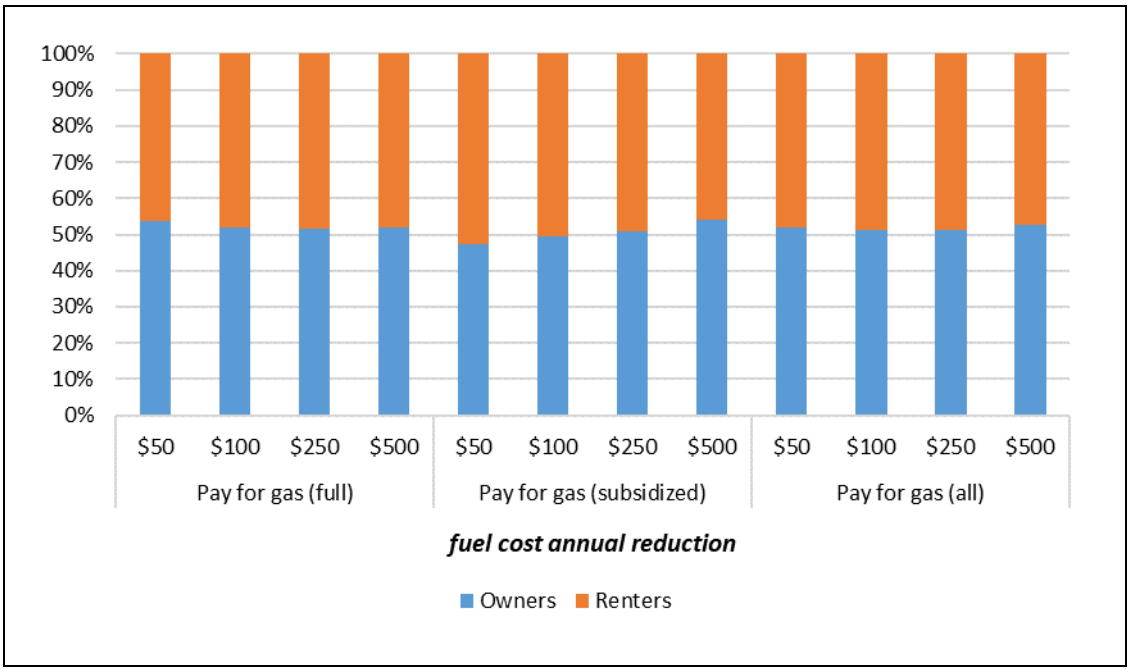


Figure 10. Shares of households willing to spend on a new DHE to reduce annual fuel cost

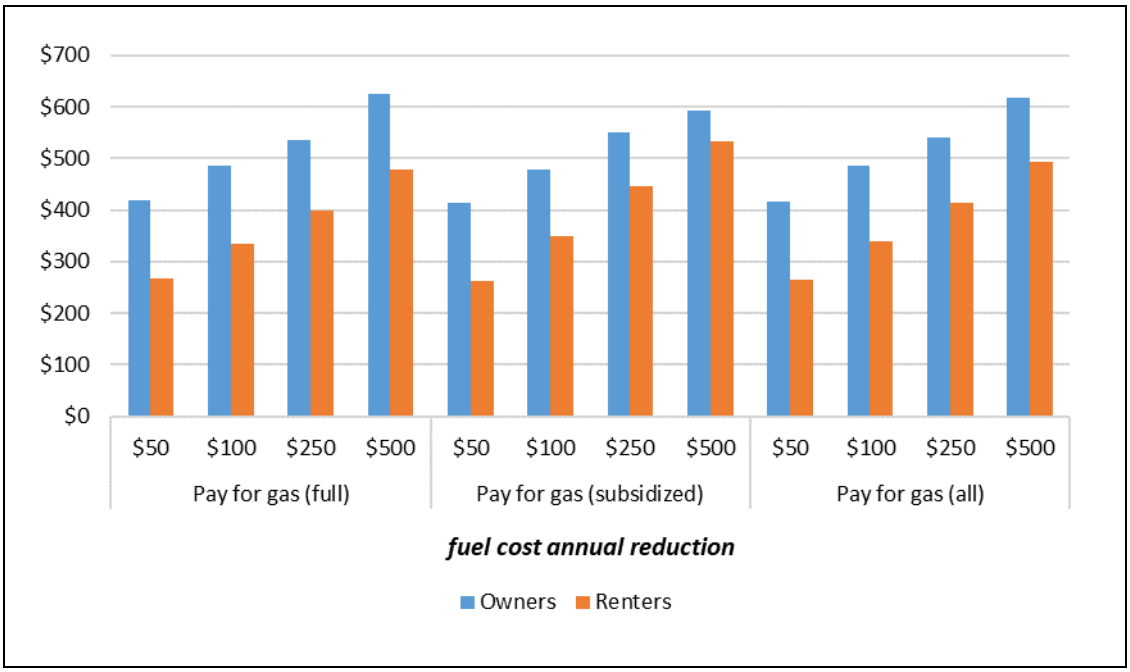


Figure 11. Willingness to spend on a new DHE to reduce annual fuel cost

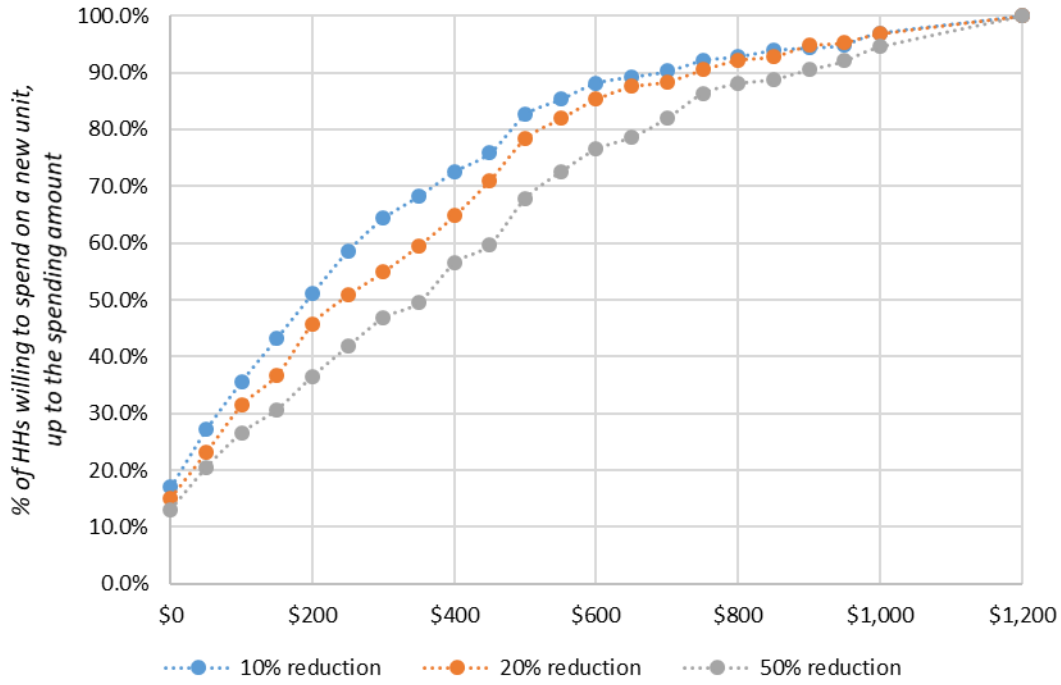
Note: The willingness to spend in the chart was estimated for households that would spend between $50 and $1,000 to reduce the annual fuel cost, and does not include households that would not spend any amount or would spend more than $1,000.

Households also indicate a willingness to spend on a new DHE unit that would reduce the environmental impact or carbon footprint of the household by reducing their energy use. Most of the households are willing to spend between $50 and $1,000, with 80.0% willing to spend an average of $326.07 to reduce their carbon footprint by 10%, 81.7% an average of $364.93 to reduce it by 20%, and 81.5% an average of $420.78 to reduce it by 50%.[47] There is no relevant association between the willingness to spend to reduce the environmental impacts from the primary DHE and the household annual income, except that for the three levels of environmental impact reductions the fraction of households that are willing to spend more than $1,000 monotonically increases with annual income. Table 52 shows the fractions of households according to what they are willing to spend to reduce the environmental impact from their primary DHE, as well as the corresponding average dollar amount. When compared with other DHE types, a lower share of households where the primary DHE is a floor furnace would not spend any amount. This may indicate that floor furnace DHE users are more aware of the environmental impacts of their primary DHE than users of the other types of DHE. Figure 12 presents the cumulative distribution of the dollar amount that households are willing to spend to reduce the environmental impacts from their primary DHE, and those values for selected percentiles. In the figure, the $1,200 value symbolically represents a willingness to spend more than $1,000.

Table 52. Willingness to spend to reduce the environmental impact of the primary DHE

Value	DHE Type				All DHE
	Upright Wall Furnace	Console Wall Furnace	Room Heater	Floor Furnace	
Reduce the impact by 10%					
$0	18.8%	11.9%	18.2%	10.6%	17.0%
$50 - $200	37.4%	27.3%	25.8%	26.6%	34.2%
$250 - $500	27.8%	38.3%	41.9%	43.3%	31.5%
$550 - $1,000	14.0%	17.1%	11.7%	9.9%	14.4%
Average value ($50 - $1,000)	$310.60	$374.43	$316.65	$339.62	$326.07
$1,000+	2.0%	5.4%	2.3%	9.6%	3.0%
Reduce the impact by 20%					
$0	16.3%	11.6%	18.1%	10.6%	15.1%
$50 - $200	33.3%	25.7%	20.5%	24.6%	30.6%
$250 - $500	30.7%	37.4%	31.3%	42.0%	32.6%
$550 - $1,000	17.2%	20.2%	27.7%	17.1%	18.4%
Average value ($50 - $1,000)	$348.38	$402.56	$404.12	$391.54	$364.93
$1,000+	2.5%	5.2%	2.3%	5.7%	3.2%

Reduce the impact by 50%					
$0	14.0%	10.2%	16.0%	6.5%	13.0%
$50 - $200	28.0%	14.2%	7.9%	17.2%	23.5%
$250 - $500	27.0%	38.9%	48.6%	41.2%	31.3%
$550 - $1,000	26.5%	29.2%	18.3%	28.9%	26.7%
Average value ($50 - $1,000)	$401.36	$468.32	$442.91	$469.34	$420.78
$1,000+	4.5%	7.5%	9.2%	6.2%	5.4%



Reduction	Min	Percentile					Max
		5%	25%	50%	75%	95%	
10%	$0	$0	$50	$200	$450	$1,000	$1,000+
20%	$0	$0	$100	$250	$500	$950	$1,000+
50%	$0	$0	$100	$400	$600	$1,000+	$1,000+

Figure 12. Cumulative distribution of households' willingness to spend to reduce environmental impacts

When it comes to purchasing a new DHE, some important questions will drive a household's purchase decision. Table 53 shows a list of relevant questions that households might want to address before purchasing a new DHE, and how they rank them in order of importance.[49] The two most important questions relate to the unit's upfront costs: the first focused on the purchasing cost and the second on the installation cost. Concerns about the energy bill come next, ranked in both the third and fourth places, while maintenance costs rank at the fifth place. Additional relevant questions suggested by respondents include questions related to the efficiency of the new unit, how long it will last, and whether it is programmable. Table 53 also presents the ranking for owner-occupied households and rented households. There are no significant differences between the responses from the former and the latter, except that while owners follow exactly the same overall ranking of questions, renters seem less concerned about maintenance costs, maybe because these are the responsibility of their property owners. There are no significant differences between users of different types of DHE either, except that the households where the primary DHE is a room heater or a floor furnace indicated some concern with whether the new unit will improve their comfort; and in households where the primary DHE is a room heater indicated some concern with the air quality of the home.

Table 53. Important questions before purchasing a new DHE

Question	Ranking				
	1st	***2nd***	***3rd***	***4th***	***5th***
1. Will the new unit improve my comfort?	9.9%	10.6%	8.2%	10.1%	7.9%
2. Will the new unit improve the air quality in my home?	8.3%	9.4%	9.1%	9.8%	10.0%
3. How safe is the new unit?	14.7%	7.8%	8.1%	8.7%	9.5%
4. What are the repair costs associated with the new unit?	3.0%	2.4%	7.2%	8.7%	8.8%
5. What are the maintenance costs associated with the new unit?	3.3%	5.3%	7.1%	12.5%	**14.4%**
6. What is the cost of the new unit?	**31.1%**	15.7%	10.3%	6.6%	6.5%
7. How much will it cost to install the new unit?	9.9%	**21.6%**	12.7%	11.2%	8.0%
8. What will my energy bill look like with the new unit?	11.6%	14.4%	**19.5%**	**13.3%**	11.1%
9. What is the environmental impact of this unit?	4.1%	4.9%	8.5%	8.5%	9.3%
Owner-occupied households (#question)	#6	#7	#8	#8	#5
Rented households (#question)	#6	#7	#8	#7	#8

Households would rely on different sources to inform their purchase of a new DHE unit. The three most important sources are (a) credible expert evaluations of the energy, economic, environmental, and health benefits; (b) reviews from other purchasers; and (c) State of California recommendations and guidelines. Table 54 presents these and other sources of

[49] Respondents were asked to select and rank five out of the ten questions available.

information with the share of households that selected them in their list of the three most important sources that they would rely on to inform their purchase decision. The table also includes those shares for owner-occupied households and rented households. There are no significant differences between the choices and priorities of owners and renters.

Table 54. Information sources that would inform the purchase decision of a new DHE

Source of Information	All	Owners	Renters
Manufacturer websites and specifications	26.8%	10.8%	15.5%
Reviews written by purchasers (consumers like you)	**49.6%**	**20.2%**	**28.9%**
State of California recommendations and guidelines	**48.4%**	**20.8%**	**26.8%**
Word-of-mouth referrals from knowledgeable friends and family	37.9%	15.8%	21.5%
Recommendations from licensed contractors/installers	29.3%	12.0%	17.0%
Seeing the DHE unit firsthand in a showroom	22.4%	10.2%	11.8%
Objective analysis from a respected consumer or advocacy group	30.1%	13.2%	15.8%
Credible expert evaluations[50]	**52.3%**	**21.2%**	**29.9%**

Most households believe that a new, high-efficiency DHE unit will provide better indoor air quality (95.3%), improve comfort in their home (93.5%), and lower their energy bill (91.5%). Households also agree and disagree with some other aspects related to high-efficiency DHE. Table 55 shows these aspects and the share of households that agree or disagree with them. Overall, households' opinions on high-efficiency DHE are unanimously positive, except when it comes to their maintenance costs and the significance of the home retrofit required to install them. In these two cases, households' perspectives are approximately balanced.

Table 55. Households' perspectives on high-efficiency DHE

A high-efficiency DHE will …	Disagree	Agree
… lower my energy bill	8.5%	91.5%
… allow me to recover my upfront costs in a few years	14.8%	85.2%
… improve the comfort in my home	6.5%	93.5%
… provide better indoor air quality	4.7%	95.3%
… be less safe	78.1%	21.9%
… break more often	75.4%	24.6%

[50] This includes credible expert evaluations that compare energy, economic, environmental, and health implications of older (less-efficient heaters) to newer high-efficiency DHEs.

A high-efficiency DHE will …	Disagree	Agree
… be less expensive to repair	26.5%	73.5%
… be more expensive to maintain	53.0%	47.0%
… require a significant home retrofit	45.4%	54.6%
… be expensive to purchase	22.4%	77.6%
… have a lower impact on the environment	11.2%	88.8%

The recent COVID-19 pandemic had some effect on households' perspectives of their major appliances. Most households (68.3%) indicated that the pandemic affected their interest in and willingness to upgrade their major appliances, including their DHE. Table 56 shows the way the pandemic affected households' views. The shares of households that are interested and willing to upgrade their major appliances to enhance comfort and promote a healthier environment grow with annual income. This is consistent with the fact that households with a higher annual income, once aware of the need to upgrade their appliances, would be more willing to make – and more likely to afford – improvements to their own home.

Table 56. How COVID-19 affected households' views of their appliances

How the pandemic impacted interest in and willingness to upgrade major appliances[51]	Share
I am spending more time at home and I am realizing that household improvements are more necessary than ever to help enhance comfort while managing costs	24.3%
I have become more aware of the health of my family and myself and I am more open to household upgrades that will promote a healthier living environment	19.5%
I would like to make household upgrades, but the timing is not right because of the economic impact of the pandemic	24.5%
I do not believe the pandemic has significantly impacted my views of our household appliances	31.7%

The households' views and perspectives about efficient appliances, including their willingness to spend on a new, high-efficiency DHE are consistent with how they describe their feelings towards major home appliances. More than half of households are committed to behaving in an environmentally friendly manner, and approximately half of them believe their health is impacted by their ability to control the temperature and air quality of their homes and that a high-efficiency DHE would enhance their family's comfort. Table 57 shows households' feelings toward high-efficiency DHE.

[51] The full question reads "How, if at all, has the COVID-19 pandemic impacted your interest in and willingness to upgrade your household's major appliances such as your DHE? Please select the ONE statement below that best reflects your feelings."

Table 57. Households' feelings towards major home appliances

	Disagree	Neutral	Agree
I consider myself an expert in identifying solutions for improving household energy usage	40.2%	31.3%	28.5%
I believe that my health (or that of a family member) is impacted by the quality and efficiency of our household's solutions for controlling temperature and air quality	18.1%	28.9%	53.0%
My family and friends consider me to be a leader in adopting new technology for personal use	31.2%	26.7%	42.1%
I am committed to behaving in an environmentally friendly manner	9.5%	28.2%	62.3%
I genuinely believe that my personal (and my family's) comfort would be enhanced by acquiring a high-efficiency DHE	18.3%	32.1%	49.6%

7. Conclusions

DHE comprises a non-negligible share of space heating appliances in California. Some households have more than one DHE unit installed, and – while not covered by this study – DHE can also be found in small commercial buildings, which makes the fleet of this appliance in the state even more relevant. We surveyed households with DHE in the state to better understand their DHE units and household characteristics.

Our survey shows that households with DHE in California are typically mid-size (500-2,000 square feet) homes, built before 1970, and with an annual income lower than $100,000. They are mostly located in Southern California and in the San Francisco Bay Area, where DHE supports moderate heating load requirements. It also shows that the market for DHE is mainly a replacement market, with approximately 50% of the households' most frequently used unit having been installed in the 10 years before the survey. In general, DHE rarely receives maintenance and is repaired only in extreme situations. However, in some extreme situations, households may opt to replace the unit instead of repairing it. Replacement, although not done frequently, can happen before the end of the life of the unit to improve heating comfort, reduce the energy bill, and because of the age of the unit. New installations of DHE, although uncommon, mostly supplement heating to a space already heated by another heater, and sometimes add heating to a space not yet being heated.

Overall, the share of households that are satisfied with their most frequently used DHE is a little higher than the share of households that are dissatisfied. The difference, though, is more noticeable for the two console-shaped DHE types. The main reason for dissatisfaction is that the heater does not provide enough heat to the space. Other reasons include indoor air quality, energy use, malfunctioning of the unit, and safety concerns.

Households are willing to invest in a new DHE unit to improve their thermal comfort and indoor air quality and to reduce their fuel cost and environmental impacts. The average amount they are willing to spend for the first two reasons and for reducing 50% of their environmental impacts is approximately the same. Concerning fuel cost, those households that are willing to spend between $50 and $1,000 on a more efficient DHE unit are willing to spend, as expected, an increasing amount as the annual fuel cost savings increase. Similarly, the same applies to the share of households that would spend more than $1,000 for the same increasing amount of annual fuel cost savings. Owner-occupied households are willing to make larger investments in a more efficient DHE than rented households.

Overall, households strongly agree over the main benefits of a high-efficiency DHE; yet present balanced opinions when it comes to their installation (retrofit) and maintenance costs. The three most important households' perspectives on high-efficiency DHE are that they will (a) provide better indoor air quality, (b) improve thermal comfort, and (c) lower the energy bill. Households believe that their health is impacted by the quality and efficiency of the solutions for controlling temperature and air quality provided by a high-efficiency DHE, and that comfort would be enhanced by acquiring one. Furthermore, the majority of the households feel they are

committed to behaving in an environmentally friendly manner when purchasing a high-efficiency DHE. When making a purchase decision for a high-efficiency DHE, households will consider the unit purchase price and installation costs, as well as the energy cost savings provided by the new DHE. In addition to their perspectives about high-efficiency DHE, most households also consider, after the COVID-19 pandemic, upgrading their major appliances to enhance comfort and promote a healthier environment, with the share of households that are willing to upgrade their major appliances increasing with household annual income.

Our findings are useful to inform state and utility programs targeting certain household segments in California with the goal of increasing the adoption of energy-efficient DHE. Increased adoption of new, energy-efficient DHE will reduce natural gas use and emissions in the state, as well as address respondents' concerns about energy cost, thermal comfort, safety, and indoor air quality, eventually increasing their level of satisfaction with their DHE. However, care should be taken when interpreting or generalizing those findings. The survey was conducted via the Internet using an online interview questionnaire. Unlike random sampling surveys, the online survey could lead to biased data due to bias in the survey panel. Therefore, even though our sample was carefully calibrated to meet some basic statistical distributions of households from other relevant surveys, our results may not be uniformly representative of households across certain household segments.

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Appendix A. Survey Methodology

The survey was conducted online by the Schlesinger Group.[52] Schlesinger soft launched (a pilot run) the online survey on March 18, 2021, and obtained 11 valid responses. The responses indicated that no changes were necessary to the survey instrument. On March 25, 2021, after LBNL approved the soft launch results, Schlesinger launched the full online survey. After about 6 weeks, on May 3, 2021, Schlesinger closed the survey with 1,201 completed surveys (including the 11 participants who responded to the soft launch).

Over this timeframe, Schlesinger sent 151,373 total emails to potential participants. All respondents were from the Schlesinger Group's Consumer Panel. A total of 5,506 participants initiated the survey (including the soft launch respondents).

In order to qualify, responding participants had to:

- be at least 18 years of age,
- be a resident of California,
- have at least one appropriate type of DHE in their household, and
- make use of at least one DHE unit.

The overall incidence rate of the survey was 42%. The incidence rate refers to the ratio of who completed or were over-quota in the survey (n=1,658) divided by the total number of completes, over-quota, and terminates (n=3,977). During the fielding process, Schlesinger periodically reviewed the surveys completed and removed the ones with poor-quality data. The following factors were used to identify surveys with poor quality data: speeding, straight-lining, poor open-ended data and/or illogical combinations of data entered, such as selecting all possible types when asked what type of DHE they have at home.

Of the total 5,506 panelists who initiated the survey, 2,319 did not qualify (according to the criteria listed above), 1,528 did not complete the survey, 457 were over-quota, and 54 were rejected due to poor-quality data. The remaining 1,201 participants who initiated the survey comprise the sample of initially valid responses.

In addition to the quality assurance of survey responses performed by Schlesinger, we defined additional conditions to indicate whether participants' responses were reliable or not. The conditions considered the consistency and reasonableness of responses across two or more questions. A total of 241 responses met at least one of the criteria that deemed them unreliable and therefore were removed from the sample.

[52] https://www.schlesingergroup.com/en/.

Appendix B. Sample Description and Calibration

The final sample of households considered in this report is comprised of 960 responses, 15 of which were taken in Spanish. The sample includes households in a range of building types, sizes, vintages, locations, and types of occupancy, as well as an array of household incomes.

Most of the participants declared that their household is in a single-family detached home (n=522), followed by households in multi-family buildings (n=318). The majority of participants declared that they own the home (n=635). Most of the buildings identified in this survey are at least 40 years old (n=545), and the home sizes are almost uniformly distributed over buildings of different sizes: 501-1,000 square feet (n=225); 1,001-1,500 square feet (n=242); and 1,510-2,000 square feet (248). Most of the respondent's households are in Southern California (n=600), particularly in the Los Angeles area (n=436). The second most represented region in the sample is the San Francisco Bay Area (n=240).

Concerning household income, of the respondents who responded to the question (n=929), most (n=578) declared an annual income equal to or higher than $80,000. Of those, 117 participants declared that their annual household income is in the range of $80,000-$99,999, 170 participants annual income is in the range of $100,000-$119,999, 125 participants annual household income is in the range of $120,000-$139,999, and 166 participants declared an annual household income equal to or greater than $140,000.

Given the way the online survey was planned and conducted, with no previous selection of participants and, therefore, no stratified sampling, we could not assume that the distributions of households above are representative of households in California. We compared the distributions of the six variables above from our sample with their corresponding distributions in the recent *2019 RASS* survey.[15] RASS was implemented in 2019-2020 with a representative sample of households in California that are in the territories of large investor-owned utilities and two of the largest municipal utilities in the state. Survey results were "weighted to provide population-level estimates representative of the participating utilities that allow comparison across utility service territories, forecasting climate zones, and other variables of interest such as dwelling type, dwelling age group, and income." (DNV GL, 2020)

We relied on the distributions of these variables in RASS to post-stratify (calibrate) our survey sample. We used the R implementation (Pasek, 2018) of the American National Election Studies raking approach (DeBell and Krosnick, 2009) for the calibration. The ANES raking approach is an iterative procedure to develop weights for a list of selected variables, such that they match the targets provided (Pasek, 2018). We selected seven variables for the post-stratification raking: building type, size, vintage, and location; household type of occupancy and income; and floor furnace saturation. Figure 13 compares our pre- (unweighted) and post- (weighted) calibration distributions of the six variables. We believe that the weights we estimated for each questionnaire make the results of our analyses closer to what would have been achieved if all households covered by RASS were surveyed.

Figure 13. Distributions of key survey descriptors in the pre- and post-stratified samples

Additional characteristics of our pre-weighted and post-weighted samples are as follows. The 15 respondents who opted to take the survey in Spanish represent 0.9% of households. While this may seem a small percentage for Spanish-speaking households in the state, it does not mean that – just because those participants decided to take the survey in Spanish – the weighted fraction of households represents the share of Hispanic-occupied households in California with a DHE.

The shares of male- and female respondents are roughly the same, with 49% of respondents self-identifying as male, and 50% as female.[53] The median age of respondents was 50.5 years old, and the maximum was 86. Those between 31 and 40 years old represent the largest share (42.1%) of respondents. Figure 14 shows the histogram of respondents' age and the corresponding cumulative distribution.

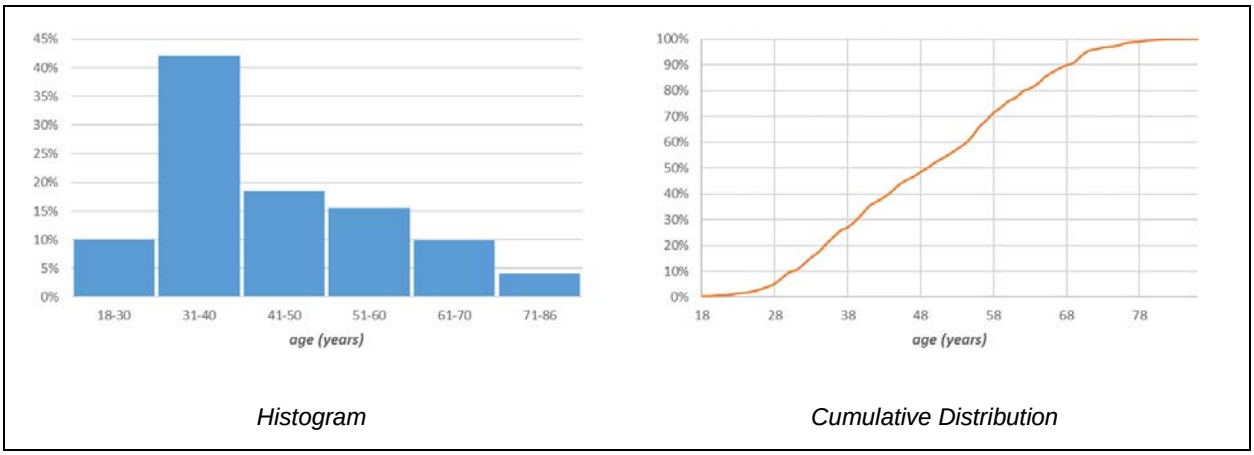

Figure 14. Distributions of respondents' age

The most frequent level of education of respondents was bachelor or associate degree (48.2%). Only 0.3% of respondents indicated that they do not have a high school or a general educational development (GED) diploma.[54] Figure 15 shows the distribution of respondents with a level of education equal to or higher than high school or GED.

[53] A small fraction, 1.5% of respondents (n=14) preferred not to say their gender, and one respondent self-identified as transgender.

[54] Note that 0.9% (n=9) preferred not to provide their level of education.

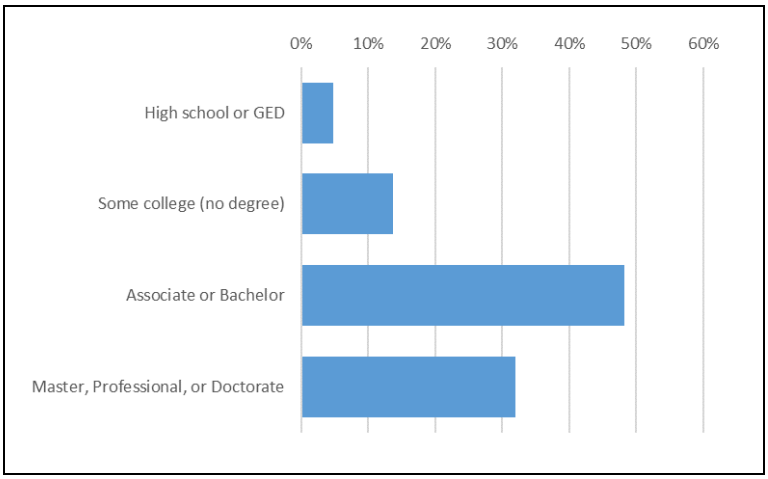

Figure 15. Distribution of respondents according to level of education

Finally, when it comes to purchasing important products – like a new DHE – for the home, most respondents (64.3%) are the primary decision-makers in the household; the remaining respondents either share the responsibility with others (24.2%) or are not involved in the process (11.6%).