NFPA® RESEARCH

Smoke Alarms in US Home Fires

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Key Findings

Smoke alarms were present in three-quarters (74 percent) of the reported home[i] fires in 2014–2018**.** Almost three out of five home fire deaths[ii] were caused by fires in properties with no smoke alarms (41 percent) or smoke alarms that failed to operate (16 percent).

The death rate per 1,000 home structure fires is 55 percent lower in homes with working smoke alarms than in homes with no alarms or alarms that fail to operate.

Of the fire fatalities that occurred in homes with working smoke alarms, 22 percent of those killed were alerted by the device but failed to respond, while 11 percent were not alerted by the operating alarm.

People who were fatally injured in home fires with working smoke alarms were more likely to have been in the area of origin and involved in the ignition, to have a disability, to be at least 65 years old, to have acted irrationally, or to have tried to fight the fire themselves. These victims were less likely to have been sleeping than those who died in fires in properties without working smoke alarms.

Hardwired smoke alarms (with or without battery backup) were found in 48 percent of the reported home fires in properties with smoke alarms; smoke alarms powered by batteries only were found in 46 percent of such fires. Almost two-thirds (65 percent) of the fatal injuries from fires in homes with smoke alarms occurred in properties with battery-powered alarms. When present, hardwired smoke alarms operated in 94 percent of the fires considered large enough to trigger a smoke alarm. Battery-powered alarms operated 82 percent of the time. Missing or non-functional power sources, including missing or disconnected batteries, dead batteries, and disconnected hardwired alarms or other AC power issues, were the most common factors when smoke alarms failed to operate.

Compared to reported home fires with no smoke alarms or automatic extinguishing systems (AES) present, the death rate per 1,000 reported fires was as follows:

- 35 percent lower when battery-powered smoke alarms were present, but AES was not,
- 51 percent lower when smoke alarms with any power source were present but AES was not,
- 69 percent lower when hardwired smoke alarms were present but AES was not, and
- 91 percent lower when hardwired smoke alarms and sprinklers were present.

The calculations above are based solely on the presence of fire protection equipment. The equipment's operation was not considered.

[i] Homes include one- or two-family homes, including manufactured homes, and apartments or other multifamily housing.
[ii] Only civilian casualties are included in this analysis.

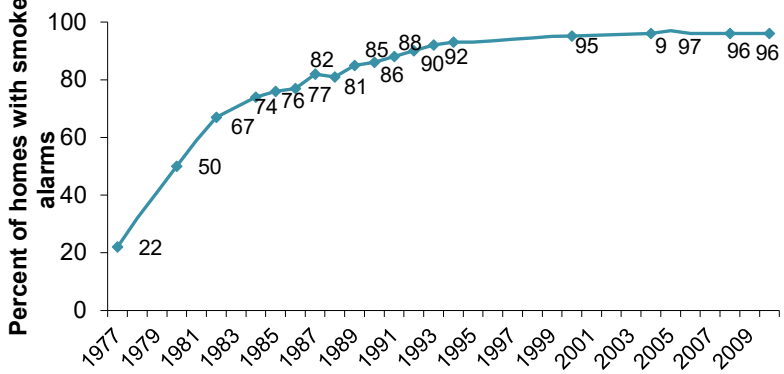
Introduction

Smoke alarms have become so common that it is easy to take them for granted. These devices have alerted countless households to developing fires. This report provides the latest information on smoke alarms in home fires reported to local fire departments in the US. Most estimates in this report were derived from the US Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and NFPA's annual fire department experience survey.

While smoke alarms are not the same as smoke detectors that are part of a system, NFIRS does not distinguish between the two. Except where specified, the term *smoke alarm* in this analysis includes all fire detection equipment. Estimates for the specific types of detection (smoke, heat, combination, etc.) are available in the supporting tables for this report.

Figure 1 shows that in 1977, less than one-quarter of all households had smoke alarms. Home smoke alarm usage increased rapidly in the late 1970s and 1980s. Telephone surveys since 2000 have found that 96–97 percent of the surveyed US households have at least one smoke alarm.[1]

Figure 1. Growth in Home Smoke Alarm Usage: 1977–2010



Based on these results, roughly five million households still have no smoke alarms.

A 2018 study by the National Institute of Standards and Technology noted that these surveys excluded those without phones and could reflect social desirability bias. Such bias occurs when respondents report what they believe is the proper answer rather than the actual answer. Consequently, the author suggested that actual smoke alarm utilization is more likely to be 92 percent.[2]

Figure 2 shows that the number of reported fires fell sharply in the 1980s as home smoke alarms became more common.[3]

Figure 3 shows that the death rate per 1,000 reported home fires in 2014–2018 was more than twice as high in homes that did not have any working smoke alarms as it was in homes with working smoke alarms.

Figure 2. Reported Home Structure Fires by Year: 1980–2019

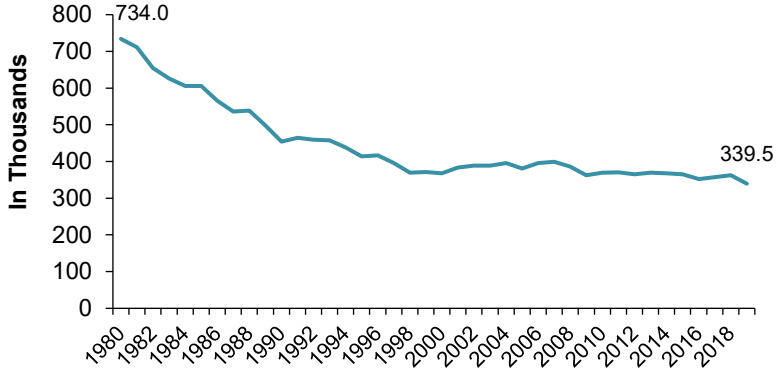
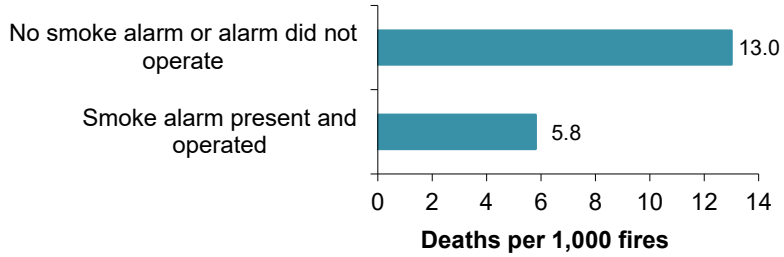


Figure 3. Death Rate per 1,000 Reported Home Fires by Smoke Alarm Status: 2014–2018



Smoke Alarm Status in Reported Fires

Fire departments responded to an estimated average of 353,100 home structure fires per year in 2014–2018. Smoke alarms, including those in fires too small to activate them, operating smoke alarms, and those that failed to operate, were present in three-quarters (74 percent) of reported home fires. Figure 4 shows that smoke alarms were present and operated in more than half of the reported home structure fires. Fires in which smoke alarms were present and were large enough to activate the smoke alarms are shown in the two shades of blue.

Almost three out of five home fire deaths resulted from fires in properties with no smoke alarms (41 percent) or smoke alarms that did not work (16 percent).

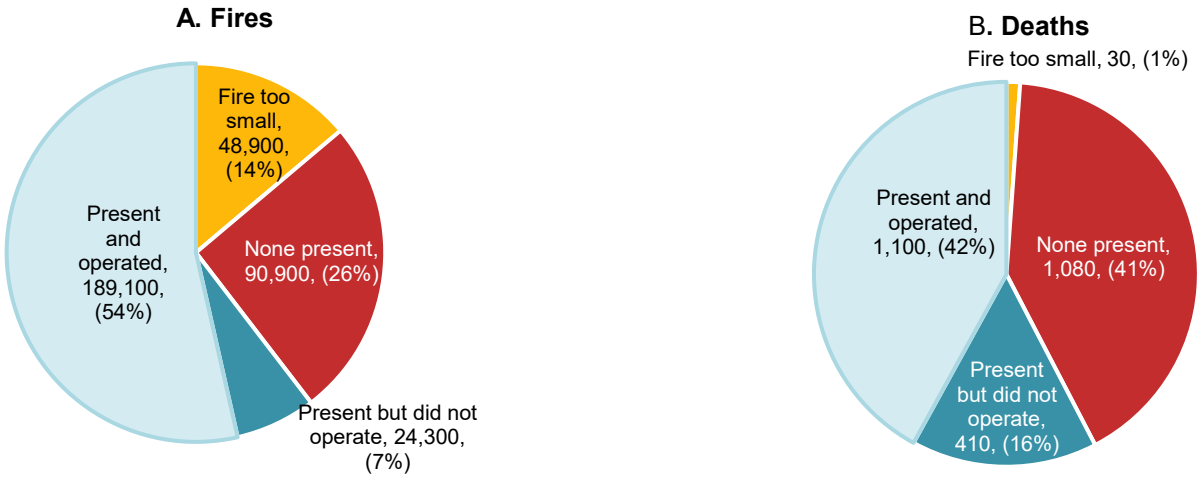
When present, smoke alarms operated in 89 percent of the reported fires large enough to activate them. Of the deaths in homes with smoke alarms and fires large enough to activate them, 73 percent resulted from incidents in which the smoke alarms operated. Some examples of fatal fires in homes without working alarms are provided.

- A Louisiana man died of smoke inhalation after a cooking fire that began while he was sleeping. No smoke alarms were present in the single-family home.[4]
- Six people, including four children under six years of age, died in a Georgia manufactured home fire caused by an improperly installed wood-burning heater. No smoke alarms were present.[5]
- The sole smoke alarm in the hallway of a one-story Michigan house did not have a battery and could not operate when a space heater ignited clothing that had been left to dry overnight in a sunroom. The room flashed over, and the fire spread to the dining area. Two residents were killed and three were injured.[6]

Although slightly more homes with reported fires have hardwired smoke alarms (with or without battery backups), smoke alarms powered solely by (or intended to be powered by) batteries were present in almost two-thirds (65 percent) of the fire deaths in homes with smoke alarms. When present, hardwired smoke alarms operated in 94 percent of the fires considered large enough to trigger a smoke alarm. Battery-powered alarms operated 82 percent of the time.

Most homes are likely to still have smoke alarms powered solely by batteries. In the 2011 *American Housing Survey* (AHS), three out of five (61 percent) respondents who reported having smoke alarms said their alarms were powered by batteries only, one-third (33 percent) said their alarms were powered by electricity and batteries, and 7 percent said their alarms were powered by electricity only.[7]

Figure 4. Reported Home Structure Fires and Fire Deaths by Smoke Alarm Performance: 2014–2018



For many years, NFPA *101*®, *Life Safety Code*®, and other codes have required smoke alarms in new construction to be hardwired with battery backups. However, the 2011 AHS study found that in 30 percent of homes that were less than five years old and had smoke alarms, the alarms were powered by batteries only.

Causes of Smoke Alarm Failure

During 2014–2018, local fire departments responded to an estimated average of 24,300 home fires per year in which smoke alarms should have operated but failed to do so. These fires caused an average of 410 deaths and 1,310 injuries annually.

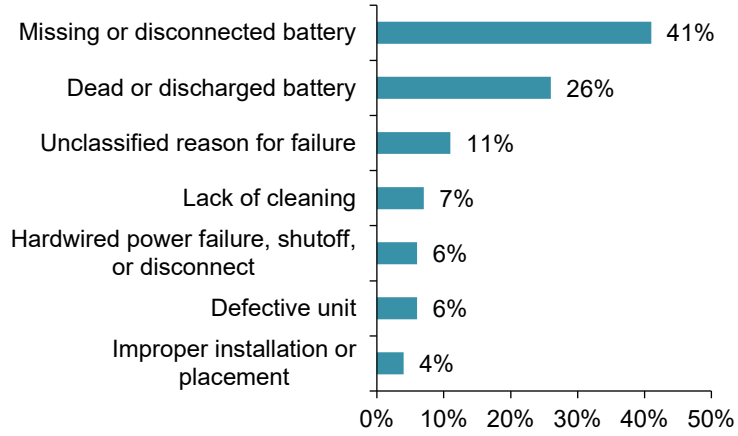
When smoke alarms failed to operate, it was typically because of disconnected or non-working power sources. Battery problems were most common. See Figure 5.

Smoke alarms powered by lithium batteries do not require annual battery changes. These batteries are sometimes referred to as 10-year batteries. Two studies, discussed below, show that installation programs should follow up more frequently to ensure smoke alarm protection where these alarms were installed.

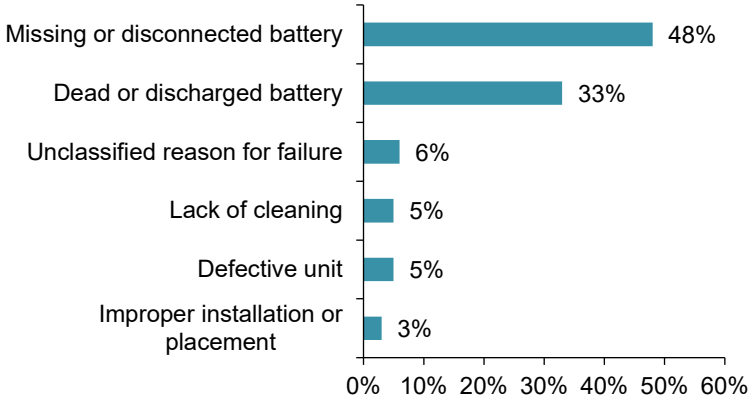
A follow-up study of lithium battery-powered smoke alarms installed in 1998–2001 in five states investigated whether these alarms were present and operational eight to ten years later.[8] At least one of the installed alarms was still present and functional in only 38 percent of the homes visited. Slightly more than one-third (37 percent) of the installed alarms had been removed, one-third (33 percent) were present and operational, and slightly less than one-third (30 percent) were present but not operational.

Figure 5. Reason Smoke Alarms Did Not Operate in Home Structure Fires Considered Large Enough to Activate by Smoke Alarm Power Source: 2014–2018

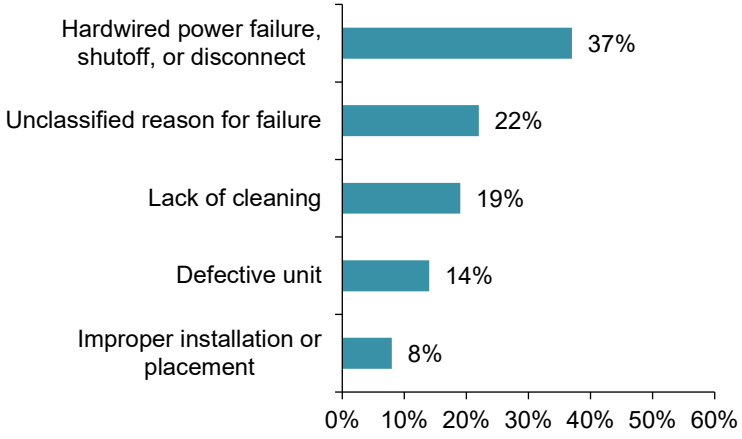
A. All Power Sources



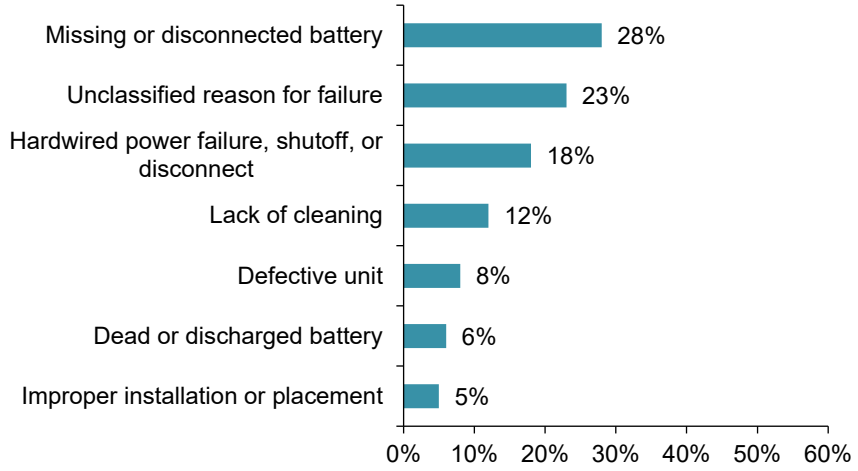
B. Battery Only



C. Hardwired Only



D. Hardwired with Battery Backup



Most of the alarms in the study had battery chambers that permitted replacement. Although all of the alarms started with lithium batteries, more than two-thirds had non-lithium batteries eight to ten years later. Three-quarters (78 percent) of the smoke alarms that still had lithium batteries were still functional at the time of the evaluation. Smoke alarms that had been installed in the kitchen were less likely to be functional.

Rental properties and properties that had changed occupants were more likely than owner-occupied properties and properties with the same occupants to be missing at least one program-installed smoke alarm at the time of the evaluation.

From December 2011 through October 2012, members of the Dallas Fire-Rescue Department (DFRD) conducted follow-up home visits to homes in which smoke alarms with lithium batteries had been installed from 2001–2010 to monitor how these smoke alarms functioned over time.[9]

- In the second-year group, 88 percent of the smoke alarms were present, and 84 percent were working.
- In the fourth-year group, 75 percent were present and 55 percent were working.
- In the sixth-year group, 71 percent were present, and 27 percent were working.
- In the eighth-year group, 63 percent were present and 20 percent were working.
- In the tenth-year group, 55 percent were present, and 22 percent were working.

Reminders to change smoke alarm batteries when changing the clock might lead some people to replace a lithium battery with a conventional battery with a shorter lifespan. New technology can complicate messaging.

Power sources are often disabled because of unwanted alarms. The low-battery chirp is sometimes considered a nuisance. While the fire safety community understands the importance of alarms, members of the public might not. In practice, even people committed to fire safety may disable an alarm that starts chirping in the middle of the night. Replacing conventional batteries in battery-powered and hardwired alarms with battery backups annually reduces the likelihood of inconvenient chirping and the subsequent disabling of alarms.

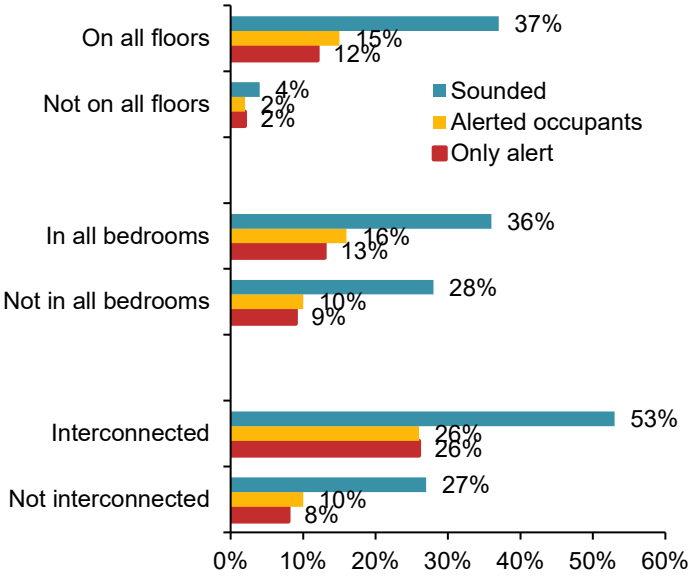
If a smoke alarm in the kitchen is sounding too often, the problem could be solved by moving the smoke alarm. *NFPA 72®*, *National Fire Alarm and Signaling Code®* states that unless designed specifically for the area, all smoke alarms should be at least 10 feet away from cooking appliances. If space constraints make it necessary to have a smoke alarm within 10–20 feet of the kitchen stove, either a photoelectric alarm or an alarm with a hush feature that can be temporarily silenced without disabling the alarm should be used. The UL requirements for smoke alarm resistance to cooking nuisance alarms, scheduled to take effect in 2022, are also expected to address this issue.[10] These requirements will be discussed later in this report.

Fire Discovery

NFIRS data does not capture the extent of smoke alarm coverage or whether the alarms were interconnected. In addition, NFIRS data does not include information on incidents that were not reported to the fire department.

While people often notice a fire before hearing the smoke alarm, a US Consumer Product Safety Commission (CPSC) survey, *2004-2005 National Sample Survey of Unreported Residential Fires*, found that interconnected smoke alarms were both more likely to operate and more likely to provide the only alert.[11] See Figure 6. In CPSC's study, when smoke alarms did not operate, it was generally because the smoke never reached the alarm.

Figure 6. Smoke Alarm Performance and Effectiveness based on CPSC's 2004-2005 Survey of Unreported Residential Fires

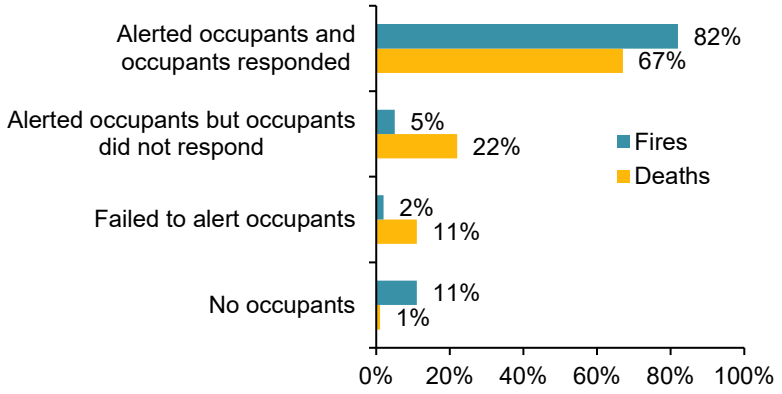


Fire statistics from England provide additional insights. In 2013/2014–2018/2019, home smoke alarms were present, operated, and alerted occupants to act in 38–43 percent of the dwelling fires reported in England. Smoke alarms operated but did not raise the alarm in 11–12 percent of the fires.[12]

- In three out of five (59–60 percent) such fires, a person raised the alarm before the system operated. Someone in the same room may noticed the fire immediately.
- In one-fifth of the fires (19–20 percent), no one was in hearing distance of the alarm.
- The occupants failed to respond in 12–13 percent of the fires.[13]

Figure 7 provides US estimates of effectiveness of operating smoke alarm warnings in alerting occupants and prompting them to act. Two-thirds of the fatalities in home fires with operating smoke alarms responded but still succumbed to the fire.

Figure 7. Effectiveness of Operating Smoke Alarms for Alerting Occupants in Reported Home Fires: 2014—2018



To be effective, a smoke alarm's warning must be heard or received. Another CPSC study found that a closed lightweight door reduced the volume of a smoke alarm signal from another room by 10 to 20 decibels. The signal was weakened by roughly 20 decibels for each level it traveled.[14]

In her literature review on sleep and waking to fire alarms,[15] Dorothy Bruck concluded that louder signals are needed when significant background noise is present. She also found that waking thresholds vary significantly. Sleep-deprived adults are less likely to be wakened by a smoke alarm, as are young children and people under the influence of alcohol, marijuana, or sleep-inducing medication. In addition, the higher frequency hearing loss that often accompanies aging reduces the probability that older adults will wake to a smoke alarm.

Moinuddin, Bruck, and Long found that the sound level of a smoke alarm decreased substantially from room to room even when doors were open. They tested the volume of smoke alarms with different sensors, sound wave frequencies, and shapes (105 dBA, 85 dBA, and 520 Hz square wave respectively) placed in different locations and different configurations.[16] A 75 dBA waking threshold sound level was recommended for reliable notification and waking. Only the 105 dBA alarm with doors open throughout the home consistently exceeded the 75 dBA threshold in rooms other than the room of sound origin. Sound from the 520 Hz square wave signal was transmitted slightly more effectively. Tests with closed doors ended after initial tests showed that so little smoke escaped that none was detected by smoke alarms in hallways or adjacent rooms. The authors concluded that "…to achieve early detection and adequate notification, smoke alarms are required in every room and should be interconnected."

While Moinuddin, Bruck, and Long found that audibility decreased as signals traveled, NIST's Thomas Cleary found that larger spaces and distance diluted the smoke and delayed smoke alarm activation.[17] Full-scale experimental test burns that began with the ignition of a chair mock-up were done in the bedroom and living room of a small home mock-up with the door open or closed. The materials in the chair and the ignition mode both influenced the time it took to activate the smoke alarms. The average time to alarm increased when smoldering fire tests were performed in the living room rather than the bedroom because of the effects of smoke transport and dilution. The time to alarm was longer when the bedroom door was open in both smoldering and flaming conditions. The smoke dilution and transport effects delayed the activation of the smoke alarms in the bedroom. The signal volume was not captured in this study.

Researchers in British Columbia, Canada found that working smoke alarms reduced the probability that residential fires attended by the Surrey Fire Services would spread beyond the room of origin regardless of the response time. In properties with no working smoke alarms, the probability that a fire would spread beyond the room of origin increased 17 percent for each one-minute increase in time needed for an effective fire department attack force to assemble. When working smoke alarms were present, the probability that a fire would spread beyond the room of origin was reduced by 71 percent regardless of the response time.[18] Fire department performance metrics of fires that spread beyond the room of origin should include the presence or absence of working smoke alarms.

Smoke Alarms in Context

NFIRS data provides information on how an occupant's location, characteristics, and activity can influence the outcome of a fire. People who died in US home fires with working smoke alarms often had characteristics or circumstances that made escape more difficult. Compared to deaths resulting from fires in which no smoke alarms were present, or alarms were present but did not operate, victims of fatal fires with working smoke alarms were more likely to have:

- Had a physical disability,
- Been in the room or area of origin and even more likely to have been in the area of origin and involved in ignition,
- Been at least 65 years old,
- Been fighting the fire themselves,
- Acted irrationally, and
- Been awake when fatally injured.

Two examples illustrate these points.

- Although operational smoke alarms were present in a Michigan house fire that started when woodstove ashes ignited a cardboard container in the basement, an elderly man's poor health prevented his escape from the ground floor. He was found in the home's doorway.[19]
- Responding firefighters heard the sound of smoke alarms at a West Virginia house fire that began when bedding was ignited by a cigarette in an ashtray on the bed. Medical oxygen was a contributing factor in the fire's development. The elderly female victim, who routinely used a walker, was found on the floor by the bed.[20]

Smoke alarms are an important part of home fire protection, but they are not the only part. The death rate per 1,000 reported home fires steadily declines as the levels of fire protection increase.

Figure 8 shows that the death rate is lowest in homes with sprinklers and hardwired smoke alarms. These rates are based on their presence in reported fires only. Whether they operated was not considered. While fires in homes in which partial sprinkler systems were present or in which sprinklers were outside the fire area and did not operate were excluded from the calculations, the data did not permit us to exclude fires that did not have enough smoke alarms or in which the smoke alarms were not audible to the occupants.

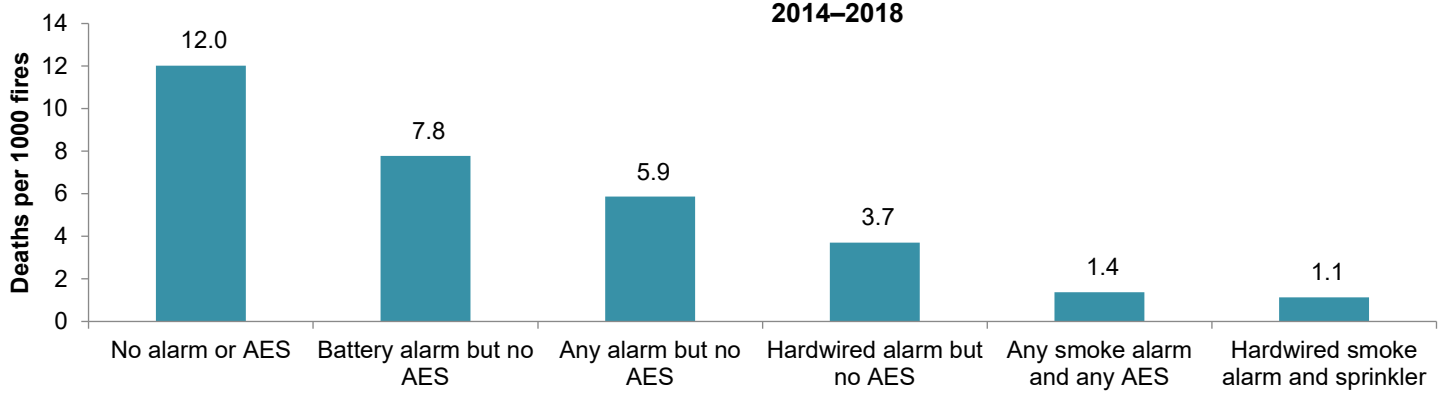
As discussed earlier, a closed bedroom door is likely to delay the operation of a single-station alarm in response to fire on the other side of the door. Similarly, a single-station alarm sounding on a different floor or behind a closed door may not be loud enough to alert someone in another part of the home.

Hardwired smoke alarms are more likely to be interconnected, although battery-powered, wireless interconnected alarms are available. New homes should have hardwired smoke alarms.

Smoke alarm testing is also essential. In a 2010 Harris poll, only one in five respondents reported testing their smoke alarms at least once a month.

It is easy to forget that a smoke alarm's sole function is to sound a warning. People also need to develop and practice escape plans so they can get out quickly if an alarm sounds. Because smoke alarms can alert occupants to fires that are still relatively small, some people might try to fight these fires themselves. Unfortunately, these attempts could be unsuccessful due to either rapid fire spread or inappropriate methods of fire control, leaving occupants with less time to escape.

Figure 8. Average Fire Death Rate per 1,000 Reported Home Structure Fires by Presence of Smoke Alarms and Automatic Extinguishing Systems (AES): 2014–2018



What Fires Are Reported? What Counts as a Fire?

The 2014–2018 US national estimates of smoke alarm performance in reported home fires are, by definition, limited to fires reported to local fire departments. Two issues come into play here. Activation of monitored fire detection systems often results in a fire department response. This results in more minor fires being reported in properties with this level of protection. These systems are often in public areas of apartments or other multifamily housing. Smoke alarms operated in 71 percent of reported fires in apartments or other multifamily housing compared to 45 percent of fires reported in one- or two-family homes. In many cases, the occupants had already handled the situation. Occupants of properties without monitored systems may not find it necessary to call the fire department for such minor fires.

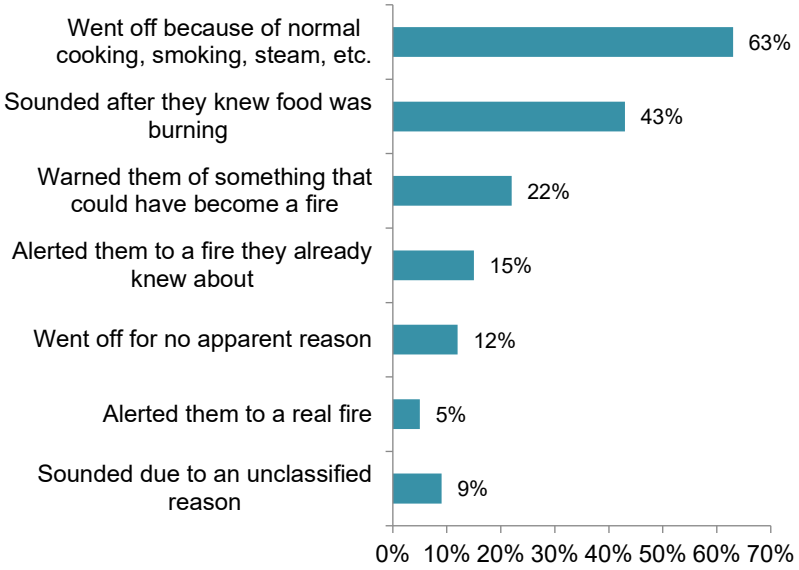
The 2004-2005 CPSC survey of unreported residential fires found that 97 percent of home fires were handled without fire department assistance.[21] The same study found that both reported and unreported fires decreased since their 1984 survey.

NFPA commissioned Harris Poll survey questions in 2010 to learn more about smoke alarm activations. The 43 percent of respondents whose smoke alarms sounded at least once were asked: **"**What do you think caused the smoke alarm to go off in the last year?" Only one answer was allowed. Cooking was cited as the reason by roughly three out of four (73 percent) respondents. Low-battery chirps accounted for 8 percent. None of the respondents said that a fire caused the activation.

Respondents were then asked to answer a series of questions about the last time the smoke alarm went off. These were phrased as "Did it?" questions to be answered either "yes" or "no." The results, shown in Figure 9, indicate several fire-type situations. More than

one in five said the sounding alarm warned them of something that could have become a fire. Smoke alarms are traditionally considered tools for fire protection, not fire prevention, yet this response suggests that they frequently alert occupants to situations that might be called *almost-fires*. With prompt occupant action, the situation can be corrected and prevent a recognizable fire. This suggests that smoke alarms have played a role in reducing the occurrence of unreported fires.

Figure 9. The Last Time a Smoke Alarm Sounded, It ...



Cooking is clearly a factor in unwanted activations. Manufacturers seeking UL listing for their smoke alarms and smoke detectors will be required to demonstrate that the devices are resistant to cooking and other nuisance alarm sources, while also activating within 3 minutes to burning polyurethane foam.[22] These smoke detector requirements have an effective date of June 30, 2021, while the requirements for smoke alarms have been delayed until 2022.[23] Studies to assess the impact of this new technology on unwanted alarms and both reported and unreported fires will be needed.

Additional Information

See *Smoke Alarms in US Home Fires: Supporting Tables* by Marty Ahrens, February 2021, for more detailed information about the material presented in this report.

For consumer information about smoke alarms, visit nfpa.org/smokealarms.

Methodology

The statistics in this analysis are estimates derived from the US Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's (NFPA's) annual survey of US fire departments. Fires reported to federal or state fire departments or industrial fire brigades are not included in these estimates. Only civilian (non-firefighter) casualties are discussed in this analysis.

NFPA's fire department experience survey provides estimates of the big picture. NFIRS is a voluntary system through which participating fire departments report detailed factors about the fires to which they respond.

To compensate for fires reported to local fire departments but not captured in NFIRS, scaling ratios are calculated and then applied to the NFIRS database using the formula below.

$$\frac{\text{NFPA's fire experience survey projections}}{\text{NFIRS totals}}$$

NFPA also allocates unknown data proportionally to compensate for fires for which information was undetermined or not reported.

Smoke alarms are not the same as smoke detectors. Most homes have what we now call smoke alarms. These devices detect the presence of smoke and sound the alarm. Some properties, particularly some multifamily complexes and newer single-family homes, have smoke detectors that are components of an alarm system with a panel. The detection unit itself does not necessarily sound the alarm. Instead, the signal is transmitted to a control unit that then sounds the alarm throughout the premises. Older studies of smoke detectors usually studied devices that would now be called smoke alarms. NFIRS does not distinguish between smoke detectors and smoke alarms. Except where specified, the term *smoke alarm* in this analysis is used inclusively for all fire detection equipment. Estimates of specific types of detection are available in the supporting tables for this report.

Some spaces in homes, such as garages, exterior parts of the structure, concealed spaces, and unoccupied attics, are not expected or required to have smoke alarms. No adjustments were made for these spaces.

Detection in apartments or other multifamily housing also poses coding challenges. A smoke alarm may be missing from or disabled in the unit of origin, but a detection system in the common areas or a smoke alarm in an adjacent unit may have operated and sounded the alarm. It is unclear whether detection would be considered present and operating in such a fire.

Confined structure fires in NFIRS include confined cooking fires, confined chimney or flue fires, confined trash fires, confined fuel burner or boiler fires, confined commercial compactor fires, and confined incinerator fires (NFIRS incident type 113–118). Losses are generally minimal in these fires, which, by definition, are assumed to have been limited to the object of origin. Although detailed data about detection is not required for these fires, it is sometimes present. Raw NFIRS data for 2014–2018 contained a total of 29,905 (5 percent) confined home structure fires in which some type of detection was present and 24,067 (92 percent) confined fires in which detection was present and its operation was known.

The raw NFIRS data for 2014–2018 contained a total of 430,829 non-confined home structure fires (NFIRS incident type 110–123, excluding incident types 113–118) in which detection presence was known (coded as either present or not present). A total of 4,394 civilian deaths; 22,042 civilian injuries; and $14.5 billion in direct property damage was associated with these fires. Detector (or smoke alarm) presence was known for 68 percent of non-confined fires, 59 percent of deaths, 77 percent of injuries, and 65 percent of direct property damage. A detection system was present in 42 percent of non-confined fires, 34 percent of deaths, 52 percent of injuries, and 48 percent of associated property loss.

When detection was present in non-confined structure fires, detection operation was known (coded fire too small to operate, operated, or failed to operate) in a five-year raw total of 220,667 fires associated with 1,671 deaths; 12,166 injuries; and $8.3 billion in direct property damage. When present, detector (or smoke alarm) operation was known for 83 percent of non-confined fires, 65 percent of deaths, 82 percent of injuries, and 77 percent of direct property damage.

For more information on the methodology used for this report see, *How NFPA's National Estimates Are Calculated for Home Structure Fires.*

Acknowledgments

The National Fire Protection Association thanks all the fire departments and state fire authorities who participate in the National Fire Incident Reporting System (NFIRS) and the annual NFPA fire experience survey. These firefighters are the original sources of the detailed data that makes this analysis possible. Their contributions allow us to estimate the size of the fire problem.

We are also grateful to the US Fire Administration for its work in developing, coordinating, and maintaining NFIRS.

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[1] Sources for number of homes with smoke alarms: 1977, 1980, and 1982 estimates from sample surveys by the US Fire Administration; 1983–1995 estimates from Louis Harris Surveys for *Prevention Magazine*; "1997 Fire Awareness Survey for NFPA"; "1999 NFPA National Fire Escape Survey"; "2004 Fire Prevention Week Survey for NFPA"; CPSC's Michael A. Greene and Craig Andres, *2004-2005 National Sample Survey of Unreported Residential Fires.*, 2009; US Harris Interactive survey, "Smoke Alarm Omnibus Question Report," 2008; Harris Poll® National Quorum: "National Fire Protection Association — Smoke Alarms," September 2010.

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