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# Reductions in Life and Property Loss by Home Fire Sprinklers

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Abstract

This research article aims to answer whether areas that have adopted residential fire sprinkler codes experienced statistically significant reductions in life and property loss in sprinklered homes. The study conducted an extensive literature review as well as an analysis of the most current home fire sprinkler data from the state of California. The data collected for this article supports the hypothesis that home fire sprinklers provide a significant property protection benefit and a substantial reduction in fire injuries and deaths for the civilian population. In the five years of data provided by the California Office of the State Fire Marshal, sprinklered homes showed a decrease in property loss of 48% or more in every year except for 2021. Civilian fire injuries and deaths were practically non-existent in fires involving sprinklered homes, and firefighter injuries were also substantially reduced. However, the study is limited by the small sample size of fires where a home fire sprinkler was documented to operate. This is due to both the relatively small number of homes in the United States equipped with fire sprinklers and the inconsistent data collection regarding their use. Fire departments and home fire sprinkler advocates should endeavor to highlight the potential property conservation benefits of home fire sprinklers alongside the life safety benefits in their public education efforts. The fire service must also strive to improve the data collection regarding home fire sprinklers by increasing mandatory reporting requirements for fire sprinklers and should consider working collaboratively with home fire sprinkler advocacy groups to establish a database where fire incidents involving home fire sprinkler systems can be reported.

*Keywords:* sprinklers, fire service, fire protection systems, fire suppression technology, home fire safety

## 1. Reductions in Life and Property Loss by Home Fire Sprinklers

Home fire sprinklers have become an increasingly recognized component of a balanced community fire risk reduction plan since at least 1973 with the publication of *America Burning* by the National Commission on Fire Prevention and Control. In this seminal document, the report commissioners recommended further research and development toward automatic extinguishing systems that would be practical for use in residential homes, writing that "one could envision the day when every American home will have its own automatic fire department (National Commission on Fire Prevention and Control, 1973, p. 125)." In 1975, the National Fire Protection Association (NFPA) introduced NFPA 13D: Standard for the Installation of Sprinkler Systems in One-and Two-Family Dwellings and Manufactured Homes. The purpose of this standard is to provide a cost-efficient home fire sprinkler system, with an emphasis on maintaining the standards of life safety (Hugo & Hartenbach, 2017). The older editions of NFPA 13D drew upon the technology that existed at the time, making more exceptions relating to water supply and spray coverage compared to the commercial standard. In 1981, the first UL-listed residential fire sprinkler was introduced (Upson, 2017). The development of the residential sprinkler system focused on quicker response time by deploying at lower temperatures and having a water discharge pattern that sprays higher on walls, with an emphasis on life safety versus property protection. Newer editions of NFPA 13D continue to incorporate new advances in technology to provide a cost-effective home fire sprinkler system (Hugo & Hartenbach, 2017).

The 2006 editions of the National Fire Protection Association's NFPA 1, Uniform Fire Code, NFPA 101, Life Safety Code, and NFPA 5000, Building Construction & Safety Code, required fire sprinklers in one-and-two-family homes (Frattaroli, Teret, & Rutkow, 2011). In 2008, the International Code Council (ICC) voted to place this same requirement in the 2009 edition of the International Residential Code (IRC), effective January 2011. This change meant that by 2011 all model building codes used in the United States had a home fire sprinkler mandate included (Frattaroli, Teret, & Rutkow, 2011). However, with some notable exceptions, most states and communities do not enforce this portion of the model codes. As of today, only Maryland, California, and the District of Columbia have kept the fire sprinkler requirement for new one-and-two-family homes in place (National Association of Home Builders, 2019). All other states have either completely removed the requirement or limited the requirement to homes over a certain size or height. Some states, such as Pennsylvania, initially adopted the requirement and then repealed it after successful lobbying from homebuilders (Roulo, 2011).

Although home fire sprinklers have been proposed as a community risk reduction tool for many decades, recent changes within the home environment have brought them into greater focus. Significant changes in the home environment include the increased propagation of lightweight construction techniques as well as the increased use of synthetic materials in the construction of home furnishings (Gately, 2017). These changes have resulted in an increased production of toxic gases and a decreased time to flashover within the fire compartment, reducing the time that residents have to evacuate. Home fire sprinklers are a potential solution to suppress fires while they are still in the incipient stage and buy residents time to evacuate safely. However, home fire sprinklers are opposed by many homebuilders' groups, who see them as too costly

for too little benefit and believe that they do not meet the required standards of affordability (National Association of Home Builders, 2006). This research article will attempt to provide insight into this debate by answering the following question: Have areas that adopted residential fire sprinkler codes experienced statistically significant reductions in life and property loss in sprinklered homes?

## 2. Background and Significance

Fire remains a significant problem in the United States despite substantial improvements in building codes, fire prevention, and public education in recent decades. According to the latest NFPA data, fire departments responded to a total of 1,353,500 fires in the United States in 2021 (Hall & Evarts, 2022). 486,500 fires, or 36% of the total occurred in or on structures. Only 25% occurred in home properties, including one or two-family homes and apartments. However, these fires were responsible for three-quarters of all civilian fire deaths and injuries. Specifically, one and two-family homes accounted for only one out of every five fires (20%), yet these fires caused nearly two-thirds of all fire deaths (Hall & Evarts, 2022). Furthermore, even though the number of home structure fires was 54% lower in 1980 and the overall number of deaths was 44% lower, the rate of death per 1,000 fires was 35% higher than it was in 1980. U.S. Fire Administrator Dr. Lori Moore-Merrell described the current fire problem in the U.S. in these words (Engel, 2023):

> Today, fire is fast; we've got synthetics, we've got lightweight furniture, we have lightweight construction. Fire is fast and it's moving faster through the built environment. You don't have time to escape anymore. You have to preplan, because what used to buy us time in our structures no longer exists – that's a huge piece of the fire prevention messaging.

In 2012, the U.S. Fire Administration (USFA) adopted the official position that "all citizens should be protected against death, injury, and property loss resulting from fire in their homes" and "all homes should be equipped with both smoke alarms and residential fire sprinklers," (USFA, 2012). Statistically, fire sprinklers are an outstanding measure to prevent death and injury in residential fires. Data gathered by Ahrens (2021) indicates that civilian fire death rates were 89 percent lower in properties protected by fire sprinklers and injuries were 27 percent lower, while firefighter injuries were 60 percent lower. Furthermore, the average dollar loss per fire in homes was 62 percent lower when sprinklers were installed. Sprinklers were also responsible for a 24 percent increase in fires that were confined to the object or room of origin as compared to structures with no sprinklers installed.

Although the above findings indicate the great effectiveness of sprinklers in preventing life and property loss, the same study also found that sprinklers were only present in seven percent of home fires from 2015-2019 (Ahrens, 2021). It would seem, therefore, that the attempts by home fire sprinkler advocates to encourage wider adoption of home fire sprinklers would be reasonable. However, efforts to increase home fire sprinkler code requirements are consistently met with opposition by home builder groups, the most prominent of which is the National Association of Home Builders (NAHB). In 2006, the NAHB adopted a resolution reaffirming

their opposition to residential fire sprinkler mandates. In their view, residential fire sprinkler systems do not meet the required standard of affordability or reliability. Specifically, the NAHB states that it will not support residential fire sprinkler codes until the systems can meet the following conditions (NAHB, 2006):

- Significantly reduce the initial installation cost of the system versus the current NFPA sprinkler systems.
- Enhance the safety of occupants without a significant reduction in housing affordability,
- Reduce the substantial costs associated with connecting to public water systems or providing water storage/delivery systems for homes not connected to public water.
- Address freezing concerns and provide low-cost solutions for homes in colder climates.
- Provide simplified design, installation, and inspection requirements that significantly reduce the associated costs.
- Minimize the maintenance of the installed system required of homeowners.
- Relieve builders of legal liability for malfunctions or failures.
- Address insurance industry rate increases, policy exceptions, or policy denials for sprinkler system malfunctions or failures.

This resolution, adopted nearly two decades ago, continues to represent the position of the NAHB to this day. The NAHB's view is that smoke alarms alone are enough to prevent most injuries and deaths and that home fire sprinklers will price many potential homeowners out of the market, stating that even a $1,000 increase in the price of a home could keep more than 200,000 people out of the market nationally (NAHB, n.d.). Notably, the NAHB's viewpoint does not claim that home fire sprinklers are ineffective; only that they are costly and unnecessary considering other safety improvements available in homes. The problem is that many of the scientific findings used by both supporters and opponents of residential fire sprinklers date to the early 2000s or earlier and may not represent the latest understanding of both fire behavior and residential fire sprinkler technology. This research article will attempt to uncover the latest data to formulate a stronger understanding of the subject.

## 3. Literature Review

The purpose of the literature review is to evaluate the existing research on the subject and provide a basis for further research conducted in this article. Existing literature is evaluated to establish a baseline on the previous results of home fire sprinkler cost/benefit studies as well as home fire sprinkler effectiveness studies. When the authors of America Burning first envisioned the concept of home fire sprinklers, they acknowledged that "very few Americans have paused to consider the wisdom of providing their own fire protection (National Commission on Fire Prevention and Control, 1973, p. 124). Since the issuance of America Burning, individual communities, districts, and states have enacted home fire sprinkler mandates. Although these areas remain a significant minority, some available data does exist to provide a factual basis for continued research.

### 3.1. Previous Cost/Benefit Studies

Ruegg & Fuller (1984) issued the first cost-benefit analysis of home fire sprinklers on behalf of the National Bureau of Standards (NBS). This study suggested that sprinkler systems were in general not cost-effective for most homeowners using the technology available at the time. This was based on the willingness-to-pay concept that is rooted in economic theory. The study had two purchase and installation cost estimates based on 1982 dollars; the lowest cost estimate was $0.50 per square foot, while the highest cost estimate was $0.80 per square foot. This translates to $1.57 per square foot and $2.51 per square foot in 2023 dollars. The study suggested the cost-effectiveness of home fire sprinklers could be improved in the future through the use of approved plastic pipe as well as through more widespread adoption and incentivization by the local government or homebuilder (Ruegg & Fuller, 1984). The study also suggested that sprinklers are more likely to be cost-effective in situations where additional protection is needed, such as when occupants are hearing-impaired or otherwise incapacitated.

The NAHB in conjunction with the USFA issued the report *Cost-Benefit Analysis of Residential Fire Sprinklers* in June 1988. The report was split into two parts; the first part evaluated the cost/benefit ratio of sprinkler installation from the perspective of an individual consumer, while the second part evaluated the cost/benefit from a societal or community perspective (NAHB, 1988). The cost/benefit model utilized in this report evaluated the fire sprinkler systems as an economic investment based on the estimated benefits and costs resulting from the purchase at the time. The system costs were estimated for selected typical designs and included items such as financing costs, maintenance costs, and activation costs (NAHB, 1988). Benefits were estimated based on enhanced life safety, property protection, and insurance premium discounts. According to the study, the cost-benefit analysis consistently indicated that the benefits of a residential fire sprinkler system fell short of the costs in a typical home from both a homeowner and societal point of view, except possibly for uninsured HUD-code homes (NAHB, 1988). The study indicated that major changes in the inputs would be necessary to alter this finding. Specifically, the report states that dramatically lower sprinkler system prices, a doubling or tripling of life safety value or insurance discount, or local fire service cost savings per sprinklered home of 30 to 40 percent would bring the cost/benefit into line (NAHB, 1988).

Butry, Brown, & Fuller (2007) conducted a similar cost/benefit analysis on behalf of the National Institute of Standards and Technology, coming to a decidedly different conclusion from the previous studies conducted two decades prior. The study compared the costs and benefits associated with the installation and use of home fire sprinklers across three prototypical single-family houses: a colonial, a townhouse, and a ranch. The study concluded that the primary costs are for the initial purchase and installation of the sprinkler system as ongoing maintenance costs are negligible (Butry, Brown, & Fuller, 2007). The benefits as measured in the study included reductions in the risk of civilian fatalities and injuries, reductions in homeowner insurance premiums, reductions in uninsured direct property losses, and reductions in uninsured indirect costs.

Notably, this study utilized a multipurpose network sprinkler system in its example homes. This decision was based on previous research by Brown (2005) which showed that the multipurpose system was the most economical out of the approved system types found in the NFPA 13D

standard. The multipurpose network design connects to the house's regular water supply and piping, as opposed to a standalone design that utilizes separate piping for the domestic water and sprinkler systems. This reduces the amount of plumbing needed and means that water is continually circulated, eliminating any need for backflow preventers and reducing the overall cost of the system. This is important because the multipurpose system was not considered in earlier studies that were previously cited. The results of this study showed that multipurpose network sprinkler systems are economical, with the expected present value of net benefits to be $2,099 for a colonial-style house, $3,099 for a townhouse, and $4,166 for a ranch-style house (Brown, Butry, & Fuller, 2007). The study cites the increase in fire sprinkler performance as well as the low life-cycle cost of the multipurpose network system as the greatest change in increasing the cost-effectiveness of home fire sprinklers.

Hayes (2008) also found that the multipurpose network system was the most economical home fire sprinkler option, costing 15% less than standalone systems. The study found that the average cost to install a residential sprinkler system in the Gainesville, Florida area was $1.81 per square foot. However, the study also found that local government regulations can add significant regulatory burden and cost to the systems by requiring additional features not specifically required by the NFPA 13D standard such as backflow preventers and flow switches as well as substantial permit, inspection, and water line tap fees (Hayes, 2008). The study also found that a relative lack of qualified contractors can drive up costs due to less competition. The study recommended that alternative methods be evaluated to facilitate and encourage home fire sprinklers, such as tax incentives and the removal of unnecessary regulatory barriers.

Jakubowski (2011) analyzed the costs of home fire sprinkler installation in six municipalities in Bucks County, Pennsylvania that had adopted home fire sprinkler ordinances between 1989 and 2000. The study found that the cost to install sprinklers in new homes where public water was not provided ranged from $1.23 to $2.71 per square foot. When public water was provided, the costs fell to $1.10 per square foot or less (Jakubowski, 2011). Two similar townhouse developments constructed adjacent to each other in the same municipality were evaluated and found to have little difference in market price despite one being sprinklered and the other not. The study also noted that home fire sprinklers were seen as an equalizer in maintaining the viability of volunteer fire departments in these communities, which can provide significant tax savings (Jakubowski, 2011).

A home fire sprinkler cost assessment study by the Fire Protection Research Foundation (2013) found the average cost of installing an NFPA 13D home fire sprinkler system was $1.35 per square foot. This was a decrease from $1.61 per square foot in 2008. The study found that the minimum per-square-foot cost nationally was $0.81 per square foot in Fresno, California and the maximum was $2.47 in Greenburgh, New York. The study found that there were many variables to the overall cost of the systems, including the system design, water supply, and local fees and regulations (Fire Protection Research Foundation, 2013). Significantly lower costs were noted in Maryland and California, the two states that have statewide home fire sprinkler mandates, than in the sample as a whole. The study states that lower costs for systems in states with statewide requirements may be a result of several factors, including more widespread

acceptance of sprinkler systems and increased experience in installation and design practices by contractors as well increased market demand (Fire Protection Research Foundation, 2013).

Van Coile et al (2023) considered the cost/benefit of home fire sprinklers from a purely private, rather than societal, perspective. Using an exemplar single-family dwelling inspired by Butry (2009), the study found that whether the cost/benefit of home fire sprinkler systems was positive or negative depended on the valuation of indirect losses in case of fire. Indirect losses were considered as business interruption or downtime, indirect financial losses, loss of buildings of significant value, evacuation and relocation of building occupants, and psychological damage (Von Coile et al, 2023). When indirect losses were given less weight, the costs of the system outweighed the benefit. When indirect losses were given more weight, the benefit outweighed the cost. Importantly, this study also factored in a theoretical 5% annual maintenance cost; this is not supported by previous literature such as Brown, Butry, & Fuller (2007) and Upham (2008), which found that ongoing home fire sprinkler maintenance costs were negligible.

### 3.2. Previous Home Fire Sprinkler Effectiveness Studies

Ford (1997) documented a 10-year history of the home fire sprinkler code in Scottsdale, Arizona, which was the first city in the country to adopt a home fire sprinkler mandate. The study found that in Scottsdale, the cost and economics associated with installing home fire sprinklers were successfully addressed through design freedoms without negatively impacting the effectiveness of the fire sprinkler systems. The average fire loss per sprinklered incident was $1,945, compared to an average loss of $17,067 for unsprinklered homes (Ford, 1997). Home fire sprinklers were documented to have had a direct role in saving eight lives. The study found that one or two sprinkler heads controlled or extinguished the fire 92% of the time, with most of the exceptions a result of flammable liquid incidents (Ford, 1997). The study found that estimated water flows were substantially reduced for the community and potential structural fire loss was dramatically reduced.

In a follow-up to the 1997 study, Ford (2002) conducted a 15-year look back on home fire sprinkler data in Scottsdale, finding that the difference in property loss between sprinklered and unsprinklered homes had increased even further, with an average loss of $3,534 in sprinklered buildings and $39,672 in unsprinklered buildings. The study found that approximately 341 gallons of water was needed to extinguish a fire with sprinklers versus an estimated 2,935 gallons of water for the same building with no sprinkler protection (Ford, 2002). The civilian fire fatality rate was noted to have been reduced by 50% overall with at least thirteen documented lives saved as a direct result of sprinkler system activation.

Weatherby (2009) analyzed the 15-year history of the home fire sprinkler ordinance in Prince George's County, Maryland. The study found that from 1992-2007, there were 101 fire deaths and 328 civilian injuries in single-family or townhouse fires with no sprinkler system installed; zero fire deaths and only six civilian injuries were recorded in sprinkler-protected homes during the same period. The study also found an average damage of $9,983 per incident in unsprinklered homes; this rose to $49,503 per incident when a fatality was involved (Weatherby, 2009). Conversely, the average property loss for a sprinklered home was $4,883

per incident. An estimated fire loss of $1,352,820 occurred in the 245 incidents where a home fire sprinkler activation was recorded, compared to a total potential loss of $42,578,420 (Weatherby, 2009).

Jakubowski (2011) analyzed six Bucks County, Pennsylvania municipalities that adopted home fire sprinkler ordinances between 1989 and 2000. Damage to structures and contents from fires in unsprinklered homes in the six municipalities studied was more than 12 times higher than the damage found in sprinklered homes, and almost 18 times as much water was needed to extinguish fires inunsprinklered homes compared to sprinklered homes (Jakubowski, 2011). The study found that there was little relationship between the age of the home and the incidence of fire. However, from 1988-2010 there were 90 deaths in unsprinklered one-and-two-family homes, compared to zero documented deaths in sprinklered homes during the same timeframe. Also, there were five documented fire incidents in sprinklered homes where lives were saved as a direct result of the fire sprinkler system (Jakubowski, 2011).

In a national study for the NFPA, Ahrens (2021) found that from 2015 to 2019, home fire sprinklers operated in 95 percent of fires large enough to activate them and were effective in controlling 97 percent of the incidents in which they operated. In 89 percent of home fires with operating sprinklers were controlled with only one sprinkler head, and 99.5 percent were controlled with five or fewer heads (Ahrens, 2021). The rate of firefighter injuries per sprinklered home fire was 78% lower compared to homes with no sprinklers, and fires were confined to the object or room of origin 97% of the time in homes with sprinklers versus 78% without. The study also found that the civilian death rate per 1,000 reported fires was 88 percent lower in homes with sprinklers than in homes without them, and the injury rate was 28% lower in sprinklered homes (Ahrens, 2021). The study found that in many cases, the injuries occurred in fires that were too small to activate the sprinkler system and were commonly caused when individuals attempted to fight the fires themselves, and failures of the sprinkler system to activate were nearly always caused by human action (I.E, shutting off the sprinkler system). The study also found that the average loss per fire was 62% lower than the average in homes with no sprinkler system. Overall, the study found that a combination of hardwired smoke alarms and an automatic fire sprinkler system provided the best possible life safety protection, with deaths per 1,000 fires being 66 percent lower with hardwired smoke detectors alone and 89 percent lower when sprinklers and hardwired smoke alarms were both present (Ahrens, 2021).

## 4. Research Procedure

To gain original data to support the research article, public record requests were made to the following jurisdictions where home fire sprinkler mandates are known to exist: California, Maryland, and Washington, D.C. Because of the limited sample size, public record requests were also made to two additional states: Pennsylvania and Florida. Although neither state has a blanket home fire sprinkler mandate, Pennsylvania requires that home builders provide customers with the option for home fire sprinklers, and Florida allows for local adoption of home fire sprinkler mandates.

The instrument utilized was a simple three-question survey that queried the following data points:

- Yearly property losses in dollar amount for one and two-family homes equipped with sprinkler systems vs. not.
- Yearly civilian fire injuries and deaths in one and two-family homes equipped with sprinkler systems vs. not.
- Yearly firefighter injuries and deaths in one and two-family homes equipped with sprinkler systems vs. not.

Collected data was analyzed and broken down to create a per-incident average for property loss in dollar amount. Data regarding civilian and firefighter injury and death was separated into tables as seen in the results section.

## 5. Results

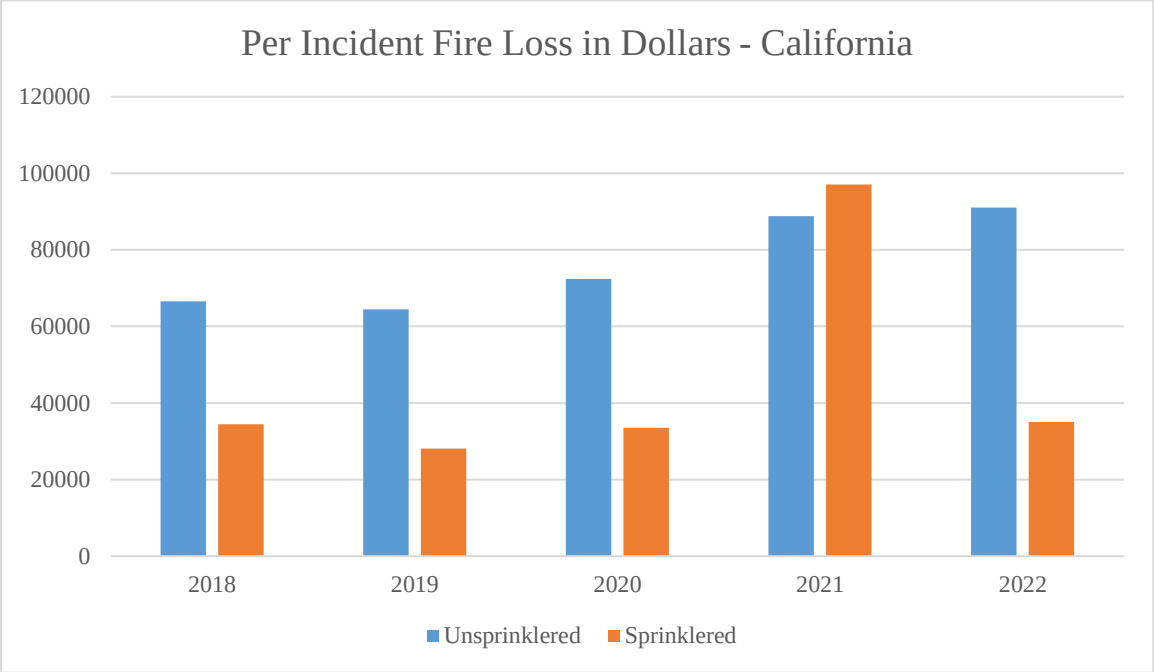
### 5.1. Response Rates

Of the five jurisdictions queried, only California and Maryland responded to the requests with data. Washington, D.C. and Pennsylvania stated that the requested data could not be found while Florida did not respond to the records request. California provided a five-year lookback on the requested data from 2018-2023, while Maryland provided three years' worth of data from 2020, 2021, and 2022. Data quality was noted to be significantly different between California and Maryland due to a lack of standardized data collection between states. Maryland was unable to provide definitive data on fires in sprinklered vs. unsprinklered one-and-two-family dwellings because the state does not require the automatic extinguishing system field to be filled out by fire departments when completing fire reports. Furthermore, the data provided by Maryland did not separate one-and-two-family dwellings from other residential dwellings, making it very difficult to determine which statistics applied to those structures and which applied to other residential dwellings such as apartments and hotels. The data from Maryland was therefore excluded from this study due to the inability to make a reliable statistical analysis.

## 5.2. Property Loss

The property loss data from California is provided in Figure 1:

Fig. 1 – Per Incident Fire Loss in Dollars - California




The property loss in California from 2018 – 2022 breaks down as follows:

- 2018: Unsprinklered homes averaged $66,598.14 in combined property and content loss per incident. Sprinklered homes averaged $34,453.40 in loss, a 48.26% decrease.
- 2019: Unsprinklered homes averaged $64,479.96 in combined property and content loss per incident. Sprinklered homes averaged $28,111.71 in loss, a 56.40% decrease.
- 2020: Unsprinklered homes averaged $72,418.87 in combined property and content loss per incident. Sprinklered homes averaged $33,540.78 in loss, a 53.68% decrease.
- 2021: Unsprinklered homes averaged $88,835.36 in combined property and content loss per incident. Sprinklered homes averaged $97,056.84 in loss, a 9.25% increase.
- 2022: Unsprinklered homes averaged $91,096.33 in combined property and content loss per incident. Sprinklered homes averaged $35,013.94 in loss, a 61.56% decrease.

### 5.3. Civilian Injury and Death

The civilian injury and death data from California is provided in Table 1 and Table 2:

Table 1 – Civilian Fire Injures - California

| Year | Injuries - Unsprinklered | Injuries – Sprinklered | Difference |
|---|---|---|---|
| 2018 | 192 | 0 | -192 |
| 2019 | 252 | 0 | -252 |
| 2020 | 256 | 0 | -256 |
| 2021 | 215 | 0 | -215 |
| 2022 | 200 | 1 | -199 |
| **Total** | **1115** | **1** | **-1114** |

Table 2 - Civilian Deaths - California

| Year | Deaths - Unsprinklered | Deaths – Sprinklered | Difference |
|---|---|---|---|
| 2018 | 45 | 0 | -45 |
| 2019 | 65 | 0 | -65 |
| 2020 | 82 | 0 | -82 |
| 2021 | 75 | 0 | -75 |
| 2022 | 75 | 0 | -75 |
| **Total** | **342** | **0** | **-342** |

5.4. Firefighter Injury and Death

The firefighter injury data from California is provided in Table 3:

Table 3 - Firefighter Injuries - California

| Year | Injuries - Unsprinklered | Injuries – Sprinklered | Difference |
|---|---|---|---|
| 2018 | 155 | 0 | +155 |
| 2019 | 200 | 2 | +198 |
| 2020 | 188 | 0 | +188 |
| 2021 | 132 | 1 | +131 |
| 2022 | 124 | 0 | +124 |
| **Total** | **799** | **3** | **+796** |

No firefighter deaths occurred in one or two-family dwellings in California from 2018-2022.

## 6. Discussion

The data analyzed in this study supports the hypothesis that fire sprinklers are responsible for a statistically significant reduction in property loss, injury, and death when installed in one-and-two-family homes. In the five years of data provided by the California Office of the State Fire Marshal, sprinklered homes showed a decrease in property loss of 48% or more in every year except for 2021. In 2021, sprinklered buildings had an average of 9.25% more combined property and content loss than unsprinklered buildings. The reason for this anomaly is not known but may be due to the very small sample size; only 19 fires occurred in sprinklered homes in California in 2021. Considering this small sample size, one or two large-loss incidents have the potential to greatly affect the average. In any event, from 2018-2022 the per-incident content and property loss in sprinklered homes was approximately 43% lower than that of unsprinklered homes in California. If the 2021 data is removed from the equation, sprinklered homes have a 55% lower per incident loss.

The analyzed data shows that civilian injuries and deaths were nearly non-existent in sprinklered home fires, with only one injury and zero deaths reported from 2018-2022 in California compared to 1115 injuries and 342 deaths in unsprinklered homes. Although it could be argued that the relatively small number of fires that occurred in sprinklered homes influences the low totals, the data supports previous literature that building occupants are significantly less likely to be injured or killed because of a fire when a sprinkler system is present. The data also suggests that this protection extends to firefighters as well; California recorded 799 firefighter injuries in unsprinklered homes from 2018-2022 versus only three in sprinklered homes. No firefighter deaths occurred in any one or two-family dwelling in the timeframes provided.

Unlike sprinkler systems installed in commercial structures, home fire sprinklers as outlined in NFPA 13D are designed to protect lives without consideration for property (Upson, 2017). NFPA 13D systems are much less extensive than their commercial counterparts in order to provide an economical life safety system that is practical for installation into homes. Despite this intentional limitation, the available evidence suggests that by suppressing fires in the incipient stage, NFPA 13D systems do have a positive property protection benefit. As mentioned in the literature review, multiple previous studies have shown a positive correlation between sprinkler system installation and a substantial reduction in property damage in one and two-family homes. These previous studies are supported by the new research conducted in this article, which shows that the per-incident property loss for sprinklered homes is generally much less than for unsprinklered homes. With an estimated $8.4 billion in property damage caused by home fires in 2021 (Hall & Everts, 2022), home fire sprinklers have the potential to prevent billions of dollars of direct property damage if they are more widely adopted. Consideration of this property protection benefit must be given when conducting a cost/benefit analysis of these systems.

Consideration should also be given to the economic cost of injury and death due to fire. Lawrence et al (2009) estimated that residential fire injuries result in a total loss to society of $18.5 billion every year, with fatalities accounting for 83 percent of that number and inhalation injuries accounting for 52 percent. Butry et al (2019) estimated the cost of firefighter injury in the United States to be between $1.6 billion and $5.9 billion annually, or a loss equivalent of approximately $50,000 to $200,000 per fire department per year. Prevention of injury and death should also factor into any cost/benefit analysis of fire protection technology, not only for the obvious human interest in protecting life but also for the economic benefit of reducing injuries and fatalities. The research as outlined in this article finds that factoring in the life safety benefits as well as indirect costs of fire swings the cost/benefit in favor of home fire sprinklers; when those benefits are not considered or not weighed as heavily, the cost/benefit becomes murkier.

## 7. Study Limitations

The primary limitation of this study is the lack of available data on home fire sprinklers. The fact that relatively few areas of the country have home fire sprinkler installations in significant numbers limits the available data that can be used to support any hypothesis. As a rule, dwellings equipped with home fire sprinklers make up a significant minority of the housing stock, even in areas that have adopted home fire sprinkler requirements for new construction. Therefore, the number of fires that occur in sprinkler-equipped homes is also much smaller compared to unsprinklered homes. Furthermore, data collection was found to be lacking even in areas where home fire sprinkler mandates exist. In conducting preliminary research for this article, the author was informed that many individual communities do not track home fire sprinkler data despite having requirements in place for these systems in new construction. In conducting the study, data from an entire state had to be excluded because it was impossible to determine the true number of fires that occurred in sprinklered versus unsprinklered dwellings, which also made it impossible to make a true comparison of property loss and injuries/deaths.

This data issue occurred simply because Maryland does not require that fire departments report whether an automatic extinguishing system was present in the structure. This field is a standard feature of the National Fire Incident Reporting System (NFIRS), and the simple act of making this field mandatory would greatly improve the ability to track the effectiveness of sprinkler systems in all types of structures.

## 8. Conclusion and Recommendations

The purpose of this research article was to answer whether areas that have adopted residential fire sprinkler codes experienced statistically significant reductions in life and property loss in sprinklered homes. The data from the state of California that was collected for this article supports the hypothesis that home fire sprinklers provide a significant property protection benefit. From 2018 through 2022, sprinklered one-and-two-family dwellings showed a decrease in property loss of 48% or more every year except for 2021. The overall per-incident property and content loss average over the five-year period analyzed was 43% lower for sprinklered homes vs. unsprinklered homes. This is not as dramatic as the differences cited by Ford (1997, 2002) or Ahrens (2021), but relatively close to the findings of Weatherby (2009) in the Prince George's County, MD study and certainly represents a statistically significant finding. Of even greater statistical significance is the decrease in civilian injuries and fatalities as well as firefighter injuries in sprinklered homes; the data analyzed in this article supports previous research that home fire sprinklers are outstanding life safety tools and when combined with smoke detectors can greatly reduce injury and loss of life in fires.

The debate around home fire sprinklers centers mostly on perceived benefits versus cost, with supporters arguing in favor of their strong life safety record and opponents citing the added cost to the homeowners as having a detrimental effect on homeownership. Home fire sprinklers designed in accordance with the NFPA 13D standard are intended for life safety rather than property conservation. However, the available data analyzed in this article as well as previous literature shows that home fire sprinklers can achieve positive property protection results through early fire suppression. Furthermore, any real cost/benefit analysis should also consider the potential economic impact of a home fire sprinkler system's ability to prevent injury and death. When this benefit is factored in, the cost/benefit tilts significantly more in favor of home fire sprinklers than if only monetary factors are considered.

As a result of the research performed in this article, the following recommendations are made:

- Fire departments and home fire sprinkler advocates should endeavor to highlight the potential property conservation benefits of home fire sprinklers alongside the life safety benefits in their public education efforts. The NFPA 13D design criteria for a home fire sprinkler system is "to prevent flashover (total involvement) in the room of fire origin, where sprinklered, and to improve the chance for occupants to be evacuated (Ray & Prichett, 2009)." However, because the system is designed to prevent flashover in the room of origin, the system will also reduce property damage due to fire as an ancillary benefit. This is supported by the available data regarding property and content loss in

sprinklered versus unsprinklered homes and is important to mention in order to capture the segment of the population that may not be swayed by the life safety benefit alone.

- The fire service must strive to improve the data collection regarding home fire sprinklers. Obtaining good data on home fire sprinklers is difficult enough due to the relatively small number of sprinkler-protected homes in the United States; this challenge is made doubly hard by the uneven standards regarding data collection. All states should consider making the automatic extinguishing system field a mandatory data point for fire departments when entering fire reports. Also, the fire service and home fire sprinkler advocacy groups should consider working collaboratively to establish a database where fire departments can report fire incidents involving home fire sprinkler systems. This system could be set up similarly to the Firefighter Rescue Survey, where fire departments and even individual fire crews can report successful rescues of civilians in structure fires. A system such as this could potentially serve as a more outcome-oriented and detailed complement to National Fire Incidents Reporting System (NFIRS) data.

The recommendations in this article are an effort to assist with prioritizing continued research regarding the cost/benefit of home fire sprinkler systems. Fire departments and home fire sprinkler advocates should seek to refine their messaging regarding home fire sprinklers by highlighting the entire breadth of potential life safety and property conservation benefits of these systems. Defining the entire potential of home fire sprinkler systems will aid in explaining the "why" to a diverse group of stakeholders that often have differing priorities. However, effective messaging must be underpinned by accurate data, which is sorely lacking despite the nearly 50-year history of NFPA 13D. The fire service must make improving data collection on home fire sprinkler systems a priority; failure to do so will make moving the needle on home fire sprinkler adoption from its current position very difficult. Fortunately, there exists a significant potential to accomplish a major improvement in data collection and analytics as the USFA prepares to transition from the existing National Fire Incident Reporting System (NFIRS) to the new National Emergency Response Information System (NERIS). Future researchers should work to build upon the research done in this article as fire incident reporting and data collection continue to improve.

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