

Sprinkler Impact on Fire Injury

Final Report

Prepared by:

John R. Hall, Jr., Ph.D.

Marty Ahrens

Ben Evarts

National Fire Protection Association



THE
FIRE PROTECTION
RESEARCH FOUNDATION
Research in support of the NFPA mission

FIRE RESEARCH

The Fire Protection Research Foundation
One Batterymarch Park
Quincy, MA, USA 02169-7471
Email: foundation@nfpa.org
<http://www.nfpa.org/foundation>

© Copyright Fire Protection Research Foundation
October 2012

FOREWORD

Since the widespread introduction of home fire sprinklers, a significant amount of statistical data has been collected and analyzed showing their impact in reducing rates per fire of fire deaths and property damage. However there had not been sufficient in depth research on reductions in rates of fire injuries associated with home fire sprinklers. This project was initiated to develop better estimates of the impact of home sprinklers on fire injury costs, using a more sophisticated approach which explores the impact of sprinklers on fire size, the impact of fire size on burn and other fire related injury, and then assesses the data available on the costs associated with those injuries.

The content, opinions and conclusions contained in this report are solely those of the authors.



THE FIRE PROTECTION RESEARCH FOUNDATION

Home Fire Sprinkler Impact on Fire Injury

Project Technical Panel

Amy Acton	Phoenix Society
David Greenhalgh	Shriner's Burn Center, University of California, Davis
Ernest Grant	University of North Carolina Hospitals
Shannon Frattaroli	Johns Hopkins Center for Injury Research and Policy
Joanne Banfield	Sunny Brook Health Sciences Centre
Bill Zamula	Consumer Product Safety Commission*
Dale Ray	Consumer Product Safety Commission*
Gary Keith	National Fire Protection Association
Lorraine Carli	National Fire Protection Association

*Note that the input provided by Commission staff on this project have not been reviewed or approved by the Commission and may not reflect the views of the Commission.

FINAL REPORT

SPRINKLER IMPACT ON FIRE INJURY

Task 5 Deliverable

John R. Hall, Jr., Ph.D.
Marty Ahrens
Ben Evarts

Fire Analysis & Research Division
National Fire Protection Association
Quincy, MA 02169-7471

October 31, 2012

Executive Summary

For more than two decades, NFPA has published annual reports on the impact of sprinklers on fire losses, focusing exclusively on civilian fire deaths and direct property damage. The latest estimates, very similar to previous estimates, for sprinkler impact on *home* fire losses are at least an 80% reduction in civilian deaths per 100 fires and about a 70% reduction in direct property damage per fire. (More recently, sprinkler impact on firefighter fireground injuries was estimated using the same years of fire data and the same methods. That analysis resulted in an estimate of **65% reduction in firefighter fireground injuries per 100 fires.**)

The current analysis goes beyond analysis of impact on number of injuries to examine impact on injury costs. A death is a death and a dollar of property damage is a dollar, but there are great variations in injury severity and in the associated costs of injury. The hypothesis was that, by making fires smaller, sprinklers might reduce not only the frequency of injuries but also the average severity of injuries when they occurred.

Analysis of injury costs and the effects of reduced fire size required a more sophisticated form of analysis. A probabilistic tree model was developed that would permit use of data from multiple sources.

The model was used to examine sprinkler impact on *injuries per 100 fires* and on *injury costs per 100 fires*. Cost data was available on (a) medical costs, (b) legal and liability costs, which are typically quite small, (c) costs associated with lost work time, which are typically of the same order as the medical costs, and (d) pain and suffering costs, which tend to dominate the total and are based in large part on analysis of jury awards. Sprinkler impact was estimated for total injury costs – the combination of (a) through (d) – and for medical costs alone.

Differential impacts were estimated for three victim age groups – children (ages 0 to 14), older adults (ages 65 and over), and other adults (ages 15 to 64) – and for four types of injury – burn only, smoke inhalation only, burn and smoke inhalation, and other injury.

The primary results of the analysis are as follows:

- Sprinkler presence is associated with a **29% reduction in injuries per 100 reported home fires**;
- Sprinkler presence is associated with a **53% reduction in medical cost of injuries per 100 reported home fires**; and
- Sprinkler presence is associated with a **41% reduction in total cost of injuries per 100 reported home fires**.

In terms of actual cost reductions, the 53% reduction in medical cost of injuries per 100 reported home fires would translate into about \$50,000 in medical cost savings per 100 reported home

fires. The 41% reduction in total cost of injuries per 100 reported home fires would translate into about \$210,000 in total injury cost savings per 100 reported home fires.

During 2006-2010, there were just under 350,000 reported home structure fires per year in homes without automatic extinguishing equipment. If all had been sprinklered, the impacts would have been as follows:

- Deaths reduced by 83% means a savings of 6.0 lives per 1,000 reported fires per year, which means \$10.4 billion a year, if a statistical life is valued at \$5 million, as is done in NFPA's annual *Total Cost of Fire* study.
- Direct property damage reduced by 69% means a savings of \$14,000 per reported fire per year, which means \$4.8 billion a year.
- Civilian fire injury medical costs reduced by 53% means a savings of \$50,000 per 100 reported fires per year, which means \$0.2 billion a year.
- Civilian fire injury total costs reduced by 41% means a savings of \$210,000 per 100 reported fires per year, which means \$0.7 billion a year.

Table of Contents and List of Tables

Executive Summary	i
Table of Contents and List of Tables	v
Project Background	1
Figure 1: Graphic Overview of Sprinkler Impact on Injuries Model	2
Model Specifications	4
Setting the Initial Specifications	4
New Specifications for This Study – Fire Size	4
Table 1. Fires and Injuries by Fire Size, for Sprinklered vs. Unsprinklered Homes	6
Table 2. Injuries by Fire Size, for Different Types of Injuries for Sprinklered Homes	6
Table 3. Injuries by Fire Size, for Different Types of Injuries for Unsprinklered Homes	7
Table 4. Percent of Fires and Injuries per 100 Fires, by Fire Size, for Sprinklered vs. Unsprinklered Homes	7
New Specifications for This Study – Type of Injury, Part of Body, and Severity (Measured by Hospitalization)	8
Table 5. Percent of Injuries and Percent Hospitalized, by Fire Size, Type of Injury, and Part of Body Injured, for Sprinklered vs. Unsprinklered Homes	10
New Specifications for This Study – Age of Victim	11
Table 6. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Sprinklered Homes	12
Table 7. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Unsprinklered Homes	14
New Specifications for This Study – Injury Cost	15
Table 8. Medical Injury Costs, by Type of Injury, Part of Body Injured, Hospitalized or Not, and Age of Victim	17
Table 9. Total Injury Costs, by Type of Injury, Part of Body Injured, Hospitalized or Not, and Age of Victim	18
Results	19
Appendix 1: Sensitivity Analysis	22
Appendix 2: Illustrative Injury Narratives	23

Background

For more than two decades, NFPA has published annual reports on the impact of sprinklers on fire losses, focusing exclusively on civilian fire deaths and direct property damage. The latest estimates, very similar to previous estimates, for sprinkler impact on *home* fire losses are at least an 80% reduction in civilian deaths per 100 fires and about a 70% reduction in direct property damage per fire. (More recently, sprinkler impact on firefighter fireground injuries was estimated using the same years of fire data and the same methods. That analysis resulted in an estimate of **65% reduction in firefighter fireground injuries per 100 fires.**)

Previous estimates did not include sprinkler impact on injuries. When the first sprinkler estimates were published in the mid- to late-1980s, almost no homes had sprinklers and fire incident data did not provide any basis for distinguishing sprinklers from other automatic extinguishing systems or equipment (AES). When the early estimates of sprinkler impact on injuries proved to be much lower than impact estimates for deaths and for property damage, there was no compelling reason to include those results.

Several things have changed. Sprinklers can now be distinguished from other AES equipment, and wet-pipe sprinklers can be separated from other sprinklers. Far more homes have sprinklers, and so there is much more data on reported fires in sprinklered homes. However, the estimated impact of sprinklers on civilian injuries per 100 reported home fires (roughly a 30% reduction) is still much lower than the estimated impacts on civilian deaths and direct property damage (80% and 70%, respectively).

The current analysis goes beyond analysis of impact on number of injuries to examine impact on injury costs. A death is a death and a dollar of property damage is a dollar, but there are great variations in injury severity and in the associated costs of injury. The hypothesis was that, by making fires smaller, sprinklers might reduce not only the frequency of injuries but also the average severity of injuries when they occurred.

Analysis of injury costs and the effects of reduced fire size required a more sophisticated form of analysis. A probabilistic tree model was developed that would permit use of data from multiple sources. Figure 1, on the next page, is a visual representation of the tree model.

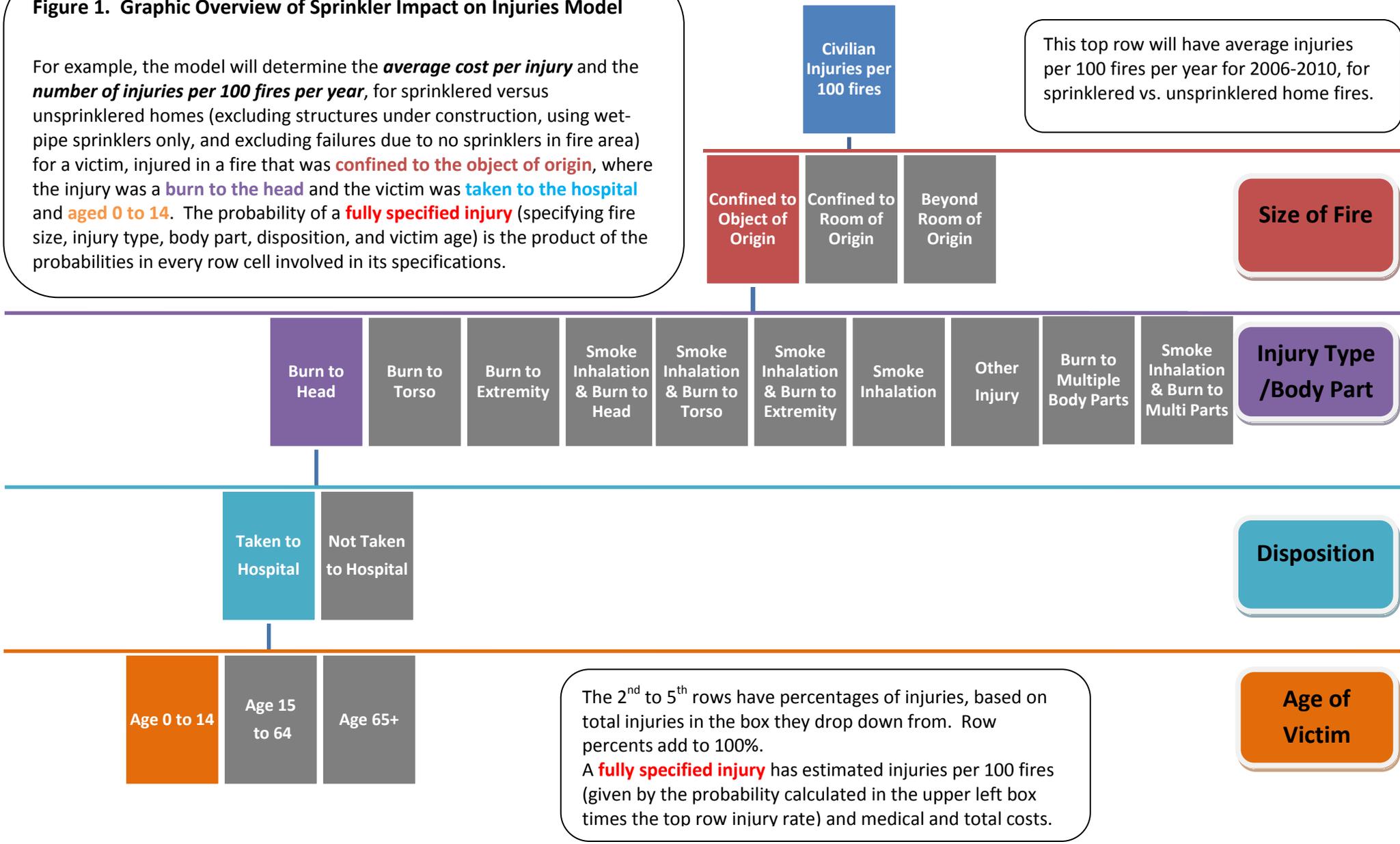
The model was used to examine sprinkler impact on *injuries per 100 fires* and on *injury costs per 100 fires*. Cost data was available on (a) medical costs, (b) legal and liability costs, which are typically quite small, (c) costs associated with lost work time, which are typically of the same order as the medical costs, and (d) pain and suffering costs, which tend to dominate the total and are based in large part on analysis of jury awards. “Pain and suffering” is a legal term for the “physical and mental distress suffered from an injury ... [including] pain, temporary and permanent limitations on activity, potential shortening of life, depression, and embarrassment from scarring”.¹

¹ *The Free Dictionary by Farlex*, accessed on September 25, 2012, from <http://legal-dictionary.thefreedictionary.com>.

Figure 1. Graphic Overview of Sprinkler Impact on Injuries Model

For example, the model will determine the **average cost per injury** and the **number of injuries per 100 fires per year**, for sprinklered versus unsprinklered homes (excluding structures under construction, using wet-pipe sprinklers only, and excluding failures due to no sprinklers in fire area) for a victim, injured in a fire that was **confined to the object of origin**, where the injury was a **burn to the head** and the victim was **taken to the hospital** and **aged 0 to 14**. The probability of a **fully specified injury** (specifying fire size, injury type, body part, disposition, and victim age) is the product of the probabilities in every row cell involved in its specifications.

This top row will have average injuries per 100 fires per year for 2006-2010, for sprinklered vs. unsprinklered home fires.



Sprinkler impact was estimated for total injury costs – the combination of (a) through (d) – and for medical costs alone.

Differential impacts were estimated for three victim age groups – children (ages 0 to 14), older adults (ages 65 and over), and other adults (ages 15 to 64) – and for four types of injury – burn only, smoke inhalation only, burn and smoke inhalation, and other injury.

Sensitivity analyses were conducted and are contained in the appendix.

Model Specifications

Setting the Initial Specifications

Many of the specifications carried over unchanged from NFPA's previous analyses of the impact of home sprinklers on civilian deaths and direct property damage. All of the following are specifications for analysis of fires reported to local departments as represented in the National Fire Incident Reporting System (NFIRS), scaled up to national estimates using the NFPA annual fire experience survey:

- “Homes” are defined to include single-unit, multi-unit and manufactured housing, which means NFIRS codes Incident Type 111-118 and 120-123 and Property Use 410-429.
- Structures under construction are excluded from the calculation.
- “Sprinklers” are wet-pipe sprinklers only, thereby excluding dry-pipe sprinklers and “other” sprinklers as coded in NFIRS. NFPA 13D or 13R systems cannot be identified within NFIRS data. Also excluded are any fires coded as failure or ineffectiveness due to sprinklers not in fire area, because this is the best available indicator of a partial system and sprinklers cannot be expected to operate in these circumstances. A limitation of this approach is that we cannot distinguish fires beginning in unsprinklered areas that are not required to be sprinklered under applicable codes.
- Homes without sprinklers are represented by homes with no automatic extinguishing equipment of any kind.
- Calculations are done separately for NFIRS confined fires (Incident Type 113-118), which are fires coded as confined to cooking vessel, fuel burner or boiler, chimney or flue, trash, incinerator or commercial compactor. Many data fields are not required for confined fires, and so the percentage of fields with data entered is much lower for confined fires. After calculations are complete for confined and non-confined fires, the totals are combined to produce the final statistics.

New Specifications for This Study – Fire Size

In this study of home sprinkler impacts on civilian injuries, the number of injuries per 100 fires was estimated by final fire size, by type and severity of injury – using hospitalization versus non-hospitalization as the only available proxy measure of injury severity, and by age of victim and part of body injured. This structure provides as detailed a structure for calculating injury cost as can be developed with existing data.

We then calculate how sprinklers shift the mix of fire sizes so that the larger fire sizes account for much smaller percentages of total reported fires.² This is how sprinklers reduce losses in fires, by reducing the sizes of fires, which then links to lower rates of injuries per fire and milder severities and costs of those injuries that do occur.

Fire size was defined by *final extent of flame damage* (also called *fire spread*) in NFIRS. There are three fire sizes:

- ***Confined to object of origin*** (including fires with confined fire incident types) [(a) Incident Type 113-118 OR (b) Incident Type 111-112 or 120-123 with Fire Spread = 1]
- ***Confined to room of origin*** but beyond object of origin [Incident Type 111-112 or 120-123 with Fire Spread = 2]
- ***Beyond room of origin*** [Incident Type 111-112 or 120-123/Fire Spread = 3-5]

Data from 2006-2010, the latest five years available, were used to estimate average fires and civilian fire injuries per year, for each of the three fire sizes, separately for confined and non-confined fires, with proportional allocation of fires with unknown or unreported fire size.

This structure to the model permits differentiation between circumstances leading to injuries and circumstances leading to deaths or damages. Sprinklers are very effective at preventing fire spread beyond the room of origin, but have less impact on fires growing within the room of origin and would not be expected to have any impact on fires just after ignition, when they are still confined to the object of origin.

Only 21% of home civilian fire deaths and only 17% of home fire direct damages occur in fires that never spread beyond the room of origin. Only 6% of deaths and 6% of damages occur in fires that never spread beyond the object of origin.

By contrast, 55% of home civilian fire injuries occur in fires that never spread beyond the room of origin, and 23% occur in fires that never spread beyond the object of origin. These percentages also suggest that, for fires that spread beyond the room of origin, a much larger share of injuries occur in the earlier stages of fire, before spread out of the room occurs, compared to the share of deaths and damages occurring in those early stages.

Table 1 shows how the fire size distributions for home fire incidents and associated home fire civilian injuries differ for sprinklered homes versus unsprinklered homes.

² In the task report on the model, it was stated that data on homes with sprinklers would only be used in estimating percentage of fires by fire size. When the model was executed and calculations made, it proved to be possible to use data on homes with sprinklers in all the calculations, because there were enough fires and injuries in the database for meaningful estimates. The original approach was then used as one of the two sensitivity studies.

Table 1. Fires and Injuries by Fire Size, for Sprinklered vs. Unsprinklered Homes

Fire spread (extent of flame)	Sprinklers present		No automatic extinguishing equipment present	
	Percent of fires	Percent of injuries	Percent of fires	Percent of injuries
Confined fire ³ or confined to object of origin	85%	54%	57%	22%
Fire beyond object of origin but confined to room of origin	12%	34%	18%	33%
Fire beyond room of origin	3%	12%	25%	46%

Tables 2-3 show how the fire size distributions for injuries differ by type of injury, for sprinklered and unsprinklered homes.

In either sprinklered homes (Table 2) or unsprinklered homes (Table 3), the injury type with the largest share of fires confined to object of origin is burn-only, which means that is the type of injury where sprinklers have the smallest margin for impact by stopping small fires from becoming large.

In either sprinklered homes (Table 2) or unsprinklered homes (Table 3), the injury type with the smallest share of fires confined to object of origin is smoke inhalation and burns, which means that type of injury has the largest margin for sprinkler impact, but it accounts for only 13% of injuries in unsprinklered homes.

The largest shares of injuries are for smoke-inhalation-only (45% for sprinklered homes, 49% for unsprinklered homes) and burns-only (38% for sprinklered homes, 27% for unsprinklered homes).

Table 2. Injuries by Fire Size, for Different Types of Injuries for Sprinklered Homes

Fire spread (extent of flame)	Sprinklers present			
	Percent of injuries, by type of injury			
	Burn only	Smoke inhalation only	Burns and smoke inhalation	Other injury
Confined fire ⁴ or confined to object of origin	64%	55%	13%	39%
Fire beyond object of origin but confined to room of origin	29%	31%	74%	40%
Fire beyond room of origin	7%	14%	13%	21%
Share of injuries, by type of injury	38%	45%	7%	10%

³ “Confined fire” refers to a fire confined to cooking vessel, chimney or flue, fuel burner or boiler, incinerator or compactor, or trash. Most data fields are not required for confined fires, and so unknowns are a much higher percentage of such fires, which is why allocation of unknowns is done separately for confined fires.

⁴ “Confined fire” refers to a fire confined to cooking vessel, chimney or flue, fuel burner or boiler, incinerator or compactor, or trash. Most data fields are not required for confined fires, and so unknowns are a much higher percentage of such fires, which is why allocation of unknowns is done separately for confined fires.

Table 3. Injuries by Fire Size, for Different Types of Injuries for Unsprinklered Homes

No automatic extinguishing equipment present	Percent of injuries, by type of injury			
	Burn only	Smoke inhalation only	Burns and smoke inhalation	Other injury
Fire spread (extent of flame)				
Confined fire ⁵ or confined to object of origin	31%	20%	12%	16%
Fire beyond object of origin but confined to room of origin	37%	34%	28%	23%
Fire beyond room of origin	32%	46%	60%	61%
Share of injuries, by type of injury	27%	49%	13%	11%

By calculating injury rates and other statistics for each fire size, we not only run the model through the primary mechanism by which sprinklers reduce losses, but also allow the model to capture and reflect the significant share of injuries occurring so early in the fire that they will not be affected by sprinkler reductions in fire size.

Note that the number of injuries per 100 fires *for a given fire size* is higher when sprinklers are present. Overall, the number of injuries per 100 fires is lower for sprinklered homes (2.5) than for unsprinklered homes (3.5). This means the dramatic drop in fire sizes more than makes up for an upward shift in the average number of injuries per 100 fires within each fire size.

Table 4. Percent of Fires and Injuries per 100 Fires, by Fire Size, for Sprinklered vs. Unsprinklered Homes

Fire spread (extent of flame)	Sprinklers present		No automatic extinguishing equipment present	
	Percent of fires	Injuries per 100 fires	Percent of fires	Injuries per 100 fires
Confined fire ⁶ or confined to object of origin	85.0%	1.59	56.8%	1.34
Fire beyond object of origin but confined to room of origin	12.3%	7.04	18.2%	6.35
Fire beyond room of origin	2.7%	11.20	25.0%	6.51

⁵ “Confined fire” refers to a fire confined to cooking vessel, chimney or flue, fuel burner or boiler, incinerator or compactor, or trash. Most data fields are not required for confined fires, and so unknowns are a much higher percentage of such fires, which is why allocation of unknowns is done separately for confined fires.

⁶ “Confined fire” refers to a fire confined to cooking vessel, chimney or flue, fuel burner or boiler, incinerator or compactor, or trash. Most data fields are not required for confined fires, and so unknowns are a much higher percentage of such fires, which is why allocation of unknowns is done separately for confined fires.

New Specifications for This Study – Type of Injury, Part of Body, and Severity (Measured by Hospitalization)

Type of Injury

The four categories of type of injury are defined as follows:

- **Burn** [NFIRS Primary Apparent Symptom 12-15, which combines thermal, scald, chemical and electrical burns; burns other than thermal burns account for very small fractions of the total].⁷
- **Smoke inhalation** [NFIRS Primary Apparent Symptom 01-03, which combines smoke inhalation, hazardous fumes inhalation, and breathing difficulty or shortness of breath].⁸
- **Burns and smoke inhalation** [NFIRS Primary Apparent Symptom 11].⁹
- **Other** [NFIRS Primary Apparent Symptom 21-98].¹⁰
- We treat NFIRS Primary Apparent Symptom codes 00 and UU as unknowns to be proportionally allocated.

Average costs per injury are estimated using the CPSC Injury Cost Model, which requires specific values rather than ranges and does not have a specification for burn and smoke inhalation injuries.

At the end of July 2012, a new study of fire-injury costs by Lawrence *et al.* was released, dated July 2009, and it included data on costs of injuries involving both burns and smoke inhalation.¹¹ This data was for all body parts and for all victim ages combined, but was available separately for hospitalized vs. not hospitalized injuries. The use of this additional data to estimate model parameters is described below as part of the larger discussion of the rules used for parameter estimation.

⁷ This is matched to the CPSC NEISS category of Burn [Diagnosis 46-49, 51, and 73, combining electrical, unspecified, scald, chemical, thermal, and radiation burns]. Thermal Burn represents the category for NEISS specs.

⁸ This is matched to the CPSC NEISS category of Anoxia [Diagnosis 65].

⁹ There is no NEISS category for burn and smoke inhalation. However, data exists that was used to relate costs for burn and smoke inhalation injuries to costs for burn-only injuries and costs for smoke-inhalation-only injuries

¹⁰ This is matched to the CPSC NEISS categories of Diagnosis 41-42, 50, 52-64, 66-72, and 74. We use Laceration, the most common of these injuries in NEISS, to represent the entire category for NEISS-related analysis.

¹¹ Bruce A. Lawrence, Eduard Zaloshnja, Ted R. Miller, and Paul R. Jones, *Estimates of the Incidence and Costs of Fire-Related Injuries*, Pacific Institute for Research and Evaluation, Calverton, MD, July 2009.

Part of Body

Only burns (and burns with smoke inhalation injuries) are subdivided by part of body, because part of body distinctions do not make much sense for smoke inhalation injuries, and “other” injuries are too few to justify further subdivision by part of body.¹²

- ***Head*** (Primary Area of Body Injured 1-2, thereby also including neck and shoulder).¹³
- ***Torso*** (Primary Area of Body Injured 3-5, thereby including thorax (with chest and back), abdomen and spine).¹⁴
- ***Extremities*** (Primary Area of Body Injured 6-7, thereby including upper and lower extremities).¹⁵
- ***Multiple body parts*** (Primary Area of Body Injured 9).¹⁶

NFIRS injuries coded as Burn with Primary Area of Body Injured 8 (Internal) or blank (Not Reported) were treated as unknowns and proportionally allocated. This parallels the practice in NEISS of never coding a Burn as Internal.

Type of Injury and Part of Body

Therefore, we had ten combinations of type of injury and part of body:

- ***Burn to Head*** group,
- ***Burn to Torso*** group,
- ***Burn to Extremities*** group,
- ***Burn to Multiple Body Parts***,

- ***Smoke Inhalation***,

- ***Burn to Head*** group ***plus Smoke Inhalation***,
- ***Burn to Torso*** group ***plus Smoke Inhalation***,
- ***Burn to Extremities*** group ***plus Smoke Inhalation***,
- ***Burn to Multiple Body Parts plus Smoke Inhalation***, and

- ***Other Injury***.

¹² All Parts of Body (NEISS Body Part 85) is used for Anoxia, and Face (NEISS Body Part 76) is used for Other injuries.

¹³ This is matched to CPSC NEISS Body Part Affected categories of 75 (Head), 94 (Ear), 77 (Eyeball), 76 (Face), 88 (Mouth), 89 (Neck), and 30 (Shoulder). Face is used to represent the category in the Injury Cost Model.

¹⁴ This is matched to CPSC NEISS Body Part Affected categories of 79 (Lower Trunk), 31 (Upper Trunk) and 38 (Pubic Region). Upper Trunk is used to represent the category in the Injury Cost Model.

¹⁵ This is matched to CPSC NEISS Body Part Affected categories of 33 (Lower Arm), 80 (Upper Arm), 37 (Ankle), 32 (Elbow), 92 (Finger), 83 (Foot), 82 (Hand), 35 (Knee), 36 (Lower Leg), 81 (Upper Leg), 93 (Toe) and 34 (Wrist). Hand is used to represent the category in the Injury Cost Model.

¹⁶ This is matched to CPSC NEISS Body Part Affected categories of 84 (25-50% of Body) and 85 (All of Body). All of Body is used to represent the category in the Injury Cost Model.

Disposition (Hospitalization) of Injury

Disposition of injury is the closest proxy for severity we have in the available data. In NFIRS, we were forced to stretch our interpretation of the only data available. NFIRS splits injuries into those that are or are not taken to an “emergency care facility,” but we know this is not the same as a split between injuries that are hospitalized versus those that are not. All NEISS injuries were reported to hospital emergency rooms, which probably qualify as emergency care facilities. Table 5 shows the percent of injuries and the percent of injuries hospitalized, for each combination of fire size, type of injury and part of body injured.

Table 5. Percent of Injuries and Percent Hospitalized, by Fire Size, Type of Injury, and Part of Body Injured, for Sprinklered vs. Unsprinklered Homes

Fire spread (extent of flame)	Type of injury and part of body injured	Sprinklers present		No automatic extinguishing equipment present	
		Percent of injuries	Percent hospitalized	Percent of injuries	Percent hospitalized
Confined to object	Burn only to head	2.0%	4.1%	3.3%	21.9%
Confined to object	Burn only to torso	0.5%	32.7%	1.6%	22.9%
Confined to object	Burn only to extremity	37.4%	15.3%	30.1%	15.7%
Confined to object	Burn only to multiple parts	5.4%	13.0%	4.3%	22.2%
Confined to object	Smoke inhalation only	45.4%	6.3%	45.1%	5.5%
Confined to object	Burn head/smoke inhalation	0.3%	65.2%	1.7%	60.9%
Confined to object	Burn torso/smoke inhalation	0.5%	34.7%	0.7%	46.9%
Confined to object	Burn extremity/smoke inhalation	0.2%	0.0%	3.4%	44.8%
Confined to object	Burn multiple/smoke inhalation	0.7%	43.0%	1.9%	44.0%
Confined to object	Other injury (not burn or smoke)	7.5%	11.8%	8.0%	8.7%
Confined to room	Burn only to head	2.9%	13.6%	2.3%	19.0%
Confined to room	Burn only to torso	0.0%	N/A	0.8%	22.6%
Confined to room	Burn only to extremity	28.0%	14.5%	24.2%	14.5%
Confined to room	Burn only to multiple parts	1.7%	16.8%	3.3%	22.9%
Confined to room	Smoke inhalation only	40.6%	6.1%	50.6%	6.2%
Confined to room	Burn head/smoke inhalation	4.2%	52.7%	2.1%	50.5%
Confined to room	Burn torso/smoke inhalation	0.5%	65.2%	0.7%	53.4%
Confined to room	Burn extremity/smoke inhalation	6.6%	57.1%	5.1%	42.5%
Confined to room	Burn multiple/smoke inhalation	3.5%	23.7%	3.3%	53.7%
Confined to room	Other injury (not burn or smoke)	12.0%	9.2%	7.5%	7.4%
Beyond room	Burn only to head	0.0%	N/A	3.2%	16.7%
Beyond room	Burn only to torso	0.0%	N/A	0.8%	19.5%
Beyond room	Burn only to extremity	16.7%	17.5%	12.2%	16.2%
Beyond room	Burn only to multiple parts	5.0%	24.9%	2.9%	25.6%
Beyond room	Smoke inhalation only	52.7%	8.4%	49.2%	7.2%
Beyond room	Burn head/smoke inhalation	2.4%	31.2%	4.0%	52.1%
Beyond room	Burn torso/smoke inhalation	0.0%	N/A	1.0%	52.1%
Beyond room	Burn extremity/smoke inhalation	2.4%	34.0%	5.2%	48.5%
Beyond room	Burn multiple/smoke inhalation	2.5%	65.2%	7.4%	54.5%
Beyond room	Other injury (not burn or smoke)	18.3%	11.3%	14.1%	9.6%

N/A – Not applicable because this category has 0.0% of injuries and so disposition is moot.

NEISS only includes injuries reported an emergency room and therefore has no basis for assigning costs to injuries that were treated on-site and not transported to an emergency room. For injuries that are transported to an emergency care facility, NFIRS has no basis for separating hospitalized injuries from non-hospitalized injuries.

In the primary analysis, all NFIRS non-transported injuries were treated as equivalent to NEISS non-hospitalized injuries. Data from the report by Lawrence et al. was used to split NFIRS transported injuries into hospitalized vs. non-hospitalized injuries, using the following percentage-hospitalized figures (considering only injuries that were hospitalized or seen in an emergency room) by type of injury:¹⁷

- 32.7% of burn-only fire injuries were hospitalized;
- 10.6% of smoke-inhalation-only fire injuries were hospitalized;
- 65.2% of burn and smoke inhalation fire injuries were hospitalized; and
- 15.4% of trauma and other non-burn, non-smoke inhalation injuries were hospitalized.

This approach provides an overall estimate of total cost per fire injury of \$148,000. This figure is roughly one-third to one-half less than the size of the total cost per fire injury used by CPSC in analyzing injury costs for fire injuries captured by NEISS. NFPA uses the same overall figure in its *Total Cost of Fire* report.

A sensitivity analysis was conducted in which all transported NFIRS injuries were considered hospitalized. This approach, described in the appendix of this report, provides an overall estimate of total cost per fire injury of \$321,000, which is roughly a third *higher* than the total cost per fire injury figure used by CPSC. In this sensitivity analysis, the percentage impacts of sprinklers on injury costs are slightly lower, but the dollar values of the reductions are almost three times as large.

Even with these higher estimates of monetary benefits, the impact of sprinklers on injury costs is much less than the impact of sprinklers on deaths and on property damage, in the same way that the monetary equivalent of the entire U.S. fire injury problem is considerably smaller than either the monetary equivalent of the entire U.S. fire fatality problem or the monetary value of property damage due to fire.

There are additional concerns in this part of the exercise. NFIRS uses a check box to identify injuries taken to an emergency care facility. Injuries not transported to an emergency care facility will be coded with a blank check box, as will injuries where it is not known whether the victim was transported to an emergency care facility. To make any distinction between injuries based on severity, blank entries must be assumed to have meaning. This is contrary to NFPA's usual methodology but seemed the best option available for this analysis.

¹⁷ Bruce A. Lawrence, Eduard Zaloshnja, Ted R. Miller, and Paul R. Jones, *Estimates of the Incidence and Costs of Fire-Related Injuries*, Pacific Institute for Research & Evaluation, Calverton, MD, July 2009 [released August 2012].

New Specifications for This Study – Age of Victim

Ages are split into three groups, separating children and older adults from everyone else:

- **Children:** Ages 0 to 14, with age 7 used to represent these ages in linking to the injury cost data
- **Adults excluding older adults:** Ages 15 to 64, with age 39 used to represent these ages in linking to the injury cost data
- **Older adults:** Ages 65 and over, with age 75 used to represent these ages in linking to the injury cost data.

Injury cost data for Males were used for both sexes.

From this point on, it will be clear from the percentage estimates that many cell entries are based on small numbers of cases. The parameters are displayed in the form and with the precision used to enter them into the model, which is usually greater than the precision justified by the data supporting the estimates.

Tables 6-7 show percentages of injuries by age of victim, in sprinklered and unsprinklered homes, respectively.

Table 6. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Sprinklered Homes

Fire spread (extent of flame)	Type of injury and part of body injured	Hospitalized?	Age of victim		
			Percent 14 or less	Percent 15 to 64	Percent 65 or more
Confined to object	Burn only to head	Yes	0.0%	100.0%	0.0%
Confined to object	Burn only to torso	Yes	0.0%	51.8%	48.2%
Confined to object	Burn only to extremity	Yes	0.0%	100.0%	0.0%
Confined to object	Burn only to multiple parts	Yes	0.0%	100.0%	0.0%
Confined to object	Smoke inhalation only	Yes	0.0%	69.1%	30.9%
Confined to object	Burn head/smoke inhalation	Yes	0.0%	0.0%	100.0%
Confined to object	Burn torso/smoke inhalation	Yes	0.0%	100.0%	0.0%
Confined to object	Burn extremity/smoke inhalation	Yes	N/A	N/A	N/A
Confined to object	Burn multiple/smoke inhalation	Yes	0.0%	100.0%	0.0%
Confined to object	Other injury (not burn or smoke)	Yes	0.0%	55.8%	44.2%
Confined to room	Burn only to head	Yes	0.0%	100.0%	0.0%
Confined to room	Burn only to torso	Yes	N/A	N/A	N/A
Confined to room	Burn only to extremity	Yes	3.5%	85.7%	10.7%
Confined to room	Burn only to multiple parts	Yes	0.0%	100.0%	0.0%
Confined to room	Smoke inhalation only	Yes	3.6%	68.5%	27.9%
Confined to room	Burn head/smoke inhalation	Yes	0.0%	62.8%	37.2%
Confined to room	Burn torso/smoke inhalation	Yes	0.0%	0.0%	100.0%
Confined to room	Burn extremity/smoke inhalation	Yes	0.0%	77.3%	22.7%
Confined to room	Burn multiple/smoke inhalation	Yes	0.0%	100.0%	0.0%
Confined to room	Other injury (not burn or smoke)	Yes	0.0%	65.4%	34.6%

Table 6. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Sprinklered Homes (Continued)

Fire spread (extent of flame)	Type of injury and part of body injured	Hospitalized?	Age of victim		
			Percent 14 or less	Percent 15 to 64	Percent 65 or more
Beyond room	Burn only to head	Yes	N/A	N/A	N/A
Beyond room	Burn only to torso	Yes	N/A	N/A	N/A
Beyond room	Burn only to extremity	Yes	26.9%	73.1%	0.0%
Beyond room	Burn only to multiple parts	Yes	0.0%	100.0%	0.0%
Beyond room	Smoke inhalation only	Yes	19.8%	68.6%	11.5%
Beyond room	Burn head/smoke inhalation	Yes	0.0%	0.0%	100.0%
Beyond room	Burn torso/smoke inhalation	Yes	N/A	N/A	N/A
Beyond room	Burn extremity/smoke inhalation	Yes	0.0%	100.0%	0.0%
Beyond room	Burn multiple/smoke inhalation	Yes	0.0%	100.0%	0.0%
Beyond room	Other injury (not burn or smoke)	Yes	18.9%	81.1%	0.0%
Confined to object	Burn only to head	No	0.0%	50.0%	50.0%
Confined to object	Burn only to torso	No	N/A	N/A	N/A
Confined to object	Burn only to extremity	No	0.0%	96.3%	3.7%
Confined to object	Burn only to multiple parts	No	39.7%	4.3%	67.8%
Confined to object	Smoke inhalation only	No	0.0%	100.0%	0.0%
Confined to object	Burn head/smoke inhalation	No	N/A	N/A	N/A
Confined to object	Burn torso/smoke inhalation	No	0.0%	100.0%	0.0%
Confined to object	Burn extremity/smoke inhalation	No	0.0%	100.0%	0.0%
Confined to object	Burn multiple/smoke inhalation	No	0.0%	100.0%	0.0%
Confined to object	Other injury (not burn or smoke)	No	0.0%	49.0%	51.0%
Confined to room	Burn only to head	No	0.0%	100.0%	0.0%
Confined to room	Burn only to torso	No	N/A	N/A	N/A
Confined to room	Burn only to extremity	No	8.0%	78.2%	13.8%
Confined to room	Burn only to multiple parts	No	0.0%	100.0%	0.0%
Confined to room	Smoke inhalation only	No	2.3%	67.1%	30.6%
Confined to room	Burn head/smoke inhalation	No	0.0%	100.0%	0.0%
Confined to room	Burn torso/smoke inhalation	No	N/A	N/A	N/A
Confined to room	Burn extremity/smoke inhalation	No	0.0%	49.2%	50.8%
Confined to room	Burn multiple/smoke inhalation	No	0.0%	60.1%	39.9%
Confined to room	Other injury (not burn or smoke)	No	7.9%	67.3%	24.9%
Beyond room	Burn only to head	No	N/A	N/A	N/A
Beyond room	Burn only to torso	No	N/A	N/A	N/A
Beyond room	Burn only to extremity	No	15.0%	85.0%	0.0%
Beyond room	Burn only to multiple parts	No	0.0%	100.0%	0.0%
Beyond room	Smoke inhalation only	No	21.8%	31.6%	46.6%
Beyond room	Burn head/smoke inhalation	No	0.0%	100.0%	0.0%
Beyond room	Burn torso/smoke inhalation	No	N/A	N/A	N/A
Beyond room	Burn extremity/smoke inhalation	No	100.0%	0.0%	0.0%
Beyond room	Burn multiple/smoke inhalation	No	N/A	N/A	N/A
Beyond room	Other injury (not burn or smoke)	No	0.0%	49.0%	51.0%

Table 7. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Unsprinklered Homes

Fire spread (extent of flame)	Type of injury and part of body injured	Hospitalized?	Age of victim		
			Percent 14 or less	Percent 15 to 64	Percent 65 or more
Confined to object	Burn only to head	Yes	6.6%	71.2%	22.3%
Confined to object	Burn only to torso	Yes	11.3%	67.2%	21.5%
Confined to object	Burn only to extremity	Yes	8.1%	84.9%	7.0%
Confined to object	Burn only to multiple parts	Yes	2.0%	85.1%	12.9%
Confined to object	Smoke inhalation only	Yes	9.0%	75.4%	15.5%
Confined to object	Burn head/smoke inhalation	Yes	5.0%	60.4%	34.6%
Confined to object	Burn torso/smoke inhalation	Yes	19.0%	60.3%	20.6%
Confined to object	Burn extremity/smoke inhalation	Yes	8.2%	77.5%	14.3%
Confined to object	Burn multiple/smoke inhalation	Yes	3.5%	65.3%	31.2%
Confined to object	Other injury (not burn or smoke)	Yes	5.0%	85.0%	10.0%
Confined to room	Burn only to head	Yes	9.5%	75.1%	15.4%
Confined to room	Burn only to torso	Yes	23.0%	72.0%	5.1%
Confined to room	Burn only to extremity	Yes	8.0%	84.8%	7.2%
Confined to room	Burn only to multiple parts	Yes	8.6%	82.3%	9.2%
Confined to room	Smoke inhalation only	Yes	12.8%	73.0%	14.2%
Confined to room	Burn head/smoke inhalation	Yes	6.3%	69.4%	24.3%
Confined to room	Burn torso/smoke inhalation	Yes	5.2%	77.5%	17.3%
Confined to room	Burn extremity/smoke inhalation	Yes	5.0%	79.8%	15.2%
Confined to room	Burn multiple/smoke inhalation	Yes	4.6%	75.6%	19.8%
Confined to room	Other injury (not burn or smoke)	Yes	3.9%	82.3%	13.8%
Beyond room	Burn only to head	Yes	9.2%	71.8%	19.0%
Beyond room	Burn only to torso	Yes	11.4%	81.8%	6.8%
Beyond room	Burn only to extremity	Yes	12.0%	80.7%	7.4%
Beyond room	Burn only to multiple parts	Yes	9.9%	81.0%	9.2%
Beyond room	Smoke inhalation only	Yes	15.4%	69.6%	15.0%
Beyond room	Burn head/smoke inhalation	Yes	6.0%	74.5%	19.5%
Beyond room	Burn torso/smoke inhalation	Yes	2.7%	73.4%	24.0%
Beyond room	Burn extremity/smoke inhalation	Yes	8.0%	78.6%	13.3%
Beyond room	Burn multiple/smoke inhalation	Yes	13.6%	72.2%	14.2%
Beyond room	Other injury (not burn or smoke)	Yes	8.9%	80.8%	10.3%
Confined to object	Burn only to head	No	18.1%	63.8%	18.1%
Confined to object	Burn only to torso	No	27.4%	45.6%	27.0%
Confined to object	Burn only to extremity	No	7.6%	83.3%	9.2%
Confined to object	Burn only to multiple parts	No	17.8%	78.1%	4.0%
Confined to object	Smoke inhalation only	No	8.5%	75.2%	16.4%
Confined to object	Burn head/smoke inhalation	No	0.0%	100.0%	0.0%
Confined to object	Burn torso/smoke inhalation	No	13.7%	71.5%	14.8%
Confined to object	Burn extremity/smoke inhalation	No	9.8%	85.4%	4.8%
Confined to object	Burn multiple/smoke inhalation	No	0.0%	81.9%	18.1%
Confined to object	Other injury (not burn or smoke)	No	7.7%	80.6%	11.7%

Table 7. Percent of Injuries, by Age of Victim, for Fire Size, Type of Injury, Part of Body Injured, Hospitalized or Not, in Unsprinklered Homes (Continued)

Fire spread (extent of flame)	Type of injury and part of body injured	Hospitalized?	Age of victim		
			Percent 14 or less	Percent 15 to 64	Percent 65 or more
Confined to room	Burn only to head	No	4.4%	78.0%	17.6%
Confined to room	Burn only to torso	No	5.7%	88.9%	5.4%
Confined to room	Burn only to extremity	No	5.9%	88.3%	5.8%
Confined to room	Burn only to multiple parts	No	4.6%	95.4%	0.0%
Confined to room	Smoke inhalation only	No	8.9%	80.7%	10.4%
Confined to room	Burn head/smoke inhalation	No	6.3%	73.8%	19.9%
Confined to room	Burn torso/smoke inhalation	No	0.0%	65.8%	34.2%
Confined to room	Burn extremity/smoke inhalation	No	2.5%	92.3%	5.3%
Confined to room	Burn multiple/smoke inhalation	No	5.0%	71.4%	23.6%
Confined to room	Other injury (not burn or smoke)	No	3.8%	83.1%	13.1%
Beyond room	Burn only to head	No	5.6%	76.7%	17.7%
Beyond room	Burn only to torso	No	13.9%	76.1%	10.0%
Beyond room	Burn only to extremity	No	8.8%	83.1%	8.1%
Beyond room	Burn only to multiple parts	No	10.3%	77.5%	12.1%
Beyond room	Smoke inhalation only	No	12.5%	76.5%	10.9%
Beyond room	Burn head/smoke inhalation	No	4.2%	76.2%	19.6%
Beyond room	Burn torso/smoke inhalation	No	17.8%	76.2%	6.0%
Beyond room	Burn extremity/smoke inhalation	No	1.7%	84.6%	13.7%
Beyond room	Burn multiple/smoke inhalation	No	10.1%	80.0%	9.8%
Beyond room	Other injury (not burn or smoke)	No	7.4%	83.8%	8.7%

New Specifications for This Study – Injury Cost

This analysis measures the impact of residential sprinklers on three measures of home fire injuries – number of injuries per 100 fires, average fire injury medical cost per 100 fires, and average fire injury total cost per 100 fires. The model is needed for the two injury cost measures, and the model has been constructed to make the most use possible of the structure of the CPSC Injury Cost Model.

The model structure specified above allows these scenarios to be linked to injury costs based on:

- One of 10 combinations of type of injury and part of body, with burn-only and burn and smoke inhalation separately matched with each of 4 parts of body (head group, torso group, extremity group, or multiple parts of body), and with smoke-inhalation-only and other (not burn or smoke inhalation) injury separately matched with 1 part of body;
- One of 2 levels of severity (hospitalized or not hospitalized); and
- One of 3 age groups (0 to 14, 15 to 64, or 65 or over)

There are 60 combinations, but only 36 of these combinations are developed directly from the Injury Cost database. The 24 combinations involving injuries with both burn and smoke inhalation are not directly represented in the database.

The report by Lawrence *et al.* provided medical and total costs for burn-only, smoke-inhalation-only, and burn and smoke inhalation injuries, separately for hospitalized and non-hospitalized injuries.¹⁸ Separate results were not provided by part of body or age of victim. Data on hospitalized injuries were provided separately for burn centers and other hospitals.

The report also documents the share of hospitalized and non-hospitalized injuries, by type of injury, that were handled by burn centers. Burn centers handle the majority of hospitalized injuries involving burns, with or without smoke inhalation. Specifically, the burn center percentages for hospitalized home fire injuries, based on 2003 Healthcare Cost and Utilization Project (HCUP) data from the U.S. Department of Health and Human Services, were:

- 67% for burn-only injuries,
- 61% for burn and smoke inhalation injuries,
- 23% for smoke-inhalation-only injuries, and
- 20% for other injuries.

The data in the report by Lawrence *et al.* and the CPSC Injury Cost Model take full account of the leading role of burn centers in treating burn injuries and their higher than average costs per case. The advisory panel reported that the Injury Cost Model also includes some adjustments for readmissions (when an injury requires additional procedures and treatment after discharge for the initial treatments), other long-term treatment requirements, and the effects of an injury victim's lost income or pain and suffering on family members.¹⁹

Using the percentages above, the project developed medical costs per case for burn, smoke, and burn + smoke injuries, both hospitalized and non-hospitalized. Data were not provided for all the other components of total injury cost but only for work loss. In examining the available statistics, it was clear that medical costs are additive for a victim with burn and smoke inhalation injuries – and possibly more than additive, as the multipliers shown below indicate – but total costs were not fully additive in all cases. Using the PIRE study, formulas were developed for costs of burn and smoke inhalation injuries, as follows:

- Medical cost, hospitalized injury – Add 7% to the sum of medical costs for burn and medical costs for smoke inhalation; the medical costs for burn will vary by part of body as shown in Tables 7-8;

¹⁸ Bruce A. Lawrence, Eduard Zaloshnja, Ted R. Miller, and Paul R. Jones, *Estimates of the Incidence and Costs of Fire-Related Injuries*, Pacific Institute for Research & Evaluation, Calverton, MD, July 2009 [released August 2012].

¹⁹ See p.7 of the ICM documentation: <http://www.cpsc.gov/library/foia/foia02/os/costmodept1.PDF> and <http://www.cpsc.gov/library/foia/foia02/os/costmodept2.PDF>. A more in-depth discussion is available if one delves into the documentation.

- Medical cost, non-hospitalized injury – Add 20% to the sum of medical costs for burn and medical costs for smoke inhalation;
- Total cost, hospitalized injury – Add the medical cost for burn to the total cost for smoke inhalation; and
- Total cost, non-hospitalized injury – Add the total cost for burn to the total cost for smoke inhalation.

These formulas were used to develop the cost estimates for those 24 combinations in Tables 8-9. The year 2008 is the current year used to state cost estimates in the Injury Cost Model, and it is also the middle year for the 2006-2010 NFIRS data used in the analysis.

**Table 8. Medical Injury Costs (in 2008 Dollars),
by Type of Injury, Part of Body Injured, Hospitalized or Not, and Age of Victim**

Type of injury and part of body injured	Hospitalized?	Cost of Injury (in 2008 Dollars)		
		Age 7 for 14 or less	Age 39 for 15 to 64	Age 75 for 65 or more
Burn only to head	Yes	\$66,782	\$60,015	\$90,876
Burn only to torso	Yes	\$76,964	\$82,167	\$88,064
Burn only to extremity	Yes	\$44,204	\$52,620	\$151,125
Burn only to multiple parts	Yes	\$259,480	\$334,740	\$279,655
Smoke inhalation only	Yes	\$28,191	\$28,191	\$28,191
Burn head/smoke inhalation	Yes	\$101,621	\$94,380	\$127,402
Burn torso/smoke inhalation	Yes	\$112,516	\$118,083	\$124,393
Burn extremity/smoke inhalation	Yes	\$77,463	\$86,468	\$191,868
Burn multiple/smoke inhalation	Yes	\$307,808	\$388,336	\$329,395
Other injury (not burn or smoke)	Yes	\$17,624	\$28,586	\$28,051
Burn only to head	No	\$4,662	\$4,662	\$4,662
Burn only to torso	No	\$4,728	\$4,728	\$4,728
Burn only to extremity	No	\$4,790	\$4,790	\$4,790
Burn only to multiple parts	No	\$5,302	\$5,302	\$5,302
Smoke inhalation only	No	\$8,114	\$10,115	\$10,115
Burn head/smoke inhalation	No	\$15,331	\$17,732	\$17,732
Burn torso/smoke inhalation	No	\$15,410	\$17,812	\$17,812
Burn extremity/smoke inhalation	No	\$15,485	\$17,886	\$17,886
Burn multiple/smoke inhalation	No	\$16,099	\$18,500	\$18,500
Other injury (not burn or smoke)	No	\$2,285	\$2,285	\$2,285

**Table 9. Total Injury Costs (in 2008 Dollars),
by Type of Injury, Part of Body Injured, Hospitalized or Not, and Age of Victim**

Type of injury and part of body injured	Hospitalized?	Cost of Injury (in 2008 Dollars)		
		Age 7 for 14 or less	Age 39 for 15 to 64	Age 75 for 65 or more
Burn only to head	Yes	\$330,798	\$352,239	\$332,097
Burn only to torso	Yes	\$391,580	\$457,619	\$323,934
Burn only to extremity	Yes	\$314,639	\$382,458	\$448,659
Burn only to multiple parts	Yes	\$853,317	\$1,052,673	\$759,076
Smoke inhalation only	Yes	\$483,472	\$540,922	\$132,831
Burn head/smoke inhalation	Yes	\$358,989	\$380,430	\$360,288
Burn torso/smoke inhalation	Yes	\$419,771	\$485,810	\$352,125
Burn extremity/smoke inhalation	Yes	\$342,830	\$410,649	\$476,850
Burn multiple/smoke inhalation	Yes	\$881,508	\$1,080,864	\$787,267
Other injury (not burn or smoke)	Yes	\$111,896	\$148,220	\$77,147
Burn only to head	No	\$59,739	\$69,295	\$50,707
Burn only to torso	No	\$79,319	\$100,645	\$62,166
Burn only to extremity	No	\$73,003	\$90,899	\$59,800
Burn only to multiple parts	No	\$105,033	\$132,172	\$78,418
Smoke inhalation only	No	\$46,255	\$69,806	\$57,745
Burn head/smoke inhalation	No	\$105,994	\$139,101	\$108,452
Burn torso/smoke inhalation	No	\$125,574	\$170,451	\$119,911
Burn extremity/smoke inhalation	No	\$119,258	\$160,705	\$117,545
Burn multiple/smoke inhalation	No	\$151,288	\$201,978	\$136,163
Other injury (not burn or smoke)	No	\$18,582	\$21,945	\$12,716

Results

The primary results of the analysis are as follows:

- Sprinkler presence is associated with a **29% reduction in injuries per 100 reported home fires**;
- Sprinkler presence is associated with a **53% reduction in medical cost of injuries per 100 reported home fires**; and
- Sprinkler presence is associated with a **41% reduction in total cost of injuries per 100 reported home fires**.

Total cost of injury includes medical cost but also includes lost work time and pain and suffering, which tend to be much more costly than medical costs alone.

Note that the reduction is smaller for total costs than for medical costs. At least in the model, for injuries in fires without sprinklers present, the total cost multiplier – total cost divided by medical cost – is highest for small fires (confined to object of origin) at 6.4 and is lower for fires confined to room of origin but not confined to object of origin (5.8) and fires spreading beyond room of origin (4.8). These differences undercut the reduction percentage when shifting from medical costs to total costs.

In terms of actual cost reductions, the 53% reduction in medical cost of injuries per 100 fires would translate into about \$50,000 in medical cost savings per 100 reported home fires. The 41% reduction in total cost of injuries per 100 fires would translate into about \$210,000 in total injury cost savings per 100 reported home fires.

During 2006-2010, there were just under 350,000 reported home structure fires per year in homes without automatic extinguishing equipment. If all had been sprinklered, the impacts would have been as follows:

- Deaths reduced by 83% means a savings of 6.0 lives per 1,000 reported fires per year, which means \$10.4 billion a year, if a statistical life is valued at \$5 million, as is done in NFPA's annual *Total Cost of Fire* study.
- Direct property damage reduced by 69% means a savings of \$14,000 per reported fire per year, which means \$4.8 billion a year.
- Civilian fire injury medical costs reduced by 53% means a savings of \$50,000 per 100 reported fires per year, which means \$0.2 billion a year.
- Civilian fire injury total costs reduced by 41% means a savings of \$210,000 per 100 reported fires per year, which means \$0.7 billion a year.

The results by type of injury are as follows:

- Sprinkler presence is associated with a 0% reduction in number of burn-only injuries per 100 reported home fires, a 23% reduction in medical cost of burn-only injuries per 100 reported home fires, and a 7% reduction in total cost of burn-only injuries per 100 reported home fires;
- Sprinkler presence is associated with a 35% reduction in number of smoke-inhalation-only injuries per 100 reported home fires, a 35% reduction in medical cost of smoke-inhalation-only injuries per 100 reported home fires, and a 38% reduction in total cost of smoke-inhalation-only injuries per 100 reported home fires;
- Sprinkler usage is associated with a 63% reduction in number of burn and smoke inhalation injuries per 100 reported home fires, a 72% reduction in medical cost of burn and smoke inhalation injuries per 100 reported home fires, and a 70% reduction in total cost of burn and smoke inhalation injuries per 100 reported home fires; and
- Sprinkler usage is associated with a 31% reduction in number of “other” injuries per 100 reported home fires, a 24% reduction in medical cost of “other” injuries per 100 reported home fires and a 35% reduction in total cost of “other” injuries per 100 reported home fires.

For any specific fire size, sprinklered homes are estimated to have higher estimated rates of injuries per 100 reported fires than unsprinklered homes. In most cases, that is much more than offset by a downward shift in the average size of fires, but if that shift is not so great, it is possible to have no change or an increase in the estimated number of injuries per 100 reported home fires. That is how it is possible to have a 0% net change in total burn-only injuries per 100 reported home fires. If the percentage of small fires is already high in unsprinklered homes – as is true for burn-only injuries but not for smoke-inhalation-and-burn injuries – then there is much less potential for a large shift toward smaller fires and so there is less potential to offset the higher estimated rates of injuries per 100 reported home fires by specific fire size.

There is still the question of why injury rates per 100 reported home fires should be higher in sprinklered homes for every specific fire size. This runs counter to the reasonable expectation that smaller fires pose a lower risk of injury than larger fires. However, some injuries occur because the victim has taken on increased personal risk to try to reduce fire loss, for example, by trying to rescue someone or trying to control the fire. Occupant firefighting accounts for far more injuries than occupant rescue attempts, which means that might be the place to look for an explanation of increased injury rates for fires of a defined size.

More of the injuries in sprinklered homes involve attempts to fight the fire (47% in sprinklered home reported fires vs. 35% in unsprinklered home reported fires). A much larger share of sprinklered home fires are confined to object of origin or reported as confined fires (85% vs. 57%), and this suggests that in sprinklered home fires, far more fires will appear to be small enough to be safely fought. More attempted firefighting might be expected to mean more injuries.

When burn victims were also injured by smoke inhalation, it was much more likely that the fire injuring them was larger, which means it was more likely that they were remote from the fire when injured. This provides more potential for sprinklers to reduce injuries by reducing fire sizes, and the estimated reductions in injuries and injury costs are consequently larger.

The results by age of victim are as follows:

- Sprinkler presence is associated with a 72% reduction in the number of fire injuries to children (ages 14 and under) per 100 reported home fires, an 85% reduction in medical cost of injuries to children per 100 reported home fires, and a 78% reduction in total cost of injuries to children per 100 reported home fires;
- Sprinkler presence is associated with a 30% reduction in the number of fire injuries to adults other than older adults (ages 15 to 64) per 100 reported home fires, a 52% reduction in medical cost of injuries to adults other than older adults (ages 15 to 64) per 100 reported home fires, and a 39% reduction in total cost of injuries to adults other than older adults (ages 15 to 64) per 100 reported home fires; and
- Sprinkler presence is associated with a 12% *increase* in the number of fire injuries to older adults (ages 65 and over) per 100 reported home fires, a 41% reduction in medical cost of injuries to older adults per 100 reported home fires, and a 23% reduction in total cost of injuries to older adults per 100 reported home fires.

If the hypothesis cited above is correct – that sprinklers make fires smaller, which makes more fires appear safe for firefighting, which leads to more injuries per 100 fires because of more injuries while firefighting – then the results by age group suggest that this effect is especially pronounced for older adults. If true, this need not mean that older adults are more likely to try to fight small fires but could mean that they are much more likely to be injured when they do attempt fire control.

Children are much less likely to be acting as cooks or otherwise close to cooking equipment when fire begins, and cooking fires account for by far the largest share of small reported fires and small-fire injuries. This means children have a lower percentage of fire injuries caused by small fires and so more potential for sprinklers to prevent their injuries by reducing the sizes of the fires that would have injured them. Sprinkler impact is much greater on injuries to children than on injuries to other victims.

As noted above, for any specific fire size, injury rates per 100 reported home fires are higher in sprinklered homes than in unsprinklered homes, possibly in part because a higher percentage of injuries in sprinklered homes involve firefighting, which is an activity one might expect to be more common when the fires to be fought are typically much smaller, as they are in sprinklered homes.

Appendix 1: Sensitivity Analysis

As noted in the text, we conducted a sensitivity analysis in which we assumed that all NFIRS injuries transported to emergency care facilities were hospitalized. This means that injury severity and associated medical costs are over-estimated across the board. This approach results in an estimated total cost per injury (in a fire with no sprinklers present) of \$321,000, which is higher than – but closer to – the overall cost per fire injury figure NFPA has used in its Total Cost of Fire (which takes the 1993 CPSC published figure of \$166,000 and adjusts it for inflation using the Consumer Price Index to a 2008 figure of \$248,000).

On the other hand, the current study incorporates many injuries not transported to any emergency care facility, and it is reasonable to expect that the average cost for those injuries would be smaller than the average cost for injuries all of which have been at least reported to hospital emergency rooms. That is why this analysis is a sensitivity analysis and not the main analysis shown in this report.

This alternative analysis showed slightly *lower* estimates for percentage reductions due to sprinklers – from a 53% reduction in medical costs per 100 reported fires to a 48% reduction, and from a 41% reduction in total injury costs per 100 reported fires to a 40% reduction.

However, because the estimates of injury severities and hence injury costs were so much higher virtually across the board in this sensitivity analysis, the estimates of dollar value of sprinkler reductions were *increased*, from \$50,000 of medical cost reduction per 100 reported fires to \$85,000, and from \$210,000 of total injury cost reduction per 100 reported fires to \$442,000.

It would also have been possible to conduct a sensitivity analysis assuming that non-transported NFIRS injuries have no costs at all. That analysis has not been conducted, but it would reduce the estimated benefits from sprinklers as part of greatly reducing the estimated importance of the fire injury problem generally.

Appendix 2: Illustrative Injury Narratives

In order to give examples of burn injuries that the model is dealing with, narratives were taken from two sources.

One source is national burn centers, in order to look at what *can* happen, when injuries may be severe and costly. The other is the Consumer Product Safety Commission's NEISS (National Electronic Injury Surveillance System) database, which collects information from hospitals around the country.

Each of the injuries shown from the NEISS database corresponds to a scenario used in the injury model. Some of these narratives may contain multiple injuries, showing that estimating these injuries is a complex task, and while the model does incorporate some "multiple injury" scenarios, it does not incorporate all of them.

The following narratives were adapted from information provided by a major hospital in North Carolina, and all incidents occurred during 2011.

- A 19 year old was admitted to a burn center with a burn of the larynx, trachea, and lung, and spent a total of 65 days in the ICU, despite having burns on only 3 percent of their body. The patient was eventually sent home, but total hospital charges were in excess of \$700,000.
- A 28 year old was admitted to the hospital with burns over 28% of their body, including burns of the larynx, trachea, and lungs. They were admitted to the burn unit and spent 45 days in the ICU. The total hospital charges were more than \$275,000.
- A two year old was admitted to the pediatric surgery department where they underwent treatment for a second degree burn of a single finger. The patient sustained the burn in their bedroom at home. The patient spent 6 days in the ICU, and total hospital costs were over \$150,000.

The table below shows incidents taken from the Consumer Product Safety Commission's NEISS database. Each injury described corresponds to an injury scenario used in the model, although not all injury scenarios used in the model have a corresponding narrative in the table below.

All Entries Based on NEISS Codes; Narrative Details May Differ Incidents Chosen to Illustrate a Scenario in the Model						
Body Part	Diagnosis	Disposition	Date	Age	Sex	Narrative
Face (including eyelid, eye area and nose)	Laceration	Hospitalized	8/7/2005	32	Male	A 32 year old man awoke to a fire in his bedroom and jumped from the window. He had burns on his face and torso and also multiple lacerations (including to the face).
Face (including eyelid, eye area and nose)	Thermal Burn	Treated and Released	9/5/2007	91	Female	A 91 year old woman fell asleep while cooking and the house caught fire. The patient was treated for burns to the face.
Hand	Thermal Burn	Treated and Released	10/2/2007	4	Male	A 4 year old boy suffered burns to the hand during a house fire.
Hand	Thermal Burn	Hospitalized	1/28/2008	4	Male	A 4 year old boy was injured during a house fire; the patient suffered burns on his back and hands. His brother also died in the blaze.
Trunk upper (not including shoulders)	Thermal Burn	Treated and Released	12/7/2008	67	Male	A 67 year old man was sleeping on a mattress in the garage when the garage caught fire. He tried to put the fire out, and sustained burns on his back. Alcohol was a factor in this incident.
Hand	Thermal Burn	Treated and Released	1/10/2009	38	Male	A 38 year man sustained a second degree burn to the hand while trying to put out a fire at home.
Hand	Thermal Burn	Hospitalized	1/17/2009	64	Male	A 64 year old man suffered burns on his hands when he opened a door during a house fire.
Trunk upper (not including shoulders)	Thermal Burn	Hospitalized	2/20/2009	80	Female	An 80 year old woman was found unconscious by the fire department during a condo fire. She had burns over 35% of her body, including the face, chest, back and arms, as well as smoke inhalation injuries.
Face (including eyelid, eye area and nose)	Thermal Burn	Hospitalized	5/11/2009	12	Male	A 12 year old boy sustained a second degree burn to the face during a house fire.
Trunk upper (not including shoulders)	Thermal Burn	Treated and Released	5/5/2009	22	Female	A 22 year old woman tried to put out a kitchen fire and suffered superficial burns to her back.

All Entries Based on NEISS Codes; Narrative Details May Differ Incidents Chosen to Illustrate a Scenario in the Model						
Body Part	Diagnosis	Disposition	Date	Age	Sex	Narrative
Hand	Thermal Burn	Treated and Released	9/7/2009	77	Male	A 77 year old man suffered burns on his hands when he tried to save his wife, who fell asleep with a lit cigarette.
Trunk upper (not including shoulders)	Thermal Burn	Hospitalized	11/2/2009	52	Female	A 52 year old woman was found in a garage fire, with 20% of her body burned, including her chest, arms, shoulder and legs.
Face (including eyelid, eye area and nose)	Thermal Burn	Treated and Released	1/1/2010	9	Male	A 9 year old male was involved in a house fire and suffered second degree burns to his upper lip, ears, and face.
All parts of body (more than 50% of body)	Anoxia	Treated and Released	1/29/2010	41	Male	A 41 year old man suffered smoke inhalation during a fire in his apartment building.
All parts of body (more than 50% of body)	Anoxia	Hospitalized	4/8/2010	73	Male	A 73 year old man awoke in a smoke-filled room, and remained there for an unknown amount of time. He was wheezing and was treated for smoke inhalation
All parts of body (more than 50% of body)	Anoxia	Hospitalized	5/23/2010	44	Male	A 44 year old male, who is quadriplegic, was involved in a house fire. Someone poured gasoline in the house and set it on fire. The man suffered from smoke inhalation injuries.
Face (including eyelid, eye area and nose)	Thermal Burn	Treated and Released	8/7/2010	34	Female	A 34 year old woman was involved in a house fire and suffered a burn injury on her nose.
All parts of body (more than 50% of body)	Anoxia	Treated and Released	8/22/2010	74	Female	A 74 year old woman was treated for smoke inhalation after a house fire. She was in the kitchen with smoke for about 10 minutes.
Face (including eyelid, eye area and nose)	Thermal Burn	Hospitalized	9/4/2010	38	Male	A 38 year old male was in a house fire for 30 minutes, and received airway burns and facial burns.
All parts of body (more than 50% of body)	Anoxia	Treated and Released	10/7/2010	7	Female	A 7 year old girl suffered smoke inhalation during a house fire.

All Entries Based on NEISS Codes; Narrative Details May Differ Incidents Chosen to Illustrate a Scenario in the Model						
Body Part	Diagnosis	Disposition	Date	Age	Sex	Narrative
All parts of body (more than 50% of body)	Anoxia	Hospitalized	11/5/2010	4	Female	A four year old female was trapped in a house fire, and was pulled out by the fire department. She suffered smoke inhalation injuries.
Face (including eyelid, eye area and nose)	Laceration	Treated and Released	12/9/2010	22	Male	A 22 year old man was injured trying to retrieve belongings from a burning house. He cut his face on a broken window.
Face (including eyelid, eye area and nose)	Thermal Burn	Hospitalized	12/31/2010	74	Female	A 74 year old woman was at her son's house when a fire occurred. She suffered burn injuries to her face and hands.
Hand	Thermal Burn	Hospitalized	12/31/2010	48	Female	A 48 year old female was burned during a house fire. She sustained second degree burns to her hands.