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# Benefit-Cost Analysis of Residential Fire Sprinkler Systems

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## Executive Summary

The objective of this study is to measure the expected economic performance of a fire sprinkler system installed in a newly constructed, single-family dwelling in the U.S. The benefit-cost analysis in this report is consistent with ASTM E 1074-06: *Practice for Measuring Net Benefits for Investments in Buildings and Building Systems*, and it is meant to provide a current benefit-cost analysis of residential fire sprinkler systems, updating NBS Technical Note 1203: *A Benefit-Cost Model of Residential Fire Sprinkler Systems*, published in 1984. In 1984, evidence suggested that sprinkler systems were not cost-effective, perhaps explaining the relatively small number of houses equipped with fire sprinklers today, even while fire professionals maintain that such systems protect lives and property from fire. Over the past two decades, advancement in the performance and cost-structure of fire sprinkler technologies have occurred, altering the cost-effectiveness of fire sprinkler systems. This report revisits the topic using the most complete fire incident data available today.

The benefits experienced by residents of single-family dwellings with sprinkler systems, as measured in this report, include reductions in the following: the risk of civilian fatalities and injuries, homeowner insurance premiums, uninsured direct property losses, and uninsured indirect costs. The primary costs examined are for initial purchase and installation of the sprinkler system. The measure of benefit-cost performance, the present value net benefits, compares differently timed benefit and cost cash flows, accruing to a homeowner, by discounting them to a reference point in time. All dollars presented in this report are in 2005 adjusted dollars. The present value net benefits are calculated by subtracting present value costs from the present value benefits.

The quantified benefits of a fire sprinkler system used in a single-family dwelling are based on reported fire incident data contained within the U.S. Fire Administration's National Fire Incident Reporting System 5.0 (NFIRS 5.0), and calibrated with reported data based on the National Fire Protection Association's annual survey of fire departments, over the period of 2002 to 2005. This study period was selected due to the relative completeness of fire incident records nationwide, thus ensuring that the nationwide trends and patterns used in this analysis are representative of U.S. fire risks. Over the 2002 to 2005 study period, houses equipped with smoke alarms and a fire sprinkler system experienced 100 % fewer civilian fatalities, 57 % fewer civilian injuries, and 32 % less direct property losses and indirect costs resulting from fire than houses equipped only with smoke alarms. In addition, homeowners of dwellings with fire sprinkler systems received an added bonus of an 8 % reduction in their homeowner insurance premium per year, according ISO. This report finds the monetized value of a residential fire sprinkler system, over a 30-year analysis period, to yield homeowners \$4994 in present value benefits (see Table ES-1).

The quantified costs of a fire sprinkler system are based on the findings of NISTIR 7277: *Economic Analysis of Residential Fire Sprinkler Systems*. NISTIR 7277 documented the design and installation costs of four different fire sprinkler systems within the three prototypical house types used in this study. Of the alternative sprinkler systems examined in NISTIR 7277, the multipurpose network system was generally the least costly (life-cycle cost) across the three house types because it did not require a backflow preventer, which requires regular professional

36 223 houses contained only smoke alarms (no sprinkler system) and that 143 houses contained smoke alarms and a wet-pipe sprinkler system. To project, into national estimates, the number of houses with only smoke alarms, and those with smoke alarms and a sprinkler system, we multiply the NFIRS 5.0 generated numbers by the scaling ratios. The fire incident scaling ratio (shown in Table 3-4) is calculated by dividing the NFPA estimated number of fire incidents by the NFIRS 5.0 generated estimate ( $287\,000/66\,292 = 4.33$ ). Multiplying the fire incident scaling ratio (4.33) by the number of NFIRS 5.0 house fires in houses with only smoke alarms (36 223) produces a national estimate of house fires in houses with only smoke alarms present of 156 846.<sup>4</sup> Likewise, multiplying the fire incident scaling ratio (4.33) by the number of NFIRS 5.0 house fires in houses with smoke alarms and a wet-pipe sprinkler system (143) produces a national estimate of 619 house fires in houses with smoke alarms and a wet-pipe sprinkler system.

### 3.3. National Fire Statistics ✓

Sprinkler systems have been designed to reduce the numbers of fatalities, injuries, and property damage resulting from structure fires. Thus residents of single-family dwellings (the focus of this study) benefit from the risk reduction of fire induced civilian fatalities, civilian injuries, and property damages (structure and content loss). To determine the expected benefits of sprinkler use, measures of risk reduction must be quantified. We summarize some of the fire statistics required for the analysis below.

#### 3.3.1. Statistics ✓

On average, over the 2002 to 2005 study period, 36 out of 10 000 single-family houses caught fire each year in the U.S. (Table 3-5). This translates into 296 500 house fires each year, resulting in 2566 civilian fatalities and 10 188 civilian injuries (NFPA 2006). Direct property loss, due to property and content destruction, averaged \$5346 million each year, which amounted to \$18 052 per fire. So for every 10 000 single-family house fires that occurred, 87 civilians died, another 344 were injured, and \$180.5 million in property losses was sustained. See Tables 3-5 and 3-6.

Dwellings without smoke alarms experienced 125 171 fires per year, which amounted to 42 % of the total, on average. Civilian fatalities and injuries occurred at an average rate of 95 and 273 people per 10 000 fires, respectively. Per fire direct property loss amounted to another \$13 344 in fire-related damages. See Tables 3-5 and 3-6.

Dwellings with only smoke alarms suffered more fires, a higher rate of civilian injuries, and greater property loss, on average, than dwellings without smoke alarms. These differences likely had less to do with smoke alarms, per se, than in underlying differences between dwellings with smoke alarms and those without. On the other hand, dwellings with smoke alarms had a lower average civilian fatality rate than those without (82 fatalities per 10 000 fires compared to 95). See Tables 3-5 and 3-6.

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<sup>4</sup> Due to rounding, this number differs from the more precise estimate shown in Table 3-6.

## **4. Baseline Benefit-Cost Analysis of Multipurpose Network Sprinkler Systems in Residential Dwellings**

### **4.1. Introduction**

This section applies the data reported in Section 3, using the benefit-cost framework discussed in Section 2, to estimate the present value of net benefits of installation of a multipurpose network sprinkler system in a residential dwelling. The benefits estimated in this analysis include: (1) reduced risk of civilian fatalities; (2) reduced risk of civilian injuries; (3) reduced expectation of uninsured direct property loss; (4) reduced expectation of uninsured indirect costs; and (5) reduced homeowner insurance premiums. The costs used in this analysis include the installation cost of the multipurpose network sprinkler system and are based on Brown's (2005) estimates. Results are presented as the present value of net benefits (PVNB) of installing residential fire sprinkler systems and are summarized in Table 4-4.

The uniform present worth factor of 15.729 (see Appendix A for formula) for annually recurring amounts is based on a 30-year study period and a real discount rate of 4.8 %, which reflects the real, after-tax annual rate of return on large-cap stocks over the period 1925 to 2005 (Ibbotson 2005).

In the cases for fatalities, injuries, and property losses, no difference in benefits is estimated for the occupant and the owner of a rental unit. This is because it is assumed that the owner of a rental unit will receive benefits equivalent in amount to those of the occupant through a rent premium that reflects the tenant's benefit of reduced risk of indirect costs.

### **4.2. Estimated Benefits of Multipurpose Network Sprinkler Systems in Residential Dwellings**

Table 4-1 summarizes the data used to calculate the present value benefits for the five classes of benefits described in Sections 4.2.1 through 4.2.5. It includes benefits from fatalities averted, injuries averted, direct property losses averted, indirect costs averted, and an insurance credit due to sprinkler use within residential properties. Appendix A discusses how the calculations are made and are based on the statistics reported in Section 3. Installation of a sprinkler system is expected to yield a present value benefit of \$4994, over the 30-year study period. Each benefit component is detailed below.

#### **4.2.1. Fatalities Averted**

One- and two-family dwellings with a wet-pipe sprinkler system were found to have zero reported fatalities over the study period 2002 to 2005. However, field tests indicate sprinklers fail to activate 3 % of the time (Hall 2007), so a 100 % reduction in fatalities, over dwellings with only smoke alarms, may be too optimistic. Section 5 deals with this uncertainty and its effects on the results. As discussed in the previous section, the value of a fatality averted is



#### **4.2.2. Injuries Averted**

One- and two-family dwellings with a wet-pipe sprinkler system were found to have a 57 % reduction in injuries over dwellings equipped with only smoke alarms. As discussed in the previous section, the value of an injury averted was estimated at \$171 620. The 57 % reduction in the injury rate results in an expected present value benefit of \$225.

#### **4.2.3. Direct Uninsured Property Loss Averted**

One- and two-family dwellings with a wet-pipe sprinkler system were found to have a 32 % reduction in direct property damages over dwellings equipped with only smoke alarms. The average direct property loss was found to be \$21 990 per fire for dwellings only equipped with smoke alarms. Because insurance is assumed to cover 80 % of any property loss (Ruegg and Fuller 1984), the uninsured direct property loss, responsible to the owner, was then \$4398 per fire. Thus the reduction in uninsured direct property damages yields a present value benefit of \$80 to residents in dwellings with smoke alarms and a sprinkler system.

#### **4.2.4. Indirect Uninsured Costs Averted**

Indirect costs in one- and two-family dwellings refers to costs such as temporary shelter, missed work, extra food costs, legal expenses, transportation, emotional counseling, and child care. Indirect losses have been systematically analyzed for house fires in a study by Munson and Ohls (1980). A review of this study leads the NFPA to use 10 % of the direct property loss as an estimate of the indirect property loss (Hall 2004). The average direct property loss per fire was found to be \$21 990, meaning the estimated indirect cost per fire is \$2199 for dwellings only equipped with smoke alarms. Part of the indirect loss of fires is covered by insurance. Munson and Ohls (1980) estimated that on average 60 % of indirect costs per fire are insured. Thus, the average uninsured indirect costs per fire were estimated at \$880. Given that one- and two-family dwellings with wet-pipe sprinkler system were found to have a 32 % reduction in direct property damages over the study period 2002 to 2005, a reduction in indirect costs results in a present value benefit of \$16.

#### **4.2.5. Insurance Premium Credit**

The U.S. average insurance premium is estimated to be \$754<sup>8</sup> and sprinklers in residential dwellings are expected to receive an 8 % reduction in the annual premium (Curry 2007). The credit results in an expected present benefit of \$949.

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<sup>8</sup> The Insurance Information Institute (2007) states that the average yearly homeowner insurance premium, as estimated by the National Association of Insurance Commissioners, was \$729 in 2004.