



UNITED STATES  
CONSUMER PRODUCT SAFETY COMMISSION  
WASHINGTON, DC 20207

**Memorandum**

Date: March 10, 2003

TO : William H. King, Jr., ESEE  
THROUGH: Warren J. Prunella, Associate Executive Director For Economic Analysis  
FROM : Terrance R. Karels, EC  
SUBJECT : Economic Considerations --- AFCI Replacements

You asked that Economic Analysis provide you with some preliminary estimates of the costs and benefits of replacement of circuit breakers with newer-technology arc-fault circuit interrupters (AFCIs). The following estimates are based on staff reports, contacts with trade and industry sources, and other readily available information regarding residential fires and AFCIs.

**Electrical Fire Cost to Society**

The Commission's Directorate for Epidemiology reports that there were an average of 41,500 residential fires involving residential electrical distribution systems over the 9 year period 1990-1998.<sup>1</sup> These fires resulted in an average of 326 deaths, 1,481 injuries, and \$646 million in property losses per year over that period. For analytical purposes, the CPSC assigns a statistical value per life of \$5 million; using the CPSC's Injury Cost Model, the estimated average cost of fire-related injury (including burns and smoke inhalation) is about \$56,000. Adding each of these three cost elements, the average total estimated cost to society of these residential electrical fires would be about \$2.360 billion per year (\$1.630 billion+\$83 million+\$646 million).

It should be noted that "societal costs" is confined in this analysis to consumer deaths, injuries, and property loss to residents involved in a residential fire. Deaths and injuries sustained by fire personnel and the cost of fighting fires were not included in the society cost estimate.

**Costs by Age of Housing Units**

According to a 1990 CPSC Epidemiological study, "Residential Electrical Distribution System Fires," 85% of all such fires involved housing over 20 years old.<sup>2</sup> Thus, the societal costs of these fires in older homes would be significantly greater than that for newer housing. If

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<sup>1</sup> Revised Residential Fire Loss Estimates, 1980-1998, National Estimates of Fires, Deaths, Injuries, and Property Losses from Non-Incendiary, Non-Suspicious Fires, July, 2002.

<sup>2</sup> The study was based on 149 investigated fires in 16 cities, and do not represent a statistically representative sample.

residential fires for the period 1990-98 (the period for which fire incident data were used) tracked the same pattern as the 1990 study, some 85% of fires --- and 85% of the expected societal costs--- would occur with housing over 20 years old. According to data derived from the **Annual Housing Survey, 1999** (US Census Bureau), there was an average of about 98.7 million housing units during the period 1990-98 (the period for which fire incident data were used). Over this period, an average of 70 million housing units (or 71%) were over 20 years old.

Thus, it appears that the age of housing units is a significant factor in the risk of residential fire involving electrical distribution systems. For houses under 20 years of age, the societal cost of these fires would be \$354 million per year ( $\$2.36 \text{ billion} \times .15$ ). Since there were an average of 28.7 million houses under 20 years old over the period, the average expected societal cost would be \$12.33 per year ( $\$354 \text{ million} / 28.7 \text{ million}$ ) per housing unit.

For housing over 20 years old, the societal costs would be \$2.01 billion per year. For the 70 million houses that were over 20 years old, the expected societal costs of these fires would be \$28.66 per unit per year ( $\$2.006 \text{ billion} / 70 \text{ million}$ ).

### **Savings Over the Life of the AFCI**

The CPSC's Engineering staff estimate that current-technology AFCIs may remain in service for 40 years or more, based on the industry's reported rate of replacement of existing circuit breakers in the US. For the purpose of this preliminary estimate, we assume that AFCIs will experience a service life of 30 to 40 years. Benefits associated with their use would accrue over the entire lifetime of the products.

The total benefits would be the present discounted value of the reduction in societal costs associated with residential electrical fires. Since the electrical fires appear concentrated after the structure is over 20 years old, the societal costs would differ depending upon when the AFCIs were installed. The following table shows the expected societal costs that would be addressed by AFCIs, under several scenarios. All societal costs were discounted at a rate of 3%.

	Present Value of Societal Costs Addressed by AFCIs	
	If a 30-year life	If a 40-year life
If installed at initial construction <sup>3</sup>	\$324	\$425
If installed after 10 years <sup>4</sup>	\$429	\$530
If installed after 20 years <sup>5</sup>	\$572	\$673

The discount rate has a significant effect on the present value of societal costs. For example, at a 7% discount rate, the discounted addressable societal costs for AFCIs installed at initial construction decline to \$184 (if a service life of 30 years) and to \$208 (if a 40 year service life). If AFCIs are installed after the housing was 10 years old, the discounted societal costs would

<sup>3</sup> This example assumes societal costs of \$12.33 annually for the first 20 years, and \$28.66 thereafter

<sup>4</sup> This example assumes societal costs of \$12.33 annually for 10 years, and \$28.66 thereafter

<sup>5</sup> This example assumes societal costs of \$28.66 annually

range from \$243 (if 30 year service life) to \$267 (if 40 year service life). If installed in housing over 20 years old, the discounted societal costs would range from \$363 (if 30 year service life) to \$387 (if 40 year service life).

### **Cost of AFCIs**

According to Engineering Sciences staff (ES), the average cost differential of residential AFCI circuit breakers compared to residential circuit breakers without the AFCI feature is \$15 to \$20 per unit. Staff also estimate that an average of 10 additional circuits per household would require AFCI protection beyond those currently required by the National Electrical Code. Thus, the cost of adding AFCI protection would total about \$150 to \$200 per housing unit. For the purposes of this preliminary analysis, we have used \$175 (the midpoint of the estimates) as the cost of adding AFCI protection, per housing unit.

### **Effectiveness and Comparison of Costs and Benefits**

As noted earlier, industry estimates put replacement sales of circuit breakers at levels that suggest that circuit breakers experience useful lives in excess of 40 years. If AFCIs experience a service life of 40 years (the most likely scenario based on the useful life of current-technology circuit breakers), and are installed at the time of initial construction of the residence, the inclusion of AFCIs would need to achieve effectiveness of about 41% in order for the estimated discounted benefits (the reduction in societal costs) to be equal to the costs of installation of the AFCIs (\$175 in costs/\$425 in benefits).

If the AFCIs were installed after the housing units were 10 years old (as might occur with early housing renovations), AFCIs would need only a 33% effectiveness in order to achieve cost-effectiveness (\$175/\$530). And if AFCIs were installed after the housing units were 20 years old (a likely time frame for major housing renovations), a 26% rate of effectiveness would yield benefits equivalent to costs (\$175/\$673).

Using a 30-year useful life for AFCIs, if installed at the time of initial construction, AFCIs would need to be about 54% effective in order to be cost-effective (\$175/\$324). If installed after the housing were over 10 years old, an effectiveness rate of 41% would yield a balance of costs and benefits (\$175/\$429). And if the AFCIs were installed after the housing was 20 years old, an effectiveness of 31% would result in costs in balance with benefits (\$175/\$572).

The inclusion of AFCI protection is expected to reduce, but not eliminate residential fires from electrical distribution systems. Citing reviews of in-depth investigations, ES staff estimate that the inclusion of AFCI protection in circuit breakers could have prevented 50% or more of these fires.

Thus, if the ES staff estimate of 50% effectiveness is correct (and assuming a 3% discount rate), the preliminary estimate of benefits of installing AFCI protection would exceed the costs in all but one scenario: for AFCIs with a 30-year useful life installed at the time of the initial construction, the projected benefits would be \$162 (50% of \$324), while the expected costs would be \$175.

However, it should be noted that the results of the analysis are sensitive to the discount rate used. If a 7% discount rate is applied to the societal costs, the benefits of installing AFCI protection expected to last 30 to 40 years in *new* housing could be less than the costs: \$92 to \$104 (50% of \$189 and \$208, respectively); if AFCIs were installed in housing over 10 years old, the benefits would be \$122 to \$134 (50% of \$243 and \$267, respectively). However, the installation of AFCIs in housing over 20 years old still results in significant benefits over costs: \$181 to \$194 (50% of \$363 to \$387, respectively).

### **Aggregated Benefits and Costs**

The preceding section described the expected benefits and costs of requiring AFCIs on a per-house basis. However, because industry sources indicate that about 1.9 million housing units undergo major electrical renovations annually, we can also describe the aggregate discounted benefits and costs associated with these renovations over the expected useful lives of the installed AFCIs. While the average age of this housing is unknown, it is likely that they are older residences. If AFCIs were incorporated in these older housing as renovations were conducted, and if such renovations involved housing over 20 years old, the aggregate discounted benefits (i.e., the reduction in societal costs) could be in the range of \$286 to \$336<sup>6</sup> each, or \$543 to \$638 million for all 1.9 million houses. The total cost of the addition of AFCIs would total \$175 per housing unit, or \$332 million for all renovated houses. Thus, in this scenario, the total benefits of such an action are almost double the expected costs.

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<sup>6</sup> Based on 50% effectiveness and 3% discount rate, and 30-year and 40-year expected life.