National Center for Healthy Housing

Evaluation of the "10-Year" Smoke Alarm Project

Prepared for the Centers for Disease Control and Prevention

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Abstract

Background: In 1998, the Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control (NCIPC) began awarding three-year cooperative agreements to 14 state health departments to implement Smoke Alarm Installation and Fire Safety Education (SAIFE) programs. CDC required the grantees to install lithium-powered "10-year" smoke alarms in homes at high risk for fires and injuries.
Objective: The project aimed to evaluate a subset of homes that received smoke alarms between 1998 and 2001 to determine if the lithium-powered smoke alarms were operational 8-10 years after installation. The study also observed whether the installed smoke alarms were present at the time of evaluation and whether carbon monoxide (CO) alarms were installed in the enrolled units.

Methods: The National Center for Healthy Housing (NCHH) randomly selected 427 homes in five participating states (Georgia, Virginia, Washington, Kentucky, and Oklahoma) for enrollment in the project. Inspectors from each state enrolled dwelling units, had residents sign a release from liability form, and conducted visual inspections of the installed smoke alarms and CO alarms (if present). Using a Smoke Alarm Visual Inspection (SAVI) form (Appendix 2), inspectors recorded their observations on the original smoke alarms. They noted whether the original smoke alarms were present or missing, if present smoke alarms were operable, and the reason for a nonfunctional smoke alarm. In homes where smoke alarms were present, inspectors tested the smoke alarms by pushing the test button. If the alarms were missing batteries, inspectors inserted a battery before using the test button. Inspectors replaced nonfunctional smoke alarms with new ones.

Results: Of the 427 enrolled dwelling units, inspectors had information about the number of alarms installed at 384 of the dwellings. At the remaining 43 units, the inspector knew that at least one alarm had been installed as part of the SAIFE program, but could not obtain specific information to evaluate each alarm installed. NCHH had information about 601 smoke alarms installed 8-10 years ago to evaluate. Eight to ten years after the installation of these smoke alarms, 33% of the alarms were functional, 37% were missing, and 30% were present but nonfunctional. Factors related to missing alarms included installation in rental properties, properties where the resident at the time of installation no longer lived as well as variability by state. Factors related to nonfunctional alarms included installation in kitchen, brand of alarm, as well as variability by state. Of the 381 alarms that were present at the time of evaluation, inspectors reported that the battery was missing from 30 of the alarms (8%). Of the remaining 351 alarms, 73 (21%) contained lithium-powered batteries, 169 (48%) had non-lithium powered batteries, and the inspectors did not report a battery-type for the remaining 109 alarms (31%). Seventy-

eight percent (78%) of the smoke alarms that had lithium batteries at the time of evaluation were operational, compared to 53% of smoke alarms with nonlithium batteries. Out of the 427 homes evaluated, 34 (8%) had a carbon monoxide alarm. Evaluators installed a total of 708 new lithium-powered 10-year smoke alarms in the homes.

Conclusion:

Although the evaluation shows that only one-third of the originally installed smoke alarms were present and operational, a number of factors play a role in the missing and present but nonfunctional alarms. These include tampering with smoke alarms, removal of lithium-powered batteries, and the location of the smoke alarm. To prevent the likelihood of residents interfering with alarm operability, future programs should consider installing tamper proof, sealed lithium-powered smoke alarms. Installing alarms with end-of-life indicators would also help occupants recognize when alarms need replacement. State health departments should work with fire departments to schedule periodic visits to homes after smoke alarm installation to assess the alarm functionality.

1. Introduction

Fatal injuries from house fires continue to be an important problem in the United States. Residential fires occurred in 412,500 homes in the United States in 2006, claiming 2,580 lives and injuring another 12,925.[1] A number of risk factors have been associated with fire related deaths at home including socioeconomic status,[2] the presence of smoke alarms in homes,[3] and older housing.[4,5] Numerous interventions and programs have been implemented in hopes of addressing this problem. Most of these interventions take the form of home safety education via counseling[6,7] and provision of low cost or free smoke alarms.[8,9] A targeted intervention in Oklahoma involving a smoke-alarm–giveaway program with installation when requested resulted in an 80% drop in hospitalizations and deaths related to fire.[9] However, when residents routinely fail to install their alarms, smoke alarm give-away programs do not reduce injuries,[8] suggesting that programs that install alarms are more effective.

The Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control (NCIPC) began funding state health departments to implement Smoke Alarm Installation and Fire Safety Education (SAIFE) programs in 1998.[10] Fourteen state health departments were awarded three-year cooperative agreements. Each grantee was required to install lithium-powered "10-year" smoke alarms in homes at high risk for fires and injuries. Programs targeted older homes and homes in low-income neighborhoods. At the time, the lithium-powered alarm was new to the market and there were concerns about whether the alarm would last 10 years as designed.

The principal objective of this evaluation project was to determine if the lithium-powered smoke alarms were operational 8-10 years after installation. The study also observed whether the installed smoke alarms were present at the time of evaluation and whether carbon monoxide (CO) alarms were installed in the enrolled units. It also aimed to replace missing or inoperable alarms.

2 Methods:

2.1 Site Selection

In consultation with the NCIPC project officer, the National Center for Healthy Housing (NCHH) identified five state programs that were awarded SAIFE funds in 1998 that are also currently funded under the CDC grant program. NCHH asked state program managers to confirm their interest in participating in the evaluation, that they had local participants available to assist with the inspections, and that they had records of the original installation sites. Through this process, CDC and NCHH selected the states of Georgia, Kentucky, Oklahoma, Virginia, and Washington to participate in the evaluation. Each state was to inspect 100 dwelling units.

To avoid selection bias in sampling, state coordinators with support from NCHH randomly selected 100 dwellings in each state from the total number of houses that received smoke alarms in 1998-2001. Due to widely spread rural counties in Washington and Oklahoma, the state coordinators narrowed the selection criteria to a set of zip codes, representative of the original projects population, and then randomly selected potential enrollees from those areas. In all the states, more homes than needed were randomly selected to increase the likelihood that 100 dwellings were actually enrolled. The state coordinators compiled a recruitment list and provided it to the designated inspectors.

Within the five states, the following communities were selected for participation in the evaluation:

Georgia:	Columbus and Macon
Kentucky:	Lawrence, Russell, and Polk* Counties
Oklahoma:	Ardmore, Enid, Muskogee, and Ponca City
Virginia:	Petersburg
Washington:	Mason (including the City of Shelton), Pend Oreille, and Stevens Counties

**Polk, Kentucky was selected for evaluation, but due to a lack of inspectors, no dwellings were enrolled in this county.*

The communities selected included urban communities in metropolitan areas in Virginia and Georgia; mid-sized cities (pop. 24,000-47,000) in Oklahoma; and rural counties in Kentucky and Washington.

2.2 Data Collection

2.2.1 Data Collection Process

The inspectors traveled to each home to gain entrance and collect data. Upon gaining entrance, participants were asked to sign a release from liability form (Appendix 1). The participant's address and phone number were collected in case follow-up was required. Residents did not receive financial compensation for their participation.[a]

NCIPC determined that to meet its objective of completing this evaluation quickly and efficiently, participant demographics and information about smoke alarm operations would not be collected. Any interview questions would have had to have gone through a Federal review as part of the Paperwork Reduction Act and would have delayed the data collection process beyond the project timeline. All demographic data collected for this study came from records from the time of installation (e.g., is resident at time of installation still present?) or from inspector observation (e.g., is there evidence of a smoker at the dwelling?) and not from resident interviews.

After enrollment, the inspectors, equipped with the Smoke Alarm Visual Inspection (SAVI) form (Appendix 2), new smoke alarms, and new lithium batteries, conducted visual inspections of the installed smoke alarms and CO alarms (if present). They checked that the smoke alarms (1) matched the number of alarms originally installed; (2) were the same alarms as those originally installed; and (3) were operable. Inspectors recorded their observations on the SAVI form. If a battery was missing and there was no physical damage to the alarm, the inspectors inserted a lithium battery to determine if the

[a] The NCIPC Human Subjects Coordinator reviewed the project design and determined that this evaluation met the criteria of nonresearch - program evaluation.

alarm was operable. Once it was determined that the alarm was nonfunctional, the inspectors replaced the old smoke alarm with a new one. Inspectors took with them powered drills that facilitated an easy and fast installation. Inspectors asked residents if they owned CO alarms. If a CO alarm was present, the inspectors conducted a visual inspection of the CO alarm to identify the characteristics of the alarms such as whether it had battery backup.

In addition to replacing missing or nonfunctional smoke alarms, NCIPC authorized the states to also replace working smoke alarms using current grant funds. It is best practice to replace all smoke alarms every 10 years whether they are functional or not, because the unit itself becomes less effective. NCIPC recommended that the states use this evaluation visit as an opportunity point to replace alarms that were generally within a year of their optimal life. During the evaluation, the inspectors installed a total of 708 new lithium-powered 10-year smoke alarms in 427 homes.

2.2.2 Data Collection Barriers

In Georgia and Virginia, the inspectors met or exceeded the data collection target of 100 dwellings per each state, but the data collection target of 100 was not reached in the other three states. In one Oklahoma community, the inspectors reported that a higher than expected percentage of homes on the recruitment list were either unoccupied or abandoned. At the end of the data collection period, the inspectors in this community were only able to recruit 17 of the 25 dwellings they anticipated. With this exception, participant recruitment was highly successful in Oklahoma.

In Washington, the rural nature of the three participating counties posed challenges. The population densities in the counties were 50 persons per square mile or fewer. The study team hoped that by using local firefighters during their down time, residents in these rural homes could be reached and would be open to participating in the study. However, firefighters did not have as much free time as originally expected; residents were not as available; and the incentives provided to firefighters were not great enough to encourage them to achieve their targets. Forty-two homes were evaluated in the state.

Inspectors in Kentucky faced similar problems with recruiting from less densely populated counties. Kentucky also adopted a model of using a single inspector and when that inspector became ill during the data collection period, the study team had to identify a new inspector late in the process. Kentucky evaluated 40 homes. Because we recognized that Kentucky would fall short of its target, Georgia was asked to recruit an additional 50 dwellings. The final count of dwellings evaluated in each state is reported in the Results section.

2.3 <u>Quality Control</u>

Inspectors prepared copies of the data forms and mailed them to NCHH. NCHH reviewed all data forms for completeness and consistency. When possible, it reconciled missing data and apparent inconsistencies with the site before data entry took place. NCHH entered the information into an Excel database. NCHH visually checked all of the entered forms for data entry accuracy. NCHH identified no major data quality deficiencies.

A staff member from NCHH observed inspectors in four of the five states during the enrollment and inspection process. The NCHH staff member provided guidance to the inspectors on ways to improve their performance. After the first site visit to Georgia, the SAVI form was revised to allow the inspector to record whether the battery in the smoke alarm was a lithium-powered battery. During the site visit, the NCHH staff member observed that some of the program smoke alarms had non-lithium nine-volt batteries, suggesting this was an important factor to capture. About 12 inspections had been conducted before the forms were revised.

As discussed above, the evaluation encountered problems in Kentucky with the inspectors being able to recruit and enroll dwellings as planned. As a result, most of that state's inspections occurred during the last two weeks of the data collection period. NCHH and NCIPC agreed that given the uncertainty about when Kentucky's inspections would occur and because any field observations would have a limited impact on improving data quality, the planned site visit to Kentucky was cancelled.

2.4 Data Analysis

NCHH prepared summary tables of all data collected as part of this evaluation. In addition, NCHH created logistic regression models to predict the probability of: (1) an alarm being functional; and (2) a home having any alarms missing. Table 1 presents the potential predictors included in the models. The model to predict functional alarms controlled for more than one alarm in the same home when present because alarms in the same home are not independent. A backward elimination procedure was used to create the final models.

Table 1: Potential Predictors in the Models

Potential Predictor	Model	
	Alarm Functional (yes/no)	Any Missing Alarms (yes/no)
Evidence of smoker in home (yes, no, cannot determine)	X	X
Resident since original installation (yes, no, unknown)	X	X
Type of residence (rental, owned, unknown)	X	X
Type of room (kitchen, non-kitchen, unknown)	X	
Make of alarm (7 Brands)[b]	X	
State of residence (GA, KY, OK, VA, WA)	X	X

[b] The government does not endorse any type of alarm. Brands of Alarm have been masked in this report because their performance in this study may not be representative of past or current performance.

3. Results

3.1 Number of Dwellings/Alarms Sampled

Local inspectors evaluated 427 dwelling units as part of the Evaluation (Table 2). For 384 of these units, the inspectors had information about the number of smoke alarms installed as part of the program and a status report for each of those alarms. The remaining 43 units were excluded because inspectors did not have information on the number of smoke alarms installed. The impact of loss of these units is described in the Discussion section. A total of 601 installed alarms were evaluated, which is an average of 1.6 alarms per dwelling unit. Fifty-seven percent (57%) of the dwellings had one alarm installed 8-10 years ago; 35% of dwellings had two installed; 5% had three installed and 3% had four or five installed. Over three-quarters of the dwellings in Georgia and Oklahoma had only one alarm installed, while over 80% of the dwellings in Kentucky and Washington had at least two alarms installed. About one-quarter of the homes in Washington had at least four alarms installed.

Table 2: Number of Dwellings and Alarms Evaluated

State	Number of Dwellings Evaluated	Number of Dwellings with Complete Smoke Alarm Data	Number of Installed Alarms Evaluated	Average Number of Installed Alarms/ Dwelling
Georgia	152	115	141	1.2
Kentucky	40	40	82	2.1
Oklahoma	93	92	117	1.3
Virginia	100	96	154	1.6
Washington	42	41	107	2.6
TOTAL	**427**	**384**	**601**	**1.6**

3.2 Demographics of Communities/Dwellings Sampled

The original enrollment plan called for a variety of community sizes to be enrolled with targets of 200 urban/metropolitan homes; 200 rural homes; and 100 homes from mid-sized cities. Enrollment in rural communities was less successful, resulting in more homes being evaluated in urban areas than in rural areas. Out of the 384 homes with complete smoke alarm data, 211 (55%) were in urban/metropolitan areas; 92 (24%) were in mid-sized cities; and 81 (21%) were in rural areas. The national distribution of homes is: 29% urban/metropolitan; 9% urban/non-metropolitan; and 25% rural, with the remaining 36% suburban.[11] Because rural homes received more smoke alarms than the urban homes, the proportion of alarms evaluated in rural areas was higher than that of the homes evaluated: 49% urban/metropolitan; 19% mid-sized cities; and 31% rural.

Limited demographic information was collected from records and inspector observation about the ownership of the homes; whether the occupants lived in the dwelling when the alarms were originally installed; and whether the current occupants smoke (Table 3). Sixty-five percent (65%) of the homes were owner-occupied, 28% were rented, while the occupancy status of 7% of the homes was unknown. Higher percentages of rental units were found in the urban/metropolitan areas. Sixty-one percent (61%) of the homes had the same resident as when the alarms were originally installed, 32% did not, and at 8% of the dwellings, the residency tenure was unknown.

Determination of the presence of a smoker was more challenging for the inspectors; no determination could be made at 24% of all homes and a determination could not be made at almost half of the homes in Virginia. At the homes where a determination could be made, 35% of all homes had a smoker present. Where smoker status could be determined, the percentages of homes with a smoker ranged from 55% in Kentucky to 25% in Georgia.

Table 3: Ownership Status, Resident Tenure and Presence of Smoker by State (384 homes)

State	Ownership			Same Resident as at Alarm Installation			Smoker Present		
	Owned	Rented	NA*	Yes	No	NA*	Yes	No	NA*
GA	56% (n=64)	41% (n=47)	3% (n=4)	61% (n=70)	30% (n=34)	9% (n=11)	23% (n=26)	68% (n=78)	10% (n=11)
KY	78% (n=31)	10% (n=4)	12% (n=5)	73% (n=29)	18% (n=7)	10% (n=4)	33% (n=13)	58% (n=23)	10% (n=4)
OK	83% (n=76)	16% (n=15)	1% (n=1)	67% (n=62)	28% (n=26)	4% (n=4)	28% (n=26)	49% (n=45)	23% (n=21)
VA	56% (n=54)	35% (n=34)	8% (n=8)	52% (n=50)	40% (n=38)	8% (n=8)	22% (n=21)	29% (n=28)	49% (n=47)
WA	59% (n=24)	22% (n=9)	20% (n=8)	54% (n=22)	39% (n=16)	7% (n=3)	41% (n=17)	34% (n=14)	24% (n=10)
TOTAL	65% (n=249)	28% (n=109)	7% (n=26)	61% (n=233)	32% (n=121)	8% (n=30)	27% (n=103)	49% (n=188)	24% (n=93)

*NA = Information either not collected or available through observation/records

3.3 Smoke Alarm Status

3.3.1 Status by Alarm

Eight to 10 years after the installation of the lithium-powered smoke alarms, the inspectors found that one-third of the alarms were still functional (Figure 1). Thirty-seven percent (37%) of the installed alarms were missing, and 30% of the alarms were present but not functioning. Of the 180 alarms that were present but not functional, 43% had a dead battery; 17% had no battery; 13% appeared to be nonfunctional because of physical damage, and the remaining 27% were not functioning for some other reason, such as missing parts and dust accumulation.

The status of the alarms varied by state (Table 4). Over half of the alarms were functional in Oklahoma, but less than 10% of the alarms in Washington were functional. In Washington, 63% of the alarms were missing. The percentage of present but nonfunctional alarms was roughly the same as for all states combined. In Kentucky, 22% of the alarms that were installed were missing; the lowest percentage of all states. However, 44% of the alarms evaluated in Kentucky were nonfunctional, a percentage that is almost 50% higher than the average for all the other states.

Table 4: Status of Alarms ~ 10 Years after Installation (601 alarms)

State	Total Alarms Evaluated	Functional	Missing	Present but Nonfunctional			
				Dead Battery	*Missing Battery*	*Other*	TOTAL Nonfunctional
GA	141	28% (n=39)	38% (n=53)	*22% (n=31)*	*5% (n=7)*	*8% (n=11)*	35% (n=49)
KY	82	34% (n=28)	22% (n=29)	*26% (n=21)*	*5% (n=4)*	*13% (n=11)*	44% (n=36)
OK	117	52% (n=61)	28% (n=33)	*4% (n=5)*	*1% (n=1)*	*15% (n=17)*	20% (n=23)
VA	154	41% (n=63)	32% (n=49)	*7% (n=11)*	*4% (n=6)*	*16% (n=25)*	27% (n=42)
WA	107	9% (n=10)	63% (n=67)	*8% (n=9)*	*11% (n=12)*	*8% (n=9)*	28% (n=30)
TOTAL	601	33% (n=201)	37% (n=220)	*13% (n=77)*	*5% (n=30)*	*12% (n=73)*	30% (n=180)

The reason that the alarms were nonfunctional also varied by state (Table 5). In Georgia and Kentucky, over half of the non-functioning alarms had a dead battery. In Oklahoma, over half of the non-functioning alarms were not working for some other reason. A dead battery accounted for a quarter of the non-functioning alarms in Virginia, while some other reason accounted for a third of their non-functioning alarms. In addition to Washington having a high percentage of missing alarms, 40% of the non-functioning alarms had a missing battery. Thirty percent of the non-functioning alarms evaluated in Washington had a dead battery.

Table 5: Reasons for Nonfunctional Alarms by State

State	Total Nonfunctional Alarms Evaluated	Reason for Nonfunctional Alarms				
		Dead Battery	Missing Battery	Physical Damage	Other Reason	Reason Not Reported
GA	49	63% (n=31)	14% (n=7)	0% (n=0)	8% (n=4)	14% (n=7)
KY	36	58% (n=21)	11% (n=4)	31% (n=11)	0% (n=0)	0% (n=0)
OK	23	22% (n=5)	4% (n=1)	17% (n=4)	52% (n=12)	4% (n=1)
VA	42	26% (n=11)	14% (n=6)	7% (n=3)	36% (n=15)	17% (n=7)
WA	30	30% (n=9)	40% (n=12)	20% (n=6)	10% (n=3)	0% (n=0)
TOTAL	180	43% (n=77)	17% (n=30)	13% (n=24)	19% (n=34)	8% (n=15)

3.3.2 Status by Dwelling Unit

At the time of this evaluation, 38% of the dwellings had at least one of the originally installed alarms still functional. Thirty percent (30%) of the dwellings had all of the originally installed alarms still functional. For 34% of the dwellings, all of the originally installed alarms in the home were missing.

As reported above, the average number of alarms installed per home varied by state. If the performance of alarms was independent of each other, the percentage of units with any or all alarms functional would be influenced by the number of alarms installed. For example, a dwelling with three alarms installed would be less likely to have all alarms functioning, but more likely to have at least one alarm functioning than a dwelling where only one alarm is installed. The data do not support the assumption of independence (Table 6). Oklahoma had a relatively high percentage of dwellings with *all* alarms functional (47%), even though they generally installed one per home, while Washington had a relatively low percentage of dwellings with *any* alarms functional (14%), even though they often installed two or more alarms per home. Over half of the dwellings in Washington had all of the originally installed alarms missing, further supporting the observation that the alarm effectiveness is not independent within a dwelling. In other words, an owner or tenant with one nonfunctional or missing alarm is likely to have other nonfunctional or missing alarms at the dwelling.

Table 6: Status of Smoke Alarms by State

State	Percentage of Dwellings with **all** Alarms Functional	Percentage of Dwellings with **any** Alarms Functional	Percentage of Dwellings with **all** Alarms **Missing**
Georgia	23.5% (n=27)	31.3% (n=36)	37.4% (n=43)
Kentucky	32.5% (n=13)	37.3% (n=15)	15.0% (n= 6)
Oklahoma	46.7% (n=43)	50.0% (n=46)	30.4% (n=28)
Virginia	31.3% (n=30)	42.7% (n=41)	32.3% (n=31)
Washington	7.3% (n= 3)	14.6% (n= 6)	51.2% (n=21)
ALL	30.2% (n=116)	37.5% (n=144)	33.6% (n=129)

3.4 <u>Influence of Other Factors on Alarm Performance</u>

A multivariate logistic analysis was conducted to consider what factors significantly predict whether a lithium-powered smoke alarm will be functional 8-10 years after installation. Six factors that were potentially related to the effectiveness of alarm functionality were considered: state where installed; brand of alarm; location of alarm placement (Kitchen v. non-Kitchen); original resident present; ownership status (i.e., rental, owner-occupied); and smoker present. Alarms that were present and functional (n=201 /53%) were compared with alarms that were present and nonfunctional (n=180 /47%).

Variables found to be significant in the model as well as the model parameter estimates are presented in Table 7. If a variable is not a predictor in a model, the cells in Table 7 contain "-."

Table 7: Logistic Model Parameter Estimates

Predictor	Level	Alarm Functional			Any Missing Alarms		
		Odds Ratio	P-value	Overall p-value	Odds Ratio	P-value	Overall p-value
Intercept		0.348	0.212	0.212	3.878	0.005	0.212
Brand of Alarm	Unknown	1.011	0.984	**0.003****	-	-	-
	Brand A	6.065	0.073		-	-	
	Brand B	0.433	0.406		-	-	
	Brand C	3.666	0.046		-	-	
	Brand D	1.363	0.667		-	-	
	Brand E	1.056	0.959		-	-	
	Brand F	0.470	0.326		-	-	
	Brand G	1.000	.		-	-	
Resident since original installation	Unknown	-	-	-	1.228	0.674	0.113
	No	-	-		1.815	**0.036****	
	Yes	-	-		1.000	.	
State	GA	1.222	0.782	**0.002****	0.233	0.001	**<0.001****
	KY	3.616	0.029		0.140	0.000	
	OK	7.246	0.006		0.166	<.0001	
	VA	1.521	0.565		0.146	<.0001	
	WA	1.000	.		1.000	.	
Type of residence	Unknown	-	-	-	0.884	0.828	0.074
	Owned	-	-		0.520	**0.027****	
	Rental	-	-		1.000	.	
Room type	Unknown	0.641	0.757	0.123	-	-	-
	Kitchen	0.443	**0.067***		-	-	
	Non-Kitchen	1.000	.		-	-	

*=P-value < 0.10 **=P-value < 0.05

Table 8: Brand of Smoke Alarms Evaluated by State

Brand	**GA**	**KY**	**OK**	**VA**	**WA**	**ALL**
Brand A	-	-	7	-	8	15
Brand B	10	-	1	-	-	11
Brand C	49	14	1	83	-	147
Brand D	6	-	4	16	1	27
Brand E	-	-	3	-	4	7
Brand F	-	50	3	-	27	80
Brand G	-	-	24	-	-	24
Unknown	*23*	*0*	*41*	*6*	*0*	*70*
All	**88**	**64**	**84**	**105**	**40**	**381**

Controlling for other factors, alarms that were installed in kitchens were less likely to be functional than alarms installed in non-kitchen areas; the odds of functioning were 55% lower in kitchens than non-kitchens. Seventy percent (70%) of the 34 alarms installed and still present in *kitchens* were nonfunctional, while 45% of the 345 alarms installed and still present in *non-kitchens* were nonfunctional. Two-thirds of the batteries in the kitchen alarms were either dead or missing, compared to 58% dead or missing batteries in the non-kitchen alarms. Because the evaluation only recorded the location of alarms that were currently present, this study cannot determine the percentage of the alarms originally installed in the kitchen that were missing and how this percentage compares to alarms installed in other rooms.

The brand of the alarm also had a significant influence on the long-term performance. Inspectors were asked to fill in a text field with the name of the brand of alarm based on either the original installation report or the name on the observed alarm. The data collection form did not require the inspector to record an exact model name or number.

Inspectors recorded a brand of alarm for 81% of the alarms inspected. The complete list of alarms is presented in Table 8. Out of all alarms, Brand C (39%) and Brand F (21%) were the most common brands installed. Brand C was the most frequently installed brand in Georgia and Virginia, while Brand F was the most frequently installed brand in Kentucky and Washington. Brand G was the most frequently reported brand used in Oklahoma, although no brand was specified for almost half of their evaluated alarms. Inspectors were not required to record the model of alarm. Some of the brands listed were manufactured by the same company (Brand A and Brand D; Brand E and Brand G) but no analysis by manufacturer was conducted.

Controlling for other factors, the Brand C alarms were more likely to function than Brand B, Brand F, Brand G and Brand D (Table 9). Brand A alarms were more likely to function than Brand B and Brand F. There were no significance differences between the other alarms.

Table 9: Odds-ratios of Alarm Functionality by Brand of Alarm (Factor 1 to Factor 2) based on Multivariate Analysis

	Factor 1					
Factor 2	Brand A	Brand B	Brand C	Brand D	Brand E	Brand F
Brand A	-	-	-	-	-	-
Brand B	13.99 p=0.060*	-	-	-	-	-
Brand C	1.65 p=0.677	0.12 p=0.006**	-	-	-	-
Brand D	4.45 p=0.228	0.32 p=0.173	2.69 p=0.021**	-	-	-
Brand E	5.74 p=0.163	0.41 p=0.433	3.47 p=0.168	1.29 p=0.786	-	-
Brand F	12.91 p=0.022**	0.92 p=0.935	7.81 p<0.002**	2.90 p=0.147	2.25 p=0.366	-
Brand G	6.06 p=0.161	0.43 p=0.393	3.67 p=0.069*	1.36 p=0.685	1.06 p=0.954	0.47 p=0.369

*=P-value < 0.10 **=P-value < 0.05

For the alarms that failed, a dead or missing battery was the most common reason for failure (59%). For the two poorest performing brands, Brand B (82% failure) and Brand F (73%), over three-quarters of the failures were attributed to dead or missing batteries. For two of the better performing brands, Brand A (20% failure) and Brand G (29%), less than half of the failures were attributed to dead or missing batteries.

The third factor that was associated with alarm performance was the state in which the alarm was installed. After controlling for other factors, alarms installed in Oklahoma were more likely to function than alarms installed in Georgia, Virginia and Washington (Table 10). Alarms installed in Kentucky performed better than alarms installed in Washington.

Table 10: Odds-Ratios of Alarm Functionality by State (Factor 1 to Factor 2) based on Multivariate Analysis

	Factor 1				
Factor 2	Georgia	Kentucky	Oklahoma	Virginia	Washington
Georgia	-	-	-	-	-
Kentucky	0.34 p=0.102	-	-	-	-
Oklahoma	0.17 p<0.001**	0.50 p=0.313	-	-	-
Virginia	0.80 p=0.501	2.38 p=0.190	4.76 p=0.003**	-	-
Washington	1.22 p=0.811	3.62 p=0.074*	7.25 p=0.015**	1.52 p=0.617	-

*=P-value < 0.10 **=P-value < 0.05

Although there appeared to be possible associations between alarm functionality and (1) the presence of a smoker in the home; (2) the presence of a resident who was there at alarm installation; and (3) the ownership status of the dwelling, these factors were **not significant** either when other factors were controlled or when they were considered independently. Alarms were present but not functional at 57% of smokers' homes versus 47% of non-smoker homes. Alarms were present but not functional at 56% of homes where the resident differed at alarm installation versus 43% of homes where the resident still resided when the alarms were installed. Finally, alarms were present but not functional at 54% of rental homes versus 43% of homes with owner-occupants. Table S-1 in Appendix 3 provides information about the bivariate odds ratios and tests of significance for all potential factors related to alarm functionality.

The influence of state and brand of alarm was related to each other and could have had an impact on the effects that were observed by state or by brand. For example, all Brand G alarms in this evaluation were installed by the state of Oklahoma. In the bivariate analyses, the Brand G alarms performed well compared to other brands and Oklahoma performed well compared to other states. The multivariate model results presented in Table 7 tend to discount the effect of the Brand G alarms in favor of the Oklahoma state effect. This is a plausible finding, but in the interest of fully exploring the brand and state effects, the multivariate model was run without state and then without brand. The results are provided in Tables S-2, S-3, and S-4 in Appendix 3.

Without state in the model, the Brand G alarms performed better than the Brand D and Brand F, and it was not significantly different from Brand C. Without brand in the model, Virginia performed better than Washington but was not significantly different from Oklahoma, while Kentucky performed worse than Oklahoma, but was not significantly different from Washington. The other results from the tests of significance were the same, although the sizes of their odds ratios were modified.

3.5 <u>Influence of Other Factors on Alarm Loss</u>

A multivariate logistic analysis was conducted to consider which factors significantly predict whether a home was missing a program smoke alarm 8-10 years after installation. Four factors that were potentially related to the presence of alarms were considered: state where installed; original resident lived in the home when the alarms were installed; ownership status (i.e., rental, owner-occupied); and smoker present. Homes with any missing alarms (n=154 /40%) were compared to homes without missing alarms (n=230 /60%). Variables found to be significant as well as the model parameter estimates are presented in Table 7.

Controlling for other factors, rental properties were more likely to have at least one alarm missing 8-10 years later than owner-occupied dwellings. The odds of any missing alarms were 48% *lower* when the unit was owner-occupied than when it was a rental. Fifty-five percent (55%) of alarms installed in rental properties were missing, compared to 29% of alarms installed in owner-occupied properties. Homes inhabited by a different resident than at the time of alarm installation were more likely to have an alarm missing than in homes inhabited by the same resident. The odds of any missing alarms were 82% *higher* when the resident at the time of the original installation had moved. Fifty-six percent (56%) of alarms installed were missing in properties where the person at installation moved, compared to 27% of alarms in homes where the resident remained. The state where the alarm was installed was also significantly associated with the probability that the alarm would be removed from the home. After controlling for other factors, alarms installed in Washington were more likely to be missing than those installed in each of the other states (Table 11).

Table 11: Odds-ratios of Missing Alarms by State (Factor 1 to Factor 2) based on Multivariate Analysis

	Factor 1				
Factor 2	Georgia	Kentucky	Oklahoma	Virginia	Washington
Georgia	-	-	-	-	-
Kentucky	1.67 p=0.226	-	-	-	-
Oklahoma	1.40 p=0.276	0.84 p=0.690	-	-	-
Virginia	1.60 p=0.120	0.96 p=0.920	1.14 p=0.692	-	-
Washington	0.23 p<0.001**	0.14 p<0.001**	0.17 p<0.001**	0.15 p<0.001**	-

*=P-value < 0.10 **=P-value < 0.05

Overall, homes of smokers were more likely to have missing alarms than homes of nonsmokers (Table S-5, Appendix 3), but this was not true when other effects were controlled. Although 39% of alarms were missing when the home was occupied by a smoker, compared to 29% in homes of nonsmokers, this result was not consistent across states. In Kentucky, more alarms were missing in the homes of nonsmokers, while in Washington there was a high percentage of missing alarms (58%) regardless of smoker status. As was done with the functionality model, the model for missing alarms was also run without state as a potential variable in the model. The results for the remaining variables were very similar to the original model (Table S-6, Appendix 3 v. Table 7).

3.6 Type of Battery Present

At an early site visit for this evaluation, the evaluators noted that the battery in the alarm was a standard non-lithium nine-volt battery. The evaluators revised the data collection forms two weeks after the start of the data collection period so that inspectors could record whether the battery found in the alarm was lithium-powered. The CDC reported that all of the alarms installed in this program had lithium-powered batteries. However, many, if not all of the alarms at the time of installation came with battery chambers that allowed the resident to replace the battery. At some point during the 10-year period, residents may have replaced the lithium-powered battery in their alarms because the battery had failed, they needed the battery for another purpose, or as a preventive measure following standard fire safety public service announcements. Anecdotally, at two of the homes visited, the residents reported that they had replaced the battery in their unit within the past six months because the alarm was “chirping.”

Of the 381 alarms that were present at the time of evaluation, inspectors reported that the battery was missing from 30 of the alarms (8%). Of the remaining 351 alarms, 73 (21%) contained lithium-powered batteries, 169 (48%) had non-lithium powered batteries, and the inspectors did not report a battery-type for the remaining 109 alarms (31%) (Table 12). Forty-seven percent (47%) of the alarms with non-lithium-powered batteries had failed at inspection, compared to 22% of the alarms with lithium-powered batteries. Half of the alarms with no report of a battery type failed. Twenty percent (20%) of the alarms with non-lithium-powered batteries had dead batteries, compared to 14% of the alarms with lithium-powered batteries. Thirty-one percent (31%) of the alarms with no report of a battery type had a dead battery.

Table 12: Type of Battery Present in Alarms by State

State	Battery Type	Number of Alarms w/Batteries	% Non-Functional Alarms	% Dead Battery
Georgia	Lithium	18	33.3% (n= 6)	22.2% (n= 4)
	Non-Lithium	30	63.3% (n=19)	46.7% (n=14)
	Not Reported	33	51.5% (n=17)	39.4% (n=13)
Kentucky	Lithium	-	-	-
	Non-Lithium	-	-	-
	Not Reported	60	53.3% (n=32)	35.0% (n=21)
Oklahoma	Lithium	32	15.6% (n= 5)	6.3% (n= 2)
	Non-Lithium	47	31.9% (n=15)	6.4% (n= 3)
	Not Reported	4	50.0% (n= 2)	0.0% (n= 0)
Virginia	Lithium	23	21.7% (n= 5)	17.4% (n= 4)
	Non-Lithium	72	41.7% (n=30)	9.7% (n= 7)
	Not Reported	4	25.0% (n= 1)	0.0% (n= 0)
Washington	Lithium	0	-	-
	Non-Lithium	20	80.0% (n=16)	45.0% (n= 9)
	Not Reported	8	25.0% (n= 2)	0.0% (n= 0)
TOTAL	**Lithium**	**73**	**21.9% (n=16)**	**13.7% (n=10)**
	Non-Lithium	**169**	**47.3% (n=80)**	**19.5% (n=33)**
	Not Reported	**109**	**49.5% (n=54)**	**31.2% (n=34)**

3.7 Presence of a Carbon Monoxide Alarm

As a supplemental analysis, inspectors observed the home for the presence of a carbon monoxide (CO) alarm. Out of the 427 homes evaluated, 34 (8%) had a CO alarm (Table 13). Half of the homes with CO alarms were in Oklahoma, and another quarter were in Virginia. Eighteen (18%) percent and 8% of evaluated homes in Oklahoma and Virginia, respectively, had CO alarms.

Table 13: Presence of Carbon Monoxide Alarms by State

State	Number of Dwellings Evaluated	Number and Percent of Dwellings with CO Alarm
Georgia	152	4 (2.6%)
Kentucky	40	2 (5.0%)
Oklahoma	93	17 (18.3%)
Virginia	100	8 (8.0%)
Washington	42	3 (7.1%)
TOTAL	**427**	**34 (8.0%)**

4. Discussion

The evaluation examined whether 10-year smoke alarms do in fact last 10 years. This evaluation observed a survival rate of 33%. The main reason for loss of the alarms was the physical removal of the device (37%). Without the benefit of further discussion with the current or past resident or property owner, this study cannot determine the cause of the removal and whether the alarm was functional at the time of removal. This evaluation found that there is an association between missing alarms and rental properties, and missing alarms and homes where the resident changed since the time of alarm installation. In other words, smoke alarms are less likely to remain in properties that experience turnover of occupancy. There are a number of possible reasons for this: previous occupants may have taken the alarms with them when they moved out, landlords may have removed them during property turnover/maintenance (e.g., painting), or new residents removed them upon occupancy.

This study also found that over half the alarms installed in Washington were missing at the time of evaluation. There is no apparent reason why homes in Washington would be more susceptible to alarm loss than homes in the other four states evaluated.

For the alarms that were present at the time of evaluation, just over half (53%) of the alarms were operational. Although less than 10% of the alarms that were still present were installed in kitchens, the findings suggest that kitchen installation is not optimal because alarms in these locations have a higher failure rate. Alarms installed in kitchens have a higher percentage of missing or dead batteries suggesting that residents are more likely to either disable or not fix a disabled unit in kitchens. Because burning food is a fairly routine occurrence in kitchens, the alarms may have been more likely to be disabled as a way to avoid false or nuisance alarms.

The findings also suggest that the Brand C and Brand A alarms, and possibly the Brand G alarms that were installed 8-10 years ago performed better than most other brands. This finding is not necessarily applicable to brands purchased today because lithium-powered smoke alarm technology has advanced since the late 1990s. For instance, many alarms being installed under the current SAIFE grants have sealed batteries which do not allow a resident to remove the lithium battery or replace it with a non-lithium battery. Given that 70% of the alarms where the inspector noted the battery type had non-lithium batteries, the sealed battery unit appears to be an important advancement in smoke alarm design.

We could not determine why the lithium batteries were replaced. Anecdotally, two residents reported during site visits that they had replaced the battery within six months of the evaluation visit because the battery in the unit was nonfunctional. If the batteries being replaced were the original lithium batteries, then this might suggest that the lithium batteries lasted only 8-9 years instead of the 10-year design life. However, it is quite possible that in other homes, residents removed the original batteries while they were still functional. Looking solely at the 73 alarms that had lithium batteries at the time of evaluation, 78% were still functional.

As with missing alarms, the evaluation observed a significant difference in performance by state even after controlling for alarm location and brand and trying to control for ownership, resident tenure and the presence of a smoker. Alarms tended to function better in Oklahoma and worse in Washington. We do not have a strong hypothesis why this was observed. It could be that public education efforts in these states differ or it could simply be due to a random effect.

The data reported in the results section only include dwellings where the inspector recorded the number of program alarms installed. NCHH excluded data from 43 dwellings, including 37 in Georgia, because they lacked this information. During follow-up conversations with the inspectors in Georgia, NCHH learned that in the most of these dwellings, the inspectors did not locate a program alarm at the property. Based on this supplemental information, a much higher percentage of homes in Georgia were missing all program alarms than described in this report. Potentially up to 58% of the homes where program alarms were installed in the state had all alarms missing at evaluation. This would suggest that the percentage missing in Georgia may have approached the percentage missing in Washington (63%).

Without an interview, inspectors were more likely leave questions concerning the ownership status, whether the resident at installation remained at the property, and whether a resident smoked blank. Inspectors also lacked information about the type and location of alarm installation for all dwellings. Yet, even without this information, this evaluation had sufficient information to investigate the impact of these factors on alarm performance.

The challenges of enrolling homes in rural areas led to a smaller proportion of rural homes in the study. A larger sample size would have been useful to better understand what was happening in each state, especially in Washington. The analysis found that both alarm performance and presence was significantly different between Washington and Kentucky, suggesting that the outcomes observed in Washington were not due to their rural location.

Another potential limitation of this study is that local inspectors were employed so regional differences could possibly have been influenced by differences in inspector performance. For example, there appears to be a large difference in subjective measures of the study such as the percentage of dwellings with unknown smoker status. However, most of the observations in this evaluation were highly objective (e.g., alarm present, alarm functional, battery present, lithium battery present), reducing the potential bias of the local inspectors. During field visits, NCHH did not observe any differences between inspectors.

A final limitation is that this evaluation was designed to specifically assess the performance of smoke alarms installed as part of the original SAIFE grants. Inspectors were instructed not to systematically report the presence or functionality of alarms that were not part of the original installation program. Inspectors could report on the presence of non-program alarms in a comments box, and there were a number of reports of non-program smoke alarms in the dwellings. Because these data were not systematically reported, it is not possible to estimate with confidence the number of homes with any working smoke alarms at the time of the evaluation, but we know that the percentage of homes with working alarms is higher than the 38% documented in this report. It is possible that there is an indirect benefit from the original SAIFE program in the form of increased use of such alarms that were not paid for by the program. In other words, the SAIFE program may have encouraged increased use of the alarms by promoting more familiarity with what was then new technology. Future evaluation efforts might attempt to capture this indirect effect.

Most of the inspectors participating in this evaluation were local fire officials. They were thankful to NCIPC for the opportunity to return to the dwellings and evaluate the fire protection at these homes. Many did not realize how many of these homes no longer had working alarms and were glad to have a reason to enter the homes and provide new alarms to the residents.

5. Conclusions/Recommendations

1) While many of the 10-Year Smoke Alarms installed 8-10 years ago did not routinely survive for full evaluation period, one-third did. *Fire departments should consider adding a provision to installation agreements which states that they will schedule a visit or visits to homes after installation to assess the alarm functionality. Reassessments are especially important in dwellings prone to occupant turnover such as rental properties. Code inspectors and occupancy certification program could also include standard inspections.*
2) The main reason that alarms did not survive was removal of the smoke alarm. *Grant recipients should consider installing smoke alarms that have tamper resistant features. CDC should consider evaluating why people remove or disable alarms in order to develop better retention strategies. For example, lease agreements or sales contracts should make it clear that the alarms are part of the building and are not to be removed upon turnover or sale.*
3) Many smoke alarms installed 8-10 years no longer had lithium batteries at the time of evaluation. *Grant recipients should strongly consider installing smoke alarms that have sealed battery chambers and end-of-life indicators. Manufacturers should consider making smoke alarms with lithium batteries incompatible with non-lithium batteries to improve long-term performance and retention.*
4) Seventy-eight percent (78%) of smoke alarms that had lithium batteries at the time of evaluation were operational. *This finding offers support to the assumption that lithium*

powered smoke alarms are a viable option, ***if*** *they remain in-place with lithium batteries.*

5) Smoke alarms were more commonly disabled in kitchens. *Smoke alarm installation programs must train their staff to select alternative locations for alarm placement. The National Fire Protection Association does not recommend installation in kitchens, bathrooms, or garages.*
6) Two or three brands of alarms that were installed 8-10 years ago performed better than other models. ***This finding should not be used to judge current brands of alarms because alarm technology has advanced over the past 10 years.*** *However, if more information is available from the grantees about the models installed, it could be valuable to examine the features that these two brands had 8-10 years ago to see if there are any lessons that can be learned from them.*
7) Eight percent (8%) of homes that were evaluated had carbon monoxide (CO) alarms. W*hen programs visit homes to provide smoke alarms, it would be a good opportunity to offer CO alarms. From 1999-2004, an average of 439 persons died annually from unintentional, non-fire-related CO poisoning.*[12]
8) The results demonstrate that evaluation and follow-up efforts are essential. *Fire departments or other local authorities should routinely evaluate how well their local smoke alarm efforts are working.*

APPENDIX 1

Evaluation of the “10-Year” Smoke Alarm Project

By signing this participation agreement:

X I understand that program representatives will inspect my existing smoke detector(s), correct any problems when possible, and/or install a new smoke detector(s) or battery(ies).

X I understand that in order to receive a new smoke detector or replacement battery, I must allow the program representative to install it.

X I understand that for a smoke detector to be effective, it should be tested monthly, its batteries may need to be changed, and it should be kept clean. I or other persons in this home should check the smoke detector(s) regularly to determine if it is working. No person or agency associated with this program is responsible for the maintenance of the smoke detector(s) in this residence.

X I hold the program and its participating individuals and agencies harmless in the event the smoke detector(s) or battery(ies) malfunctions.

X I understand that my participation in this program is voluntary. I have a right to privacy and my identity will not be used by this program in any way.

Name (please print): ____

Address: ____

City: ____________________ State _______ ZIP Code _________________

Phone Number ____

Signature of Resident ______________________________ Date: _______________

Witnessed by: ______________________________ Date: _______________

APPENDIX 2

National Center for Healthy Housing
Evaluation of the "10-Year" Smoke Alarm Project
Smoke Alarm Visual Inspection Form

Date of Inspection: ___/___/___

SECTION I – RESIDENCE LOCATION

Name of Resident ____ County ______________________

Street Address ____

City ______________________ State ______________ ZIP Code __________________ Phone Number ______________________

Resident since Original Installation? [ ] Yes [ ] No [ ] Unknown **Type of Residence** [ ] Rental [ ] Owned [ ] Unknown

SECTION II – SMOKE ALARM INSPECTION

Please complete this section carefully. Print legibly.

Number of Original Program Alarms Installed __________________

Number of Original Program Alarms Missing __________________

Alarm Location	Make of Alarm	Does Alarm Currently Have A Lithium Battery	Alarm Functional?	If Alarm Is NOT Functional, Why?	Replaced Alarms?
		[ ]Yes [ ] No	[ ]Yes [ ] No	[ ] No Battery [ ] Dead Battery [ ] Physical Damage [ ] Other	[ ]Yes [ ] No
		[ ]Yes [ ] No	[ ]Yes [ ] No	[ ] No Battery [ ] Dead Battery [ ] Physical Damage [ ] Other	[ ]Yes [ ] No
		[ ]Yes [ ] No	[ ]Yes [ ] No	[ ] No Battery [ ] Dead Battery [ ] Physical Damage [ ] Other	[ ]Yes [ ] No
		[ ]Yes [ ] No	[ ]Yes [ ] No	[ ] No Battery [ ] Dead Battery [ ] Physical Damage [ ] Other	[ ]Yes [ ] No
		[ ]Yes [ ] No	[ ]Yes [ ] No	[ ] No Battery [ ] Dead Battery [ ] Physical Damage [ ] Other	[ ]Yes [ ] No

Evidence of Smoker in Home (ex. ash trays, smell of smoking etc)? [ ] Yes [ ] No [ ] Can not determine

SECTION III – CO ALARM INSPECTION

Please complete this section carefully. Print legibly. Include all CO alarms in the residence.

CO Alarm Present? [ ] Yes [ ] No If "Yes", please complete table below.

Alarm Location	Battery Backup	Peak Level Recorder (Digital Display)	End of Life Indicator	Age (General)
	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	
	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	
	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	[ ]Yes [ ] No [ ] Unknown	

Appendix 3: Supplemental Data Tables

Table S-1: Odds-Ratios of Smoke Alarm Functionality based on *Bivariate Analysis*

Predictor / Overall Test of Significance	Factor 1	Factor 2	Odds-Ratio of Factor 1 to Factor 2	P-value for test that odds-ratio = 1
Smoker Present	No	Yes	1.45	0.220
Original Resident	No	Yes	0.60	0.114
Location of Alarm	Kitchen	Non-Kitchen	0.34	0.005**
Ownership Status	Owner-occupied	Rental	1.59	0.129
Brand of Alarm p<0.001**	Brand A	Brand B	18.00	0.014**
	Brand A	Brand C	2.19	0.377
	Brand A	Brand D	5.00	0.090*
	Brand A	Brand E	5.33	0.115
	Brand A	Brand F	10.55	0.012**
	Brand A	Brand G	1.65	0.615
	Brand B	Brand C	0.12	0.010**
	Brand B	Brand D	0.28	0.149
	Brand B	Brand E	0.30	0.2226
	Brand B	Brand F	0.59	0.539
	Brand B	Brand G	0.09	0.010**
	Brand C	Brand D	2.28	0.055*
	Brand C	Brand E	2.44	0.164
	Brand C	Brand F	4.82	<0.001**
	Brand C	Brand G	0.75	0.582
	Brand D	Brand E	1.07	0.929
	Brand D	Brand F	2.11	0.148
	Brand D	Brand G	0.33	0.073*
	Brand E	Brand F	1.98	0.333
	Brand E	Brand G	0.31	0.132
	Brand F	Brand G	0.16	0.002**

Table S-1: Odds-Ratios of Smoke Alarm Functionality based on Bivariate Analysis (con't)				
Predictor / Overall Test of Significance	Factor 1	Factor 2	Odds-Ratio of Factor 1 to Factor 2	P-value for test that odds-ratio = 1
State	GA	KY	1.02	0.956
p<0.001**	GA	OK	0.30	<0.001**
	GA	VA	0.53	0.037**
	GA	WA	2.39	0.114
	KY	OK	0.29	0.007**
	KY	VA	0.52	0.116
	KY	WA	2.33	0.172
	OK	VA	1.77	0.108
	OK	WA	7.96	<0.001**
	VA	WA	4.50	0.007**

*=P-value < 0.10 **=P-value < 0.05

Table S-2: Logistic Model Parameter Estimates for Alarm Functioning Models without State or Brand

Predictor	Level	Without State			Without Brand		
		Odds Ratio	P-value	Overall p-value	Odds Ratio	P-value	Overall p-value
Intercept		2.520	0.040	0.040	0.373	0.008	0.008
Make of Alarm	Unknown	0.487	0.159	<0.001	-	-	-
	Brand A	1.587	0.558		-	-	
	Brand B	0.093	0.009		-	-	
	Brand C	0.775	0.599		-	-	
	Brand D	0.335	0.066		-	-	
	Brand E	0.368	0.267		-	-	
	Brand F	0.171	0.001		-	-	
	Brand G	1.000	.		-	-	
State	GA	-	-	-	2.267	0.056	0.001
	KY	-	-		2.415	0.049	
	OK	-	-		7.330	<.0001	
	VA	-	-		4.109	0.001	
	WA	-	-		1.000	.	
Room type	Unknown	0.512	0.638	0.116	1.181	0.907	0.089
	Kitchen	0.454	0.058		0.460	0.060	
	Non-Kitchen	1.000	.		1.000	.	

Table S-3: Odds-ratios of Alarm Functionality by Brand of Alarm (Factor 1 to Factor 2) based on *Multivariate Analysis* *__without State__*

	Factor 1						
Factor 2	Brand A	Brand B	Brand C	Brand D	Brand E	Brand F	Brand G
Brand A	-	-	-	-	-	-	-
Brand B	17.01 p=0.016**	-	-	-	-	-	-
Brand C	2.05 p=0.420	0.12 p=0.010**	-	-	-	-	-
Brand D	4.74 p=0.103	0.28 p=0.152	2.31 p=0.059**	-	-	-	-
Brand E	4.31 p=0.163	0.25 p=0.164	2.10 p=0.224	0.91 p=0.894	-	-	-
Brand F	9.30 p=0.017**	0.55 p=0.487	4.54 p<0.001**	1.96 p=0.200	2.16 p=0.253	-	-
Brand G	1.59 p=0.643	0.09 p=0.011**	0.78 p=0.630	0.34 p=0.085*	0.37 p=0.191	0.17 p=0.003**	-

*=P-value < 0.10 **=P-value < 0.05

Table S-4: Odds-Ratios of Alarm Functionality by State (Factor 1 to Factor 2) based on *Multivariate Analysis* *__without Brand__*

	Factor 1				
Factor 2	Georgia	Kentucky	Oklahoma	Virginia	Washington
Georgia	-	-	-	-	-
Kentucky	0.94 p=0.879	-	-	-	-
Oklahoma	0.31 p<0.001**	0.33 p=0.015**	-	-	-
Virginia	0.55 p=0.054*	0.59 p=0.207	1.78 p=0.108	-	-
Washington	2.27 p=0.136	2.42 p=0.150	7.33 p<0.001**	4.11 p=0.011**	-

*=P-value < 0.10 **=P-value < 0.05

Table S-5: Odds-Ratios of Missing Smoke Alarms based on *Bivariate Analysis*

Predictor / Overall Test of Significance	Factor 1	Factor 2	Odds-Ratio of Factor 1 to Factor 2	P-value for test that odds-ratio = 1
Smoker Present	No	Yes	0.60	0.042**
Original Resident	No	Yes	2.53	<0.001**
Ownership Status	Owner-occupied	Rental	0.39	<0.001**
State	GA	KY	2.03	0.078*
p<0.001**	GA	OK	1.67	0.080*
	GA	VA	1.47	0.179
	GA	WA	0.25	<0.001**
	KY	OK	0.82	0.644
	KY	VA	0.72	0.436
	KY	WA	0.12	<0.001**
	OK	VA	0.88	0.678
	OK	WA	0.15	<0.001**
	VA	WA	0.17	<0.001**

*=P-value < 0.10 **=P-value < 0.05

Table S-6: Logistic Model Parameter Estimates for Any Missing Alarms without State

Predictor	Level	Odds Ratio	P-value	Overall p-value
Intercept		0.812	0.452	0.452
Resident since original installation	Unknown	1.035	0.943	0.924
	No	1.791	0.032	
	Yes	1.000	.	
Type of residence	Unknown	1.236	0.678	0.034
	Owned	0.529	0.022	
	Rental	1.000	.	

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