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Home Cooking Fire Mitigation: Technology Assessment. Final Report

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Prepared by:
Joshus Dinaburg
Daniel T. Guttuk
Hughes Associates, Inc.
3610 Commerce Drive, Suite 817
Baltimore, MD 21227-1652

Prepared for:
The Fire Protection Research Foundation
One Batterymarch Park
Quincy, MA 02169-7471

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Notice

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Home Cooking Fire Mitigation: Technology Assessment

Final Report

Prepared by:

Joshua Dinaburg
Daniel T. Gottuk, Ph.D., P.E.
Hughes Associates, Inc.

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

FOREWORD

Cooking related fires are a leading cause of U.S. fire loss. Beginning in the mid 1980's, the National Institute of Standards and Technology, Consumer Product Safety Commission, and the home appliance industry undertook a comprehensive review[1] of strategies to mitigate death, injury and property loss from cooking fires with a focus on cooking range technologies. In February of 2010, a Vision 20/20 workshop on this topic was convened in Washington D.C. Participants recommended that an additional study be undertaken to identify the barriers to the utilization of these technologies and to develop an action plan towards improving cooking fire safety.

The Fire Protection Research Foundation has been asked by the National Institute of Standards and Technology to develop an action plan to mitigate loss from home cooking fires by investigating safety technologies related to home cooking. Elements of the study include an in-depth assessment of cooking fire scenarios, a review of current and emerging technologies, and development of an assessment methodology to consider the utility and effectiveness of mitigation technologies against a range of fire and use scenarios and other criteria. On July 14, leaders in the fire safety community met together in Baltimore Maryland to review the results of the Foundation study and to develop an action plan for implementation of these technologies.

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

[1] CPSC Study (with AHAM Support): "Technical, Practical, and Manufacturing Feasibility of Technologies to Address Surface Cooking Fires." May 22, 2001. Arthur D. Little

Home Cooking Fire Mitigation: Technology Assessment

Project Technical Panel

Jennifer Cleary, Association of Home Appliance Manufacturers (AHAM)
Jim Crawford, Vision 20/20
Thomas Fabian, Underwriters Laboratories Inc.
Jack Jordan, State Farm Insurance Companies
Mike Love, Vision 20/20
Daniel Madrzykowski, National Institute of Standards and Technology
Wayne Morris, Association of Home Appliance Manufacturers (AHAM)
Andrew Trotta, U.S. Consumer Product Safety Commission

Project Sponsor

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Project Contractor

Joshua Dinaburg, Daniel Gottuk, Hughes Associates, Inc.
Marty Ahrens, John Hall, NFPA

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HOME COOKING FIRE MITIGATION: TECHNOLOGY ASSESSMENT

Prepared for

Kathleen Almand
The Fire Protection Research Foundation
1 Batterymarch Park
Quincy, MA 02169-7471
Ph. 617-984-7282

Prepared by

Joshua Dinaburg and Daniel T. Gottuk, Ph.D., P.E.
Hughes Associates, Inc.
3610 Commerce Drive, Suite 817
Baltimore, MD 21227-1652
Ph. 410-737-8677 FAX 410-737-8688

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EXECUTIVE SUMMARY

Cooking-equipment related fires are a leading cause of U.S. fire loss. The National Fire Protection Association reports that in 2003-2006, for example, there were 150,200 reported home cooking related fires per year (40% of all reported home fires), with associated annual losses of 500 civilian deaths (17% of home fire deaths), 4,700 civilian injuries (36% of home fire injuries), and $756 million in direct property damage (12% of home fire damages).

Beginning in the mid 1980's, the National Institute of Standards and Technology, Consumer Product Safety Commission, and home appliance industry undertook a comprehensive review of strategies to mitigate death, injury and property loss from cooking fires. All strategies were engineering strategies defined by a condition to be detected (e.g., overheat of pan or food in pan, absence of person actively engaged in cooking process, early-stage fire on stovetop) and an action to be taken (e.g., shut off cooking heat, sound alarm, suppress fire). As part of this study, a comprehensive review of existing technologies was done by Arthur D. Little. The result was a report that summarized pros and cons in terms of reliability, effectiveness, and important side effects, including customer acceptance and impact on cooking effectiveness. The ADL study summarized these results qualitatively, less so quantitatively, and looked at some variations by fire scenario but did not examine results systematically by scenario. The work concluded that pan contact temperature sensors represented the most promising concept, but that "the current sensor approach is not technically feasible due to a lack of reliability and durability." The development committees decided not to pursue standards changes.

In February of 2010, a Vision 20/20 workshop on this topic was convened in Washington D.C. Participants recommended that a study be undertaken to identify the barriers to the utilization of these technologies and to develop an action plan towards improving cooking fire safety.

This report presents the results of a study commissioned by the National Institute of Standards and Technology whose objective was to develop an action plan to mitigate loss from home cooking fires by furthering the implementation of proven effective safety technologies related to home cooking. The study was to focus particularly on prevention technologies suitable for use on or with home cooking appliances. The study was overseen by a project technical panel consisting of stakeholder leaders, and consists of a literature and technology review; the development of an enhanced technology evaluation methodology, building on the ADL study described above to include a basis in an in-depth review of cooking fire statistics; and the evaluation of currently available technologies using this methodology. A complete table of assessed technologies and total scores, considering the prevention of fire related deaths, impacts on cooking, and the costs and conveniences associated with their use is shown in Figure ES-1. In addition, a review of installations of a stove top retrofit sensor – type technology (Safe-T Element) was conducted.

The project culminated with a one day workshop of 35 leaders from the kitchen appliance, fire service, and user communities who met to review the above findings and identify gaps in information. An action plan was developed.

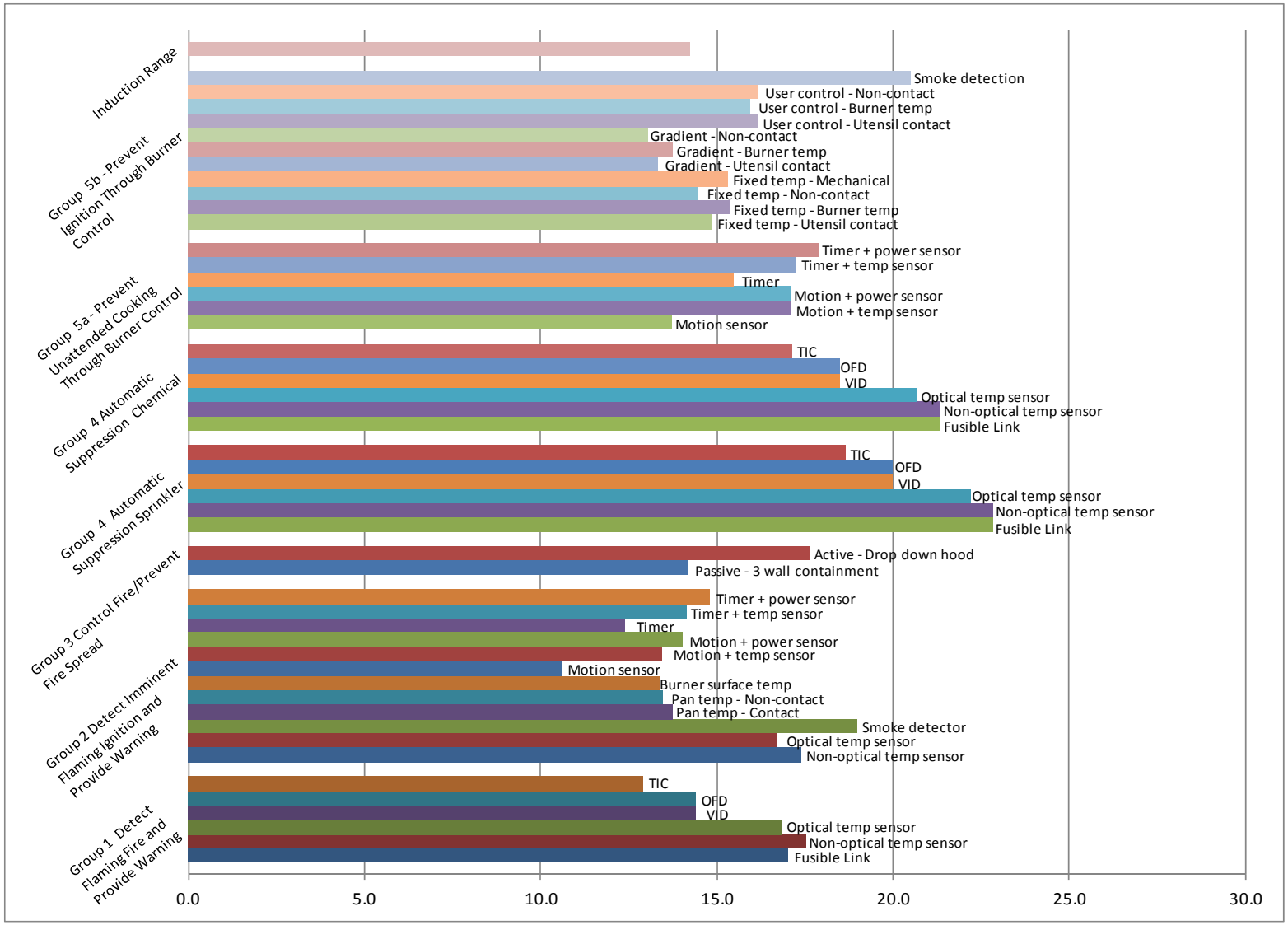

Figure ES-1 – Summed scores for all evaluated stovetop cooking fire prevention technologies, with regard to prevention of fire deaths, impacts on cooking performance, and the costs and convenience related issues of using the technologies (higher scores indicate overall more desirable).

TECHNOLOGIES TO MITIGATE HOME COOKING FIRES: KEY ACTION ITEMS

Research

- Develop standard fire scenarios and create test methods and performance criteria which can feed into standards development
- Improve understanding of pre-ignition detection
  - Research time to detection vs. time to ignition
  - Further research on pre-ignition indicators
- Conduct societal cost/benefit study

Product Development

- Pursue a multi-sensor or multi-threshold approach.
- Product development should have a specific design focus such as a product specifically designed for the:
  - Type of range (gas, electric, flat top, or induction)
  - Specific population (elderly, low income, students)
  - Items first ignited (clothing, oil)
  - High risk cooking such as deep fat fryers, high heat cooking

Technology Transfer

- Standard performance criteria should be developed and integrated in to UL 858(electric) and UL Z2121(gas) as supplemental requirements for fire mitigation which would receive a special listing (gold star)
- Market as an option for consumer choice
- Consumer education

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1.0 BACKGROUND

Surface cooking fires remain a leading cause of U.S. fire incidents, injuries, property loss, and death despite continued research efforts to study and develop technology to lessen the inherent risks associated with the elevated temperatures involved in cooking. During 2004–2008, ranges accounted for 59% of the total reported home cooking equipment fires while accounting for 89% of deaths and 77% of injuries (Ahrens, 2010).

Primary efforts have remained focused upon identifying potential technological solutions to prevent the accidental ignition of both cooking and non-cooking materials due to cooking equipment. The feasibility of technological devices to mitigate the extent of the problem has been investigated in the form of concepts and patents, laboratory testing, and relatively widespread consumer installations.

Potential technologies were previously identified and assessed with regard to fire protection performance and various other product features for the Consumer Product Safety Commission (CPSC) and the Association of Home Appliance Manufacturers (AHAM) by Arthur D. Little (ADL) in 2001 (ADL, 2001). Several potentially feasible protection technologies or concepts were identified, including monitoring and controlling the temperature of objects on range tops and preventing unattended cooking through motion sensors. This report is intended to serve as an update of the status of the development of such technologies over the past decade. In addition, the status of potential safety devices developed or implemented since the initial report have been reviewed.

A primary difference between this evaluation and the previous CPSC/AHAM study will be in the assessment methodology. The previous CPSC/AHAM study was primarily qualitative in the analysis of the fire protection features and the consumer features for potential fire mitigation technologies. This analysis takes advantage of a fire incident data analysis (conducted as a parallel study to this effort) to statistically determine the influence of potential technologies upon the actual residential stovetop cooking fire scenarios.

2.0 OBJECTIVE

As determined during the initial CPSC/AHAM work by ADL, the intent of a technology assessment is to identify promising technological options that are capable of reducing the number of home cooking fires or reducing the extent of home cooking fire losses without the need for a person to ever actively fight any occurring fire. It is intended that the prevention of fires avoid any potential sources of user error and not require major changes in cooking use, performance, or cost. The objective of this study is to develop an action plan to mitigate loss from home cooking fires by furthering the implementation of proven effective safety technologies related to home cooking. The study is to focus particularly on an assessment of the state of the art of prevention technologies suitable for use on or with home cooking appliances.

3.0 APPROACH

This work was accomplished via several stages of research and analysis divided into specific tasks as discussed below.

3.1 Task 1 – Literature Review

This document serves as an update to the previous cooking range fire mitigation investigation performed for the CPSC/AHAM (ADL, 2001). The conclusions of that report were reviewed, and the current status of the promising technologies identified were investigated to determine if products had been further developed and/or tested or if the proposed concepts had been updated, enhanced, or abandoned as feasible protection options. Consistent with the conclusions of the CPSC/AHAM technology assessment, this report does not address technologies that require a user to directly interact with a fire or actively attempt to fight a fire.

A literature search was conducted to identify research projects involving technological concepts, cooking fire ignition factors, the feasibility or effectiveness of potential detection or mitigation technologies/concepts, or the statistical scope of the surface cooking fire problem. The purpose of this review was to determine the extent of the advancement of knowledge about the scope, both of the problems and status of technological product development.

3.2 Task 2 – Identification of Candidate New Technologies

In addition to determining the developmental status of the technologies identified in the CPSC/AHAM report, this work also determined whether innovative new concepts or technologies had been developed over the past decade to address the fire protection issue. This search focused upon new patents filed since the publishing of the CPSC/AHAM report as well as internet searches for existing products. Commercial products were identified, and product literature has been included when available. Based upon the results of the technology update and literature search, a table of potential cooking fire mitigation technologies was created.

3.3 Task 3 – Development of Assessment Methodology

The assessment methodology outlined in the CPSC/AHAM study was updated and enhanced to have a concise, quantitative, and comprehensive format designed to draw attention to information gaps and also to facilitate comparisons and decisions about the most promising technologies. Statistical fire data or quantitative market and test data was incorporated whenever possible in analyzing potential range top cooking fire mitigation technologies. When sufficient data was not available, this analysis has continued to utilize qualitative assessments similar to the previous CPSC/AHAM analysis. The residential cooking fire mitigation and prevention technologies were evaluated on the basis of three general criteria: 1) Fire Protection Effectiveness (FPE), 2) Cooking Performance, and 3) Cost and Convenience. Each technology received a three part score corresponding to each of the three criteria, as each is considered an essential element to the success of a mitigation technology.

3.4 Task 4 – Gap Analysis

The assessment methodology was utilized to develop quantitative comparisons of the proposed technologies. Existing products were assigned to the technology categories with any major changes to the basic technology or unique product features emphasized. The scores generated for the three key criteria were used to rank and analyze the technologies. Any gaps in required information for a complete assessment of a technology or for understanding of a potential fire prevention concept have been noted and referenced for future consideration.

3.5 Task 5 – Workshop

A one day workshop with industry stakeholders (facilitated by the Foundation) was conducted to gain additional input on technology updates, the assessment methodology and preliminary assessment results and to develop an action plan to implement technology solutions for cooking fire mitigation.

4.0 EXISTING LITERATURE

4.1 Previously Assessed Technology Classes

The technology review developed for CPSC/AHAM included numerous technology classes for assessment (ADL, 2001). These technologies were generally sorted by determining the method of fire loss prevention and then by the architecture used to achieve the protection. The CPSC/AHAM technology classes are summarized below in Table 1 and given numerical identification numbers.

Table 1 – Fire Mitigation Technology Classes Assessed by Arthur D. Little (ADL, 2001)

Method of Fire Loss Prevention	Functional Architecture	ID
Detect and Extinguish Fire	Fusible Parts	1
	Non-optical Temperature Sensor	2
	Optical Temperature Sensor	3
	Smoke and Temperature Sensor	4
Detect a Fire – Provide Warning Only	Non-optical Temperature Sensor	5
	Optical Temperature Sensor	6
	Smoke Sensor	7
Contain or Manage Fire	Passive	8
	Active	9
Prevent Unattended Cooking – Warning and Control	Motion Sensor	10
	Motion Sensor and Power Level	11
	Motion Sensor and Temperature Sensor	12
	Power Level Sensor and Timer	13
Prevent Unattended Cooking – Warning Only	Motion Sensor Only	14
	Motion Sensor and Power Level	15
	Power Level Sensor and Timer	16
Prevent Food Ignition in Pan	Electronic Signal Processing, Mode Selection, Pan-contact Temperature Sensor	17
	Electronic Signal Processing, Mode Selection, Non-contact Temperature Sensor	18
	Electronic Signal Processing, Auto-Control to Temperature Threshold, Pan-contact Temperature Sensor	19
	Electronic Signal Processing, Auto-Control to Temperature Threshold, Non-contact Temperature Sensor	20
	No Signal Processing, Mechanical Actuation	21
Boil Dry/Spill-over Sensor and Control	No additional description	22

In the 2001 CPSC/AHAM report, ADL made the following conclusions (ADL, 2001):

- Pan temperature sensors would be feasible options for fire prevention, but reliability and installation are of primary concern.
- Potential effects upon cooking time and quality ranging from very minor to very major are possible depending upon the measurement location and type. Also, contact pan surface temperature measurements could not be implemented for smooth top electric or induction heaters.
- Detection and extinguishing systems are often expensive and require maintenance and installation and also do not prevent fires from starting.
- Motion detectors or reset switches will require significant user behavior modifications and while they present viable safety devices, the market may not desire them due to annoyance and consumer dissatisfaction.

4.2 Subsequent Patents

Since the release of the CPSC/AHAM report, several new U.S. patents and products have been introduced. The new patents are summarized below, including two patents that pre-date the CPSC/AHAM report but were not included as part of the listed and reviewed patents. The term utensil, as commonly used in the patents, refers to pots and pans.

Stove Alarm System (4446444) – 1984 – Nashawaty

- The burner element is only capable of turning on when a utensil is sensed, preventing the accidental powering of burner elements.

Stove timer and automatic cut off system (5854520) – 1998 – Buck and Tibbitt

- When cooking is initiated, a timer with discrete time setting is used to control all the burners and an automatic cutoff system disconnects power after the pre-determined amount of time.

Cooktop control and monitoring system including detecting properties of a utensil through a solid-surface cooktop (6140617) – 2000 – General Electric Company

- A system for detecting utensil properties including presence, size, etc. through a solid-surface cooktop. May be only for monitoring properties or may be used for controlling the energy source.

Appliance Timer (6140620) – 2000 – Aldridge and Stewart

- A timer circuit is used to control a relay that is powering an electric device. When the pre-determined time has passed the timer circuit deactivates the relay, cutting off power to the device.

Acoustic sensing system for boil state detection and method for determining boil state (6236025) – 2001 – General Electric Company

- An acoustic sensing system is used to determine if the contents of a cooking utensil are boiling by detecting acoustic emissions in specific frequencies characteristic of boiling.

Appliance attendance monitoring apparatus (624994) – 2001 – Hoellerich

- A timer assembly is connected to a motion sensor assembly and to a current controller for an electrical appliance. When a person is not detected for the pre-determined amount of time, electrical power is removed from the appliance.

Timer with resettable alarm and automatic turn-off (6323777) – 2001 – Durston and Durston

- A means of removing electrical power to devices after a pre-determined amount of time. An audible or visual warning is used to identify when power is to be removed and a means of manually continuing power flow, such as resetting is provided.

Spring mounted bayonet probe for an electric fryer (6388236) – 2002 – Lyu Jan Co., Ltd.

- An electric burner located within a base includes a bi-metal plate and a temperature probe. When the temperature of the pot is too great, the bi-metal plate makes contact with only one plate and the flow of power to the burner is interrupted.

Methods and systems for cooktop control (6717117) – 2004 –General Electric Company

- A cooktop heater with user controlled temperature settings and computer programmed logic to control the output of the heater.

Electric heater with a sensor preventing no-water heating (6834160) – 2004 – Chen-Lun and Chuan Pan

- A water level probe, sensing electrode, or water level sensor determine if water levels on an electric heating element have dropped below threshold levels, triggering the shutdown of the heater. The sensors are intended to be attached to the heating surface and detect water levels through the changes in electrical potential of the utensil.

Programmable power level control for a cooking appliance (6967314) – 2005 – Maytag Corporation

- A user can select a power level and time duration for a heating element to operate based upon pre-determined levels for performing specific cooking tasks. Multiple subsequent levels and times can be programmed and selected. The power levels and time increments are user controlled, and thus the reliability as a fire mitigation device may be very low.

Automatic stove timer and alarm apparatus and method of use (7002109) – 2006 – Klask

- Audio and visual indicators of a hot stove condition are announced at pre-determined time intervals to continuously remind user of hazardous condition.

Remote reminding system (7196623) – 2007 – Wang

- A remote receiving unit, potentially located in an automobile or other remote location, is used to constantly monitor the status of an electrical appliance and notify the user of undesirable conditions.

System and method of detecting temperature of a cooking utensil over a radiant cooktop (7307246) – 2007 – General Electric Company

- A temperature detector is located to measure the lower surface temperature of a radiant cooktop, where the utensil would be located on the top surface. The sensor is thermally insulated from the radiant heater to ensure an accurate measurement of the surface temperature rather than the heater itself.

Magnetic safety feature for cookware and cooking stoves (7355151) -2008 – Rael

- Cooking utensils are secured to a burner magnetically to prevent accidental knockovers using either electromagnets or permanent magnets.

Temperature-limiting device (7388175) – 2008 – Ceramaspeed Limited

- A bimetallic means is utilized to measure the temperature of a heatable surface and is used to operate a switch at a pre-determined temperature to remove power to the heating element.

Magnetic element temperature sensors (7794142) – 2010 – TSI Technologies, LLC

- Temperature sensors with magnetic properties that alter at set point temperatures, for example the Curie Temperature, are used with a magnetic field and sensor to measure the temperature of a closed loop heating system to control a heating element.

Stove knob timer device (7816818) – 2010 – Sellecchia

- A stove timer produces an audible alarm at a preset time interval when a stove is operating. The alarm gets increasingly aggressive until the reset button is activated.

4.3 Existing Products in Market

Several products have been developed and are currently being sold in the market that meet the general technology classes designated above. Products include suppression systems, motion sensors and alarms to prevent unattended cooking, and contact temperature sensors to prevent food ignitions.

4.3.1 Home Kitchen Suppression Systems

Most kitchen suppression systems are large, expensive, and require extensive installation. For this reason, they are generally designed and intended for commercial kitchen environments. Such products generally consist of fusible links or other temperature sensors installed in exhaust hoods that activate dry or wet chemical suppression. Several products are marketed to residential applications but have very limited sales or function data available. Products developed for this purpose can be qualified according to UL 300A, *Outline of Proposed Method for Fire Testing of*

Extinguisher Units for Residential Range Top Cooking (Underwriters, 1991). These devices may include exhaust hoods, fusible links or other temperature detectors, wet or dry chemical or water based suppression systems, or accessories to cut-off the gas flow or electric current to the burners. In addition to testing of the entire system, each component is also subject to applicable testing per individual UL standards. In general, the test is used to demonstrate that all flames are extinguished without reigniting in 5 minutes and that the temperature of oil in a pan is reduced below the auto-ignition temperature.

Among the simplest of existing, suppression products that is available for residential scale kitchen applications is the StoveTop FireStop. This device consists of a 12 oz. canister of primarily sodium bicarbonate extinguishing agent. The canister attaches magnetically or by a screw connection inside a vent hood above the stove and is activated by the heat of a fire and the chemical release is driven by gravity across approximately 2 burners per canister. The product is applicable for small stove top fires, including those involving grease, but should not be used for deep-fat frying. Testing information presented by John Donovan of State Farm Insurance during the workshop (Appendix E) has indicated a concern of splattering and spreading of a deep oil fire due to the discharge of the system. Each canister costs between $25–50 and has a lifetime of approximately 5 years. In addition, a microhood installation is available when a ventilation hood is not available over the stovetop and these devices retail for approximately $75. This device has been tested by Wyle Laboratories, a nationally recognized testing facility (NRTF) for fire suppression testing guided by UL1254 and UL300 standards but is not UL listed.

4.3.2 Motion Detectors to Prevent Unattended Cooking

The HomeSensor (HSE Uniwire) is a small electric device that detects when an electric stove burner is turned on. Simultaneously, a motion sensor is used to determine if the cook is present. When the stove is on but no user is detected, the sensor begins a 6 minute countdown. If the cook returns and is sensed during the 6 minute window, no action is taken and the stove burner continues to operate normally. If however, the full 6 minutes elapses without detection, the device emits visual and audible warnings for 2 minutes. If the user returns during this time, the stove continues normal operation and begins another 6 minute cycle. If the user does not respond to the alarm signals, the power is cut off to the stove at the end of the 2 minute alarm cycle. Cooking can only be restored by returning all the burner element controls to “OFF” and then restarting the burner.

This device retails for approximately $300 and is marketed as a safety device for the elderly and infirmed. It is only applicable to electric ranges and requires qualified installation. Currently, the producers of this product are developing a version that will be applicable to gas stoves and a product called the CommonSenser, which could be used for electric-space heaters, ovens, coffee pots, or any other plug-in appliance that produces heat and may cause fires if operated unattended.

The StoveGuard is also a motion sensing device that is used to automatically shut off a stovetop when a user is not detected. The StoveGuard can be operated in both “AUTO” and “TIMER” settings. The “AUTO” setting automatically turns off the stove is a user is not detected within the range of approximately 12 ft. of the sensor after a preset time. The default time is one minute, but the time can be user controlled. After shutting off, the stove will automatically turn

back on after a user is detected. The “TIMER” setting allows the user to program the stove to shutoff after a preset time regardless of the detection of a user, and should be considered more as a cooking feature than for safety. The StoveGuard retails for approximately $360 and is available for both electric stoves and installed cooktops. The cooktop model does require professional installation.

4.3.3 Contact Burner Temperature Sensor and Control

Currently, a contact burner temperature sensor and control device is available called the Safe-T-element. This device consists of a solid cast iron plate containing a thermocouple that fits over the top of electric coil burners. Each plate sensor is attached to a relay that cycles the burner power to maintain the temperature of the plate below a preset value of 350°C (662°F) designed to prevent ignition of food or other products on the stovetop. It can be installed on most new electric coil stoves or retro-fit to most existing electric coil stovetops and retails for approximately $200 for a four burner stove plus installation costs.

The device is intended to prevent the ignition of foods, including oils and grease, due to unattended or careless cooking. In addition, the device has been shown to prevent the ignition of other materials on the burner including plastics, cloth and clothing, or other combustibles. Use of the product does require very flat bottom cooking utensils to maintain good contact with the cast iron plate in order to prevent adverse effects on the quality of cooking. The burners do not glow red hot when operating and tend to stay hot longer than plain coil elements after shutdown; both of these conditions may result in contact burns if people are unaware of the hot surface. The device has been listed for use by the Canadian Standards Association (CSA). However, a stovetop that has been retrofitted is not considered CSA certified. Additional test data is available and is summarized in Section 4.4.3 of this report (Underwriters, 2005) (On-Spex, 2010). Additionally, a summary of consumer surveys for this device have been conducted and included in Appendix A.

4.3.4 Over-range Temperature Sensor with Burner Control

The Innohome Stove Alarm SA100 is a non-optical temperature sensor that can be mounted magnetically to an exhaust hood over a cooking range and detect elevated temperatures associated with the stove overheating or from an empty burner left on. The device operates by detecting sudden and rapid changes in temperature, and identifies such occurrences as potential ignition hazards. The sensitivity of the device can be manually controlled through 15 separate levels, allowing the user to customize the response of the alarm. The alarm can be used to remotely activate the Stove Guard SFC201, a device that will cut electricity off to the stove burner elements when an alarm is detected. This device uses an auditory sensor to identify the sound emitted by alarms, and does not require additional wiring. The Stove Guard device can also be activated by the response of other fire alarms, carbon monoxide alarms, or other gas detection alarms. The devices have been listed for use by the European standards organization Conformité Européenne (CE).

4.3.5 Smoke Detection with Burner Control

A product has been developed by Fidepro that uses a smoke detector to control a range burner. The Fidepro intelligent fire detector cuts off electricity to electrical appliances when the smoke detector is activated. It can be installed with a photoelectric smoke alarm or a combination photoelectric and ionization smoke alarm wired to the electrical control device. The smoke alarms are attached to the Fidepro unit that can be used as a shutoff switch for any electrical outlets or appliances, including electric range tops. The electrical control device can also be configured to initiate to other alarm devices, including gas detectors, heat detectors, or other smoke detection devices. This device has is being studied by the European standards organization CENELEC.

4.3.6 Induction Cooktop

Induction heating is a technology that is currently used to produce heat on a stovetop differently than electric coils or smoothtops or gas burners. Induction cooktops use a magnetic field to induce an electric current that produces heating within ferrous (cast iron or stainless steel) cookware. This technology has not been directly designed to serve as a fire protection device, but does include some features that may prevent the ignition of fires on stovetops, and thus is considered as a potential kitchen fire mitigation device for this analysis.

During induction heating, only the cooking utensil (pan or pot) on the burner gets hot, while the cook surface itself remains cool to the touch. This reduces the potential for the ignition of clothing or other adjacent materials and would also reduce burn hazards from contact with the stovetop. In addition, the burner only operates when a large piece of ferrous metal, such as cookware, is present atop the burner (induction will not heat aluminum, copper, Pyrex glass, or ceramic cookware). The burners cannot be accidentally turned on or produce heat unless a utensil is sitting atop them.

While the induction cooktop does reduce the likelihood of some stovetop ignitions, it does not address one of the common fire scenarios, the potential ignition of food overheating due to carelessness or unattended cooking. Currently, induction cooktops are more expensive (retailing for approximately $1200–$3000) to purchase and install than conventional electric or gas stoves

4.4 Related Research Projects and Studies

4.4.1 Cooking Fire Incident Data

In the latest release of *Home Fires Involving Cooking Equipment,* Ahrens has compiled a summary of the fire statistics related to cooking fires for the five-year period of 2004–2008 (Ahrens, 2010). This data has shown little statistical change in the scope of the problem from previous data sets. Cooking fires have resulted in an annual average of 460 deaths, 4,850 injuries, and $724 million in direct property damage resulting from an average of 154,700 fires annually. Ranges or cooktops were shown to be the heat source in 59% of cooking equipment fires and caused 89% of civilian deaths. The data provides a solid basis for establishing a fire safety improvement goal of developing technologies to reduce home cooking fires. The ignition of cooking materials and food accounts for 66% of all cooking fires. Unattended cooking accounts for 34% of cooking fires and 48% of civilian deaths. Despite being the item first ignited

in less than 1% of cooking fires, clothing ignitions resulted in 15% of the cooking fire deaths. Thus, technology driven towards the elimination of clothing ignitions should also be emphasized.

Recent statistical data on fire incidents in Canada from 2009 has also recently been made available (Ontario, 2009). This study was focused upon determining the scope of the current home cooking fire problem in Ontario. In this study, cooking equipment was identified as the ignition source in 25% of home fires. Fires involving cooking equipment were shown to cause the most injuries and the second most deaths among all residential fires. Of the cooking fires, 74% were attributed to the stovetop, but stovetop fires were reported to decrease by 32% over the last decade. Unattended cooking constituted the cause of 69% of fires.

Current market data shows that 91% of Ontario stovetops are electric coil, but smooth top ranges have been increasing to 57% of market sales and thus will eventually become the predominant range type. With regard to fire ignitions, the smooth top ranges were shown to reduce clothing ignitions, but did not affect the ignition of unattended oil left on a burner. Gas ranges were generally responsible for a lower proportion of fires (5%) than their market representation (12%) (Ontario, 2009).

It was also shown that although the 20–29 years age group accounted for the most fire incidents, the 65+ age group accounted for the most deaths, at 41%. Clothing ignitions were shown to be a factor in senior fatalities, as they were shown to cause 69% of the senior fatalities but just 5% of the adult fatalities. The adult age group fatalities were shown to be attributed to alcohol in 53% of incidents. Stovetop fire incident rates were also 2 times greater in multi-unit dwellings and 3 times greater in subsidized housing than in detached homes (Ontario, 2009).

John Hall with the National Fire Protection Association (NFPA) has analyzed the latest incident data on cooktop fires in the U.S. This work was developed in parallel with this study as part of the same FPRF program. Hall's analysis specifies and quantifies cooktop fire and behavioral scenarios for use in the evaluation of stovetop fire prevention or mitigation technologies. Hall's analysis is included as Appendix C of this report.

The first section of his analysis focuses on fire scenarios with respect to the specific location and circumstances of stovetop fire ignitions. The second section focuses on cook location and characteristics for unattended stovetop fires. In both sections, analysis begins with the specification of different categories of kitchen range home structure fires and the quantification of annual averages and percentages of fires, civilian deaths, civilian injuries, and direct property damage for each category, based on 2005–2009 NFIRS national estimates. Analysis is done separately for gas and electric ranges.

Hall's analysis uses special studies and other one-time data bases to develop factors (sometimes called splitting percentages) to convert the categories of fires that can be developed directly from NFIRS coding of fires into categories of fires better suited to the goal of evaluating stovetop fire prevention technologies.

The final section of Hall's report develops statistical models used to estimate the potential effectiveness of various fire mitigation methods. The statistical effectiveness of methods

including warning alarms, containment of fires, and automatic suppression systems at preventing deaths, injuries, and property damages are estimated on a per fire basis.

The data presented in Hall's report is used to assess the likely fire scenarios that may be addressed by a mitigation technology and to estimate the overall impact of each technology may have on mitigating deaths, injuries, and property losses.

4.4.2 Cooking Fire Ignition Scenario Studies

Several studies have been conducted to analyze the ignition hazards presented by various food products left unattended or heated too rapidly on a stovetop. The majority of these studies are directed at determining the ignition properties of various oil and fat products.

In 2004, UL sponsored an investigation conducted at the University of Illinois at Urbana-Champaign to study the ignition of various oils in open pan configurations. This study recognized that cooking oil presented the most hazardous cooking material and examined the ignition properties of soybean oil, which represents 86% of oil sales in the US. The study found that the flash point of soybean oil was 329°C (624°F), but that the flash point decreased with an increase of the free fatty acid content of the oil. The study referred to the fact that various oils have different fatty acid contents, but that the fatty acid content of all oils would increase with repeated heating and cooking use. Thus, the recycling of oil for cooking represents a potential hazard due to the increased risk for ignition from fatty acid concentration increases (Preventing, 2004). This study was referenced as part of the 2010 Vision 20/20 Workshop proceedings (Vision, 2010).

Additional testing conducted as part of the UL study was intended to examine the possible inclusion of an effective pan temperature sensor for glass-top ranges. Discussion of this portion of the test is included in Section 4.4.3.

In 2006, a study was conducted at NIST by Dan Madrzykowski in an attempt to characterize the heat release rates of various types and amounts of oils and fuels burning in skillets and pots (Madrzykowski NIST, 2007). This was an attempt to characterize the thermal threat produced by such fires occurring on range tops. Various oils examined included canola, corn, olive, peanut, sunflower, and vegetable. In addition, tests were also conducted using heptanes as a comparison.

The testing included characterization of the standard UL300A (Underwriters, 1991) oil fires. This included various pans and skillets with multiples depths and types of oils. The results of these fires included ignition times ranging from 18–145 seconds, including no ignition of a peanut oil skillet on a gas stove. The heat release rates of the fires ranged from 65–400 kW for a 10" pan of peanut oil or a 10" pot of corn oil, respectively, with all other test fires falling within this range. This study was referenced as part of the NIST Workshop on Residential Kitchen Fire Suppression Research Needs in 2006 (Madrzykowski Residential, 2007). In addition to examining the ignition and heat release characteristics of oil fires, the NIST study also examined the ability of suppression systems to extinguish these types of fires. Discussion of this portion of the test is included in Section 4.4.3.

In 2008–2009, the European Committee for Standardization (CEN) tested various oils including corn, peanut, cotton seed, soybean, sunflower, coconut, and palm oils for smoke, flash,

and fire points. Smoke points were found to range from 194°C (381°F) for coconut oil to 242°C (468°F) for soybean oil. Flash points were found to range from 288°C (550°F) for coconut oil to 333°C (631°F) for peanut oil. Fire points were found to range from 329°C (624°F) for coconut oil to 363°C (685°F) for peanut oil. The general conclusion of the study was that ignition of oils in cooking pans could occur below 350°C (662°F), and thus this should be considered as a limiting temperature in design of fire prevention technology. Additional testing was performed on cooking performance when limiting utensil temperatures below the potential ignition temperature and is discussed in Section 4.3.3. Discussion of this data is included in the Vision 20/20 Workshop Proceedings (Vision, 2010).

In 2010, a research project conducted by the Fire Protection Engineering Department at the University of Maryland examined the smoke point, flame point, and auto-ignition temperatures of canola, soybean, and olive oil, as well as margarine and butter (Buda_Ortins, 2010). In the experiment, small, 5 mL (0.17 oz.) samples of each substance were heated in an aluminum dish on a hot plate, observed visually, and measured with a thermocouple. The oils had similar measured auto-ignition temperatures, which appeared to have a loose negative correlation with the polyunsaturated fat content of the cooking material. The correlation appeared to hold consistent with solid butter and margarine that were also tested. A summary of the auto-ignition temperatures and polyunsaturated fat contents of the tested materials is shown in Table 2.

Table 2 – Polyunsaturated Fat Content and Auto-Ignition Temperature of Various Cooking Oils (Buda_Ortins, 2010)

Cooking Material	**Polyunsaturated Fat (g/mL)**	**Auto-ignition Temperature (°C)**
Olive Oil	0.13	435.5
Canola Oil	0.27	424
Soybean Oil	0.53	406
Margarine	0.23	424
Butter	0.02	Did not ignite

4.4.3 Cooking Fire Mitigation Technology Studies

In 2002, a UL 858 Cooktop Fires Working Group developed “Technical Feasibility Performance Goals” (TFPG) with the intent of defining minimum performance goals for a device that senses the temperature of a range top or utensil and then controls the temperature of that object in order to prevent ignition through overheating (Underwriters, 2002). A general summary of the requirements for such a device would include:

- Detection of an incipient fire due to overheating of food including an alarm and automatic shutdown of power and/or fuel flow;
- Sensor must be usable for new and used cookware of multiple types, including stainless steel, aluminum, cast iron, glass, ceramic, and copper-clad;
- Device should operate for both gas and electric coil stovetops;
- Device should not affect the ability to cook, including time, functionality, and quality;

- Device should operate successfully even with food waste burned onto sensor;
- Routine cleaning of the sensor can be performed easily and not interfere with product operation;
- Provide adequate endurance, including 2000 removals and reinstalls and 50,000 draws of a utensil over the burner surface; and,
- Be designed to last twice the expected range lifetime.

Analysis of the TFPG is included in the Vision 20/20 Workshop Proceedings (Vision, 2010).

In addition to defining a general set of criteria for the performance of contact temperature sensors used for burner control, UL also conducted a preliminary study in 2003. This study focused on determining whether use of temperature control on a burner could prevent the ignition of oil with various types of cookware. Heating was conducted with burners both with and without temperature sensors or controls. This work demonstrated that control of the temperature of a cooking utensil below the ignition temperatures of oil could significantly reduce the possibility of ignition in all types of utensils (Underwriters, 2003). This research is also discussed in the Vision 20/20 Workshop Proceedings (Vision, 2010).

After confirming the conceptual basis for using temperature measurements to prevent ignition of oil in cooking utensils (Underwriters, 2003), UL then performed testing to determine whether such devices could be developed that could meet the TFPG (Underwriters, 2002) and thus be developed into marketable products.

Tests were developed and conducted by UL in 2004 to measure the performance of a Japanese temperature sensor used on a gas burner. The device was subjected to durability, endurance, cleaning, burned on food waste, and ignition and cooking tests for a wide variety of material and type of cookware. In general, this study was to determine whether testing could be performed on a device with regard to meeting the TFPG. In general, the tests were easily conducted and could be referenced to the performance goals. Some concerns regarding the testing of multiple types and conditions of cookware and the effect of such a device on the performance of inherently dangerous cooking activities, such as blackening, was also discussed (Underwriters, 2004).

Continuing an examination of the use of temperature senses on ranges, UL then commissioned a research project on the applicability of such devices to smooth glass or ceramic top ranges in 2004. This work was conducted by the University of Illinois at Urbana-Champaign. Part of this work consisted of examining the ignition properties of oils, as was discussed in Section 4.3.2. In addition to the oil characterizations, the study attempted to determine the proper method for using a non-contact temperature sensor placed below the glass surface to measure utensil temperature.

The study determined several key findings. First, that the emissivity of a utensil would affect the measurement of the radiant temperature signal and that the emissivity of a utensil may vary depending upon material. As a solution, the study presented the option of using a dual wavelength pyrometer that could utilize the ratio of the dual signals to determine the temperature of the surface independent of emissivity. Secondly, the effects of the transmissivity of the glass

material were considered and options for wavelengths and ratios based upon actual glass properties were presented. In general, the study showed that under-glass temperature measurements were feasible for smooth top ranges and that sensors could be developed to operate under such conditions with good product lifetimes due to the protection of the smooth glass surface (Preventing, 2004).

An additional study was conducted on the development of a temperature sensor and controlling device for glass ceramic cooktops by Advanced Mechanical Technology, Inc. with the support of the CPSC in 2003. It was determined that the smooth glass surfaces could not be machined to allow penetration of temperature sensors without weakening the glass sufficiently to fail a UL drop test. This study also determined that the emissivity of the utensil would greatly affect the response of a radiant temperature sensor placed beneath the glass surface. Instead, a contact temperature sensing device was used to measure the glass temperature at the bottom surface. The temperature of this surface was found to greatly lag the temperature response of the utensil due to the thermal mass of the smooth glass surface. In order to remedy this condition, the first derivative, or slope, of the glass bottom surface temperature was incorporated into the algorithm for control and was found to better prevent dangerous ignition levels (US CPSC, 2003).

Continued work into the development of temperature sensors for use on smooth top and induction ranges was performed by CENELEC in 2008–2009 and presented in the Vision 20/20 Workshop Proceedings (Vision, 2010). This research focused upon determining the effect of such devices upon the overall cooking performance of a range incorporating such a device. For these experiments, the glass surface temperatures were regulated below a set point of 370°C (698°F). Testing included analysis of multiple foods including searing of steaks, stir frying of vegetables, and sautéing. In general, the analysis of the cooking of food on the temperature controlled glass top range proved very unsatisfactory to the authors. Foods were reported to be wet and/or having poor flavor, or in the case of steaks unable to sear or cook properly when compared to the steaks cooked on the uncontrolled cooktop (Vision, 2010).

In addition to the cooking performance of the glass smooth top range, the CENELEC study also analyzed the performance of a temperature controller for an induction range. In this case, the temperature measurement was made of the top glass surface, and this resulted in some problems with the induction range. In induction cooking, the utensil gets hot while the glass surface remains cool. The only driving factor in heating the glass surface is maintaining good thermal contact with the utensil. For this reason, the temperature control worked well when good, flat bottom utensils were used. If a warped cooking utensil was used, however, the utensil would continue to heat while the glass remained cool, and ignition of oil was observed (Vision, 2010).

The Safe-T-element, a cast iron plate product that controls a burner based on temperature of the burner plate, has been made available and has undergone numerous performance tests as well as actual user installation case studies. Testing was conducted on the Safe-T-element in 2005 by UL to determine the ability of the device to prevent fires from occurring with 100 mL of oil in multiple types of utensils and to determine the overall effect upon the ability of the device to cook foods effectively. The results of the testing showed a significant reduction in the ignition of oil, but also noted significant increases in the time to cook water, pasta, fries, and bacon (Underwriters, 2005).

Based in part on the UL results, modifications were made to the solid cast iron plate to enhance flatness and thus provide an increased thermal connection with cooking pots and reduce overall cook times. Cooking performance testing was again conducted in 2010 by the Canadian Standards Association (CSA) by OnSpex Consumer Product Evaluation. This test series was conducted to measure the effect of the Safe-T-element upon the overall cooking performance compared to electric coil and glass-ceramic stovetops. Tests showed that the device was slower than a standard electric coil burner by approximately 10–20% for most cooking procedures, including boiling, hamburgers, and fish. Most cook times were increased on the order of 30 seconds to 2 minutes overall. However, the Safe-T-element was faster or equivalent to the performance of a glass-ceramic stove for the same processes.

Testing of deep-fat frying showed longer cook times for Safe-T-element versus glass or electric coil burners. The Safe-T-Element was shown to take approximately 50% longer than electric coils and 25% longer than glass, taking approximately 6 minutes longer than an electric coil, including preheat and cook times. After the completion of the cooking duration, the appearance and consistency of the cooked food from all three devices appeared similar (On-Spex, 2010).

During 2007–2010, installations of the Safe-T-Element were made at multiple universities and public housing authorities complexes. Installations included both pre-installed and retrofit units and encompassed a wide variety of demographics, including age, gender, race, financial standing, and mental capacity. Installations were conducted through the use of a federal grant program. Interviews of the persons involved in the acquisition and installation of the devices were conducted with regard to determining the overall function and acceptance of the Safe-T-element devices. A complete summary of the interviews is included in Appendix A.

While there were numerous responses, some general conclusions could be drawn from the data. Some of the older model stoves required replacing burner elements to be properly retrofit due to design or damaged coils. The user perception of the devices was noted as a major factor in regard to satisfaction. In general, users were happier with pre-installed devices over retrofit due to the lack of direct comparison and the impression of affecting their cooking habits. Education about the devices was an integral part of the installation process.

The devices were noted to reduce the maximum cooktop temperatures and take longer to heat up and cool down. In some cases, slow heat up and cool down influenced cooking behavior and results. In addition, audible “ticks and clicks” were observed when the device was operating. In addition, some users noted that the surface did not glow when hot, and thus it would be helpful to add an indicator for hot burners. Glass top burners have the same issue, and these ranges do include warning indicators of hot burners.

In general, the fire reduction performance was noted to be very effective in all installations and no injuries had been reported. Multiple universities and housing complexes reported a quantitative reduction in fire incidents after the installation of the Safe-T-elements.

In addition to the development and study of temperature sensing devices, work has also been conducted to examine the performance of suppression systems for range top fire protection. In

2006, NIST conducted experiments with the goal of developing a cost effective, retrofit option that could significantly reduce cooking fire losses through suppression.

This study focused upon the performance of several fire protection options, including a passive intumescent paint, wet and dry chemical suppression systems, and single pendant and sidewall sprinklers. The study did not examine the performance of full sprinkler installations or devices that could de-energize or cutoff fuel to the stove burners due to the high cost of retrofit.

Intumescent paint is a coating material that is designed to expand and form a thick char layer that a fire cannot penetrate, thus cutting off the fuel supply and preventing fire growth and spread. Testing of an intumescent paint applied to adjacent walls and cabinets did reveal some limited delay of fire spread, but did not greatly reduce the measured kitchen temperature or heat release rates of fires. The dry chemical system was able to extinguish the fire, but only protected the area above the range, and it did cause some splashing of oil for oil fires. The wet chemical was able to extinguish the fire but only protected the area above the range and retained a potential for re-ignitions. The single sprinklers were shown to suppress the fires but did require larger initiating fires in order to operate. This work also included the oil ignition and heat release rate scenarios discussed in Section 4.3.2 (Madrzykowski NIST, 2007). Additional work to be conducted upon the suppression of range top fires is expected but is not yet available (Vision, 2010).

The suppression work was presented at a NIST Workshop on Residential Kitchen Fire Suppression Research Needs in 2006. The workshop consisted of members of industry, standards, and fire protection fields. After several presentations and breakout sessions regarding the problem and solutions involved in preventing residential cooking fires, the members determined that education was the best short term goal for protecting public safety. The key to a long term solution was determined to be development of a low cost, low maintenance, low volume, retrofit system capable of gaining wide consumer acceptance. It was also recommended that the fire statistics, capabilities, and limitations of existing products should be examined (Madrzykowski Residential, 2007). Addressing these long term goals are the intent of this document and research.

5.0 EVALUATED FIRE MITIGATION TECHNOLOGIES

Cooking range fire protection technologies have been categorized based upon the mitigation method used by the technology. Potential mitigation methods include the detection of a flaming fire, the detection and warning of an imminent flaming ignition, controlling a fire/preventing fire spread, automatic suppression of an occurring fire, and the automatic prevention of an ignition event. The mitigation methods have been sorted based upon the effectiveness of the method at the overall prevention of fire losses, from warning, to suppression, to fire prevention. In general, the categories and technologies closely follow those identified in the CPSC/AHAM study (ADL, 2001).

5.1 Detect Flaming Fire and Provide Warning

These technologies would take no action toward the prevention of a fire or toward the suppression of a fire. After a fire has begun, they would provide an audible alarm or warning to

indicate to occupants that a fire is occurring. These technologies would be expected to address all flaming fires occurring on or around the range, regardless of the ignition factors or materials ignited. Warning of an occurring flaming fire would be intended to instruct occupants to exit the home and contact the fire department. Three of every five non-fatal injuries in home cooking fires occurred when the victim was trying to fight the fire, and thus manual fire fighting by occupants should not be encouraged (Ahrens, 2010).

The technologies capable of detection of a flaming fire occurring on or around the range are:

1. **Fusible link** – A fusible link is a robust mechanically operated device that severs a connection when heated above a threshold temperature. It would require relatively no maintenance or cleaning with a low occurrence for false alarms. When activated, a fusible link would require replacement. For most applications, the fusible link must be placed directly above the range, often within an exhaust hood, making it not applicable for downdraft or island installations.
2. **Non-optical temperature sensor** – A temperature sensor, such as a thermocouple, could be used to measure the air temperature over the cooking range and produce an alarm when a threshold temperature is reached. This would require relatively no maintenance or cleaning with a low occurrence for false alarms. When activated, the temperature sensor would require replacement. For most applications, the temperature sensor must be placed directly above the range, often within an exhaust hood, making it not applicable for downdraft or island installations.
3. **Optical temperature sensor** – An optical temperature sensor, such as an infrared device, would be placed in view of the cooking range. When the infrared signal increased above a threshold beyond that expected for regular cooking, an alarm would be activated. The optical temperature sensor may be susceptible to false alarms due to high temperature cooking or external infrared signals. An optical sensor may require additional cleaning operation, and the life of the sensor may require some replacement or maintenance over the lifetime of the range. The optical temperature sensor would be applicable to all range installations.
4. **Video Image Detection (VID)** - In general, a video image detection (VID) system consists of video-based analytical algorithms that integrate cameras into advanced flame and/or smoke detection systems. The video image from an analog or digital camera is processed by proprietary software to determine if smoke or flame from a fire is identified in the video. The detection algorithms use different techniques to identify the flame and smoke characteristics and can be based on spectral, spatial or temporal properties; these include assessing changes in brightness, contrast, edge content, motion, dynamic frequencies, and pattern and color matching. Although VID technology can be embodied in a standard surveillance-size camera, VID technology requires substantial computing hardware and is currently very expensive. Smoke detection would be more susceptible to nuisance sources than flame detection.
5. **Optical flame detector** – Optical flame detectors (OFD) are similar to the optical temperature sensors but use additional algorithms to distinguish flames from other high temperature input signals, making it less susceptible to false alarms than optical temperature sensors. Generally, purchasing cost is considerably greater than the

optical temperature sensors, and the additional micro-processing creates additional potential failure modes.

6. **Thermal imaging** – Thermal imaging (TI) is similar to the optical temperature sensor and flame detector but includes an entire visual array of the range top in order to provide additional information about fire size and location. TI can provide temperature as well as feature (i.e., flame) identification with appropriate software. This is a very high cost option.

5.2 Detect Imminent Flaming Ignition and Provide Warning

When the ignition of a flaming fire appears likely to occur, these devices would provide an audible alarm or warning to indicate to occupants that pre-flaming indicators have been detected. These technologies would take no action toward the prevention of a fire or toward the extinguishment of a fire. In general, the likelihood of obtaining a false alarm is increased for technologies utilizing this mitigation method, due to the lower detection thresholds required to detect an impending flame ignition as opposed to an existing fire.

Detection of an imminent flaming fire is considered separately from detection of a fire that is already occurring because occupants can still take steps to prevent a fire without attempting to fight the fire. For examples, these technologies would provide occupants an opportunity to lower or turn off the range prior to flaming ignition. Depending on the pre-flame conditions monitored for detection, these technologies could be expected to address all fires occurring on, around, or within the range, or may be limited in the scope of detectable fire scenarios.

The technologies capable of detection of an imminent flaming fire on or around the range are:

1. **Non-optical temperature sensor** – The installation of this device would be the same as for the non-optical temperature sensor used for detection of a fire, but the temperature threshold would be adjusted to a lower value, resulting in warning prior to flaming ignition but at the cost of a higher potential for false alarms.
2. **Optical temperature sensor** – The installation of this device would be the same as for the optical temperature sensor used for detection of a fire, but the temperature threshold would be adjusted to a lower value, resulting in warning prior to flaming ignition but at the cost of a higher potential for false alarms.
3. **Smoke detector** – Installation of a smoke detector above the cooking range provides a fairly cheap and reliable option for warning prior to a flaming fire ignition. However, the potential for false alarms is nearly unavoidable for most detectors on the market. Some maintenance would be required, such as cleaning, testing and potentially changing the battery depending on the type. Many kitchen ranges already have a working smoke alarm/detector protecting the general vicinity outside the kitchen.
4. **Utensil temperature sensor**
    a. **Contact sensor** – The temperature of a utensil on a burner would be monitored using a utensil-contact temperature sensor, such as a spring loaded

thermocouple. When the utensil temperature exceeds a pre-determined threshold, a warning alarm would be activated. It is possible, depending upon product design that product durability could become an issue, as the contact method may wear down over time with use or be affected by cleaning.

b. **Non-contact sensor** – An optical temperature sensing device, such as infrared, would be used to monitor the utensil temperature. When the utensil temperature exceeds a pre-determined threshold, a warning alarm would be activated. The sensor would require cleaning to maintain optical integrity. The reliability of the sensor over the life of a cooking range may be questionable. Different utensil materials could impact measurement accuracy.

5. **Burner surface temperature sensor** – The temperature of the burner element would be monitored using a sensor, such as an embedded thermocouple. When the burner temperature exceeded a pre-determined threshold, a warning alarm would be activated. This type of temperature sensor installation would generally prove more robust than a utensil temperature sensor, but may not be applicable to both gas and electric ranges. Successful operation to accurately determine a satisfactory threshold temperature depends on appropriately correlating burner temperature to the temperature of the cooking food, which will be impacted by the type of utensil. Determinations of effective temperature thresholds are an issue of product design, and existing products have been shown to obtain feasible temperature settings.

6. **Unattended cooking warning alarm** – The technology would employ one of several potential methods to determine if a person is present during the cooking operation. The presence of the cook is a key factor in the prevention of fires on cooking ranges, and has been shown to be a primary factor contributing to ignition in one-third of all reported home cooking fires (Ahrens, 2010). Within this mitigation method, these devices are only used to provide a warning alarm and are not used to control the burner output or initiate shutdown. These devices would generally treat unattended cooking as an indication for potential flaming ignition, even when no fire is likely to occur, thus having a significant impact upon the behavior of cooks.

    a. **Motion Sensor** – A motion sensing device placed on the cooktop would detect the presence of a user when the range is on. If a pre-determined amount of time is allowed to pass without detection of the user, an alarm would sound. The alarm would shutoff automatically if a person were detected. There are multiple types of motion sensor technology, including passive infrared (PIR), microwave, ultrasonic and even video. The motion sensor may be susceptible to unwanted positive signals due to the motion of pets, children, curtains, etc, and thus fail to acknowledge unattended cooking. A motion sensor would require additional cleaning operation from food wastes and oil mists. In addition, the life of the sensor may require some replacement or maintenance over the lifetime of the range.

    b. **Motion Sensor + Temperature Sensor** – This system would employ the same motion sensor apparatus described above. The system would be modified by inclusion of a utensil or burner temperature sensor such that the motion alarm would not alarm unless the range had reached a pre-ignition

temperature condition. This would reduce the overall impact on the user of the range by alerting them only when a fire condition may be likely. In addition to the requirements for the motion sensor, the durability of the temperature sensor may require additional maintenance.

c. **Motion Sensor + Power Sensor** – This system is similar to the motion sensor and temperature sensor described above, except that instead of a temperature sensor, a range power level sensor is utilized. This device would determine the operating power of the range and incorporate the motion sensor when the power is above a pre-determined threshold. The intention of this technology would be such that the motion sensor would not operate for simmering or other low power cooking, but would require the presence of the user for high temperature cooking. Application of a power sensor for electric or gas ranges would require separate parts, installation, and cost, although both are technically feasible.

d. **Timer** – After a pre-determined amount of time, an alarm would sound unless the range user pressed a reset button to identify their presence. This is a simple system for providing an alarm during unattended cooking, but would require the user to repeatedly push the button while operating the range.

e. **Temperature Sensor + Timer** – The automatic timer and reset button described above would be employed, but a utensil or burner temperature sensor would be used to determine the time until the alarm sounds, where the length of time is inversely proportional to the measured temperature.

f. **Power Sensor + Timer** – The automatic timer and reset button described above would be employed, but a power sensor is used to determine the time until the alarm sounds, where the length of time is proportional to the range power.

5.3 Control Fire/Prevent Fire Spread

These technologies would be intended to prevent a fire from spreading from the range to surrounding combustibles. This would prevent range fires from growing, thus, decreasing the likelihood for destruction and fatalities. They do not prevent fires from occurring or provide a warning alarm, but are solely intended to prevent fires from developing into major hazards to life and property.

1. **Passive containment** – Fire resistant panels would be permanently attached to the back, sides, and/or above the range. The panels would prevent any flames from spreading from within the confines of the range top, reducing the potential for growth into a major fire. There is no actuation or working parts, making this technology extremely durable.

2. **Active drop-down hood** – This device would include a complete hood located above the range top with a temperature sensor. When the temperature in the hood exceeded a pre-determined threshold, the hood would lower onto the range top, containing and smothering the existing fire. This device would require an operating temperature sensor as well as the moving parts required to lower the hood onto the range top. This

technology would not necessarily address fires of materials on adjacent countertops that catch on fire by being too close to a burner.

5.4 Automatic Fire Suppression

These technologies require a sensor to detect a fire and initiate the release of suppressant across the range top. They may also initiate a shutdown of the burner elements to prevent any possible re-ignition scenarios. They do not prevent a fire from occurring, but are effective at suppressing the fires before they become a serious hazard. The release of the suppressing agent may require significant cleanup or cause damage to property, but injuries and deaths due to fire should be prevented.

For the purposes of this analysis, the suppressant technologies include sprinklers and wet or dry chemical suppressants. Each suppressant category is analyzed separately in conjunction with each fire detection method.

The primary difference between the suppressant mitigation technologies for this analysis will be the selection of the fire detection system. These are the same devices described in Section 5.1 with regards to detecting fires and providing warnings, and are listed again within this section without further description.

1. Fusible link
2. Non-optical temperature sensor
3. Optical temperature sensor
4. Video image detection
5. Optical flame detector
6. Thermal imaging

5.5 Prevent Fire

These technologies are considered to provide the highest level of fire protection because they are intended to automatically prevent range fires from occurring, regardless of the actions of the user. The various technologies may be limited in the types of fires they control, or the types of ranges they can be applied to, but they are intended to automatically prevent the ignition of fires through various methods.

1. **Prevent unattended cooking through burner control** – This technology would detect the presence of a user and actuate control of the burner element, either through temperature control or complete shutdown when a user is not present at the range. The primary difference between the technologies is the method of detection for the presence of the range user. These are the same devices described in section 5.2.f with regard to detecting users and providing warnings, and are listed again in this section without providing additional explanation.
    a. Motion sensor

b. Motion sensor + temperature sensor

c. Motion sensor + power sensor

d. Timer

e. Temperature sensor + timer

f. Power sensor + timer

2. **Prevent ignition through burner temperature control** – This technology would measure the temperature of a utensil on a burner or a burner itself and identify pre-flame conditions. When an excessive temperature is measured, the device would act to reduce the burner power until the pre-flame condition is eliminated. This technology is intended to prevent the user from applying too much heat to a utensil that can cause a fire. Some versions of this technology may also eliminate the ability of an electric burner from igniting other loose combustibles, such as paper or fabrics by reducing the temperature below the ignition temperature. Technology of this type may affect the quality and time of cooking certain foods due to the control of the burner below ignition temperatures.

    a. **Fixed temperature control** – A fixed temperature threshold would be determined and the burner power would be reduced or eliminated to ensure that the temperature was never exceeded. This requires no input from the user and the temperature is determined by the technology manufacturer to ensure the highest cooking performance with the greatest fire prevention. In general, this technology would use the same utensil and burner temperature technologies described for warning in section 5.2 and they have been listed here. The mechanically actuated switch is unique for this technology and is given further description.

        i. Temperature sensor contacts utensil

        ii. Temperature sensor on burner

        iii. Non-contact temperature sensor

        iv. Mechanical actuation – The temperature sensor used is a mechanical device in contact with the utensil that changes properties at a pre-determined temperature threshold. The device may be a bi-metallic strip, a magnetized piece whose properties are affected by temperature, or an expandable liquid sensor. The device can be used to control the burner temperature or for complete shutdown.

    b. **Gradient temperature control to prevent boil over/spills** – This technology would identify a rapid change in the utensil or burner temperature as an indication of a spill or boil over condition, and control the burner to prevent the ignition of the spilled or boiling contents. This technology would use the same utensil and burner temperature technologies described for warning in section 5.2 and are listed here:

        i. Temperature sensor contacts utensil

ii. Temperature sensor on burner

iii. Non-contact temperature sensor

c. **User selected cook-type or temperature option with microprocessor control** – This technology would allow the user to specify the type of cooking operation to be performed, such as frying, boiling, blackening, etc., and the allowable utensil or burner temperature threshold would be determined accordingly. This technology would require the user to understand cooking processes and would put additional responsibility on the user to not always use the setting that allows the highest temperature of cooking. This technology would use the same utensil and burner temperature technologies described for warning in section 5.2 and are listed here:

i. Temperature sensor contacts pot

ii. Temperature sensor on burner

iii. Non-contact temperature sensor

3. **Smoke Detection with Burner Control** – A smoke detection device would be placed in the vicinity of the range and alarm activation would be used to control the burner output, either through temperature reduction or complete shutdown. The smoke detection device could be any number of potential devices, including photoelectric, ionization, combination, or aspiration type detectors. While nuisance alarms may be of concern for smoke detection, the sensitivity and placement of such a device used for control could be modified from existing home smoke detection installation standards to reduce such occurrences. Such a device would be intended to detect the small particles of smoke emitted by combustibles prior to flaming ignitions, but this category of device may also include other potential detection methods, including but not limited to carbon monoxide detection.

4. **Induction range** – An induction range is a technology of range top that would replace either a gas or electric range. It creates an oscillating magnetic field that induces electric currents within the cooking utensil, producing heat from electrical resistance. It has been considered as a mitigation technology for this analysis due to the inherent prevention of several fire types. For example, an induction range is capable of detecting whether a pot is located on the burner, and will not energize if a pot is not detected. This would prevent ignition scenarios where the burner was accidentally turned on. In addition, the burner surface remains cool to the touch during cooking with only the utensil getting hot. This would prevent ignition of materials placed too close to the burner or spilled or boiled over contents. It would not prevent the overheating of food contents within a utensil operating on the burner. The induction range is more expensive than the gas or electric alternatives and would require some education for users, but could prevent the occurrence of several common range fire types.

The full set of cooking range fire mitigation technologies that are examined in this study are summarized in Table 3.

Table 3 – Cooking Range Fire Mitigation Technologies Included in This Analysis

Mitigation Method	Description		
Detect flaming fire and provide warning	Fusible link		
	Non-optical temperature sensor		
	Optical temperature sensor		
	Video image detection		
	Optical flame detector		
	Thermal imaging		
Detect imminent flaming ignition and provide warning	Non-optical temperature sensor		
	Optical temperature sensor		
	Smoke detector		
	Pan temperature sensor - Contact Sensor		
	Pan temperature sensor - Non-contact sensor		
	Burner surface temperature sensor		
	Unattended Cooking Warning Alarm	Motion Sensor	
		Motion Sensor + Temperature Sensor	
		Motion Sensor + Power Sensor	
		Timer	
		Timer + Temperature Sensor	
		Timer + Power Sensor	
Control fire/prevent fire spread	Passive 3 wall system		
	Active drop down hood		
Provide automatic suppression	Sprinkler System	Fusible link	
		Non-optical temperature sensor	
		Optical temperature sensor	
		Video image detection	
		Optical flame detector	
		Thermal imaging	
	Wet/Dry Chemcal	Fusible link	
		Non-optical temperature sensor	
		Optical temperature sensor	
		Video image detection	
		Optical flame detector	
		Thermal imaging	
Prevent fire	Prevent unattended cooking through burner control	Motion Sensor	
		Motion Sensor + Temperature Sensor	
		Motion Sensor + Power Sensor	
		Timer	
		Timer + Temperature Sensor	
		Timer + Power Sensor	
	Prevent ignition through burner temperature control	Fixed Temperature Control	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
			Mechanical actuation
		Temperature Gradient for boil over/ spills	Utensil contact temperature
			Burner temperature
			Non-contact temeperature sensor
		User selected cook-type or temperature option with microprocessor control	Utensil contact temperature
			Burner temperature
			Non-contact temeperature sensor
	Smoke Detection		
	Induction range		

6.0 EVALUATION METHODOLOGY

A method for assessing the utility and effectiveness of cooking range fire mitigation technologies was previously developed as part of the 2001 CPSC/AHAM study (ADL, 2001). The performances of the technologies were evaluated with regard to a range of fire and use scenarios and other criteria. The following analysis provides an updated assessment methodology with additional emphasis placed upon the critical performance criteria while maintaining a concise, quantitative, and comprehensive format. The intent of the assessment method is to draw attention to information gaps and also to facilitate comparisons and decisions about the most promising technologies.

It is not the intent of this evaluation to eliminate potential technologies from consideration, nor to endorse any particular concepts or technologies as primary solutions. The rankings and evaluations provided are merely intended to identify the current status of potential cooking fire mitigation technologies with regard to performance and product features. The rankings are intended to initiate further discussion and development of solutions by highlighting both the positive and negative aspects of a range of potential mitigation options.

For this study, residential cooking fire mitigation and prevention technologies were evaluated on the basis of three general criteria: 1) Fire Protection Effectiveness (FPE), 2) Cooking Performance, and 3) Cost and Convenience. Each technology received a three part score corresponding to each of the three criteria, as each is considered an essential element to the success of a mitigation technology. FPE scores were given a rating from 0–10 and cooking performance and cost were given scores ranging from 1–9, due to the evaluation method used for determination of each score. Rankings of mitigation technologies were developed for each of the three criteria and observations noted based upon these three rankings.

In general, each of the performance metrics considered for each technology closely resemble those used in the study previously developed as part of the 2001 CPSC/AHAM study (ADL, 2001). For example, the effect upon cooking time, the need for the device to fail safe, and the prevention of false positives and negatives were all still considered as essential performance metrics within the larger categories. The use of essentially the same metrics allowed for a more direct comparison between this study and the CPSC/AHAM work. However, as described above, the approach taken in this study regrouped these metrics to reflect the importance of the three primary criteria. For example, in the CPSC/AHAM study, the performance metric of “Ease of System Verification” was weighted the same as whether the system adequately mitigated the fire. The scoring scheme used by the CPSC/AHAM study equally weighted all 21 performance metrics and summed to a single total score. Therefore, the effect on cooking performance was only 1/21 of the total score and 1/7 of the combined “Efficacy of Technology as Cooking Fire Deterrent.” The approach in this study evaluated the three primary criteria as fire performance, cooking performance and cost and convenience. For the most part, the other performance metrics impacted these three main criteria.

The following is a description of how each of the three main criteria was specifically evaluated for this study and how the scoring was determined to provide a quantitative ranking of the technologies. In addition to adjusting the grouping and importance of the various performance metrics from the CPSC/AHAM study, this method also assessed the fire protection

effectiveness through a quantitative analysis of impact on incidents, fatalities, injuries and property loss. All assessments and scores were assigned by the author of this report.

6.1 Fire Protection Effectiveness Calculation Method

A statistical approach was taken toward ranking technologies with regard to fire protection performance. A statistical approach was selected over a qualitative approach due to the availability of fire loss data. The fire protection score was determined by considering the amount of fire loss (death, injury, property) that could be addressed by the installation of the technology. Statistical data was applied to represent the potential effectiveness of the various mitigation groups described in Section 5. The intent of the fire protection analysis was to determine the maximum potential for each technology/concept, without the influence of the current developmental status of the concept. The fire protection score was not influenced by product lifetime, manufacturing or installation concerns, or any other shortcomings of existing products or concept architectures.

The fire protection effectiveness, *FPE*, is a statistical score from zero to ten representing the maximum potential percentage of fire losses that could be reduced through the application of a mitigation technology as shown in Eq. (1). A score of zero would imply that the technology would have no impact upon the fire losses, and a score of ten would imply that the technology could completely eliminate 100% of the fire losses.

$$FPE = \%\ of\ potential\ fire\ losses\ reduced\ by\ a\ mitigation\ technology\ (scaled\ 0\text{–}10) \qquad \text{Eq. (1)}$$

For each analyzed mitigation technology, a separate score was calculated for each of the fire loss categories, including fire incidents, civilian deaths, civilian injuries, and direct property damages.

The FPE was calculated by summing the impact of the technology to reduce fire losses occurring from both gas and electric ranges separately. The percentage of addressed fire losses for each range type were determined in each of seven fire categories determined by NFIRS statistics, and then each percentage was multiplied by the percentage of range fires resulting from gas and electric ranges, respectively. A conceptual summary of the FPE calculation is shown in Eq. (2).

$$FPE = \begin{pmatrix} \%\ of\ all \\ range\ fire\ loss \\ occurring\ on \\ gas\ range \end{pmatrix} x \begin{pmatrix} Total\ \%\ of \\ fire\ scenarios \\ addressed\ by \\ technology\ for \\ gas\ ranges \end{pmatrix} + \begin{pmatrix} \%\ of\ all \\ range\ fire\ loss \\ occurring\ on \\ electric\ range \end{pmatrix} x \begin{pmatrix} Total\ \%\ of \\ fire\ scenarios \\ addressed\ by \\ technology\ for \\ electric\ ranges \end{pmatrix} \qquad \text{Eq. (2)}$$

The derivation of the complete numerical formula used to calculate FPE is described in the following section. The statistical data used for calculation of the FPE and rationale for fire categories is presented in Appendix D.

Separate fire protection effectiveness scores were calculated for each technology for each of the fire loss categories. FPE_y represents each individual fire loss score, where the subscript *y* is used to denote the fire loss category. These categories include:

y = 1 [Fire Incidents]
y = 2 [Civilian Deaths]
y = 3 [Civilian Injuries]
y = 4 [Direct Property Damage]

The percentages of addressed fires were determined from NFIRS statistics in each of seven fire categories. The fire categories include:

n = 1A [Cooking materials and unattended]
n = 1B [Cooking materials and not unattended]
n = 2 [Unattended but not cooking materials]
n = 3 [Mechanical or electrical failure]
n = 4 [Behavioral errors and not cooking materials]
n = 5 [Factors not related to cooking behaviors and not cooking materials]
n = 6 [Unclassified]

The statistical contributions of each category are further subdivided into three splitting factors, including:

m = 1 [Fire begins in a cooking vessel on burner]
m = 2 [Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner]
m = 3 [Fire begins on stovetop but not during cooking activities]

The number of fires addressed by a mitigation technology was determined by comparing the number of fires occurring for each scenario and determining whether the technology could mitigate such fires. The statistical fraction of occurrences for each fire splitting factor and category, $x_{n,m}$, are provided in Table 4.

Table 4 – Fraction of Fire Occurrences for Each Splitting Factor Within Each Fire Category, $x_{n,m}$

$x_{n,m}$	**m = 1** **Fire begins in a cooking vessel on a burner**	**m = 2** **Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner**	**m = 3** **Fire begins on stovetop but not during cooking activities**
n = 1A (cooking materials and unattended)	1.000	0.000	0.000
n = 1B (cooking materials and not unattended)	0.892	0.107	0.000
n = 2 (unattended but not cooking materials)	0.500	0.250	0.250
n = 3 (mechanical or electrical failure)	0.000	0.331	0.667
n = 4 (behavioral errors and not cooking materials)	0.000	0.000	1.000
n = 5 (factors not related to cooking behaviors and not cooking materials)	0.000	0.000	0.000
n = 6 (unclassified)	0.000	0.286	0.714

The functional operation of a mitigation technology was assessed to determine if the technology could address each specific fire ignition scenario. If the technology could address fires occurring in fire category *n* and splitting factor *m*, then the scenario factor, $p_{n,m}$, was set equal to one. If the application of the technology could have no influence on fires of that type, then $p_{n,m}$ was equal to zero. Further breakdown of the potential influence of the technology or upon the reduction of fires within a subset, $x_{n,m}$, was beyond the scope of this project, and a simple [p = 0,1] binary analysis was used for each fire scenario.

The fraction of fires expected to be addressed by the technology in each fire category, a_n, was obtained by summing the product of the scenario factors and the fractions of occurrences for each fire category as shown in Eq. (3).

$$a_n = \sum_{m=1}^{3} p_{n,m} x_{n,m} \qquad \text{Eq. (3)}$$

Where:

- $\boldsymbol{n}$ = Fire category
- $\boldsymbol{m}$ = Splitting factor/Ignition scenario
- $\boldsymbol{p_{n,m}}$ = Fire scenario factor for fire category n and splitting factor m (binary input to determine if technology would affect each specific fire scenario, 1 = yes, 0 = no)
- $\boldsymbol{x_{n,m}}$ = Fraction of all category *n* fires occurring with ignition scenario *m*
- $\boldsymbol{a_n}$ = Fraction of fires expected to be addressed by the mitigation technology in fire category *n*

Once the addressed fires were determined for each category, the ability of the technology to prevent real fire losses was examined. The fraction of fire losses resulting from each of the seven fire categories are provided in Table 5 and Table 6 for gas and electric range tops, respectively.

Table 5 – Fraction of Fire Losses Resulting from Each of the Fire Categories for Gas Ranges, $c_{n,y}$

	y = 1	**y = 2**	**y = 3**	**y = 4**
Gas Ranges – $c_{n,y}$	**Fires**	**Civilian Deaths**	**Civilian Injuries**	**Direct Property Damage (in Millions)**
n = 1A (cooking materials and unattended)	0.179	0.268	0.255	0.199
n = 1B (cooking materials and not unattended)	0.419	0.040	0.321	0.275
n = 2 (unattended but not cooking materials)	0.034	0.040	0.068	0.093
n = 3 (mechanical or electrical failure)	0.086	0.040	0.062	0.071
n = 4 (behavioral errors and not cooking materials)	0.163	0.317	0.171	0.184
n = 5 (factors not related to cooking behaviors and not cooking materials)	0.023	0.000	0.020	0.010
n = 6 (unclassified)	0.096	0.295	0.102	0.167
Total	1.000	1.000	1.000	1.000

Table 6 – Fraction of Fire Losses Resulting from Each of the Fire Categories for Electric Ranges, $d_{n,y}$

Electric Ranges – $d_{n,y}$	y = 1 Fires	y = 2 Civilian Deaths	y = 3 Civilian Injuries	y = 4 Direct Property Damage (in Millions)
n = 1A (cooking materials and unattended)	0.282	0.389	0.383	0.292
n = 1B (cooking materials and not unattended)	0.462	0.127	0.409	0.354
n = 2 (unattended but not cooking materials)	0.042	0.129	0.058	0.089
n = 3 (mechanical or electrical failure)	0.036	0.051	0.013	0.035
n = 4 (behavioral errors and not cooking materials)	0.093	0.220	0.087	0.138
n = 5 (factors not related to cooking behaviors and not cooking materials)	0.008	0.000	0.003	0.006
n = 6 (unclassified)	0.078	0.085	0.047	0.085
Total	1.000	1.000	1.000	1.000

The percentage of total losses occurring from gas or electric range top fires for each fire category, *n*, are provided separately for each fire loss category, *y*. These percentages for gas ranges are represented by $c_{n,y}$ and the percentages for electric ranges are represented by $d_{n,y}$. The percentage of gas and electric range fire losses expected to be addressed by the technology were calculated separately by summing the products of the addressed fire scenarios and the loss ratios for each fire category as shown in Eq. (4) and Eq. (5).

$$\begin{pmatrix} Total\ fraction \\ of\ fire\ scenarios \\ addressed\ by \\ technology\ for \\ gas\ ranges \end{pmatrix} = \sum_{n=1A}^{6} a_n c_{n,y} \qquad \text{Eq. (4)}$$

$$\begin{pmatrix} Total\ fraction \\ of fire\ scenarios \\ addressed\ by \\ technology\ for \\ electric\ ranges \end{pmatrix} = \sum_{n=1A}^{6} a_n d_{n,y} \qquad \text{Eq. (5)}$$

Where:

$\boldsymbol{n}$ = Fire category
$\boldsymbol{y}$ = Fire loss category
$\boldsymbol{c_{n,y}}$ = Fraction of total gas range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{d_{n,y}}$ = Fraction of total electric range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{a_n}$ = Fraction of fires expected to be addressed by the mitigation technology in fire category *n*

The total fraction of fire scenarios addressed for each loss type (e.g., fatalities, injuries, property) were then adjusted to compensate for the losses due to clothing ignitions for both gas and electric ranges. The applicable fraction of losses in each fire category, Ign_{cy} and Ign_{dy}, are provided in Table 7 for gas and electric ranges.

Table 7 – Fraction of Fire Losses Across All Fire Categories Occurring as a Result of Clothing Ignitions for Both Gas and Electric Range Types

	y = 1	**y = 2**	**y = 3**	**y = 4**
Clothing Ignition Fire Losses by Range Type	**Fires**	**Civilian Deaths**	**Civilian Injuries**	**Direct Property Damage (in Millions)**
Gas Range, Ign_{cy}	0.004	0.346	0.038	0.001
Electric Range, Ign_{dy}	0.000	0.107	0.003	0.003

The clothing ignition scenarios were then removed as a fraction of the overall calculated scenario score and then the total number of clothing ignition scenarios addressed were added to the overall total as shown in Eq. (6) and Eq. (7), for gas and electric ranges, respectively. The clothing ignition factor, *CI*, is equal to zero if the technology does not address clothing ignitions and one if such scenarios would be addressed.

$$\begin{pmatrix} Total\ fraction\ of\ fire\ scenarios\ addressed\ by\ technology\ for\ gas\ ranges\ incl.\ clothing\ ignitions \end{pmatrix} = C_y = \left[\left(\sum_{n=1A}^{6} a_n c_{n,y}\right) x \left(1 - Ign_{cy}\right)\right] + CI\left(Ign_{cy}\right) \qquad \text{Eq. (6)}$$

$$\begin{pmatrix} Total\ fraction\ of\ fire\ scenarios\ addressed\ by\ technology\ for\ electric\ ranges\ incl.\ clothing\ ignitions \end{pmatrix} = D_y = \left[\left(\sum_{n=1A}^{6} a_n d_{n,y}\right) x \left(1 - Ign_{dy}\right)\right] + CI\left(Ign_{dy}\right) \qquad \text{Eq. (7)}$$

Where:

$\boldsymbol{n}$ = Fire category
$\boldsymbol{y}$ = Fire loss category
$\boldsymbol{c_{n,y}}$ = Fraction of total gas range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{d_{n,y}}$ = Fraction of total electric range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{a_n}$ = Fraction of fires expected to be addressed by the mitigation technology in fire category *n*
$\boldsymbol{Ign_{cy}}$ = Fraction of gas range fire losses in category *y* resulting from clothing ignitions
$\boldsymbol{Ign_{dy}}$ = Fraction of electric range fire losses in category *y* resulting from clothing ignitions
$\boldsymbol{CI}$ = Clothing ignition factor, equal to one if applicable to clothing ignitions, zero if not

The addressed fire scenarios for gas and electric range types were then adjusted to reflect the mitigation method, *z*, of the technology. The statistical contribution of each mitigation method to reduce fire losses, on a per fire basis, within each category *y*, is summarized in Table 8 and Table 9 for gas and electric ranges, respectively. Each value represents the observed effectiveness of the mitigation group at reducing a fraction of fire losses for gas and electric ranges separately. The fraction of reductions for each mitigation method, *z*, in each fire loss category, *y*, is represented by $R_{y,z}$ and $S_{y,z}$ for gas and electric ranges, respectively. Further description of the origin of the statistical groups is provided in Appendix D.

Table 8 – Fraction of Fire Losses Reduced When Mitigation Method Present for Gas Range Fires, $R_{y,z}$

	y = 1	**y = 2**	**y = 3**	**y = 4**
Type of Mitigation	**Fires**	**Civilian Deaths**	**Civilian Injuries**	**Direct Property Damage (in Millions)**
Alarm/Warning z=1	0.000	0.320	0.350	0.020
Containment z=2	0.000	0.490	0.150	0.700
Suppression-Sprinkler z=3	0.000	0.850	0.000	0.710
Suppression-Chemical z=4	0.000	0.670	0.000	0.560
Prevention z=5	0.900	0.900	0.900	0.900

Table 9 – Fraction of Fire Losses Reduced When Mitigation Method Present for Electric Range Fires, $S_{y,z}$

	y = 1	y = 2	y = 3	y = 4
Type of Mitigation	**Fires**	**Civilian Deaths**	**Civilian Injuries**	**Direct Property Damage (in Millions)**
Alarm/Warning z=1	0.000	0.090	0.090	0.300
Containment z=2	0.000	0.630	0.100	0.570
Suppression-Sprinkler z=3	0.000	0.850	0.000	0.710
Suppression-Chemical z=4	0.000	0.670	0.000	0.560
Prevention z=5	0.900	0.900	0.900	0.900

The fraction of fire losses from each mitigation method and range type is then multiplied by the total number of addressed fire scenarios for the specific technology to determine the total fraction of fire losses potentially reduced by the technology for gas and electric ranges independently. These individual gas and electric scores shown in Eq. (8) and Eq. (9), respectively, are denoted as $FPE_{y,gas}$ and $FPE_{y,elec}$. These values will be referenced during the analysis with regard to evaluating the potential of technologies with regard to specific applications.

$$FPE_{y.gas} = C_y R_{y,z} \quad \text{Eq. (8)}$$

$$FPE_{y.elec} = D_y S_{y,z} \quad \text{Eq. (9)}$$

Where:

- $\boldsymbol{y}$ = Fire loss category
- $\boldsymbol{z}$ = Mitigation method
- $\boldsymbol{C_y}$ = Fraction of gas range fire losses of type *y* affected by technology
- $\boldsymbol{D_y}$ = Fraction of electric range fire losses of type y affected by technology
- $\boldsymbol{R_{y,z}}$ = Fraction of fire losses reduced when mitigation method present for gas range fires
- $\boldsymbol{S_{y,z}}$ = Fraction of fire losses reduced when mitigation method present for electric range fires

The overall reduction in fire losses was then determined by calculating the ratio of fire losses resulting from gas and electric stoves, respectively. The total amount of fire losses of type *y* resulting from fires occurring on gas ranges, electric ranges, and all ranges are provided in Table 10.

Table 10 – Fire Losses Resulting From Gas and Electric Stoves and the Total Amount of Losses

Type of Fuel or Power	y = 1 Fires	y = 2 Civilian Deaths	y = 3 Civilian Injuries	y = 4 Direct Property Damage (in Millions)
Gas – $B_{c,y}$	15,200	84	500	$86
Electric – $B_{d,y}$	74,640	247	3,187	$461
Other	280	0	10	$1
Total – $B_{t,y}$	90,120	330	3,697	$548

These values were used to calculate the ratio of total fire losses resulting from gas and electric ranges for the specific loss category, *y*. The specific range type losses, $B_{c,y}$ for gas ranges or $B_{d,y}$ for electric range losses, were divided by the total amount of loss, $B_{t,y}$, to determine the fraction of all range fire losses resulting from each range type as shown in Eq. (10) and Eq. (11). If the technology is not applicable for either gas or electric ranges, then the fraction was assigned a value of zero and hence no fire losses would be prevented.

$$\begin{pmatrix} Fraction\ of\ all \\ range\ fire\ loss \\ occurring\ on \\ gas\ range \end{pmatrix} = \frac{B_{c,y}}{B_{t,y}} \qquad \text{Eq. (10)}$$

$$\begin{pmatrix} Fraction\ of\ all \\ range\ fire\ loss \\ occurring\ on \\ electric\ range \end{pmatrix} = \frac{B_{d,y}}{B_{t,y}} \qquad \text{Eq. (11)}$$

Where:

$\boldsymbol{y}$ = Fire loss category
$\boldsymbol{B_{c,y}}$ = Total amount of fire losses of type *y* resulting from gas range fires
$\boldsymbol{B_{d,y}}$ = Total amount of fire losses of type *y* resulting from electric range fires
$\boldsymbol{B_{t,y}}$ = Total amount of fire losses of type *y* resulting from all range fires

The resulting fraction of addressed fire losses for gas and electric range fires were then summed to obtain the total fraction of losses that could be addressed through application of the mitigation technology. The sums were multiplied by 10 to appropriately scale the fire protection effectiveness for reducing fire losses of type *y*. The complete fire protection effectiveness calculation is shown in Eq. (12).

$$FPE_y = 10\left\{R_{y,z}\frac{B_{c,y}}{B_{t,y}}\left(\left[\sum_{n=1A}^{6}\left(\sum_{m=1}^{5}p_{n,m}x_{n,m}\right)c_{n,y}\right]x\left(1-Ign_{cy}\right)+CI\left(Ign_{cy}\right)\right)+ S_{y,z}\frac{B_{d,y}}{B_{t,y}}\left(\left[\sum_{n=1A}^{6}\left(\sum_{m=1}^{5}p_{n,m}x_{n,m}\right)d_{n,y}\right]x\left(1-Ign_{dy}\right)+CI\left(Ign_{dy}\right)\right)\right\} \qquad \text{Eq. (12)}$$

Where:

$\boldsymbol{n}$ = Fire category
$\boldsymbol{m}$ = Splitting factor/Ignition scenario
$\boldsymbol{y}$ = Fire loss category
$\boldsymbol{p_{n,m}}$ = Fire scenario factor for fire category n and splitting factor m (binary input to determine if technology would affect each specific fire scenario, 1 = yes, 0 = no)
$\boldsymbol{x_{n,m}}$ = Fraction of all category *n* fires occurring with ignition scenario *m* (Table A)
$\boldsymbol{B_{c,y}}$ = Total amount of fire losses of type *y* resulting from gas range fires (Table B)
$\boldsymbol{B_{d,y}}$ = Total amount of fire losses of type *y* resulting from electric range fires (Table B)
$\boldsymbol{B_{t,y}}$ = Total amount of fire losses of type *y* resulting from all range fires (Table B)
$\boldsymbol{c_{n,y}}$ = Fraction of total gas range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{d_{n,y}}$ = Fraction of total electric range fire losses of type *y* resulting from category *n* fires
$\boldsymbol{Ign_{cy}}$ = Fraction of gas range fire losses in category *y* resulting from clothing ignitions
$\boldsymbol{Ign_{dy}}$ = Fraction of electric range fire losses in category *y* resulting from clothing ignitions
$\boldsymbol{CI}$ = Clothing ignition factor, equal to one if applicable to clothing ignitions, zero if not
$\boldsymbol{R_{y,z}}$ = Fraction of fire losses reduced when mitigation method present for gas range fires
$\boldsymbol{S_{y,z}}$ = Fraction of fire losses reduced when mitigation method present for electric range fires
$\boldsymbol{FPE_y}$ = Fire protection effectiveness score for fire loss category *y*

In summary, the fire protection effectiveness, FPE, is a statistical score from zero to ten representing the maximum potential percentage of fire losses that could be reduced through the application of a mitigation technology. A score of zero would imply that the technology would have no impact upon the fire losses, and a score of ten would imply that the technology could completely eliminate 100% of the fire losses. The FPE as formulated in Eq. (12), includes the potential for a technology to affect both gas and electric ranges. The FPE score can also be developed for just gas or electric by zeroing out the appropriate term.

6.2 Cooking Performance

This criterion is intended to account for the effect of the technology on the cooking performance when compared to a range without the technology. The method of qualitative evaluation used was modeled after the method used in the previous CPSC/AHAM cooking fire mitigation report. Each product feature analyzed is given a ranking according to:

High – Feature meets the desired level of performance, score of 9

Medium – Feature provides capable performance, but with some limitations, score of 5

Low – Feature provides poor or unacceptable performance, score of 1

The cooking performance was calculated by determining the impact of the technology upon three performance metrics, including:

1. Cooking time
2. Cooking quality

3. Cook behavioral modifications

Each performance metric was given a score as described above. The overall cooking performance was calculated as the geometric mean of the performance metric scores as calculated by Eq. (13), where N is the total number of metrics and x_i is the score of each metric. The use of the geometric mean placed greater significance on obtaining a low score in any metric upon the total, as opposed to the direct averaging of the values.

$$\left(\prod_{i=1}^{N} x_i\right)^{1/N} \quad \text{Eq. (13)}$$

6.3 Cost and Convenience

Additional performance metrics were combined into a third category referred to as Cost and Convenience, including:

1. Initial purchasing cost
    a. Installation cost
    b. Product life-cycle costs
        i. Serviceability
        ii. Durability
    c. Cookware applicability
    d. Consumer Responsibilities
        i. Cleaning/maintenance required for proper operation
        ii. Additional safety risks to users
    e. Functional Considerations and Reliability
        i. Restoration of range of actuation
        ii. Potential for and consequences of false actuation
        iii. Functional system verification
        iv. Fail-safe operation
        v. Operate with reasonable user error or misuse

Each performance metric was scored as described in Section 6.2 and the geometric means were combined within each factor. When a factor does not have any individual performance metrics, it was scored independently as described in Section 6.2. The six factor scores were then combined using the geometric mean to determine the overall cost and convenience score.

The scoring results are summarized in the next section. An Excel workbook for investigating the technology evaluations and containing all the individual scores is included with Appendix B. The workbook allows a user to edit individual scoring criteria and determine the effect upon the comparative scoring of various technologies.

7.0 RESULTS

Technology evaluation scores are presented in the following section. The raw scores contain six separate scoring categories. The Cooking Performance and Cost and Convenience scores are presented, as well as the four Fire Protection Effectiveness (FPE) Scores, including prevention of incidents, deaths, injuries, and property damages. The Cooking Performance and Cost and Convenience scores are tallied from a possible range of 1–9, with 1 indicating the lowest quality and 9 indicating the highest quality. It should be noted that a high score in Cost and Convenience is indicative of a low overall cost and impact on convenience of use.

FPE scores range on a possible scale from 0–10. The score represents the fraction (multiplied by 10) of fire related losses that could potentially be eliminated through a universal installation of the technology. The scores are developed by statistical analysis of likely fire scenarios and general reliability and effectiveness data as described in Section 6.1.

In addition, three potential methods of combining these scores have also been presented, and the technologies with the greatest potential (overall scores) are identified within each mitigation method group. The three methods of combining scores include a sum total of the six individual scores, a sum total of the Cooking Performance and Cost and Convenience with the average of the four Fire Protection Effectiveness scores, and a geometric mean of the Fire Protection Effectiveness for death only and the Cooking Performance and Cost and Convenience Scores. Each of the combination scores are presented normalized from 0–10 by dividing by the maximum possible score for each combination method and multiplying by 10. For example, the total sum is normalized by a maximum score of 58 [sum of 10, 10, 10, 10, 9, 9], the average FPE total sum is normalized by a maximum score of 28 [sum of 10, 9, 9], and the FPE death with geometric mean is normalized by a maximum score of 9.3 [geometric mean of 10, 9, 9]. The scaling from 0–10 was used to maintain consistency with the scoring of the primary categories.

Each score combination method explored places different weight and emphasis upon certain facets of the analysis. When combining the total sum of all scores, four of the six values are fire protection based scores, and thus this combination places the greatest emphasis upon the reduction of various fire losses. The second method of utilizing the average of all FPE scores reduces the total weight to 1/3 of the analysis, and thus places more importance upon the Cooking Performance and Costs and Convenience of the devices. The third method is only concerned with the reduction of fire related deaths, and thus places total fire protection emphasis upon this point.

Where applicable, some additional analysis is presented for determining the potential impact of a technology for use on gas or electric only ranges. The intent of this analysis is to not exclude technologies that have limited applicability due to the reduction in the overall score. A technology that receives high overall scores for electric or gas only range tops can be identified as a potential solution for a select market.

7.1 Group 1 – Detect Flaming Fire and Provide Warning

The first mitigation method group includes the devices intended to detect flaming fires and provide audible or visual warnings to occupants. The methods for detection of these fire types

include fusible links, non-optical temperature sensors, optical temperature sensors, VID, OFD, and TI technologies. The overall scoring in the six categories is shown in Figure 1.

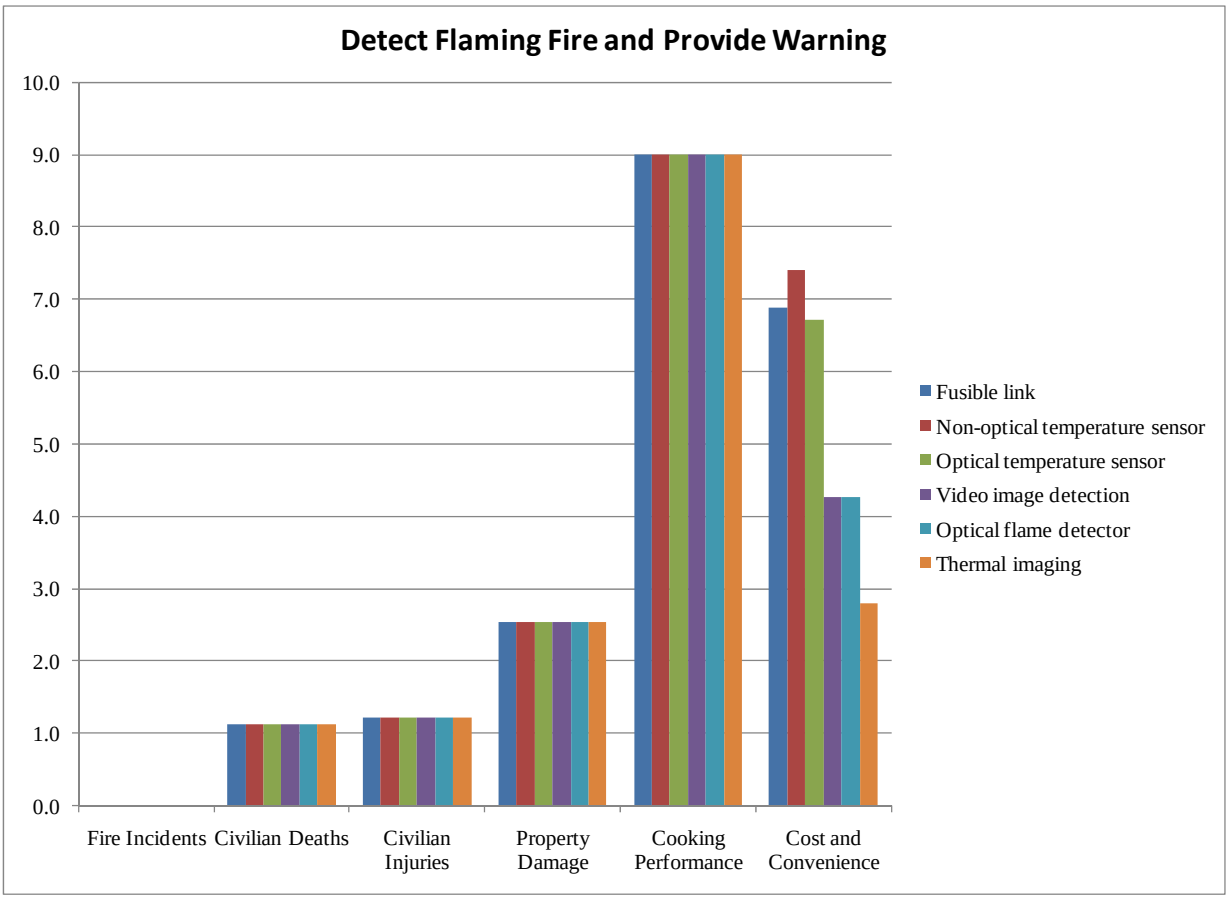

Figure 1 – Mitigation Group 1 – Detect flaming fire and provide warning scored in the six major categories

All detection technologies are capable of detecting the same range top fire scenarios, and thus no variation exists between any technologies in these FPE categories. The impact of warning alarms upon reducing fire losses is included within these results. A warning will have no impact upon the number of fire incidents, while having the greatest impact upon the amount of property damages. Simply providing a warning of an occurring fire could potentially reduce property losses by as much as 25% (score = 2.5), and reduce deaths and injuries by 11 or 12%, respectively (1.1, 1.2).

None of the Group 1 detection technologies should have any effect upon the Cooking Performance of the range top, thus all score a perfect 9.0 in this category.

The differences between the various Group 1 technologies exist in the costs required to install and maintain the devices and the impact upon the user to upkeep the devices in proper working order. VID, OFD, and TI technologies are generally more expensive and require additional cleaning and upkeep when compared to the fusible link, non-optical, and optical temperature sensors. The non-optical temperature sensor yields best overall result in this group,

scoring 7.4, due to low cost and maintenance. The fusible link is also reliable and relatively cheap, but requires replacement after actuation, thus reducing the score to a 6.9. The optical temperature sensor is also reliable and relatively inexpensive, but requires cleaning and maintenance of the optical detection element, also reducing its convenience score to a 6.7. The VID and OFD devices expense contribute to yield scores of 4.3, while the TI scores a 2.8.

The overall combined scores for the Group 1 technologies are shown in Figure 2. The various technologies do not demonstrate unique impacts upon FPE or Cooking Performance, and thus the differences in the total scores are entirely generated by differences in the Costs and Convenience category. The non-optical temperature sensor is the highest scoring of the Group 1 technologies, scoring a 6.3 when combined using an average FPE value. The fusible link scores comparably with a 6.1, as well as the optical temperature sensor with a 6.0. The TI devices scored the lowest, obtaining a 4.7 for this combination method. The other methods of combination yield similar scoring distributions. No Group 1 technologies are exclusive to gas or electric range tops, and thus a separate analysis is not included.

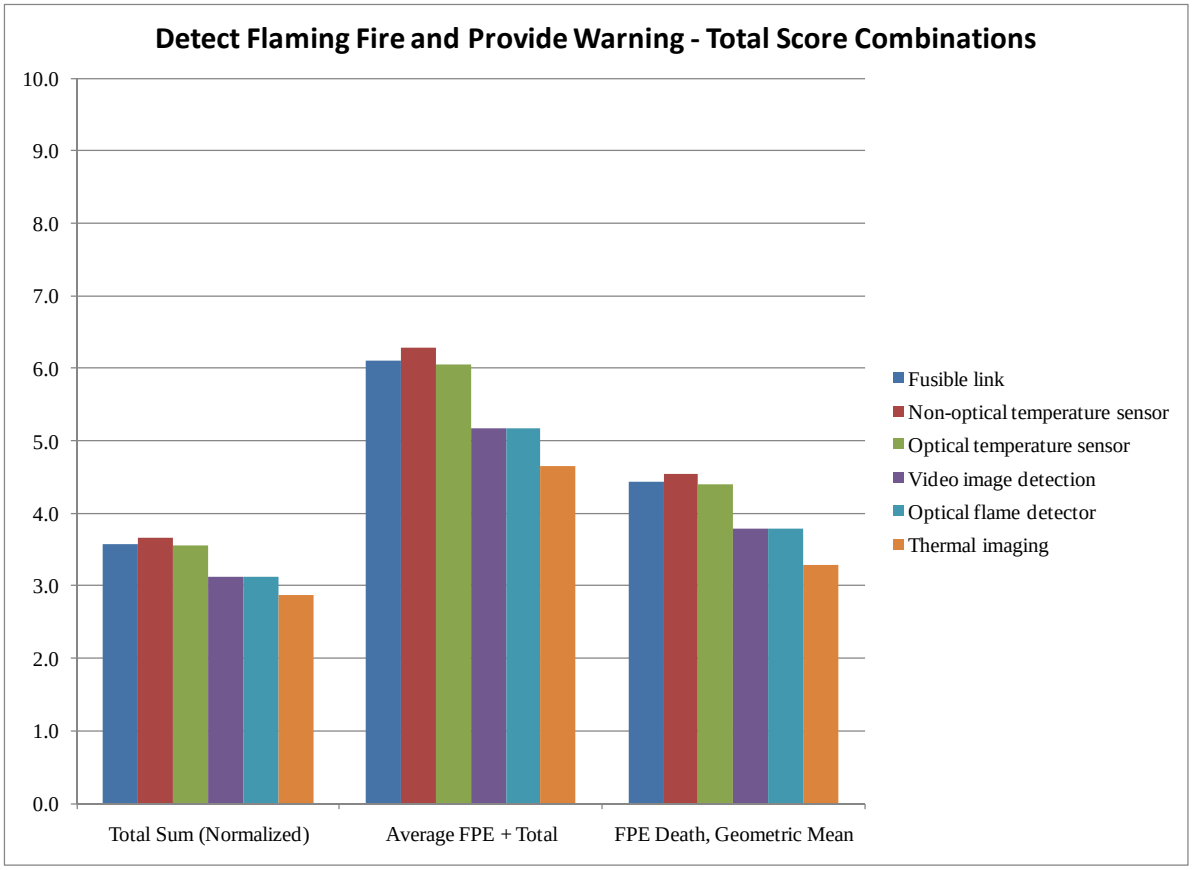

Figure 2 – Mitigation Group 1 – Detect flaming fire and provide warning normalized combined scores

7.2 Group 2 – Detect Imminent Flaming Ignition and Provide Warning

Mitigation Group 2 includes the devices intended to detect imminent flaming ignitions and provide audible or visual warnings to occupants. The primary methods for detection of these fire

types include detection of unattended cooking and detection of pre-flame conditions, such as excessive heat or smoke. Unattended cooking can be detected through use of motion sensors and timers, and these devices can be combined with pan temperature sensors or burner power sensors to direct their impact towards realistic flaming ignitions. The overall scoring for the unattended cooking detectors in Group 2 in the six categories are shown in Figure 3.

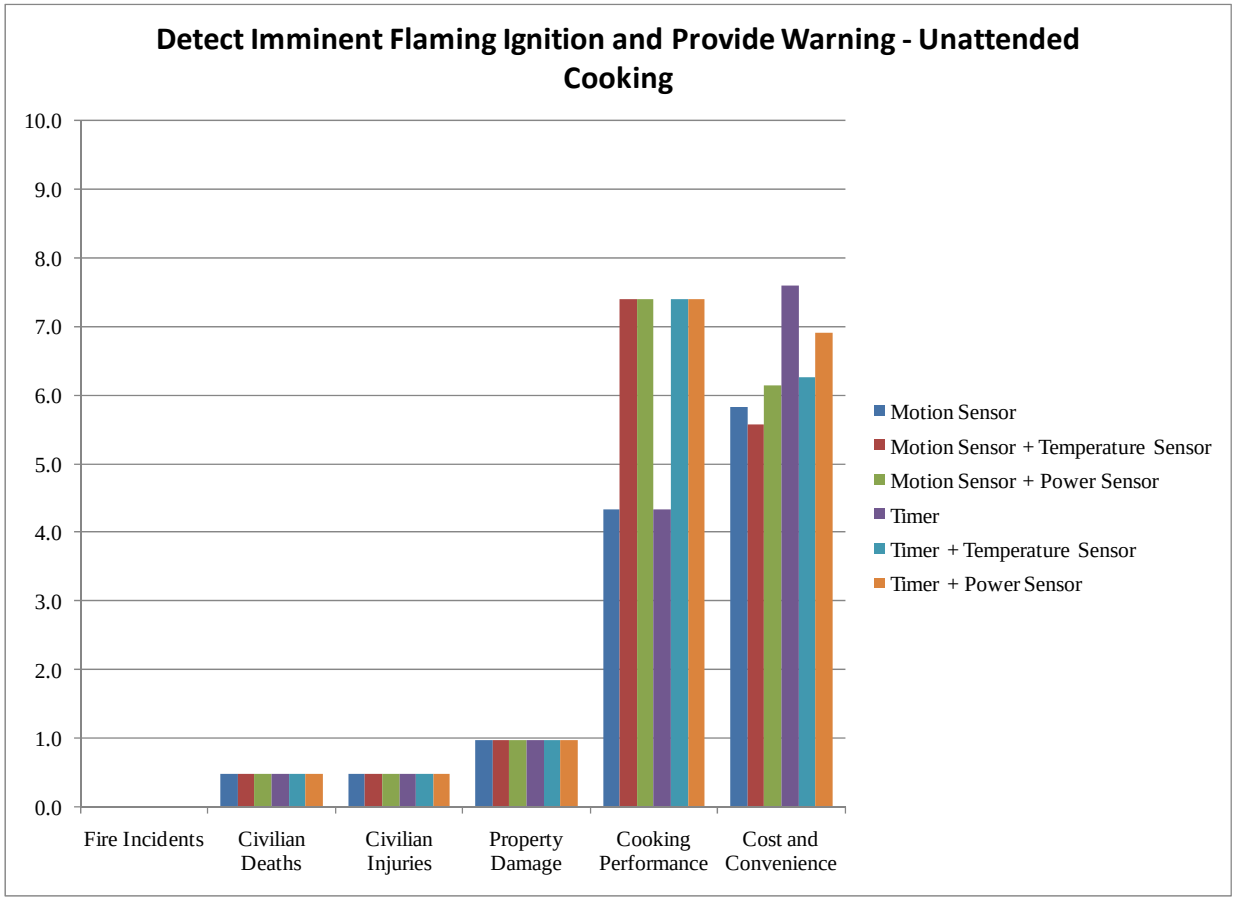

Figure 3 – Mitigation Group 2 – Detect imminent flaming ignition and provide warning scored in the six major categories

Warning alarms related to unattended cooking are not expected to address a large number of fire scenarios, as evidenced by the FPE scores all calculated below 10% (i.e., scores <1). Such devices are calculated to reduce 5% of civilian deaths and injuries and 10% of property damages. While a large number of fires are a result of unattended cooking, only focusing upon these fires and using only a warning alarm result in a low probability of reducing realistic fire losses. All devices should be applicable to the same fire scenarios, and thus all receive the same FPE scores.

The extra requirement of the cook to be in the vicinity of the range, either in motion or pushing a timer reset button, represent the effect upon Cooking Performance reduction evidenced by the scoring. The combination of the motion detector with a pan temperature sensor or burner power sensor reduces such nuisance by limiting the alarm to situations realistically capable of resulting in flaming ignitions, ignoring low power and low temperature cooking scenarios. The

overall increase in the Cooking Performance scores from a 4.3 for both motion sensors or timers alone to a 7.4 through the addition of these features is evident.

The addition of the temperature or power sensors are expected to increase the installation and potential maintenance costs of the technologies. The pan temperature sensor would require constant interaction with the cooking area and utensils, and thus would be expected to have increased wear and durability issues compared to the burner power sensor, that could be hidden within the range and not require constant contact. Thus, in general, the power sensor scores better overall in the Cost and Convenience than the pan temperature sensor option. The timer is a simple clock and button device, and the timer scores a 7.6 compared to the more complex motion sensing device, scoring a 5.6. The simplicity of the timer results in higher scores than the motion sensor when combined with additional sensors as well. This is due to the potential product life, maintenance, and potential for false positives (moving curtains, children, pets) resulting from the use of motion detection devices.

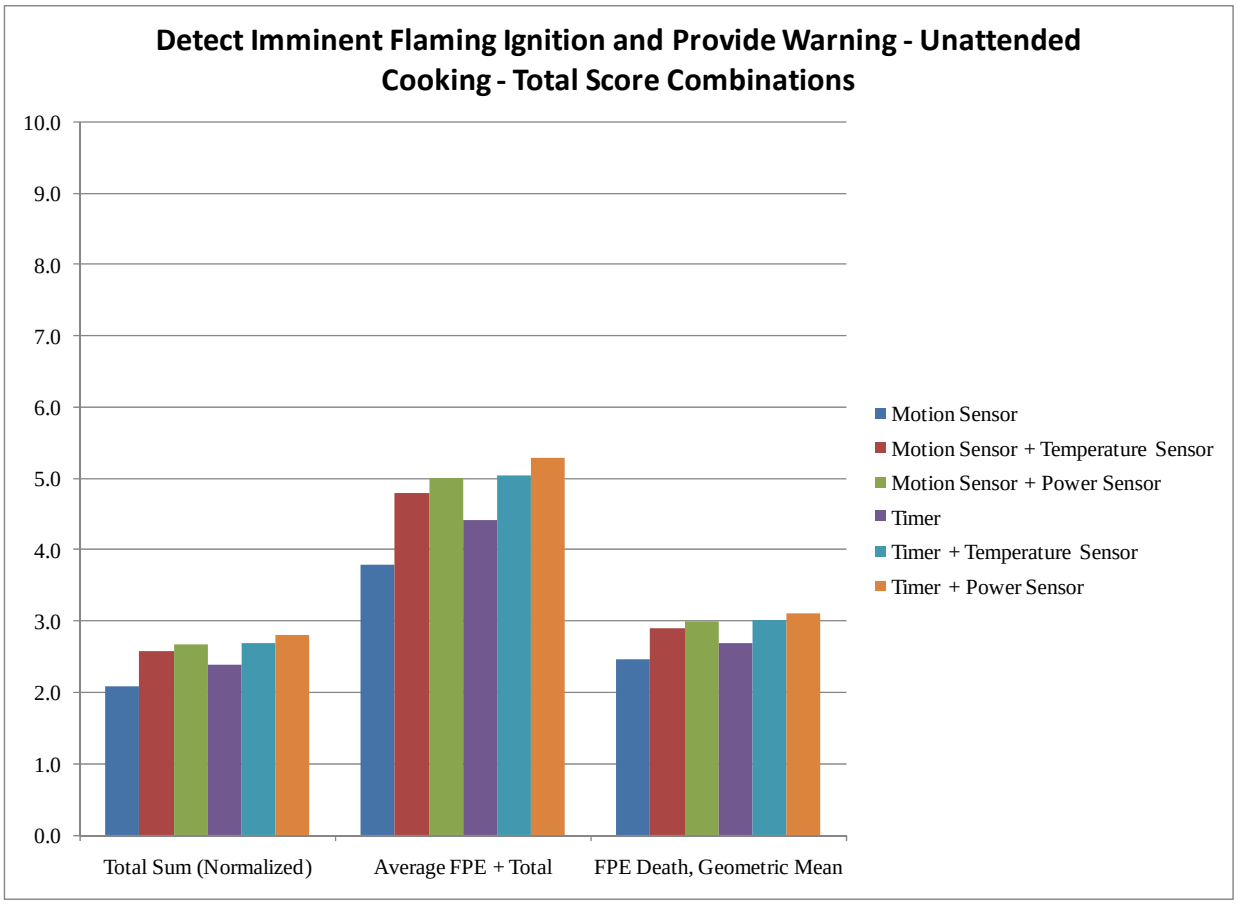

Figure 4 – Mitigation Group 2 – Detect imminent flaming ignition and provide warning through unattended cooking detection normalized combined scores

The overall combined scores for the Group 2 unattended cooking detection technologies are shown in Figure 4. For all three score combination methods, the timer combined with burner power sensor received the highest overall score, obtaining a 2.8, 5.3, and 3.1 for the total, average, and death combinations, respectively. This is a result of the expected reduced nuisances

from the addition of the power sensor to the timer, the simplicity of the timer over the motion sensor, and the increased product durability of the power sensor over the pan temperature sensor. The timer with the temperature sensor (2.7, 5.1, 3.0) and motion sensor with burner power sensor (2.7, 5.0, 3.0) also scored comparably well. No Group 2 unattended cooking technologies are exclusive to gas or electric range tops, and thus a separate analysis is not included.

Imminent flaming ignitions can also be detected through various pre-ignition conditions, such as elevated temperatures over the range with a non-optical or optical temperature sensor, smoke production from the range, pan temperature sensors, both contact and non-contact, and burner surface temperature measurements. The overall scoring for the pre-flaming ignition detection technologies in Group 2 in the six categories are shown in Figure 5.

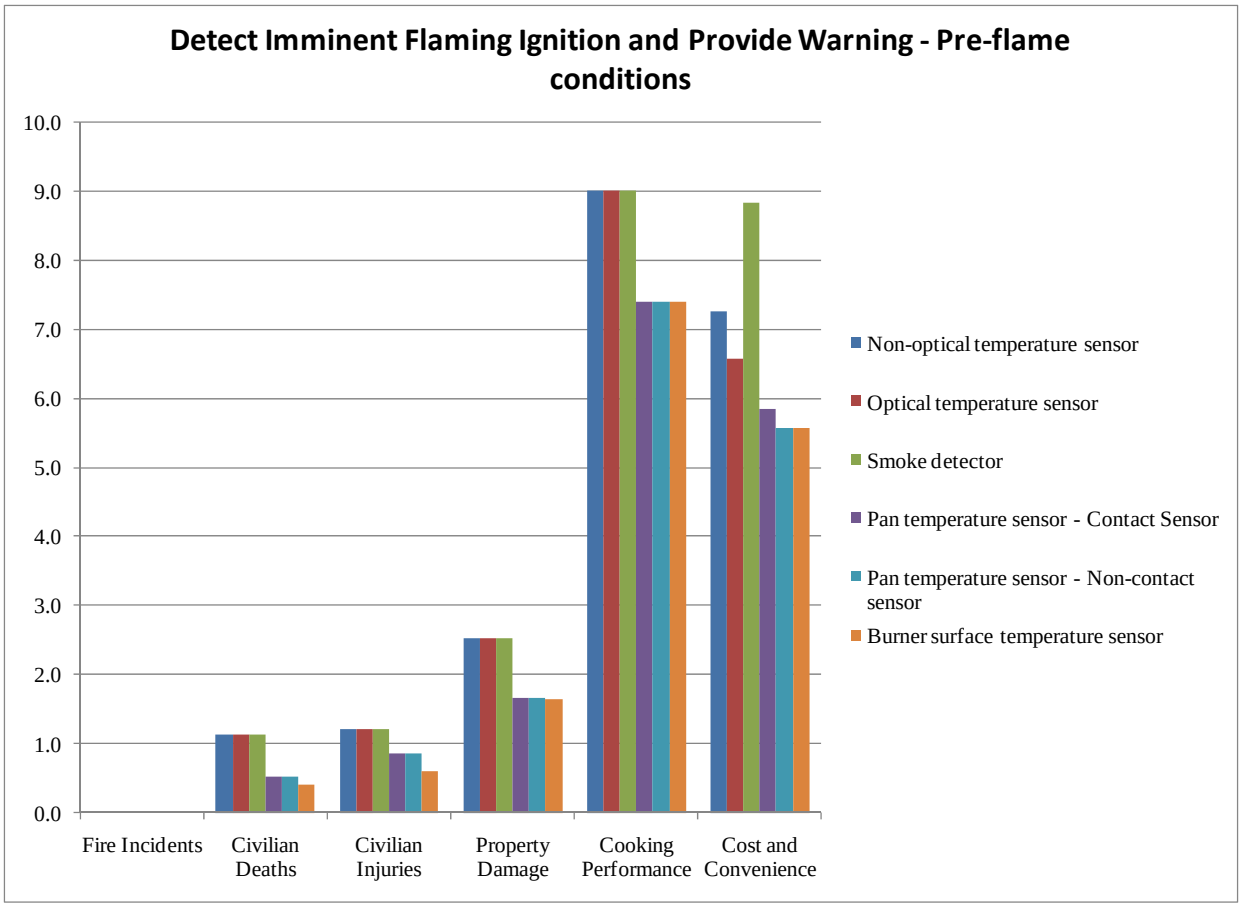

Figure 5 – Mitigation Group 2 – Detect pre-flame conditions and provides warning scored in the six major categories

Detection of elevated temperatures or emission of smoke particles over the range top should be applicable to the ignition of all range fire scenarios. The FPE scores for the optical, non-optical, and smoke detection technologies are greatest due to this ability to detect any fire occurring on the range top. While not able to prevent any fire incidents (0.0), these devices could reduce fire deaths by 11%, fire injuries by 12%, and property damages by 25%. Measurements of the pan or burner temperature limit detection to fires occurring in a food pan or on the burner surface due to excessive heat. By limiting the addressed scenarios, the pan or burner surface

temperature devices limit the amount of fire losses that can be prevented. The pan temperature sensors could reduce fire deaths by 5%, injuries by 9%, and property damages by 17%. The burner surface temperature device is only applicable to electric range devices, and thus the FPE scores are slightly reduced (approximately 1%) due to this limitation.

Detection of elevated pan and burner temperatures can also limit the cook in the range of available cooking temperatures, and thus could limit cooking performance. This is evidenced in the reduction of the cooking performance score for the pan and burner temperature sensors from a 9.0 to a 7.4.

Smoke detection receives high scores in the Cost and Convenience category due to product development status and the universal availability of smoke detectors, obtaining a score of 8.8. It is important to recognize that a smoke detector used specifically for cooking fire mitigation can be optimized and have higher alarm settings than standard household smoke alarms in order to provide satisfactory performance relative to potential nuisance alarms. The durability and reduced maintenance of the non-optical and optical temperature sensors also result in greater Cost and Convenience scores (7.3, 6.6) over pan and burner temperature sensor options (5.8, 5.6). Constant pan and burner contact brings into question potential issues with durability and product lifetime, as reflected in the scoring of such technologies.

The overall combined scores for the Group 2 pre-flame condition detection technologies are shown in Figure 6. For all three score combination methods, the smoke detection sensor received the highest overall scores, obtaining a 3.9, 6.8, and 4.8 for the total, average, and death combinations, respectively. This is a result of applicability to all range fire scenarios and the product availability and current product costs. The burner surface temperature devices scores the lowest overall among the Group 2 warning devices, obtaining a 2.7, 4.9, and 2.8 for the total, average, and death combinations, respectively. This is mostly due to the applicability of the burner surface temperature sensor to electric range tops only. This applicability directly influences the calculation of the FPE scores. The FPE scores are shown in Figure 7 when only fire losses resulting from electric range tops are considered.

When the fire protection impact is considered only for application to electric ranges, the burner surface temperature scores comparably to the pan temperature sensors. When only losses related to deaths are considered, the burner surface temperature alarm scores a 0.6, slightly better than either pan temperature sensor, 0.5.

7.3 Group 3 – Contain Fire/Prevent Fire Spread

Mitigation Group 3 includes the devices intended to contain fires occurring on the range and prevent them from spreading to adjacent combustibles in the kitchen. The primary methods for containment of range fires include passively restricting flame with non-combustible walls and actively dropping a containment hood or other vessel over the top of the burning range surface. The overall scoring for the Group 3 technologies in the six categories is shown in Figure 8.

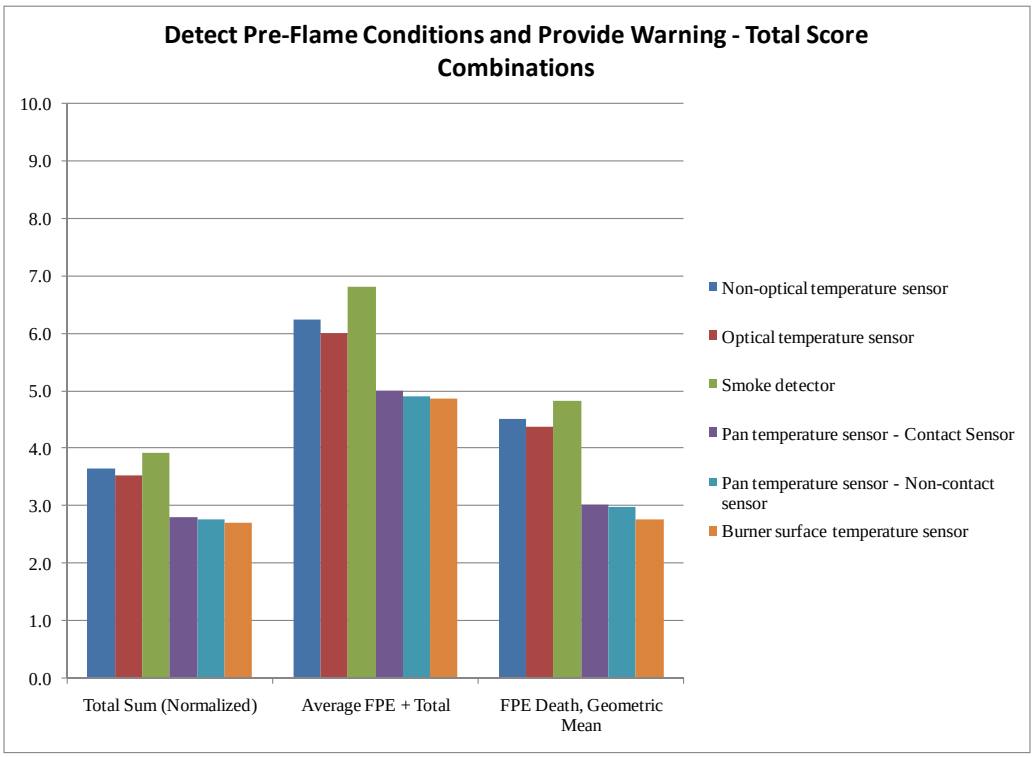

Figure 6 – Mitigation Group 2 – Detect pre-flame conditions and provides warning normalized combined scores

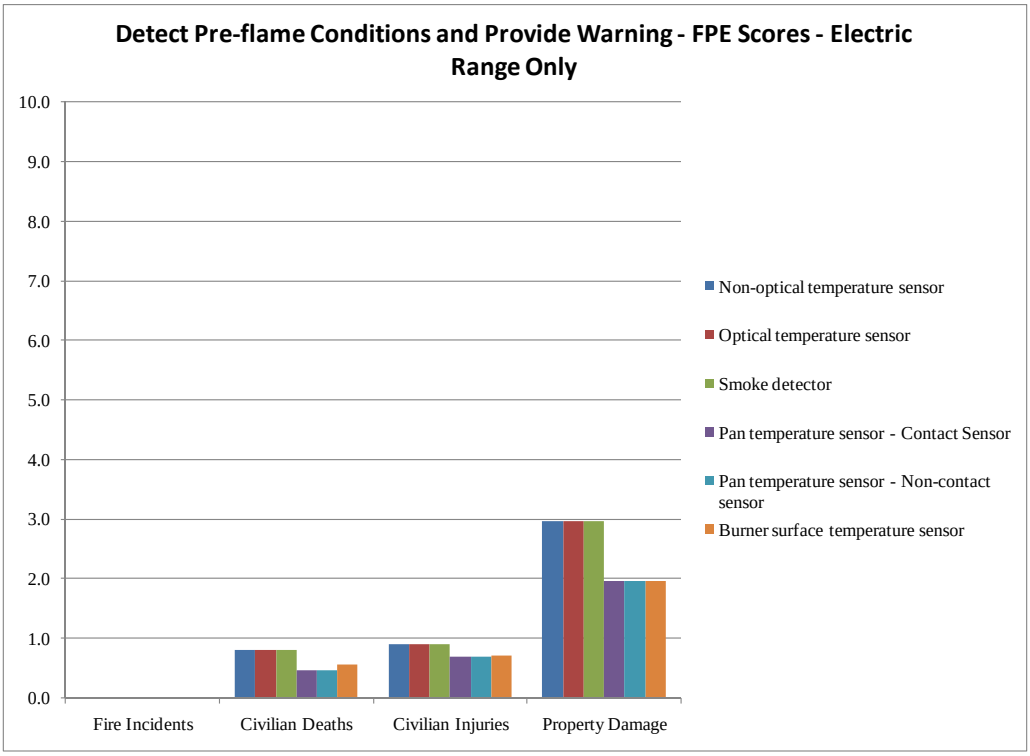

Figure 7 – Mitigation Group 2 – Detect pre-flame conditions and provides warning electric range FPE scores only

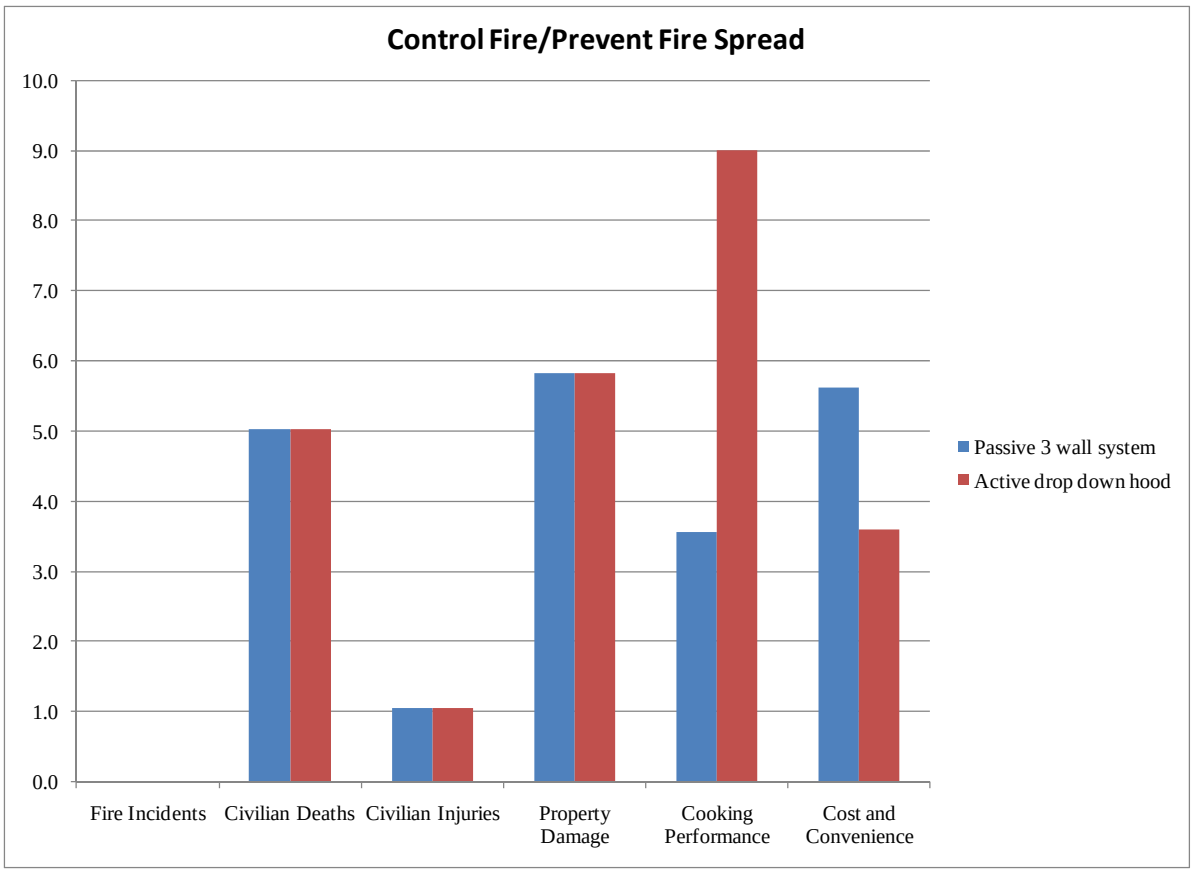

Figure 8 – Mitigation Group 3 – Contain fire/prevent fire spread technologies scored in the six major categories

While containment of a fire prevents a comparably low number of injuries, 10%, it can be quite effective at reducing deaths and property losses. Simply by preventing fires from spreading from the range top, 50% of civilian deaths and 58% of property damages resulting from range top fires could be prevented. Both technologies are applicable to contain the same range top fire scenarios, and thus receive identical scores.

The three wall system reduces cooking performance by limiting the use of the range and changing the cook behavior, obtaining a score of 3.6. This is generally due to the physical barriers of the non-combustible walls preventing easy use of the back burners on the range. The active system is invisible to the user during cooking unless activated, thus receives a max Cooking Performance Score of 9.0.

The passive system is much more cost effective and simple to maintain than the active hood. The added burn risks associated with working around the passive system, potentially contacting front burners to access the back, does reduce the convenience score considerably to a 5.6. The additional costs, maintenance, and product functions of the active hood system reduce its Cost and Convenience Score to a 3.6.

The overall combined scores for the Group 3 technologies are shown in Figure 9. For all three score combination methods, the active hood system received a higher overall score than the

passive, non-combustible walls. The greatest disparity occurs when the average of the FPE scores are used, with the active hood scoring a 5.6 to the passive systems 4.3 total scores. Despite the increased costs and service requirements of the active device, the negligible impact upon cooking and the ease of use of the range result in better overall scores for the active dropdown hood. Both devices are applicable to both gas and electric range tops and thus no further analysis was conducted.

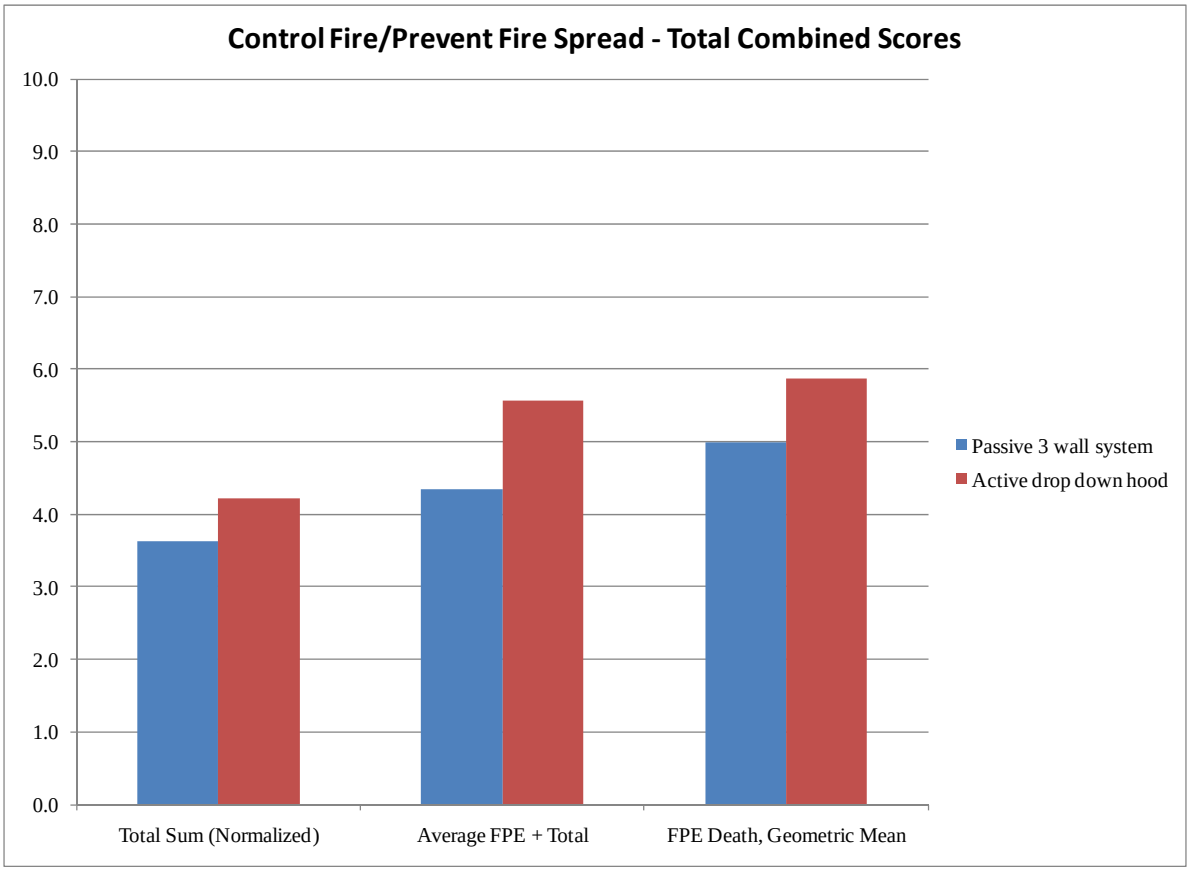

Figure 9 – Mitigation Group 3 – Contain fire/prevent fire spread normalized combined scores

7.4 Group 4 – Provide Automatic Suppression

Mitigation Group 4 includes the devices intended to detect flaming fires occurring on the range and provide automatic suppression. The methods for detection of these fire types include fusible links, non-optical temperature sensors, optical temperature sensors, VID, OFD, and TI technologies. After detection, suppression can be provided by either sprinklers or wet/dry chemical suppressants. The overall scoring for the various detection methods using sprinklers in the six categories is shown in Figure 10.

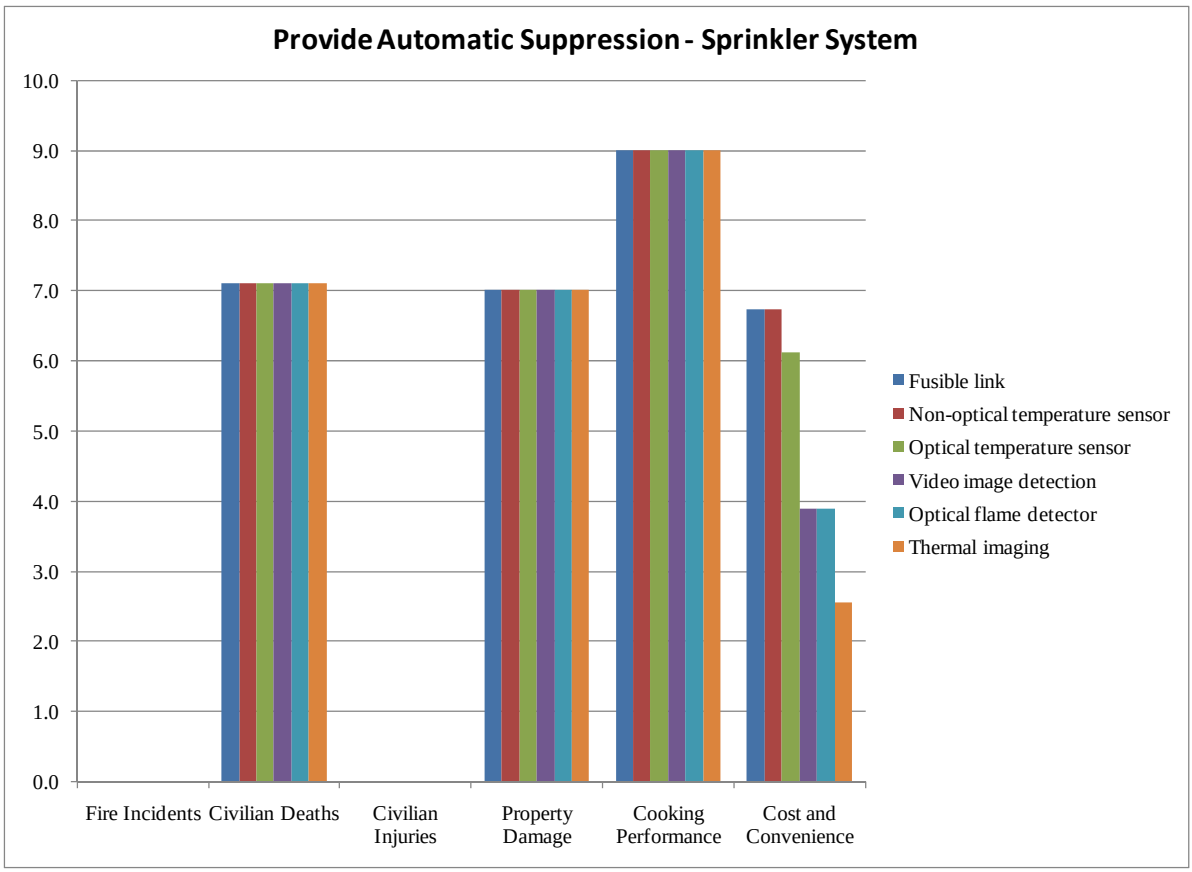

Figure 10 – Mitigation Group 4 – Provide automatic suppression with sprinklers scored in the six major categories

Automatic suppression systems do not have any impact upon the number of fire incidents, and are not shown to impact civilian injury rates, receiving scores of 0.0 in these categories. These devices are effective at reducing the number of deaths and property damages resulting from fire incidents by as much as 70% for all range fire losses. It should be noted, however, that the reduction in property damages represents only those losses caused by fire damage, and does not account for damages occurring due to water damages from the sprinkler system itself. All detection technologies are applicable to the same fire scenarios, and thus all FPE scores are identical.

Cooking is unaffected by the use of a suppression system or the various flame detection methodologies analyzed. All detection options receive perfect scores of 9.0 for the Cooking Performance category.

The differences between the various Group 4 technologies exist in the costs required to install and maintain the devices and the impact upon the user to upkeep the devices in proper working order. VID, OFD, and TI technologies are generally more expensive and require additional cleaning and upkeep when compared to the fusible link, non-optical, and optical temperature sensors. The non-optical temperature sensor and fusible link yield the best overall results in this group due to low cost and maintenance, scoring a 6.7. The optical temperature sensor is also reliable and relatively inexpensive, but requires cleaning and maintenance of the

optical detection element, also reducing its convenience score to a 6.1. The costs and complexity of the VID and OFD devices reduce the scores to a 3.9, while the TI received a 3.9.

The overall combined scores for the Group 4 sprinkler technologies are shown in Figure 11. The fusible link and non-optical temperature sensors receive the highest overall scores for flame detection devices used to activate sprinkler suppression, obtaining a 5.1, 6.9, and 8.1 for the total, average, and death combinations, respectively. These devices are generally reliable, durable, and inexpensive compared to the other detection options. The optical temperature sensor also scored comparably, receiving a 5.0, 6.7, and 7.9 for the total, average, and death combinations, respectively.

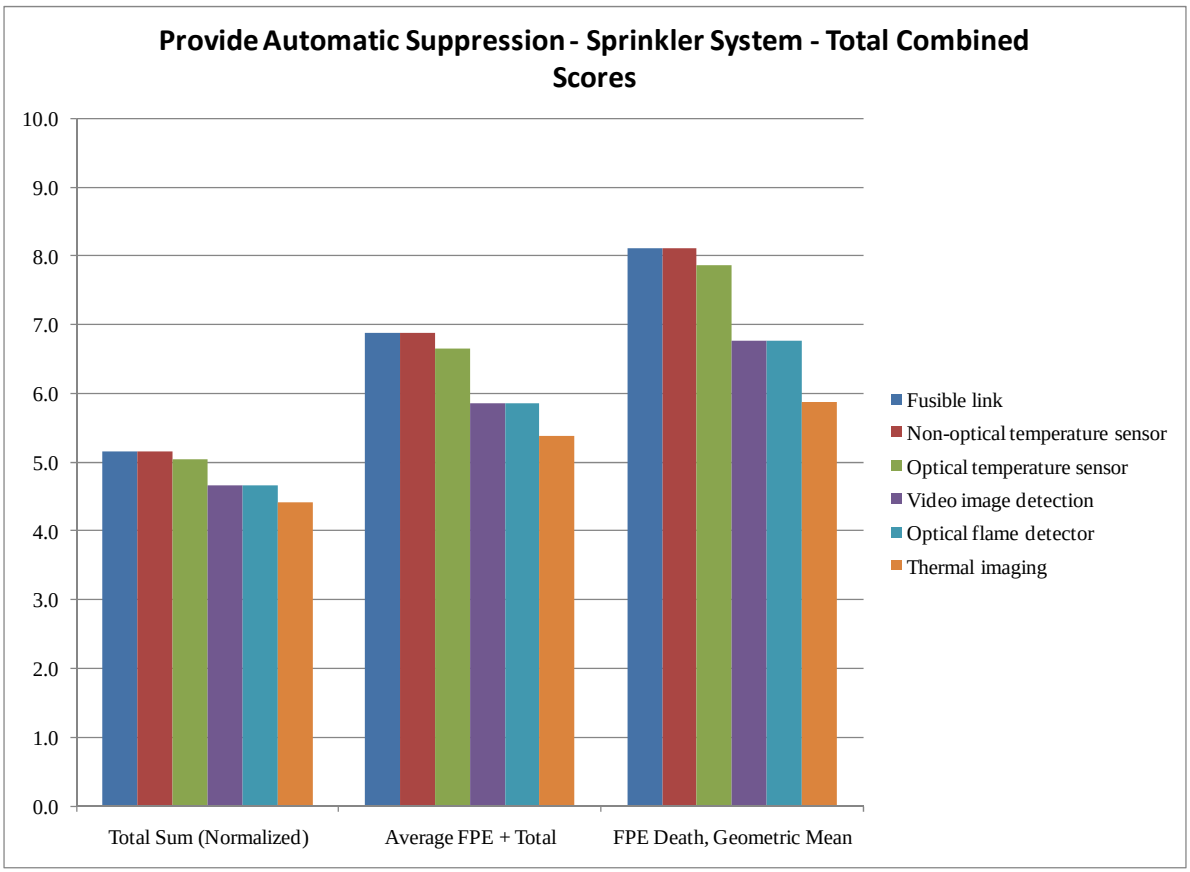

Figure 11 – Mitigation Group 4 – Automatic suppression through sprinklers, normalized combined scores

When comparing the use of wet/dry chemical suppression systems to sprinkler systems, no differences are calculated in the Cooking Performance or Costs and Convenience categories. The primary differences between the two types of suppression are derived by the reliability of the systems to operate, and the effectiveness of the system to suppress fires once activated. These attributes are included within the calculation of the FPE scores. The FPE scores for the highest overall rated sprinkler detection devices (fusible link and non-optical temperature sensor) are shown along with the wet/dry chemical systems in Figure 12.

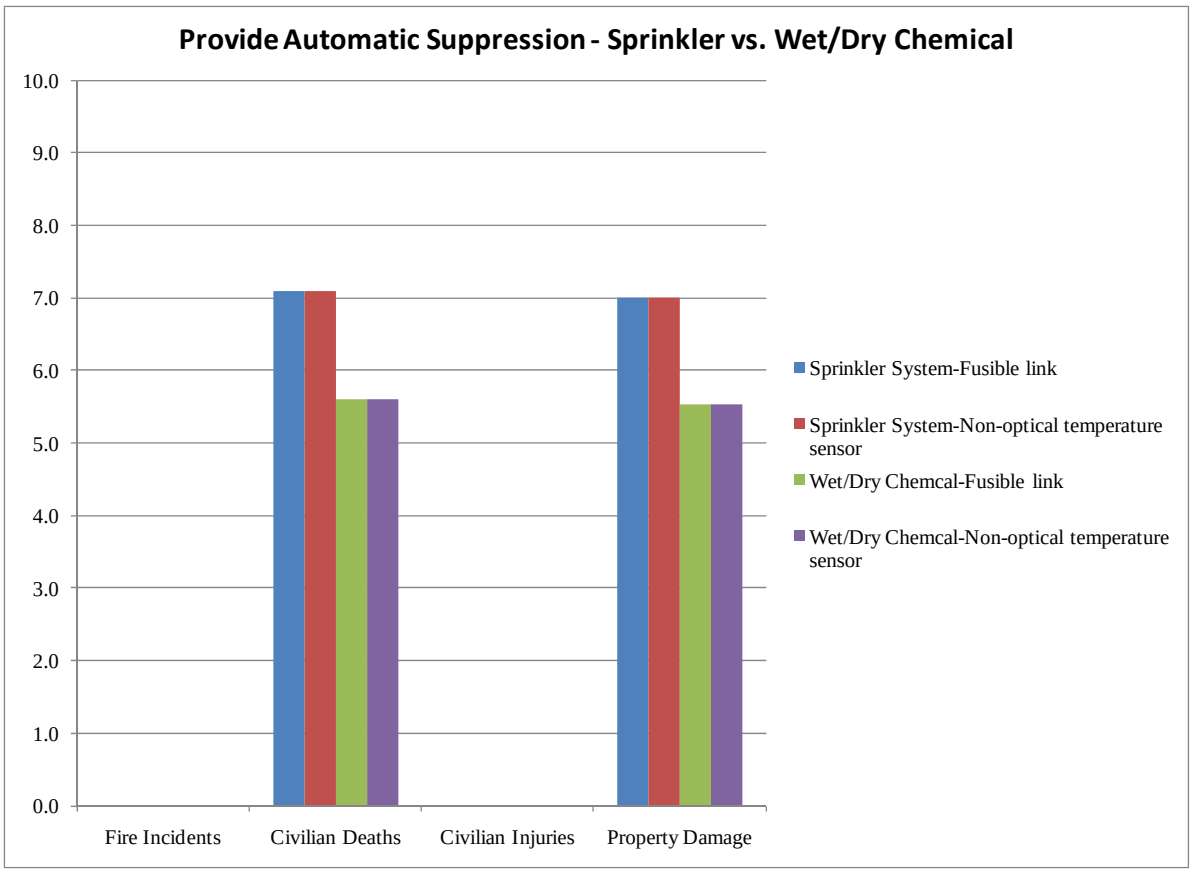

Figure 12 – Comparison of calculated FPE scores for sprinkler and wet/dry chemical suppression systems

The reliability and effectiveness of sprinkler systems has been demonstrated to reduce more deaths and property losses, 71% and 70%, respectively, than expected for the wet/dry chemical suppression systems, 56% and 55%. None of the automatic suppression technologies are limited in applicability to gas or electric range tops and thus no further analysis has been included.

7.5 Group 5 – Prevent Fire

Mitigation Group 5 includes the technologies intended to automatically prevent the ignition of fire on the range top. The primary methods for detection of these ignition scenarios include detection of unattended cooking and detection of pre-flame conditions, such as excessive heat or smoke. Once a potential ignition scenario is detected, the technology will act to automatically eliminate the threat and prevent ignition form occurring. Unattended cooking can be detected through use of motion sensors and timers, and these devices can be combined with pan temperature sensors or burner power sensors to eliminate nuisance alarms when low power cooking makes ignitions unlikely. When unattended cooking is detected, the burner power or gas supply would be cutoff, preventing ignitions from occurring. The overall scoring for the unattended cooking detectors in Group 5 in the six categories are shown in Figure 13.

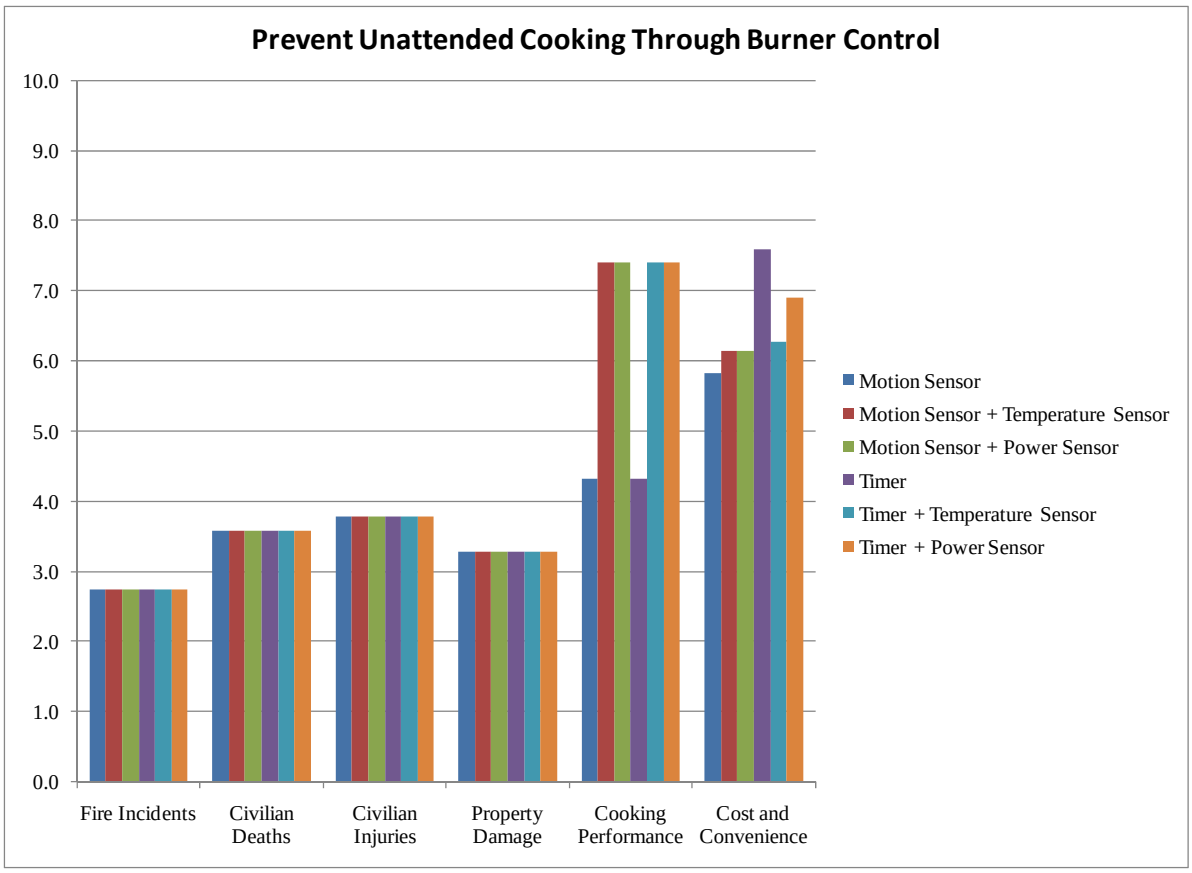

Figure 13 – Mitigation Group 5 – Prevent fire through unattended cooking detection and burner control scored in the six major categories

Prevention of fires related to unattended cooking could impact 27% of fire incidents, including 36% of range fire deaths. The greatest reduction in fire losses is shown to occur for injuries; a reduction of 38% is calculated. All devices should be applicable to the same fire scenarios, and thus all receive the same FPE scores.

The extra requirement of the cook to be in the vicinity of the range, either in motion detection or pushing a timer reset button, represent the effect upon Cooking Performance reduction evidenced by the scoring. The combination of the motion detector with a pan temperature sensor or burner power sensor reduces the nuisance by limiting the alarm to situations realistically capable of resulting in flaming ignitions, ignoring low power and low temperature cooking scenarios. The overall increase in the Cooking Performance scores from a 4.3 for either motion sensors or timers alone to a 7.4 through the addition of these features is evident.

The addition of the temperature or power sensors are expected to increase the installation and potential maintenance costs of the technologies; however, the pan temperature sensor would require constant interaction with the cooking area and utensils, and thus would be expected to have increased wear and durability issues compared to the burner power sensor, that could be hidden within the range and not require constant contact. Thus, for the timer device, the power sensor scores better overall in the Cost and Convenience (6.9) than the pan temperature sensor option (6.3). The timer is a simple clock and button device, and the timer-based options score

better overall (7.6) than the motion sensor options (5.8) for Cost and Convenience as well. This is due to the potential product life, maintenance, and potential for false positives (moving curtains, children, pets) resulting from the use of motion detection devices.

The overall combined scores for the Group 5 unattended cooking detection technologies are shown in Figure 14. For all three score combination methods, the timer combined with burner power sensor received the highest overall score, obtaining a 4.8, 6.3, and 6.1 for the total, average, and death combinations, respectively. This is a result of the reduced nuisances resulting from the addition of the power sensor to the timer, the simplicity of the timer over the motion sensor, and the increased product durability of the power sensor over the pan temperature sensor. The scores obtained for the motion sensor with temperature or power sensor (4.6, 6.0, 5.9), and the timer with a temperature sensor (4.7, 6.1, 5.9) were very comparable to the timer with power sensor. No Group 5 unattended cooking technologies are exclusive to gas or electric range tops, and thus a separate analysis is not included.

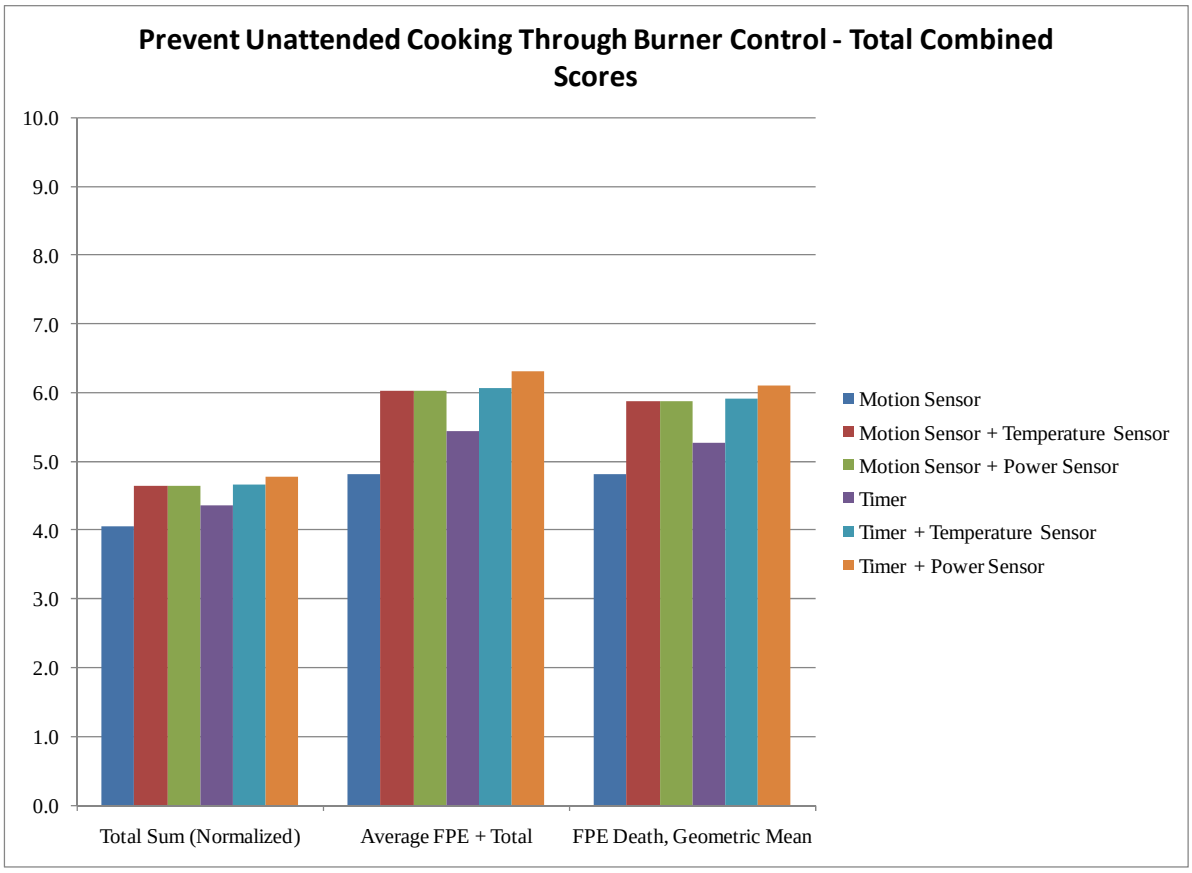

Figure 14 – Mitigation Group 5 – Prevent fire through unattended cooking detection and burner control normalized combined scores

Imminent flaming ignitions can also be detected through temperature detection on cooking pans or upon the burner surface. Several potential temperature methods can be used to indicate such pre-ignition conditions. Such temperature indicators include a fixed temperature threshold value to indicate ignition or a sharp temperature gradient to indicate a boil over or spill. The fixed over temperature condition can also be variable depending on a user identified cooking

type. If these potential ignition conditions are observed, the burner power can be interrupted until safe operating conditions have been restored.

If a single, fixed temperature threshold is to be set for limiting cooking temperatures, the over temperature condition could be detected by a pan contact temperature sensor, a non-contact pan temperature sensor, a burner surface temperature sensor, or a mechanically actuated switch. The overall scoring for the fixed-temperature detection technologies in Group 5 in the six categories are shown in Figure 15.

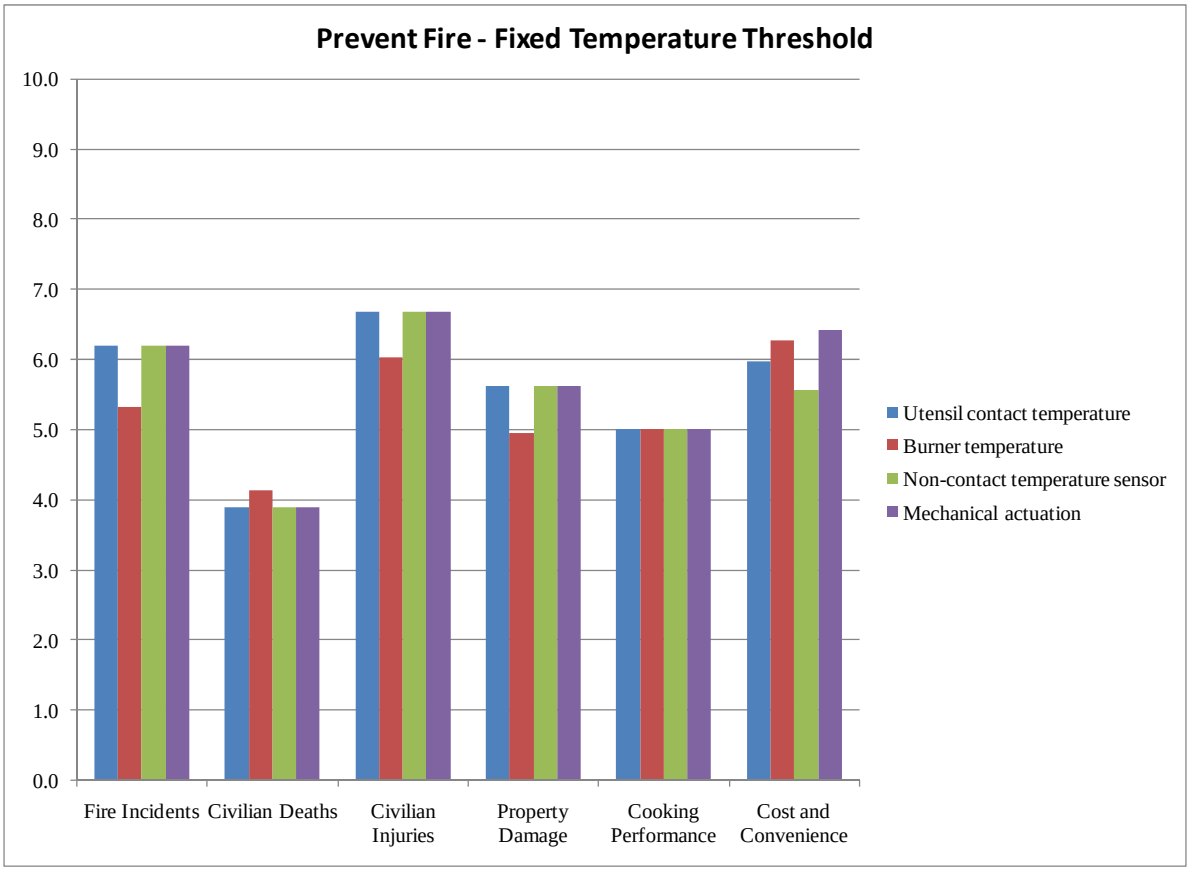

Figure 15 –Mitigation Group 5 – Prevent fire through fixed temperature burner control scored in the six major categories

Compared to other mitigation technology groups, preventing fires with fixed temperature burner shut-off systems has a significant impact on both reducing fire incidents as well as reducing deaths, injuries and property damage. The number of fire incidents could be reduced by upwards of 50 to 60%. Deaths are potentially reduced by about 40% and injuries and property damage are reduced by about 50 to 65%. The FPE scores for the pan contact temperature sensors, including contact, non-contact, and mechanical are equivalent and greater than the burner surface temperature sensor with regard to the reduction of incidents, injuries, and property losses. This is due to the burner surface temperature sensor being applicable only to electric range top fires. The ability of the burner surface temperature measurement device to prevent the ignition of clothing provides a significant increase in the prevention of deaths, giving the burner surface device a greater score than the other technologies.

Control of elevated pan and burner temperatures can potentially limit the cook in the range of available cooking temperatures, and thus could limit Cooking Performance. All fixed temperature burner control technologies receive Cooking Performance Scores of 5.0 due to the potential cooking impact.

With regard to Cost and Convenience the increased durability and reduced costs of the mechanically actuated switch score slightly higher (6.4) when compared to the burner surface temperature (6.3) pan contact temperature sensor (6.0) and non-contact sensor (5.6).

The overall combined scores for the Group 5 fixed temperature burner control technologies are shown in Figure 16. Although relatively close, when the total sum is considered, the mechanically actuated switch received the highest overall score, while the burner surface temperature receives the lowest. When the influence of the FPE score is averaged, rather than counting as 2/3 of the total, the burner surface temperature scores third after the mechanical switch and the pan contact sensor. When only the impacts upon reduction of deaths are considered, however, the burner surface temperature devices receive the highest overall score.

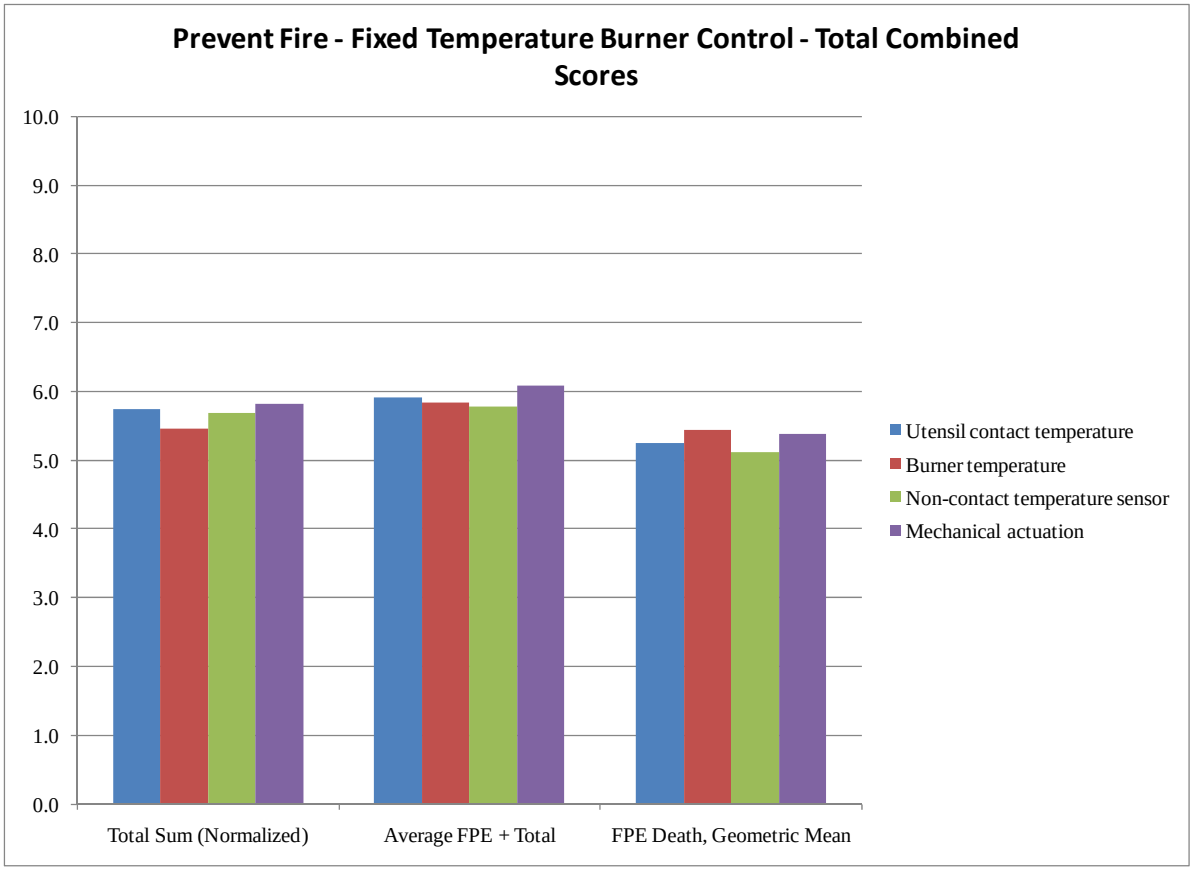

Figure 16 – Mitigation Group 5 –Fixed temperature burner control technologies normalized combined scores

The FPE scores of fixed temperature burner control devices applicable to electric ranges only are shown in Figure 17. When only electric range fire losses are considered within the analysis, the burner surface temperature devices score the same as all fixed temperature burner control

devices with regard to prevention of incidents, injuries, and property damages. Preventing the burner surface from overheating can also prevent clothing ignition scenarios, and this is reflected in the civilian death score, increasing the total from a 4.6 to a 5.5. The Cooking Performance and Cost and Convenience Scores are unaffected by reducing the analysis to electric ranges only.

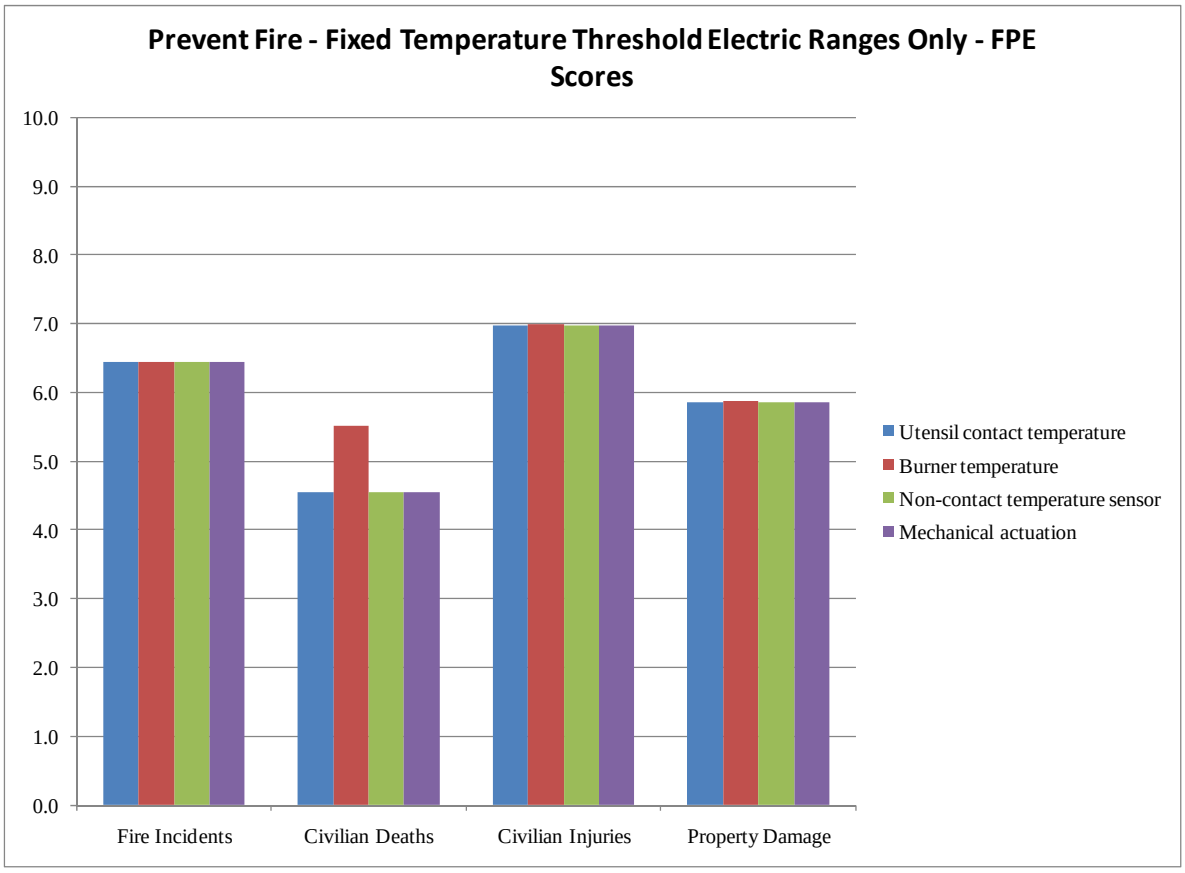

Figure 17 – Mitigation Group 5 – Fixed temperature burner control technologies for electric range fire losses normalized combined scores

If a maximum temperature gradient threshold is to be set for detection of boil overs and spills, the temperature gradient could be detected by a pan contact temperature sensor, a non-contact pan temperature sensor, or a burner surface temperature sensor. The overall scoring for the gradient temperature detection technologies in Group 5 in the six categories are shown in Figure 18.

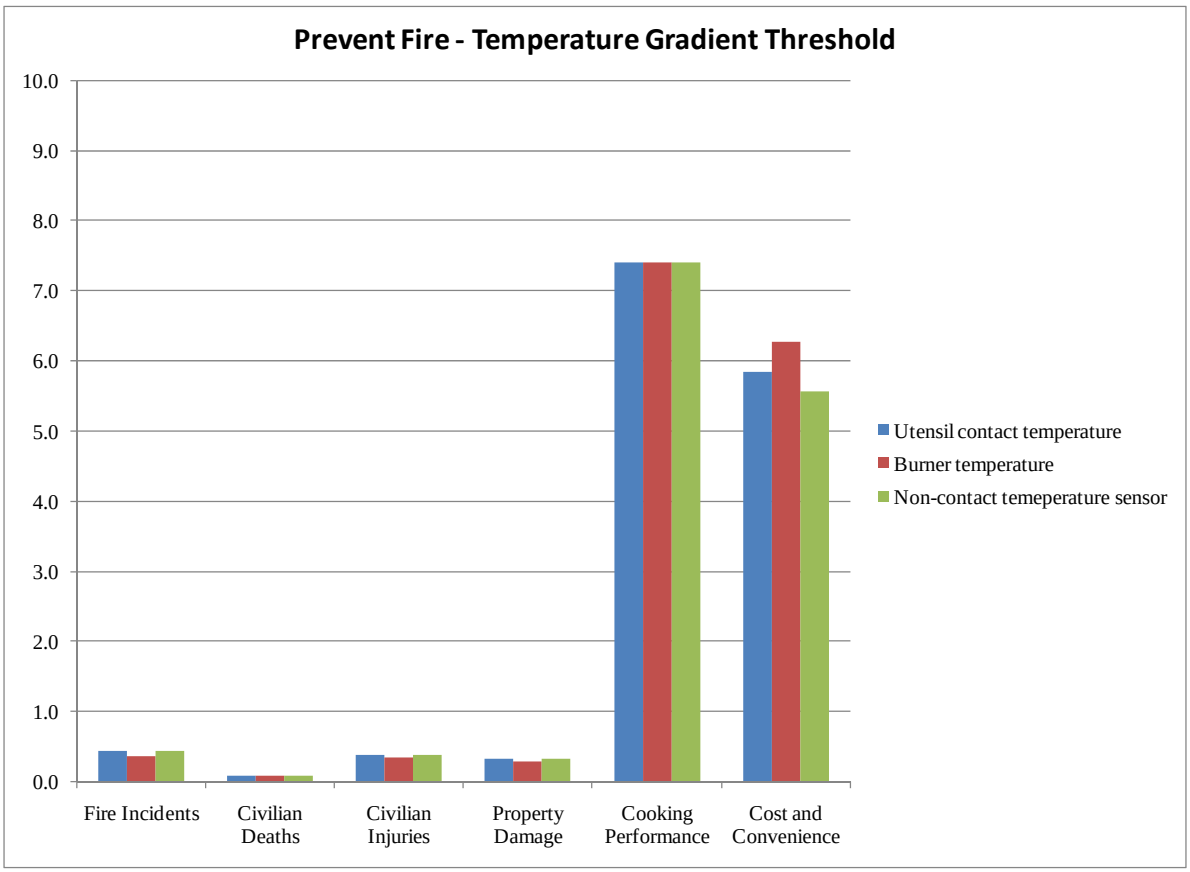

Figure 18 – Mitigation Group 5 – Prevent fire through temperature gradient burner control scored in the six major categories

The FPE scores for the gradient control devices are all in the range of 0.1-0.4. This is due to the fact that boil-overs and spills do not represent a significant portion of the damaging range top fire scenarios. The burner surface temperature control with a gradient threshold is not capable of prevention of clothing ignitions like the fixed temperature threshold control. The reduction in FPE compared to the pan temperature sensors is a result of the burner surface being applicable only to electric range top fires.

Control of elevated pan and burner temperature gradients could potentially limit the cook in the range of available cooking temperatures, but would have less cooking impact than the use of a fixed temperature setting. All gradient temperature burner control technologies receive Cooking Performance Scores of 7.4 due to the limited potential cooking impact.

With regard to Cost and Convenience the increased durability of the burner surface temperature (6.3) compared to the pan contact temperature sensor (5.8) and non-contact sensor (5.6) is indicated in the overall score.

The overall combined scores for the Group 5 gradient temperature burner control technologies are shown in Figure 19. In general, the three gradient temperature detection methods score comparably for both the total sum and FPE Death combinations, receiving scores of 2.4–2.5 and 1.7 for the total and death combinations, respectively. The burner surface

temperature and pan contact sensor received the 2.5 in the total sum category, while the non-contact temperature sensor received 2.4. The overall scores are considerably higher when the average FPE is utilized, as these devices score well for both Cooking Performance and Cost and Convenience, but the FPE scores are severely limited by the applicability of boil over and spill ignition scenarios. The burner surface temperature sensor receives a 5.0, the pan contact temperature a 4.8, and the non-contact sensor a 4.7 when the average of all FPE scores are used for calculation.

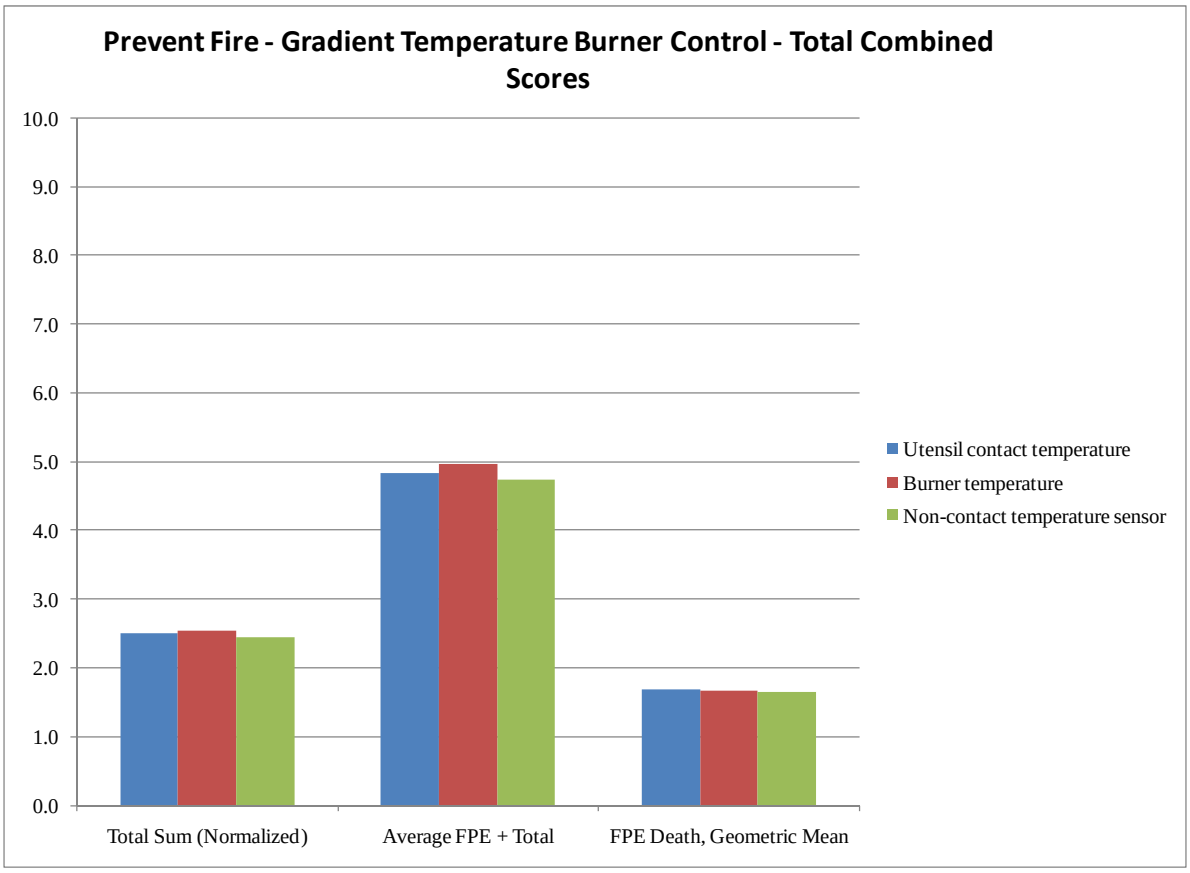

Figure 19 – Mitigation Group 5 – Fixed temperature burner control technologies normalized combined scores

When the analysis is performed with consideration to electric ranges only, the FPE scoring for the burner surface temperature is increased, but generally by less than 1% of all fire losses. The low percentage of addressed fire scenarios, <10%, does not generate a significant statistical increase when only electric ranges are considered.

Utilization of the fixed temperature threshold can be applied but with the option of allowing the user to determine the temperature threshold through selectable cooking options. The over temperature condition could be detected by a pan contact temperature sensor, a non-contact pan temperature sensor, or a burner surface temperature sensor. The overall scoring for the User-controlled temperature detection technologies in Group 5 in the six categories are shown in Figure 20.

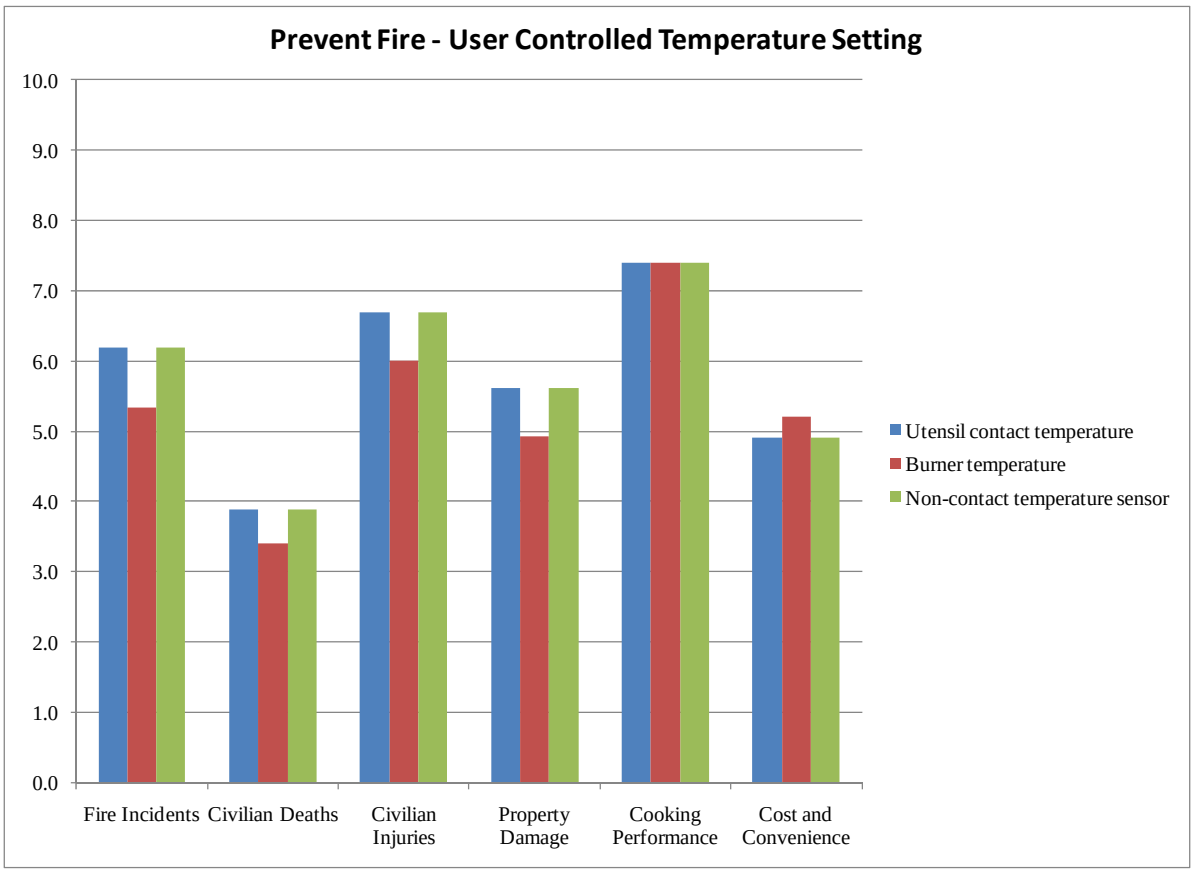

Figure 20 – Mitigation Group 5 – Prevent fire through user controlled temperature control scored in the six major categories

The FPE scores for the pan temperature sensors, including contact and non-contact are equivalent for all fire loss categories, accounting for 62% of incidents, 39% of deaths, 67% of injuries, and 56% of property damages. The burner surface temperature sensor is only applicable to electric ranges, and thus scores lower in all categories, scoring 53%, 34%, 60%, and 49% for incidents, deaths, injuries, and property damages, respectively. The burner surface temperature control with a user controlled temperature cannot be assured to prevent clothing ignitions like the fixed temperature threshold control, and thus does not receive the observable increase in the death prevention score.

Setting specific temperature limitations for various cooking operations would require some deal of additional input from a user, but the additional control should reduce the impact to cooking performance from fixed temperature devices, with user control receiving scores of 7.4 for all sensor types.

The Cost and Convenience of user controlled devices would be impacted by the ability of a user to operate this device in an unsafe manner. It could be expected that a user would always select the highest temperature cooking option, thus eliminating the ability of the device to prevent many fires. The increased durability of the burner surface temperature (5.2) over the pan temperature sensors (4.9) results in slightly improved scoring for Cost and Convenience.

The overall combined scores for the Group 5 user controlled temperature burner control technologies are shown in Figure 21. The utensil temperature sensor options score highest for the user controlled temperature burner control technologies, obtaining a 6.0, 6.4, and 5.6 for the total, average, and death combinations, respectively. The burner surface temperature measurement receives slightly reduced scores, obtaining a 5.6, 6.2, and 5.4 for the total, average, and death combinations, respectively. It should be recognized, however, that when only electric range fire incidents are considered, the burner surface temperature receives increased scores, obtaining a 6.3, 6.5, and 6.0 for the total, average, and death combinations, respectively. .

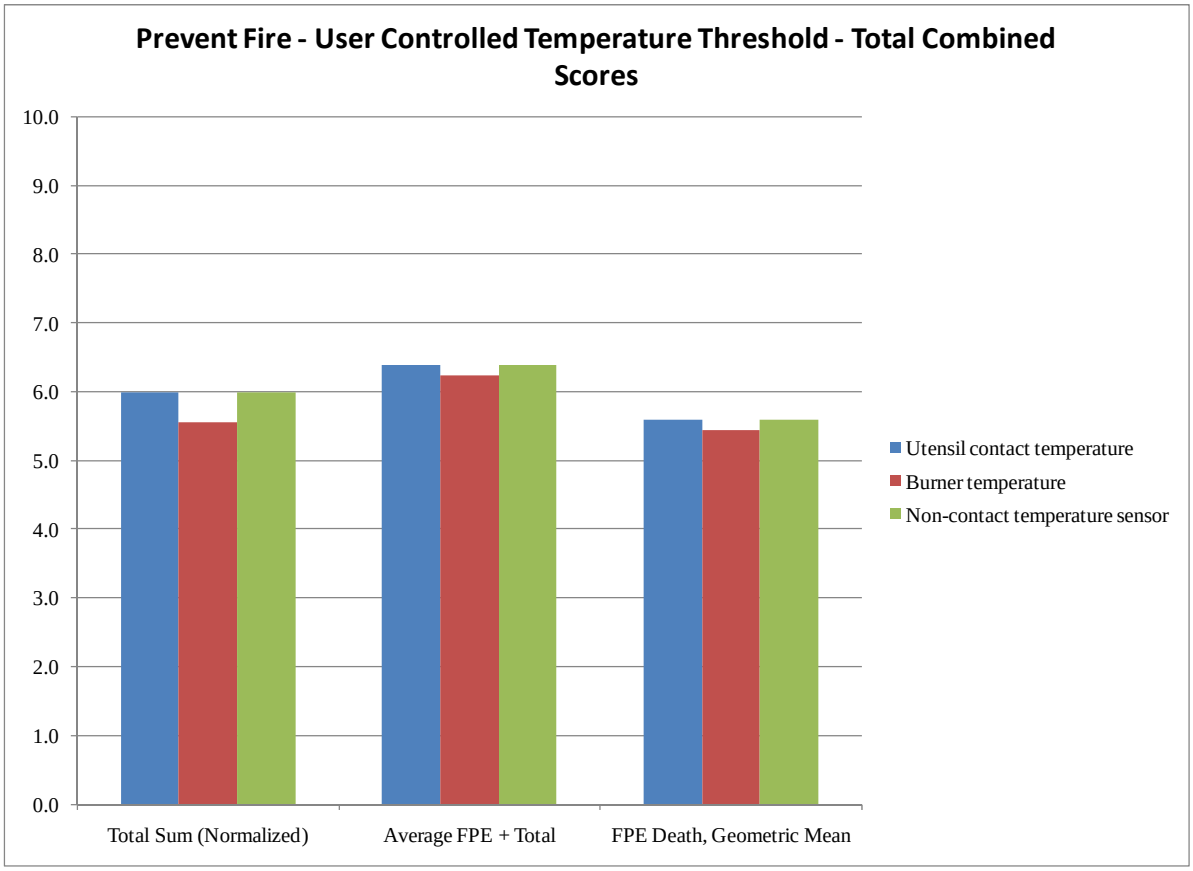

Figure 21 – Mitigation Group 5 – User controlled temperature threshold burner control technologies normalized combined scores

In addition to the various methods of detecting and controlling burner and pan temperatures, a potential ignition scenario could be detected and burner control initiated through use of a specialized smoke detection device. Also, range top fires can be prevented by application of an induction range top, which does not allow ignition of clothing or other loose combustibles placed on the range. Specialized smoke detection with burner control and induction ranges are compared to the utensil contact temperature sensors for each of the three temperature control methods described above in Figure 22.

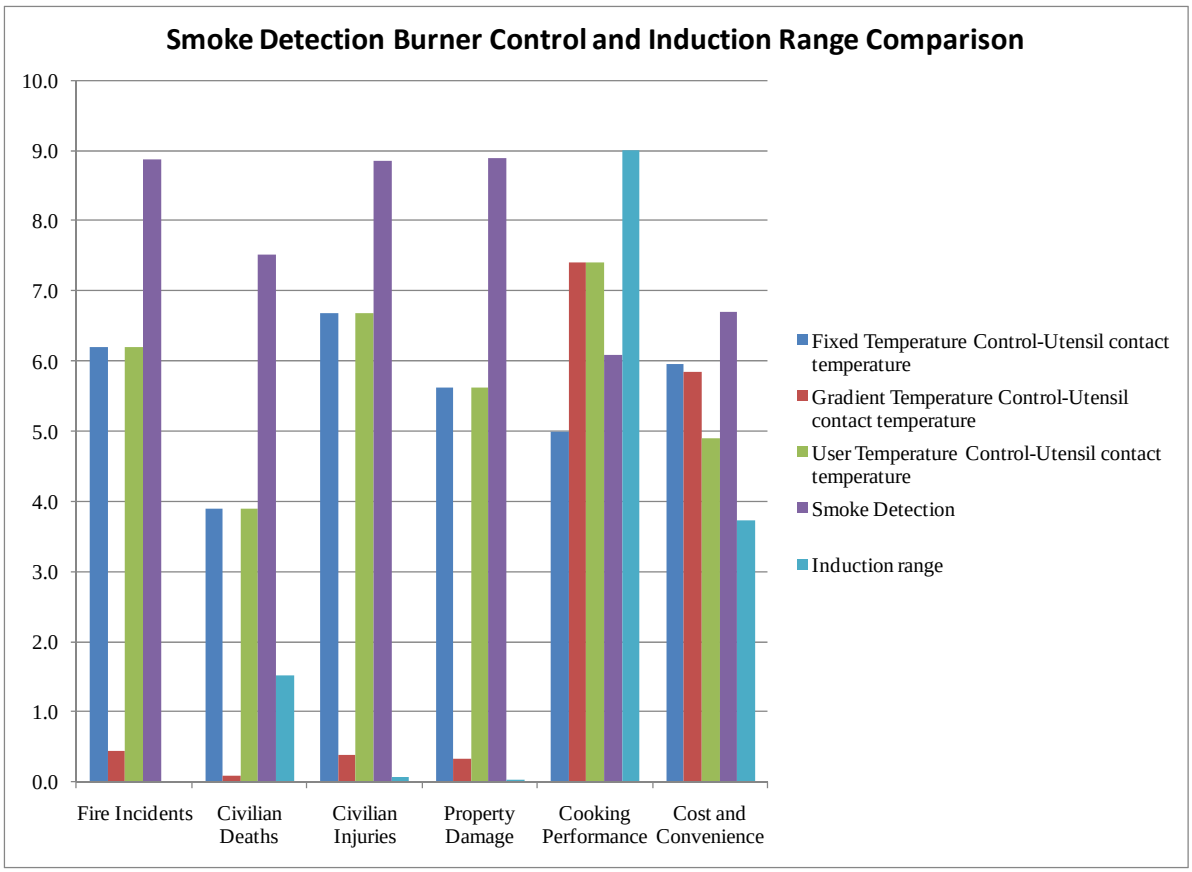

Figure 22 – Mitigation Group 5 – Various utensil temperature control methods, smoke detection with burner control, and induction range technologies compared in the six major categories

Smoke detection is applicable to the greatest number of fire loss scenarios, because it is capable of detecting nearly all ignition scenarios, with the exception of clothing ignitions. Smoke detection is applicable to the prevention of 89% of incidents, 75% of deaths, 89% of injuries, and 89% of property damages. The induction range is applicable only to a very select range of ignition scenarios, but prevention of clothing ignitions does represent 15% of the deaths related to range fires.

Induction ranges have been demonstrated to have excellent cooking performance, and thus receive a perfect 9.0 score in that category. The gradient and user temperature controls (7.4) limit the cooking times and performance less than the fixed temperature setting (5.0), and thus receives the greater Cooking Performance score. The smoke detection with control could impact some cooking processes, such as blackening, and this impact is reflected in the Cooking Performance score of 6.1.

The smoke detector used for burner control scores highest in Costs and Convenience, receiving a 6.7. It is important to recognize that a smoke detector used specifically for cooking fire mitigation can be optimized and have higher alarm settings than standard household smoke alarms in order to provide satisfactory performance relative to potential nuisance alarms. The induction range is extremely expensive to purchase, and this is Costs and Convenience score of

3.7 obtained for this technology. When considering the pan temperature control options, the fixed temperature (6.0) ranks highest above the gradient temperature (5.8) and user controlled temperature (4.9) options.

The overall combined scores for utensil temperature, smoke detection, and induction range Group 5 prevention technologies are shown in Figure 23. The applicability to a wide range of fire scenarios results in the smoke detection device used for burner control having the highest overall scores, obtaining a 8.1, 7.6, and 7.3 for the total, average, and death combination methods, respectively. The gradient temperature control scores lowest among death prevention technologies, obtaining a 1.7. The induction range is the lowest scoring technology when the total sum and average FPE are considered, obtaining a 2.5 and 4.7, respectively. But when the prevention of death is considered, it obtains a total score of 4.0. The user controlled temperature control (6.0, 6.4, 5.6) scores higher than the fixed temperature control (5.7, 5.9, 5.2) for all three combination methods.

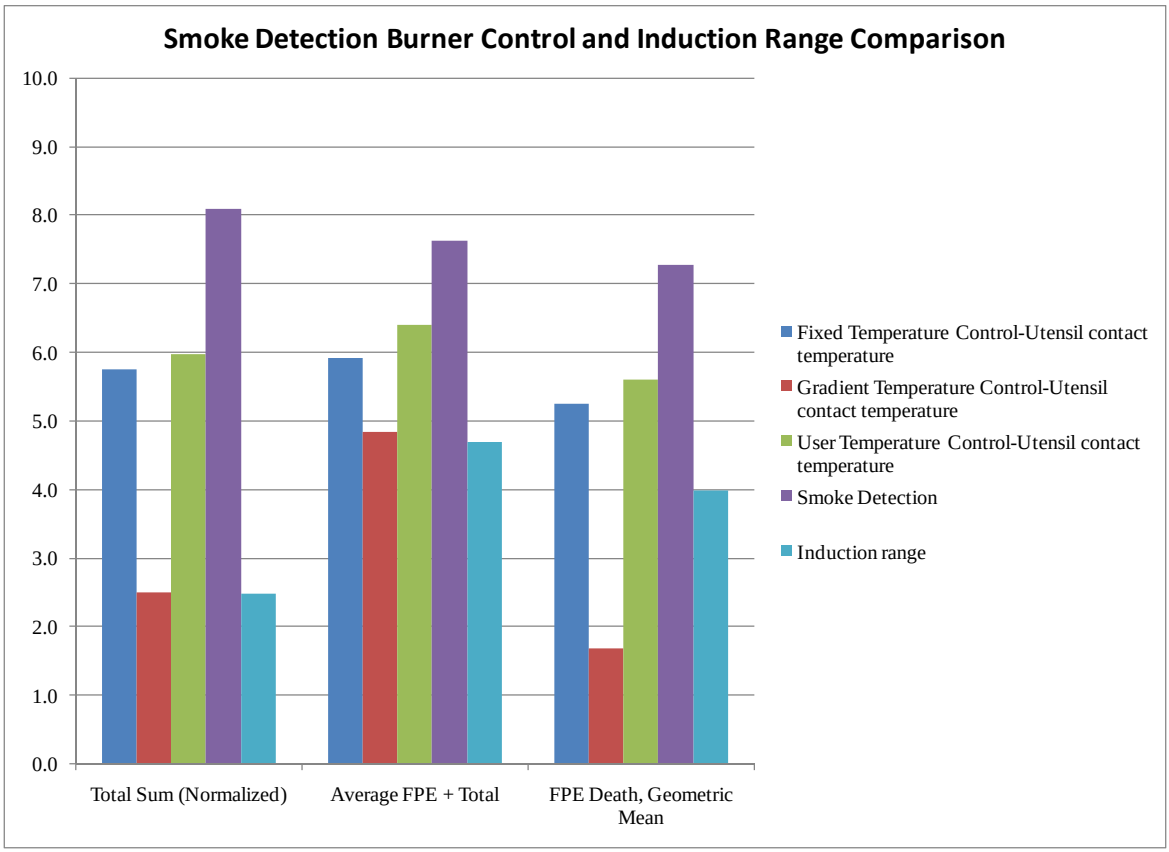

Figure 23 – Mitigation Group 5 – Various utensil temperature control methods, smoke detection with burner control, and induction range technologies normalized combined scores

7.6 Global Technology Comparison

Various technologies between mitigation groups are compared in Figure 24 by selecting only the highest scoring technologies from each of the groups. Where applicable for mitigation technology groups, a technology of each class has been included. For example, a device that

prevents unattended cooking fires is included in addition to one that actuates from temperature to control burners, as well as the smoke detection burner controller. It should be noted that all devices have not been included in the analysis of Figure 24, but rather representative technologies of the various mitigation methods have been considered.

The impact of warning, containment, suppression, and prevention is clearly demonstrated among the various technologies when comparing the FPE scores. Only prevention technologies are capable of preventing fire incidents, and all other methods receive scores of 0. The effectiveness of warning only devices can be observed in obtaining FPE scores of no greater than 1.2 for deaths or injuries (i.e., 12% reduction) or 2.5 for property losses (i.e., 25% reduction). Active containment and suppression are both applicable to a wide array of fire scenarios, receiving FPE death scores as high as 5.0 and 7.1, respectively (i.e., 50 and 71 percent reduction in deaths). Unattended detection and prevention technologies are applicable to prevent fewer fire losses overall than those that detect elevated temperatures, which are less applicable than those that detect smoke emissions. The smoke detection method of burner control and prevention was found to be applicable to the greatest number of fire losses in all categories, with applicability to 89% of incidents, 75% of deaths, 89% of injuries, and 89% of property damages.

The over range non-contact temperature sensor for warning, the active containment hood, and the suppression system all obtained perfect 9.0 cooking performance scores. None of these devices would impact cooking quality, time, or cooking behaviors. The unattended cooking warning and control timer with a power sensor and the pan contact warning device all have some impact upon cooking performance, and receive scores of 7.4. The smoke detection with burner control is expected to have additional impacts upon the ability to perform certain cooking operations, receiving a score of 6.1, and the burner surface temperature control receives a score of 5.0.

Relative to Cost and Convenience, the warning of a flaming fire through a non-optical hood temperature sensor receives the highest overall score of 7.4. The next highest scoring device is the timer with power sensor used for burner control, receiving a 6.9 and the smoke detection with burner control and suppression system receiving a 6.7. The use of pan temperature measurement sensors fell into the next group receiving scores of 5.6-5.8. The active dropdown hood received the lowest Costs and Convenience scores, obtaining a 3.6.

The total combined scores of the various technologies, utilizing the three unique combination methods, are shown in Figure 25. When considering the total sum of all scores, the smoke detection for burner control significantly outscores all other options, receiving a normalized total score of 8.1. This is due to the high applicability of smoke detection to numerous fire scenarios, and the total sum rates FPE scores as 4/6 of the total. Among the warning only technologies, the detection of a flaming fire with a non-optical temperature sensor scores highest, with a normalized 0.37. In general, comparing the technologies using a sum-total places additional emphasis upon fire protection, and thus the prevention technologies obtain the highest overall scores.

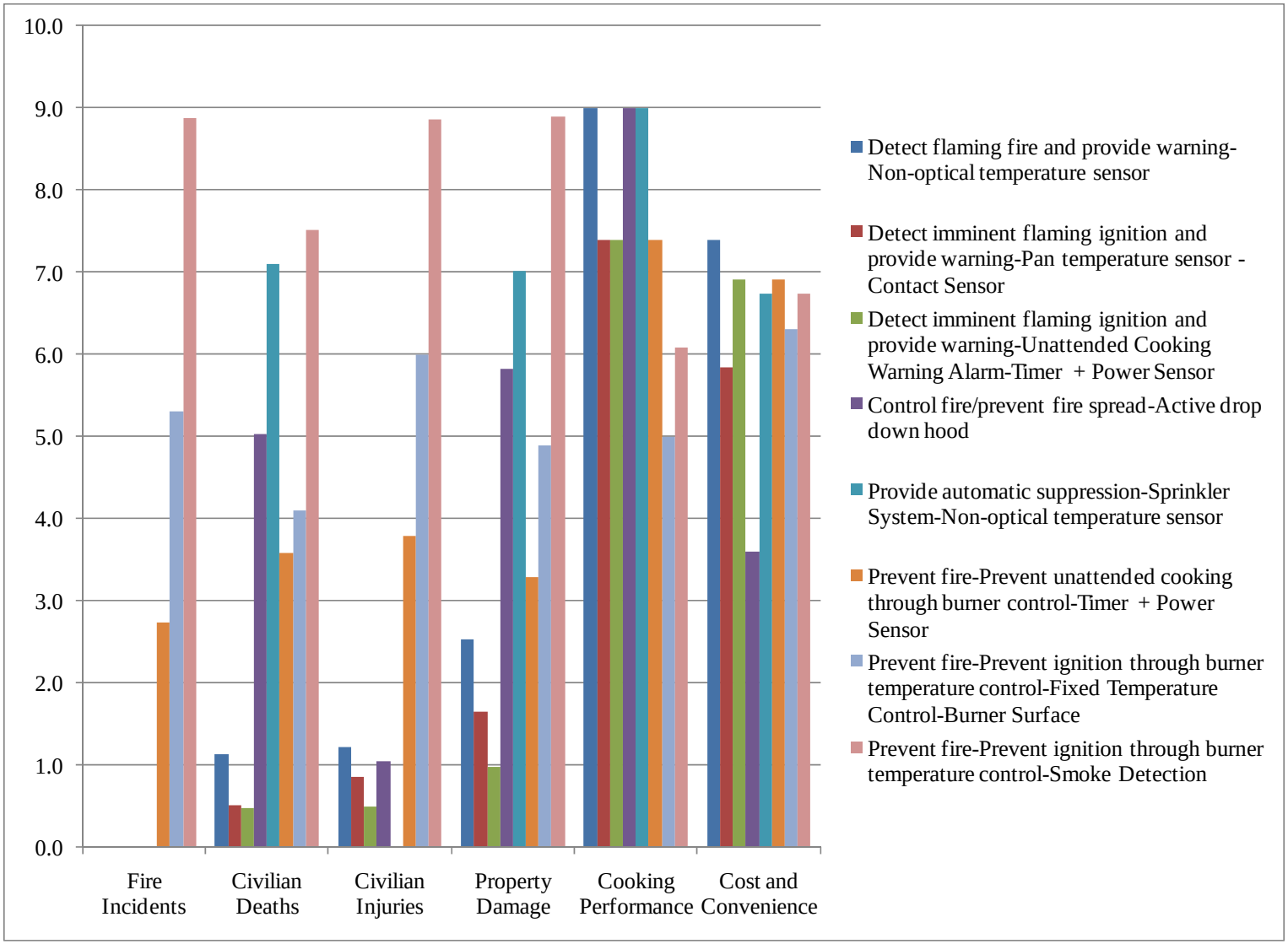

Figure 24 – Comparison of representative technologies from the various mitigation groups and methods

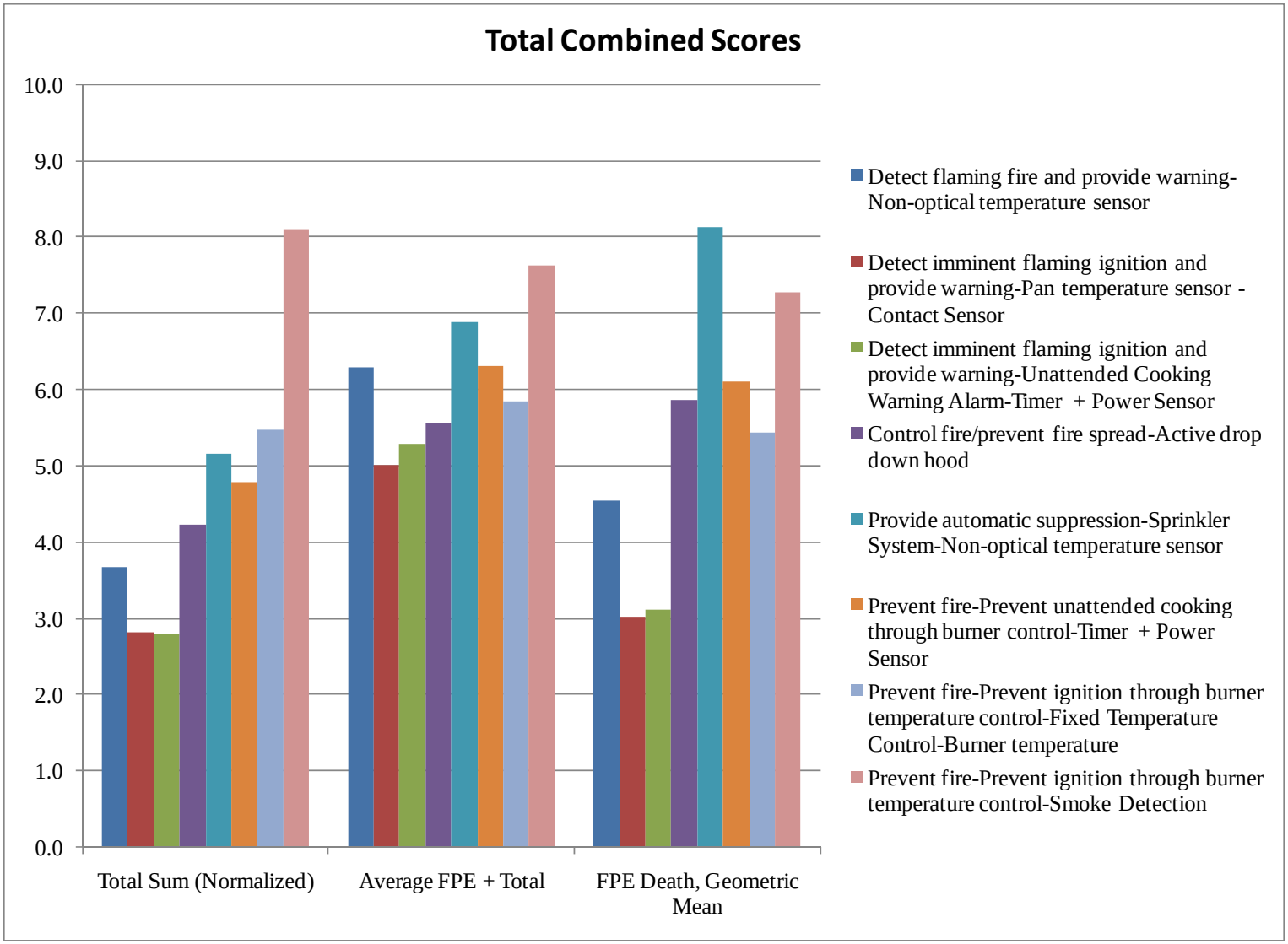

Figure 25 – Comparison of representative technologies from the various mitigation groups and methods normalized combined scores

If the four FPE scores are averaged and then summed together with the Cooking Performance and Costs and Convenience scores, the smoke detector with burner control still receives the highest overall score of 7.7. Automatic suppression activated by a non-optical temperature sensor receives the second highest score with a total of 6.9. A warning only pan contact temperature sensor receives the lowest score with a 5.0.

When only the prevention of deaths are considered, and the score is geometrically averaged with the Cooking Performance and Costs and Convenience scores, the automatic sprinkler suppression receives the highest total score with a 8.1. The smoke detection with burner control receives the second highest score with a 7.3, and a timer with power sensor used for burner control is third among the compared technologies with a 6.1. The warning only technologies are the lowest overall scoring with the pan contact sensor and timer with power sensor receiving scores of 3.0 and 3.1, respectively, due to their limited ability to prevent fire deaths.

The data compared in the previous figures only compared the results of several technologies used as representatives of the various mitigation methods. A complete analysis of the scoring and ranking of all technologies simultaneously is available in the Excel Workbook of Appendix B. The top scoring technologies, among all technologies, for each of the three score combination methods are summarized in Table 11.

Table 11 – Highest Total Scoring Mitigation Technologies for Various Score Combination Methods

	Score Combination Method		
Ranking	**Total Sum**	**Average FPE, Total Sum**	**FPE Death, Geometric Mean**
First	Smoke Detection – Burner Control	Smoke Detection – Burner Control	Automatic Sprinkler Suppression with Fusible Link or Non-contact temp
Second	Utensil Temperature Sensor – User Temp Control	Automatic Sprinkler Suppression with Fusible Link or Non-contact temp	Automatic Suppression – Optical Temperature Sensor - Sprinkler
Third	Fixed Temperature Mechanically Actuated Switch	Smoke Detection – Warning Only	Automatic Wet/Dry Chemical Suppression with Fusible Link or Non-contact temp

When only applicability to electric range tops are considered, the top ranking total sum technologies are adjusted to include the burner surface temperature in second place overall as shown in Table 12. This identifies that the burner surface temperature measurement is a viable option when applicability to electric only ranges are considered. The top ranking technologies for the other score combination methods are unaffected.

Table 12 – Total Sum Score Combination Rankings When Only Electric Ranges are Considered

Ranking	Total Sum
First	Smoke Detection – Burner Control
Second	Burner Surface Temperature– User Temp Control
Third	Utensil Temperature Sensor – User Temp Control

8.0 GAP ANALYSIS

Throughout the course of the mitigation technology analysis, several gaps in key information necessary to make a thorough evaluation became apparent. The various limitations and gaps in information are noted and discussed in the following section.

A major limitation of the evaluation method was in the lack of hard, statistically based data required to evaluate the cooking performance, costs, and convenience for various technologies. The vast amount of statistical data available for analysis of the Fire Protection Effectiveness (FPE) allowed for detailed calculations of the potential ability of the various technologies to reduce actual fire losses. Such data was not available for cooking performance, costs, or convenience related evaluations, and the scoring was limited to general engineering judgments resolved to a level of detail of high, medium, and low. The criteria were sorted according to categories and weighted to provide a better picture of the overall performance, but at the root, the scoring of these categories were basic at best. Additional data could be used to enhance this portion of the evaluation.

Required additional data would have included a uniform investigation into the cooking abilities of all investigated technologies. While some technologies had been investigated, it was not possible to apply any of the data mathematically to the analysis without a uniform application across all technologies.

In addition, a complete cost analysis of the various technologies, including material costs, manufacturability, product life-cycle, durability, and serviceability would be required to provide additional accuracy to the analysis of total costs. Such a research project was well beyond the scope of this analysis.

Although the analysis was able to account for the potential applicability of the various technologies to gas and electric range tops separately, no discussion was included regarding the implementation of such systems. In general, this analysis remained focused upon the conceptual detection methods for various stovetop cooking fire risks, but implementation would require complete systems that would account for safe control of gas and electric supplies, user interfaces, installation requirements, and maintenance programs.

While the statistical method used to evaluate the various FPE scores was a significant upgrade over the low, medium, high scoring method utilized in previous analyses, there were still limitations to the statistical data. The primary limitation in the data is that no analysis was made into determining the reliability of each specific technology with regard to prevention of fires. The impact of reliability was only considered with regard to the ability of the various

mitigation methods to impact real fires. For example, all technologies that utilized a warning were scaled according to the observed statistical impact of warning devices on the prevention of various fire losses. Overwhelmingly, this data is based upon the presence of smoke alarms in range top fires and the reduction of fire losses in such scenarios. The reliability number does not directly measure or include the specific reliability of using a fusible link vs. an optical temperature sensor vs. a thermal imaging camera. Specific data identifying the specific reliability of the detection technologies would help provide a better determination of the impact of each technology individually.

The secondary limitation in the evaluation of the FPE scores was the result of determining scores based upon the maximum possible number of prevented fire losses assuming the technology was immediately installed in all residential homes. Obviously, this is not a reasonable expectation of any technology. The primary influences upon the ability of a technology to infiltrate the market would be the cost of the device, and the potential for retro-fit vs. requiring a new install to be effective. A device with an excessive purchasing cost would not infiltrate the market effectively and would not have a great impact upon the measured fire losses. In addition, the ability of a technology to be retro-fit would allow the device to impact the fire losses at a much faster rate than one that required install on only new ranges, due to the relatively long product life of existing ranges. Vast market statistics would be required to determine the time-applied impact of a technology based upon its ability to infiltrate home installations.

"In this analysis, three separate methods of combining the FPE, Cooking Performance, and Cost and Convenience scores were investigated. Each method yielded fairly different results with regard to the highest rated technologies. It is recognized that reasonable arguments can be made for different combination scores and which may be more representative of overall success. However, the comparison of technologies via the various combination scores and more importantly the individual criteria scores (i.e., FPE, Cooking Performance, and Cost and Convenience) is instructive to identifying potentially promising mitigation strategies.

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APPENDIX A –
SAFE-T-ELEMENT INSTALLATION REVIEWS SUMMARY

Prepared by

Brian Merrifield
Fire Protection Research Foundation

SAFE-T-ELEMENT INSTALLATION REVIEW SUMMARY

INTRODUCTION

As part of the Fire Protection Research Foundation's Cooking Fire Mitigation Technologies project, informal interviews were conducted with representatives of facilities who were recipients of a Federal Fire Grant for a installation of a device designed to specifically target and prevent electric stovetop kitchen fires, called Safe-T-element, manufactured by Pioneering Technology. Of the eighteen fire grant recipients identified, twelve were willing to discuss their experiences with the device. Among the twelve, there was a wide variety of quantities of units installed, demographics, pre-installed/retrofit units, and experiences. There were three categories of facilities: six housing authorities, one fire department, and five universities. The units were installed between 2008 and 2010. The quantity of units installed in each facility ranged from 20 to 2000; three quarters of the facilities had between 200 and 400 units installed. The telephone interviews with facility contacts were open-ended discussions on their experience with the Safe-T-element installation, maintenance, and other feedback. Notes on the calls were sorted by general topic questions for easier use.

There are several limitations in this study which should be considered in generalizing results including: the lack of verified fire incident reports (NFIRS data); the lack of comprehensive input from the users of the cooking equipment (as opposed to the facility management representative); the fact that these installations were at no cost to the facility; and the fact that by reason of the limited sample size the comments on performance are anecdotal and do not have statistical significance. Nevertheless, the responses given provide useful subjective and anecdotal information on performance and other issues related to the technology.

SUMMARY OF PHONE CONTACTS AND COMMENTS

Locations and Contacts

- There were two basic categories of installations: Universities and Housing Authorities.
- There was a mix of both pre-installed and retrofit units.
- The years of installation ranged from 2008 thru 2010.
    - Residents of the facilities included a wide variety of demographics: mixed age, gender, race, financial standing, mental capacity, etc.
- The number of stove installations ranged from 20 units to 2000 units
    - The majority (7 of the 12 reviews) installed between 200 and 400 units.
- All the contacts were recipients of a federal grant for the units.
    - A few bought additional units beyond the grant's funding.
    - Many have re-applied for another Federal Grant.
        - 4 of 7 Housing Authorities
        - 1 of 5 Universities

- Those interviewed were identified as the main contact for both the grant application and the installation oversight.
- Frequent Comment: Many would install at home (if they had an electric stove and/or children/elderly living with them.)

Comments on Installation

- In general there were no major complaints related to installation difficulty.
- Some compatibility issues should be expected if installing on 10+ year old units.
    - Requires 4-coil burner elements.
    - Must replace burner first if it is warped or hard-wired.
    - Possible incompatible drip pans.
    - Requires some space behind the stove.
- Full access to the stove for prolonged time should be expected for retrofits.
    - Some recommendations included: removing the stoves, installing when no one is living there, or having the fire department conduct a fire safety inspection and education program while the contractor installs the units.
- Electrical background or specialized training required for installation.
- Recommended a check of the coil burners first if retrofitting an older stove to ensure they are in working condition to begin with.

Comments on Training

- Perception is a major factor in user satisfaction (if retrofit, user will compare to the old stove's performance; if pre-installed, user accepts as part of the overall stove's performance.)
    - Education can ease transition.
- Two installations used the installation time to have the Fire Department train the tenant not only on the Safe-T-element, but also on home safety such as smoke detectors, trip hazards, and emergency planning.
- Pamphlets and other information were given to the tenants regarding the Safe-T-elements for each installation.
    - Two installations created a video to be shown on the busing system to demonstrate the benefits of the technology.
- Cooking demonstrations at a community meeting were used in some installations to raise awareness and ease hesitations.

Comments on Use

- Previous cooking results can be recreated with some slight modifications to cooking habits.

        - Flat bottom on new cooking pans or the use of a lid can decrease cooking time.
    - Element takes longer to heat up and longer to cool down. This may influence cooking behaviors and results.
    - "Ticks and Clicks" while heating and cooling to be expected.
    - The maximum burner temperature is now limited to ~600 deg F as compared to conventional ~1300 deg F.
        - May influence searing and wok-based cooking styles.

Comments on Maintenance

- Ease of cleaning comments were mixed.
- A few units were replaced due to cracked or warped burner plates

Comments on Perceived Fire Performance

- Some facilities (retrofits) noticed a marked decrease in reported cooking fires.
- No injuries from an STE stove have been reported.

RECOMMENDATIONS

Directed at Facility Owners

- Install a pilot location prior to full installation.
- Consider use for Multi-family, student, "latch key" (children cooking without supervision), and elderly housing.
- Label wires and connectors on units prior to removal if removing completely for maintenance.

Directed at Safe-T Element Manufacturer

- Provide labels for wires and connectors to prevent miswiring
- Consider adding an indicator to identify hot burners (color changing stripe, light, etc.)
- Would like to see an Energy Saving Comparison chart with vs. without units.

Installations

Location:
University of Maryland – Eastern Shore
University of Delaware
Eastern Connecticut State University
City of Sandy Springs
Providence Housing Authority
Missouri State University
Bellevue Fire Department
City of Green Bay Housing Authority
University of Miami
Suffolk Housing Authority
King County Housing Authority
Norfolk Redevelopment Housing Authority

APPENDIX B –
TECHNOLOGY EVALUATION WORKBOOK AND SUMMARY OF COMBINED SCORE RESULTS

An attached workbook has been provided to evaluate the scoring of the various mitigation technologies. Various fire statistical data tables are provided in sheets:

- Table A
- Table B
- Table C and D

Each individual mitigation technology is provided a page in the worksheet “Technology Evaluations.” All cells where a scoring decision has been applied are highlighted in green and are available for editing. All applied evaluation scores are available for editing. This is intended to allow users to apply different scores for various technologies and observe the impact upon the overall score of the technology. The various equations are shown, and calculated intermediate variables are displayed in yellow. A sample technology score card is shown below.

Prevent Fire - Prevent Ignition Through Burner Temp Control -User Select Temp/Cook Type - Utensil Contact Temp (5-b-iii-(1))

$p_{n,m}$	Fire begins in a cooking vessel on a burner	Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	Fire begins on stovetop but not during cooking activities
Category 1A (cooking materials and unattended; item first ignited = 76; factor contributing to ignition = 53)	1	1	1
Category 1B (cooking materials and not unattended; item first ignited = 76; factor contributing to ignition ≠ 53)	1	0	1
Category 2 (unattended but not cooking materials: item first ignited ≠ 76; factor contributing to ignition = 53)	1	0	0
Category 3 (mechanical or electrical failure or malfunction or design, manufacturing, or installation error and not cooking materials: item first ignited ≠ 76; factor contributing to ignition 53; factor contributing to ignition 20-44)	1	0	0
Category 4 (not cooking materials and behavioral errors: item first ignited ≠ 76; factor contributing to ignition ≠ 20-44, 53; factor contributing to ignition 10-12,14,17, 19,51-52,54-58)	1	0	0
Category 5 (not cooking materials and factors not related to cooking behaviors: item first ignited ≠ 76; factor contributing to ignition ≠ 10-12,14,17,19,20-58; factor contributing to ignition 13,15-16,18,60-75)	1	0	0
Category 6 (not cooking materials and unclassified or unknown factors: item first ignited ≠ 76; factor contributing to ignition ≠ 01-99; factor contributing to ignition 00,NN,UU, blank)	1	0	0

$$a_n = \sum_{m=1}^{3} p_{n,m} x_{n,m}$$

Fire Category Contributions

				a_n
n= 1A	1.000	0.000	0.000	1.000
n = 1B	0.892	0.000	0.000	0.892
n = 2	0.500	0.000	0.000	0.500
n = 3	0.000	0.000	0.000	0.000
n = 4	0.000	0.000	0.000	0.000
n = 5	0.000	0.000	0.000	0.000
n = 6	0.000	0.000	0.000	0.000

$$R_{y,x}\left(\left[\left(\sum_{n=1A}^{6} a_n c_{n,y}\right) x\left(1 - Ign_{cy}\right)\right] + CI\left(Ign_{cy}\right)\right)$$

Gas Range Fire Scenarios Addressed

	y = 1 Fire Incidents	y = 2 Civilian Deaths	y = 3 Civilian Injuries	y = 4 Property Damages
	0.179	0.268	0.255	0.199
	0.374	0.036	0.286	0.245
	0.017	0.020	0.034	0.047
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
Ry,xC_y	**0.511**	**0.191**	**0.498**	**0.441**

Prevention of Clothing Ignition? No

Mitigation Method Prevention

$x=5$

Applicable To Gas Ranges? Yes

$$S_{y,x}\left(\left[\left(\sum_{n=1A}^{6} a_n d_{n,y}\right) x\left(1 - Ign_{dy}\right)\right] + CI\left(Ign_{dy}\right)\right)$$

Electric Range Fire Scenarios Addressed

	y = 1 Fire Incidents	y = 2 Civilian Deaths	y = 3 Civilian Injuries	y = 4 Property Damages
	0.282	0.389	0.383	0.292
	0.412	0.113	0.365	0.316
	0.021	0.065	0.029	0.045
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
Sy,xD_y	**0.644**	**0.456**	**0.697**	**0.585**

Applicable to Electric Ranges? Yes

$\frac{B_{c,y}}{B_{t,y}}$	Fire Incidents	Civilian Deaths	Civilian Injuries	Property Damages
	0.169	0.255	0.135	0.157

FPEy - Gas Contribution

Fire Incidents	Civilian Deaths	Civilian Injuries	Property Damages
0.086	0.048	0.067	0.069

$\frac{B_{d,y}}{B_{t,y}}$	Fire Incidents	Civilian Deaths	Civilian Injuries	Property Damages
Electric Range Contribution to Fire Losses	0.828	0.748	0.862	0.841

FPEy - Electric Contribution

Fire Incidents	Civilian Deaths	Civilian Injuries	Property Damages
0.533	0.341	0.601	0.492

$$FPE_y = 10\left\{R_{y,x}\frac{B_{c,y}}{B_{t,y}}\left(\left[\sum_{n=1A}^{6}\left(\sum_{m=1}^{5} p_{n,m}x_{n,m}\right)c_{n,y}\right] x\left(1 - Ign_{cy}\right) + CI\left(Ign_{cy}\right)\right) + S_{y,x}\frac{B_{d,y}}{B_{t,y}}\left(\left[\sum_{n=1A}^{6}\left(\sum_{m=1}^{5} p_{n,m}x_{n,m}\right)d_{n,y}\right] x\left(1 - Ign_{dy}\right) + CI\left(Ign_{dy}\right)\right)\right\}$$

Fire Protection Effectiveness, FPE_y	y = 1 Fire Incidents	y = 2 Civilian Deaths	y = 3 Civilian Injuries	y = 4 Property Damages
	6.2	**3.9**	**6.7**	**5.6**

Cooking Performance — 7.4

Cooking Time	9.0
Cooking Quality	9.0
Cook Behavior	5.0

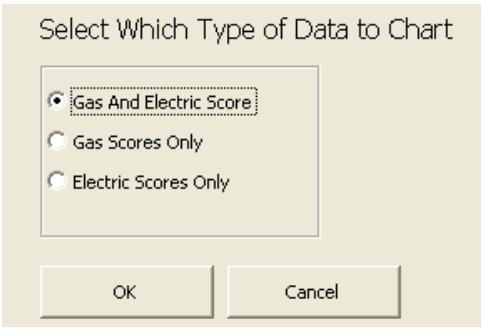
Cost and Convenience — 4.9

Initial Purchasing Cost	5.0	
Installation Cost	5.0	
Product Life-Cycle Costs	5.0	
		Serviceability: 5
		Durability: 5
Cookware Applicability	5.0	
Consumer Responsibilities	6.7	
		Cleaning/Maintenance: 5
		Additional Safety Risks: 9
Functional Considerations and Responsibilities	3.3	
		Restoration after system activation: 9
		Potential for and consequences of false activation: 5
		Functional system verification: 9
		Fail-safe operation: 1
		Can operate with reasonable user error or misuse: 1

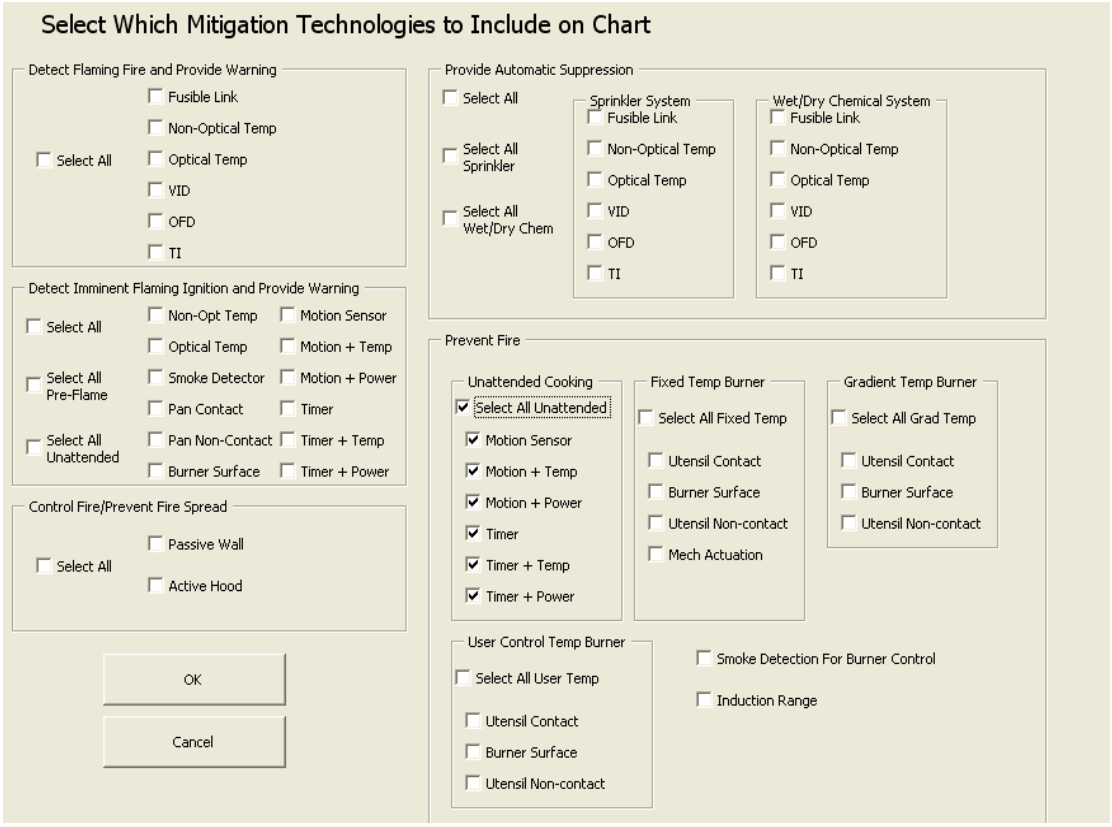
The tallied scores and the rankings of each technology are provided in the worksheet "Rankings-Total." In addition, the separate scores and ranking of the various technologies with respect to only gas or electric range fires are included in worksheets "Rankings-Gas Only" and "Rankings-Elec Only," respectively. Data on these sheets will be updated instantly if scores are edited on the individual evaluation sheets.

On each of the Rankings worksheets, a button appears in the upper left corner that reads "Make Bar Chart of Select Data." Clicking this button will allow the user to create a bar chart of various technologies or scoring options. The graphs can be generated by:

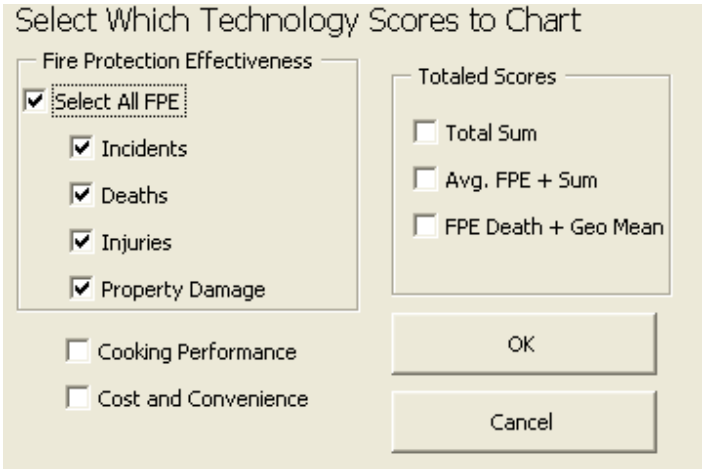
1. Clicking the mouse on the "Make Bar Chart of Select Data Button"
2. Selecting whether the data will be taken from the "Total", "Gas Only", or "Electric Only" data table and pressing "OK"



3. Selecting which mitigation technologies to include on the chart and pressing "OK"

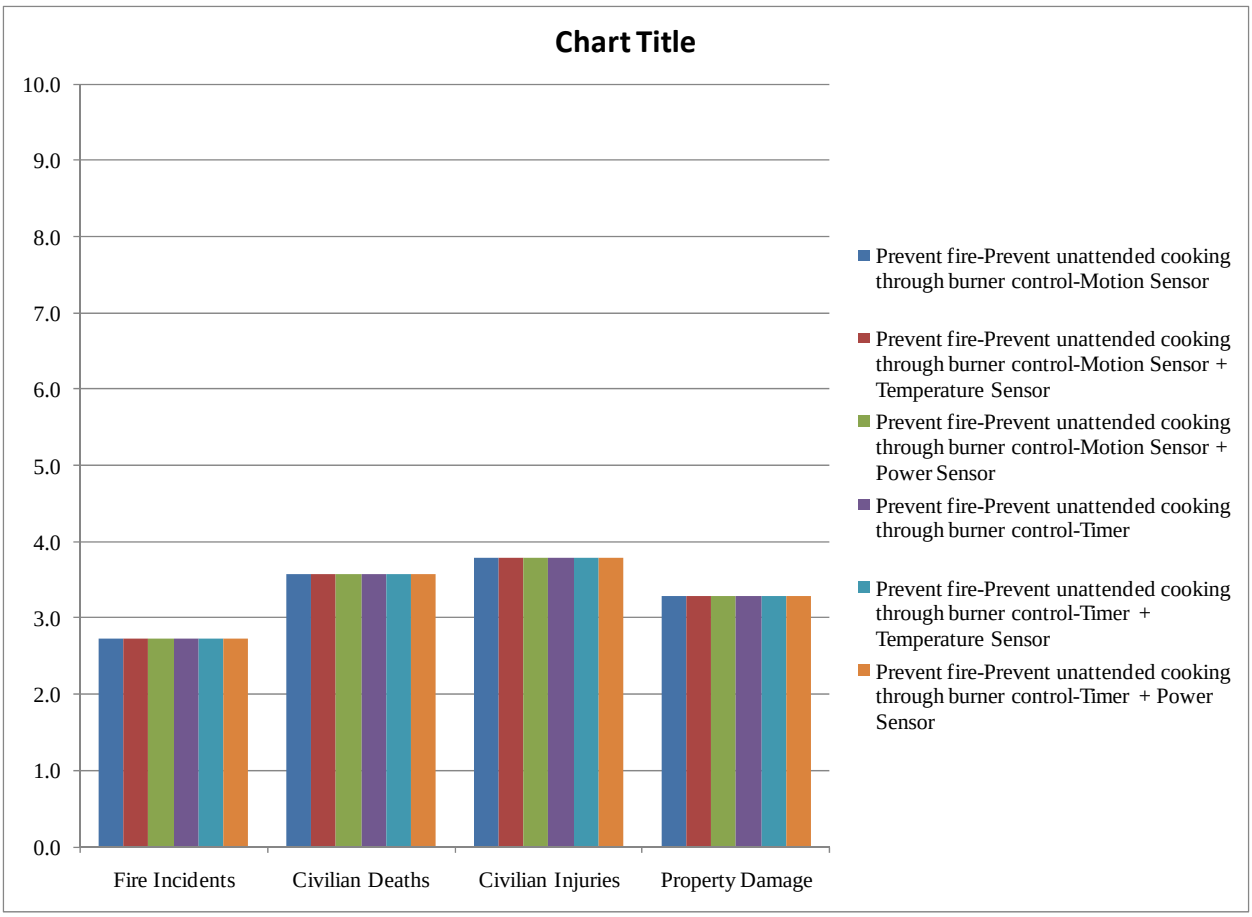


4. Selecting the various scoring categories to include on the chart and press “OK”

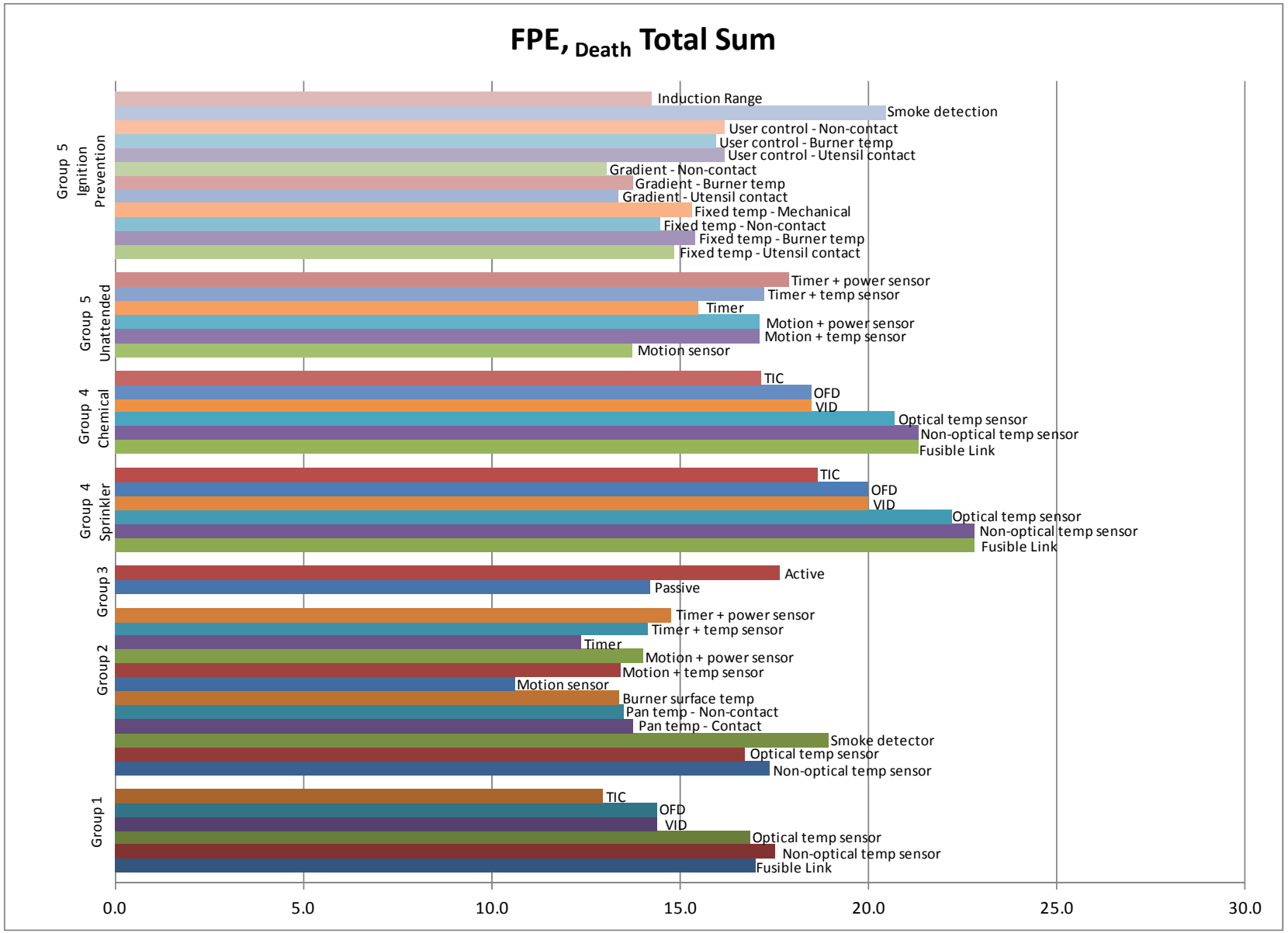


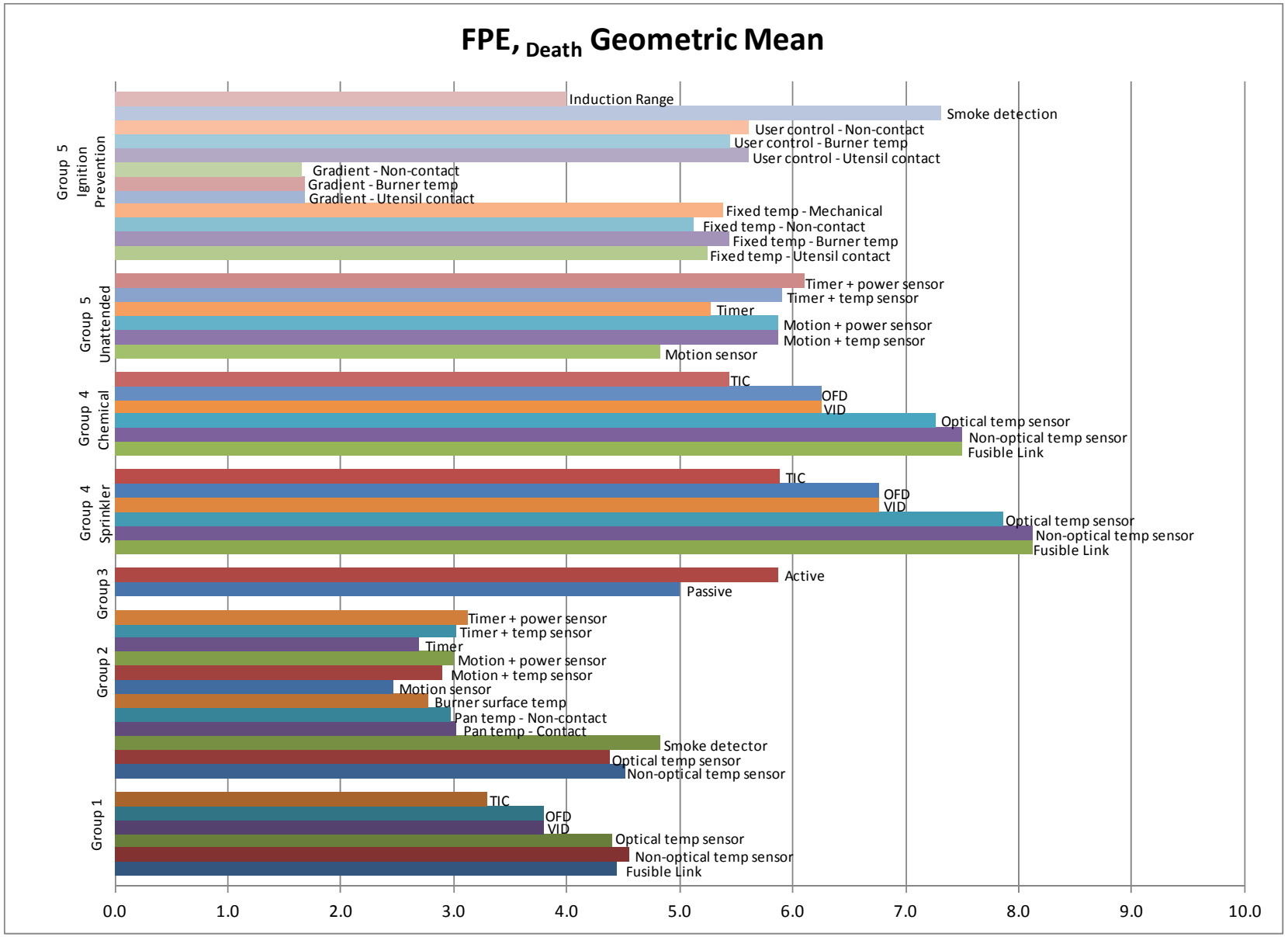
5. Enter a title for the bar chart and press “OK”

6. View the bar chart



A complete summary of the computed scores for all technologies is provided in the two plots below based on the total sum and the geometric mean (respectively) of combining the impact on reducing fire deaths score with the cooking score and costs and convenience score.


FPE, Death Total Sum
Group 5 Ignition Prevention
Induction Range
Smoke detection
User control - Non-contact
User control - Burner temp
User control - Utensil contact
Gradient - Non-contact
Gradient - Burner temp
Gradient - Utensil contact
Fixed temp - Mechanical
Fixed temp - Non-contact
Fixed temp - Burner temp
Fixed temp - Utensil contact
Group 5 Unattended
Timer + power sensor
Timer + temp sensor
Timer
Motion + power sensor
Motion + temp sensor
Motion sensor
Group 4 Chemical
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
Group 4 Sprinkler
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
Group 3
Active
Passive
Group 2
Timer + power sensor
Timer + temp sensor
Timer
Motion + power sensor
Motion + temp sensor
Motion sensor
Burner surface temp
Pan temp - Non-contact
Pan temp - Contact
Smoke detector
Optical temp sensor
Non-optical temp sensor
Group 1
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
0.0
5.0
10.0
15.0
20.0
25.0
30.0


FPE, Death Geometric Mean
Group 5 Ignition Prevention
Induction Range
Smoke detection
User control - Non-contact
User control - Burner temp
User control - Utensil contact
Gradient - Non-contact
Gradient - Burner temp
Gradient - Utensil contact
Fixed temp - Mechanical
Fixed temp - Non-contact
Fixed temp - Burner temp
Fixed temp - Utensil contact
Group 5 Unattended
Timer + power sensor
Timer + temp sensor
Timer
Motion + power sensor
Motion + temp sensor
Motion sensor
Group 4 Chemical
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
Group 4 Sprinkler
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
Group 3
Active
Passive
Group 2
Timer + power sensor
Timer + temp sensor
Timer
Motion + power sensor
Motion + temp sensor
Motion sensor
Burner surface temp
Pan temp - Non-contact
Pan temp - Contact
Smoke detector
Optical temp sensor
Non-optical temp sensor
Group 1
TIC
OFD
VID
Optical temp sensor
Non-optical temp sensor
Fusible Link
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

APPENDIX C – STATISTICAL FIRE DATA

FIRE SCENARIO STRUCTURE SPECIFICATION TASK

FINAL REPORT FOR THE PROJECT ON MITIGATING FIRE LOSSES FROM RESIDENTIAL COOKING FIRES FOR THE FIRE PROTECTION RESEARCH FOUNDATION FOR NIST BUILDING AND FIRE RESEARCH LABORATORY

John R. Hall, Jr.
Marty Ahrens
NFPA Fire Analysis & Research Division
August 23, 2011

This task report provides the results of statistical analysis performed to specify and quantify fire and behavioral scenarios for use in the evaluation of stovetop fire prevention or mitigation technologies and strategies.

The first section provides probability weights with respect to the specific location and circumstances of stovetop fire ignitions. The second section focuses on estimates of expected percent reductions in fires and losses by type of technology, incorporating reliability considerations where possible. The third section focuses on cook location and characteristics for unattended stovetop fires.

Statistical Methodology

In both sections, analysis begins with the specification of different categories of kitchen range home structure fires and the quantification of annual averages and percentages of fires, civilian deaths, civilian injuries, and direct property damage for each category, based on 2005-2009 NFIRS national estimates. Analysis is done separately for gas and electric ranges.

The next step in the analysis is to use special studies and other one-time data bases to develop factors (sometimes called splitting percentages) to convert the categories of fires that can be developed directly from NFIRS coding of fires into categories of fires better suited to the goal of evaluating stovetop fire prevention technologies.

SECTION 1. SPECIFIC LOCATION AND CIRCUMSTANCES OF STOVETOP FIRE IGNITION

Groups and Categories of Fires

The first grouping of fire scenarios is organized around the major circumstances of range fires. Each group is based only on fires that did not qualify for membership in an earlier group. For example, Category 4 is based only on fires that were not unattended, did not involve cooking materials as item first ignited, and did not involve mechanical or electrical failures or malfunctions, or design, manufacturing or installation deficiencies.

- Category 1A: Unattended/first item ignited was cooking materials

- Category 1B: Not unattended/first item ignited was cooking materials
- Category 2: Unattended/first item ignited was not cooking materials
- Category 3: Mechanical or electrical failures and malfunctions; and design, manufacturing or installation deficiencies
- Category 4: Various behavioral errors related to kitchen activity, such as heat source too close to combustible
- Category 5: Various factors not related to kitchen activity, such as cutting or welding too close to combustibles
- Category 6: Unknown, unclassified or no factor contributing to ignition

These groupings indicate how fire began but not where fire began. Behavioral strategies – such as education – can be assessed using these groups directly. For most technological strategies, however, the prevention technology is designed around a set of circumstances and a particular location. For example, one technology involves detection of elevated temperature of a cooking vessel or food in a cooking vessel on a stovetop burner. Other technological strategies are focused on the presence or absence of a cook, which means they focus on fires involving cooking activities. Most but not all of the numbered groups above indicate whether ignition occurred while cooking activities were underway.

To assess technologies that are designed around particular fire locations, it is necessary to locate the fire on the stovetop, in the oven, or somewhere else within, behind or beside the range. The following five categories of fires are designed to provide the necessary fire location information and to answer the question of cooking activities on a stovetop or no cooking activities on a stovetop, when that is not answered by the Group categories:

- Group 1: Fire beginning in food in a cooking vessel on a burner
- Group 2: Fire beginning on stovetop during cooking activities but not food in a cooking vessel on a burner (e.g., materials not coded as cooking materials but clearly being used as cooking materials are ignited in or around a cooking vessel on a burner)
- Group 3: Fire beginning on the stovetop, cooking activities not involved (e.g., burner unintentionally turned on or not turned off, ignited a rag left on stovetop)
- Group 4: Fire beginning in the oven part of the range
- Group 5: Fire beginning in or on the range but not on the stovetop or in the oven

A technology that detects the temperature of a cooking vessel or of food in a cooking vessel on a burner should address all the Group 1 fires and possibly all of the Group 2 and Group 3 fires (depending on the ignitability of the non-food items in Group 3), but would not address the Group 4 and Group 5 fires. For such a technology, there should be no need to consider the information captured in the numbered Categories to perform the assessment. If the effectiveness depended on the specific ease of ignition of specific items first ignited, then it might be necessary to drill down into the Group 3 fires, for example, and break out groups of items first

ignited. Such breakouts have not been prepared in this exercise but would not be difficult to develop.

A technology that scans for the presence of a cook at the stovetop might be considered effective for Category 1A and Category 2 fires but only the ones that are also Group 1 or Group 2.

Clothing on a person as item first ignited accounts for a negligible share of fires, civilian injuries and direct property damage but a significant share of civilian deaths. Therefore, the statistical tables have been annotated to show clothing-ignition civilian fire deaths for each Group of fire.

It is assumed here that fires beginning in any type of cooking equipment other than a range cannot be detected by either type of technology and is not the subject of this study.

Detailed Steps in the Analysis

The two coded fire cause characteristics identifiable in NFIRS that appear to provide the best basis for working toward a sort into the five final categories shown above are item first ignited (specifically, items that do or do not qualify as food in a cooking vessel and clothing on a person) and factor contributing to ignition.

The rules for fire reporting permit more than one factor contributing to ignition to be reported. Therefore, we need to use a hierarchical sorting protocol in order to produce initial categories of fires that are non-overlapping.

Step 1: *Sequentially sort NFIRS data into categories:*

1.01 Use a recent 5-year average of home structure fires with equipment involved in ignition 646 (range). Participation in NFIRS Version 5.0 was still increasing prior to 2004, and 2009 is the latest year of data loaded for analysis. Therefore, one can use 2005-2009 or 2004-2008 data. We have used 2005-2009.

1.02 Analyze confined to cooking vessel fires and non-confined fires separately; then combine them.

1.03 Analyze gas vs. electric powered equipment separately.

1.04 Allocate fires with unknown (UU), blank, unclassified (00), or multiple items first ignited (99) over all other known items.

1.05 Allocate fires with factor contributing to ignition 50 (unclassified or unknown-type operational deficiency) over factor contributing to ignition 51-58, treating factor 50 as a partial unknown.

1.06 Do NOT allocate fires with unclassified, unknown, or no factors contributing to ignition over the other factors, but make them the lowest category in the hierarchy. This is because the special databases provide a positive basis for allocating these fires among the five final categories, just as is done for the other Categories.

1.07 Category 1A consists of fires with item first ignited 76 (cooking materials) and factor contributing to ignition 53 (unattended). Category 1B consists of fires with item first ignited 76 and factor contributing to ignition *not* equal to 53. All other main categories

will be based on factor contributing to ignition, after fires with item 76 have been removed.

1.08 Category 2 consists of fires with factor contributing to ignition 53 (unattended) and item first ignited not equal to 76.

1.09 Based on fires with item first ignited not equal to 76 and no factor contributing to ignition 53 entry, Category 3 consists of fires with factor contributing to ignition 20-44, which consists of mechanical or electrical failures and malfunctions and design, manufacturing or installation deficiencies. The narratives we received and used to characterize these fires in terms of the final five categories of fires had narratives with factors 20, 30, 32, 33, 34, and 36.

1.09.01 Factor 20 (unclassified or unknown-type mechanical failure or malfunction)

1.09.02 Factor 21 (automatic control failure)

1.09.03 Factor 22 (manual control failure)

1.09.04 Factor 23 (leak or break)

1.09.05 Factor 25 (worn out)

1.09.06 Factor 26 (backfire)

1.09.07 Factor 27 (improper fuel used)

1.09.08 Factor 30 (unclassified or unknown-type electrical failure or malfunction)

1.09.09 Factor 31 (water-caused short circuit arc)

1.09.10 Factor 32 (short circuit arc from mechanical damage)

1.09.11 Factor 33 (short circuit arc from defective or worn insulation)

1.09.12 Factor 34 (unspecified short circuit arc)

1.09.13 Factor 35 (arc from faulty contact or broken conductor)

1.09.14 Factor 36 (arc or spark from operating equipment)

1.09.15 Factor 37 (fluorescent light ballast)

1.09.16 Factor 40 (unclassified or unknown-type design, manufacturing or installation deficiency)

1.09.17 Factor 41 (design deficiency)

1.09.18 Factor 42 (construction deficiency)

1.09.19 Factor 43 (installation deficiency)

1.09.20 Factor 44 (manufacturing deficiency)

1.10 Based on fires with item first ignited not equal to 76 and no factor contributing to ignition entries of 20-44 or 53, Category 4 consists of various behavioral errors with factor contributing to ignition codes of 10-19, 51-59 except for 13, 15, 16, 18, and 53. (Recall that code 50 was proportionally allocated in step 1.05.) The narratives we

received and used to characterize these fires in terms of the final five categories of fires had narratives with factors 10, 11, 12, 14, 51, 52, 53, 55, 56, 57, and 58.

1.10.01 Factor 10 (unclassified or unknown-type misuse of material)

1.10.02 Factor 11 (abandoned material)

1.10.03 Factor 12 (heat source too close to combustibles)

1.10.04 Factor 14 (spill of flammable liquid or gas)

1.10.05 Factor 17 (washing or painting part or material with flammable liquid)

1.10.06 Factor 19 (playing with fire)

1.10.07 Factor 51 (collision, knock down, turn over)

1.10.08 Factor 52 (unintentionally turned on or not turned off)

1.10.09 Factor 54 (overloaded)

1.10.10 Factor 55 (failure to clean)

1.10.11 Factor 56 (improper startup/shutdown procedure)

1.10.12 Factor 57 (equipment not used for purpose intended)

1.10.13 Factor 58 (equipment not operated properly)

1.11 Based on fires with item first ignited not equal to 76 and no factor contributing to ignition entries of 10-12, 14, 17, 19, 20-58, Category 5 consists of a number of factors contributing to ignition that are presumed to have little or nothing to do with cooking as an activity or the operation of ranges and that collectively contribute very little to the fire statistics on range fires. The narratives we received and used to characterize these fires in terms of the final five categories of fires had narratives for only one of these factors, and that was factor 62 (storm), which was associated with a lightning strike fire beginning behind the range.

1.11.01 Factor 13 (cutting or welding too close to combustibles)

1.11.02 Factor 15 (improper fueling technique)

1.11.03 Factor 16 (flammable liquid used to kindle fire)

1.11.04 Factor 18 (improper container or storage procedure)

1.11.05 Factor 60 (unclassified or unknown-type natural condition)

1.11.06 Factor 61 (high wind)

1.11.07 Factor 62 (storm)

1.11.08 Factor 63 (flood or other high water)

1.11.09 Factor 64 (earthquake)

1.11.10 Factor 65 (volcanic action)

1.11.11 Factor 66 (animal) – this could be grouped instead with unintentionally turned on or not turned off, but the numbers are so small that it makes little difference

1.11.12 Factor 70 (unclassified or unknown-type fire spread or control)

1.11.13 Factor 71 (exposure fire)

1.11.14 Factor 72 (rekindle)

1.11.15 Factor 73 (outside/open fire for debris or waste disposal) – if relevant, this will normally be coded as used for not intended purpose

1.11.16 Factor 74 (outside/open fire for warming or cooking) – this could be treated as another unknown, adding to that category below, but the numbers are so small that it would make little difference

1.11.17 Factor 75 (agricultural or land management burns, including controlled burns)

1.12 Category 6 consists of factor unknown (UU), blank, unclassified (00), or none (NN). These fires are not proportionally allocated but are given their own splitting factors.

Step 2: *Estimate splitting factors (that is what proportion of fires in Category X should be assigned to each of the five final categories of fires) using narratives*

2.01 The splitting factors for Category 1A (cooking-material and unattended) are based on 25 narratives:

- fires beginning in food in a cooking vessel on a burner – 25/25 = 1.000
- other fires beginning on the stovetop during cooking activities – 0/25 = 0.000
- other fires beginning on the stovetop but not during cooking activities – 0/25 = 0.000
- fires beginning in the oven part of the range – 0/25 = 0.000
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 0/25 = 0.000

2.02 The splitting factors for Category 1B (cooking-material and not unattended) are based on 31 narratives:

- fires beginning in food in a cooking vessel on a burner – 25/31 = 0.806
- other fires beginning on the stovetop during cooking activities – 3/31 = 0.097 (consisting of spills of food from pans while being moved off burners)
- other fires beginning on the stovetop but not during cooking activities – 0/31 = 0.000
- fires beginning in the oven part of the range – 2/31 = 0.065
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 1/31 = 0.032 (the one narrative was a short circuit inside the range)

2.03 The splitting factors for Category 2 (unattended and not cooking materials) are based on 5 narratives:

- fires beginning in food in a cooking vessel on a burner – 2/5 = 0.400 (consisting of two fires that appeared to begin with flammable or combustible liquid in a pan

or pot on a burner, presumed to be grease or cooking oil, that is, presumed to be cooking materials although not coded as item 76, cooking materials)

- other fires beginning on the stovetop during cooking activities – 1/5 = 0.200 (based on one ignition of wallpaper, presumed to be ignited by a stovetop food-in-pan fire that spread to wallpaper)
- other fires beginning on the stovetop but not during cooking activities – 1/5 = 0.200 (based on one ignition of a box)
- fires beginning in the oven part of the range – 1/5 = 0.200 (based on one ignition of multiple items where it was unknown whether fire began on stovetop, in oven, or elsewhere on or in range)
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 0/5 = 0.000.

2.04 The splitting factors for Category 3 (mechanical, electrical, design, installation, or manufacturing deficiency, failure or malfunction, not unattended and not cooking materials) are based on 18 narratives:

- fires beginning in food in a cooking vessel on a burner – 0/18 = 0.000
- other fires beginning on the stovetop during cooking activities – 1/18 = 0.055 (based on one fire due to arc or spark from operating equipment igniting unknown-type item while cook was at the range)
- other fires beginning on the stovetop but not during cooking activities – 2/18 = 0.111 (based on two stovetop fires due to unclassified or unknown-type electrical failure or malfunction, one igniting wallpaper when stove turned itself on, and one igniting an unknown-type item with no other details reported)
- fires beginning in the oven part of the range – 2/18 = 0.111
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 13/18 = 0.722 (consisting of six fires beginning inside range, five fires beginning behind range, and two fires where it was unknown whether fire began on stovetop, in oven, or inside or behind range)

2.05 The splitting factors for Category 4 (various behavioral factors; not unattended, mechanical, electrical, design, installation, or manufacturing; and not cooking materials) are based on 34 narratives:

- fires beginning in food in a cooking vessel on a burner – 0/34 = 0.000
- other fires beginning on the stovetop during cooking activities – 0/34 = 0.000
- other fires beginning on the stovetop but not during cooking activities – 27/34 = 0.794 (based on 27 fires where either the factor contributing to ignition or the item first ignited (coded or revealed in narrative) indicated that the fire definitely or probably did not involve cooking activities: (a) 14 fires coded as heat source too close to combustibles, including five fires where the narrative indicated that the range was unintentionally turned on and so not turned on for cooking, one fire

involving ignition of unknown-type item[1], and eight fires where the item first ignited does not suggest cooking and the other aspects of the narrative indicated cooking was definitely not involved (two each of unspecified fabric and unspecified plastic object; one fire each involving ignition of pot holder, box or bag, mini-blinds, and wicker plate holder); (b) 7 fires coded as unintentionally turned on or not turned off, including one with multiple items first ignited[2] and the other six involving items first ignited that clearly do not involve cooking – two ignitions of wicker baskets, two ignitions of utensils, and one ignition each of decorations and wall coverings; (c) 3 fires coded as unknown misuse of materials, including two fires with items first ignited that definitely do not involve cooking (one each of box and unclassified appliance) and one fire with unknown-type item first ignited[3]; (d) 2 fires coded as abandoned material – one each of papers and pot holder; and (e) 1 fire coded as collision or turnover – boxes)

- fires beginning in the oven part of the range – 5/34 = 0.147
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 2/34 = 0.059

2.06 The splitting factors for Category 5 (natural, exposure, and other known factors; while also being not, all presumed non-cooking, non-range, and excluding any of the higher priority factors cited earlier; and not cooking materials) are based on no narratives:

- fires beginning in food in a cooking vessel on a burner = 0
- other fires beginning on the stovetop during cooking activities = 0
- other fires beginning on the stovetop but not during cooking activities = 0
- fires beginning in the oven part of the range = 0
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) = 1.000 (equivalent to treating these fires as irrelevant to any stovetop fire prevention or mitigation technology)

2.07 The splitting factors for Category 6 (unknown, unclassified, multiple or no factor and not cooking materials) are based on 21 narratives. Grouping and allocation were done in two stages for this category. Of the 21 narratives, two clearly involved the oven and not the stovetop; four involved the stove top and seemed likely to involve cooking activity; ten involved the stovetop and seemed likely not to involve cooking activity; and the other five involved the stovetop but lacked details to suggest whether cooking

[1] In Category 4, fires involving unknown-type items or multiple items are all treated as not involving cooking activities because there were no fires that clearly did involve cooking activities; therefore, a proportional allocation of these unknown items would allocate them all to the not-cooking category.
[2] In Category 4, fires involving unknown-type items or multiple items are all treated as not involving cooking activities because there were no fires that clearly did involve cooking activities; therefore, a proportional allocation of these unknown items would allocate them all to the not-cooking category.
[3] In Category 4, fires involving unknown-type items or multiple items are all treated as not involving cooking activities because there were no fires that clearly did involve cooking activities; therefore, a proportional allocation of these unknown items would allocate them all to the not-cooking category.

activity was involved. Therefore, the latter five incidents were statistically allocated over the other 14 stovetop incidents, to produce the final splitting percentages.

- fires beginning in food in a cooking vessel on a burner – 0/21 = 0.000
- other fires beginning on the stovetop during cooking activities – 4 x (19/14)/21 = 0.259 (based on four fires deemed very likely to involve cooking activities – ignition of oil in pan before ignition of the cabinetry coded as item first ignited, heating up of a pan on the burner sufficiently that radiative heat from the pan directly ignited cabinets, and two fires beginning with ignition of flammable or combustible liquid that both appear to be cooking oil in a pot; and a proportional share of five fires where the involvement of cooking activity was unclear – four involving unknown-type items first ignited and one involving multiple items first ignited)
- other fires beginning on the stovetop but not during cooking activities – 10 x (19/14)/21 = 0.646 (based on ten fires deemed very unlikely to involve cooking activities – two ignitions of papers, two ignitions of clothing not on a person, two ignitions of appliance housings, and one ignition each of wall covering, rag, utensil, and wax flowing out of a jar candle that broke due to heat from the burner; and a proportional share of five fires, listed above, where the involvement of cooking activity was unclear)
- fires beginning in the oven part of the range – 2/21 = 0.095
- fires beginning elsewhere in or on the range (e.g., inside, behind, beside or under the range) – 0/21 = 0.000

Ignitions of clothing on a person are analyzed separately and only for civilian deaths. They all fall into Categories 4 and 6.

Table A summarizes the results of this exercise:

Table A. Splitting Factors for Each of Six Categories of Home Range Fires
Defined by Item First Ignited and Factor Contributing to Ignition

	Group 1: Fire begins in a cooking vessel on a burner	**Group 2: Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner**	**Group 3: Fire begins on stovetop but not during cooking activities**	**Group 4: Fire begins in oven**	**Group 5: Fire begins in or on range but not on stovetop or in oven**
Category 1A (cooking materials and unattended; item first ignited = 76; factor contributing to ignition = 53)	1.000	0.000	0.000	0.000	0.000
Category 1B (cooking materials and not unattended; item first ignited = 76; factor contributing to ignition ≠ 53)	0.806	0.097	0.000	0.065	0.032
Category 2 (unattended but not cooking materials: item first ignited ≠ 76; factor contributing to ignition = 53)	0.400	0.200	0.200	0.200	0.000
Category 3 (mechanical or electrical failure or malfunction or design, manufacturing, or installation error and not cooking materials: item first ignited ≠ 76; factor contributing to ignition ≠ 53; factor contributing to ignition 20-44)	0.000	0.055	0.111	0.111	0.722
Category 4 (not cooking materials and behavioral errors: item first ignited ≠ 76; factor contributing to ignition ≠ 20-44, 53; factor contributing to ignition 10-12,14,17, 19,51-52,54-58)	0.000	0.000	0.794	0.147	0.059
Category 5 (not cooking materials and factors not related to cooking behaviors: item first ignited ≠ 76; factor contributing to ignition ≠ 10-12,14,17,19,20-58; factor contributing to ignition 13,15-16,18,60-75)	0.000	0.000	0.000	0.000	1.000
Category 6 (not cooking materials and unclassified or unknown factors: item first ignited ≠ 76; factor contributing to ignition ≠ 01-99; factor contributing to ignition 00,NN,UU, blank)	0.000	0.259	0.646	0.095	0.000

Note: Factors sum to 1.000, or 100%, on each row.

Size of U.S. Home Range Fire Problem, by Type of Fuel or Power and by Category and Group of Fire

Table B provides annual averages of fires, civilian deaths, civilian injuries, and direct property damage for 2005-2009 home structure fires, by type of fuel or power.

Table B. Annual Average Fires and Losses for Range Fires 2005–2009
Home Structure Fires Reported to Municipal Fire Departments
by Type of Fuel or Power

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Gas	15,200	84	500	$86
Electric	74,640	247	3,187	$461
Other	280	0	10	$1
Total	90,120	330	3,697	$548

Table C provides numbers and percentages for fires, civilian deaths, civilian injuries and direct property damage for gas home range structure fires, by major category of fire cause, based on the totals in Table B. Tables C-1, C-2, and C-3 provide detailed breakouts by leading factors contributing to ignition for Category 3, 4 and 5 fires, respectively. Fires can be reported with multiple factors contributing to ignition. That is why the sums may be larger than the totals in Tables C-1, C-2, and C-3, unlike Table C, which is developed using a priority sorting protocol.

Table D provides corresponding numbers and percentages for electric home range structure fires, by major category of fire cause. Tables D-1, D-2, and D-3 are the detailed counterparts for electric ranges to the detailed results in Tables C-1, C-2, and C-3.

Table C. Estimated Distributions by Major Category of Fire Cause
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Category 1A (cooking materials and unattended)	2,730 (17.9%)	22 (26.8%)	127 (25.5%)	$17 (19.9%)
Category 1B (cooking materials and not unattended)	6,370 (41.9%)	3 (4.0%)	160 (32.1%)	$24 (27.5%)
Category 2 (unattended but not cooking materials)	520 (3.4%)	3 (4.0%)	34 (6.8%)	$8 (9.3%)
Category 3 (mechanical or electrical failure, malfunction or design, manufacturing, or installation error, and not cooking materials)	1,300 (8.6%)	3 (4.0%)	31 (6.2%)	$6 (7.1%)
Category 4 (behavioral errors and not cooking materials)	2,470 (16.3%)	27 (31.7%)	86 (17.1%)	$16 (18.4%)

Table C. Estimated Distributions by Major Category of Fire Cause
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009 (Continued)

Category 5 (factors not related to cooking behaviors and not cooking materials)	350 (2.3%)	0 (0.0%)	10 (2.0%)	$1 (1.0%)
Category 6 (unclassified, multiple, no, or unknown factors and not cooking materials)	1,460 (9.6%)	25 (29.5%)	51 (10.2%)	$14 (16.7%)
Total	15,200 (100.0%)	84 (100.0%)	500 (100.0%)	$86 (100.0%)
Ignition of clothing on person	*100 (0.4%)*	*29 (34.6%)*	*19 (3.8%)*	*$0 (0.1%)*

Table C-1. Estimated Distributions by Specific Mechanical, Electrical, Design, Manufacturing or Installation Failures (Category 3)
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Leak or break	610 (4.0%)	0 (0.0%)	16 (3.1%)	$4 (4.2%)
Unclassified mechanical failure or malfunction	350 (2.3%)	3 (4.0%)	10 (2.0%)	$2 (1.8%)
Worn out	100 (0.7%)	0 (0.0%)	3 (0.7%)	$0 (0.3%)
Automatic control failure	50 (0.4%)	0 (0.0%)	0 (0.0%)	$0 (0.1%)
Unspecified short-circuit arc	50 (0.3%)	0 (0.0%)	0 (0.0%)	$0 (0.5%)
Unclassified electrical failure or malfunction	50 (0.3%)	0 (0.0%)	0 (0.0%)	$0 (0.2%)
Manual control failure	40 (0.3%)	0 (0.0%)	0 (0.0%)	$0 (0.0%)
Other specific Category 3 causes	100 (0.7%)	0 (0.0%)	5 (1.1%)	$0 (0.5%)
Category 3 total	1,300 (8.6%)	3 (4.0%)	31 (6.2%)	$6 (7.1%)

Table C-2. Estimated Distributions by Specific Behavioral Errors (Category 4)
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Heat source too close to combustibles	810 (5.3%)	20 (24.1%)	38 (7.6%)	$4 (4.4%)
Unclassified misuse of material or product	350 (2.3%)	0 (0.0%)	23 (4.6%)	$5 (5.5%)
Unintentionally turned on or not turned off	320 (2.1%)	0 (0.0%)	9 (1.9%)	$4 (4.4%)
Abandoned or discarded material or product	260 (1.7%)	0 (0.0%)	4 (0.8%)	$3 (2.9%)
Failure to clean	260 (1.7%)	0 (0.0%)	0 (0.0%)	$0 (0.1%)
Washing or painting with flammable liquid	210 (1.4%)	0 (0.0%)	6 (1.1%)	$1 (1.1%)

Table C-2. Estimated Distributions by Specific Behavioral Errors (Category 4)
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009 (Continued)

Equipment used for not intended purpose	100	(0.7%)	3	(3.8%)	2	(0.4%)	$0	(0.5%)
Equipment not being operated properly	90	(0.6%)	3	(3.8%)	6	(1.1%)	$0	(0.5%)
Other specific Category 4 causes	160	(1.1%)	0	(0.0%)	9	(1.7%)	$1	(0.7%)
Category 4 total	2,470	(16.3%)	27	(31.7%)	86	(17.1%)	$16	(18.4%)

Table C-3. Estimated Distributions by Specific Natural or
Miscellaneous Non-Cooking-Related Behavioral Cause (Category 5)
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Improper container or storage	260	(1.7%)	0	(0.0%)	5	(1.0%)	$0	(0.5%)
Animal	30	(0.2%)	0	(0.0%)	0	(0.0%)	$0	(0.1%)
Unclassified fire spread or control	20	(0.2%)	0	(0.0%)	2	(0.3%)	$0	(0.1%)
Storm	10	(0.1%)	0	(0.0%)	0	(0.0%)	$0	(0.2%)
Other specific Category 5 causes	20	(0.1%)	0	(0.0%)	3	(0.7%)	$0	(0.0%)
Category 5 total	350	(2.3%)	0	(0.0%)	10	(2.0%)	$1	(1.0%)

Table D. Estimated Distributions by Major Category of Fire Cause
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Category 1A (cooking materials and unattended)	21,050	(28.2%)	96	(38.9%)	1,221	(38.3%)	$135	(29.2%)
Category 1B (cooking materials and not unattended)	34,490	(46.2%)	31	(12.7%)	1,303	(40.9%)	$163	(35.4%)
Category 2 (unattended but not cooking materials)	3,110	(4.2%)	32	(12.9%)	185	(5.8%)	$41	(8.9%)
Category 3 (mechanical or electrical failure, malfunction or design, manufacturing, or installation error, and not cooking materials)	2,700	(3.6%)	12	(5.1%)	42	(1.3%)	$16	(3.5%)

Table D. Estimated Distributions by Major Category of Fire Cause
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009 (Continued)

Category 4 (behavioral errors and not cooking materials)	6,910	(9.3%)	54	(22.0%)	277	(8.7%)	$64	(13.8%)
Category 5 (factors not related to cooking behaviors and not cooking materials)	570	(0.8%)	0	(0.0%)	8	(0.3%)	$3	(0.6%)
Category 6 (unclassified, multiple, no, or unknown factors and not cooking materials)	5,820	(7.8%)	21	(8.5%)	149	(4.7%)	$39	(8.5%)
Total	74,640	(100.0%)	247	(100.0%)	3,187	(100.0%)	$461	(100.0%)
Ignition of clothing on person	*30*	*(0.0%)*	*26*	*(10.7%)*	*11*	*(0.3%)*	*$1*	*(0.3%)*

Table D-1. Estimated Distributions by Specific Mechanical, Electrical, Design, Manufacturing or Installation Failures (Category 3)
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	**Fires**		**Civilian Deaths**		**Civilian Injuries**		**Direct Property Damage (in Millions)**	
Unclassified electrical failure or malfunction	780	(1.0%)	4	(1.6%)	13	(0.4%)	$5	(1.2%)
Unspecified short-circuit arc	530	(0.7%)	0	(0.0%)	7	(0.2%)	$5	(1.0%)
Unclassified mechanical failure or malfunction	510	(0.7%)	0	(0.0%)	8	(0.3%)	$2	(0.4%)
Worn out	240	(0.3%)	0	(0.0%)	4	(0.1%)	$0	(0.0%)
Arc or spark from operating equipment	220	(0.3%)	0	(0.0%)	0	(0.0%)	$1	(0.2%)
Arc from faulty contact or broken conductor	140	(0.2%)	0	(0.0%)	2	(0.0%)	$0	(0.0%)
Short circuit arc from defective or worn insulation	130	(0.2%)	0	(0.0%)	5	(0.2%)	$3	(0.6%)
Short circuit arc from mechanical damage	100	(0.1%)	9	(3.5%)	2	(0.1%)	$1	(0.2%)
Other specific Category 3 causes	200	(0.3%)	0	(0.0%)	3	(0.1%)	$1	(0.2%)
Category 3 total	2,700	(3.6%)	12	(5.1%)	42	(1.3%)	$16	(3.5%)

Table D-2. Estimated Distributions by Specific Behavioral Errors (Category 4)
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Heat source too close to combustibles	2,170	(2.9%)	19	(7.8%)	102	(3.2%)	$18	(3.9%)
Unintentionally turned on or not turned off	1,720	(2.3%)	26	(10.4%)	66	(2.1%)	$26	(5.6%)
Abandoned or discarded material or product	1,160	(1.6%)	0	(0.0%)	34	(1.1%)	$11	(2.4%)
Unclassified misuse of material or product	1,020	(1.4%)	0	(0.0%)	49	(1.6%)	$5	(1.1%)
Failure to clean	450	(0.6%)	0	(0.0%)	2	(0.1%)	$1	(0.2%)
Equipment not being operated properly	240	(0.3%)	6	(2.5%)	10	(0.3%)	$1	(0.2%)
Flammable liquid or gas spilled	180	(0.2%)	0	(0.0%)	10	(0.3%)	$1	(0.2%)
Equipment used for not intended purpose	120	(0.6%)	3	(1.3%)	14	(0.4%)	$1	(0.2%)
Other specific Category 4 causes	170	(0.2%)	0	(0.0%)	6	(0.2%)	$2	(0.5%)
Category 4 total	6,910	(9.3%)	54	(22.0%)	277	(8.7%)	$64	(13.8%)

Table D-3. Estimated Distributions by Specific Natural or
Miscellaneous Non-Cooking-Related Behavioral Cause (Category 5)
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Improper container or storage	420	(0.6%)	0	(0.0%)	5	(0.2%)	$1	(0.3%)
Animal	50	(0.1%)	0	(0.0%)	0	(0.0%)	$1	(0.2%)
Unclassified fire spread or control	40	(0.0%)	0	(0.0%)	3	(0.1%)	$0	(0.1%)
Storm	20	(0.0%)	0	(0.0%)	0	(0.0%)	$0	(0.0%)
Other specific Category 5 causes	40	(0.1%)	0	(0.0%)	0	(0.0%)	$0	(0.1%)
Category 5 total	570	(0.8%)	0	(0.0%)	8	(0.3%)	$3	(0.6%)

Tables E and F convert distributions from the major categories of fire cause to the five categories of fire location and circumstances tailored to the project. Table E combines the splitting percentages of Table A with the distributions shown in Table C to provide numbers and percentages for gas ranges. Table F combines the splitting percentages of Table A with the distributions shown in Table D to provide numbers and percentages for electric ranges.

Splitting percentages from the narratives are only available based on fires. There are too few fires to obtain meaningful results by deaths and injuries, and any results by property damage would likely be overly influenced by the few costliest fires. However, it is quite possible that the splitting percentages would be different for different measures of loss. This needs to be considered when working with this data.

Table E. Estimated Distributions by Fire Location and Circumstances
Annual Averages of Gas Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Group 1. Fire begins in a cooking vessel on a burner	8,070 (53.1%)	26 (31.6%)	270 (54.1%)	$39 (45.8%)
Group 2. Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	1,170 (7.7%)	8 (9.1%)	37 (7.5%)	$8 (9.2%)
Clothing on person ignition		*2 (3.0%)*		
Group 3. Fire begins on stovetop but not during cooking activities	3,150 (20.8%)	38 (45.5%)	111 (22.2%)	$24 (28.1%)
Clothing on person ignition		*22 (25.8%)*		
Group 4. Fire begins in oven	1,160 (7.7%)	7 (9.0%)	38 (7.6%)	$8 (8.7%)
Clothing on person ignition		*4 (4.5%)*		
Group 5. Fire begins in or on but not on stovetop or in oven	1,640 (10.8%)	4 (4.9%)	43 (8.6%)	$7 (8.1%)
Clothing on person ignition		*1 (1.4%)*		
Total	15,200 (100.0%)	84 (100.0%)	500 (100.0%)	$86 (100.0%)
Clothing on person ignition		*29 (34.6%)*		

Table F. Estimated Distributions by Fire Location and Circumstances
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Group 1. Fire begins in a cooking vessel on a burner	50,090 (67.1%)	134 (54.3%)	2,345 (73.6%)	$282 (61.3%)
Group 2. Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	5,630 (7.5%)	16 (6.3%)	205 (6.4%)	$35 (7.6%)
Clothing on person ignition		*4 (1.5%)*		
Group 3. Fire begins on stovetop but not during cooking activities	10,160 (13.6%)	64 (26.0%)	359 (11.3%)	$86 (18.7%)
Clothing on person ignition		*19 (7.6%)*		

Table F. Estimated Distributions by Fire Location and Circumstances
Annual Averages of Electric Home Range Structure Fires Reported in 2005–2009 (Continued)

Group 4. Fire begins in oven	4,730	(6.3%)	20	(8.0%)	181	(5.7%)	$34	(7.3%)
Clothing on person ignition			*3*	*(1.3%)*				
Group 5. Fire begins in or on but not on stovetop or in oven	4,030	(5.4%)	13	(5.4%)	97	(3.0%)	$24	(5.1%)
Clothing on person ignition			*1*	*(0.3%)*				
Total	74,640	(100.0%)	247	(100.0%)	3,187	(100.0%)	$461	(100.0%)
Clothing on person ignition			*26*	*(10.7%)*				

SECTION 2. ESTIMATES OF IMPACT OF STOVETOP FIRE PREVENTION OR MITIGATION TECHNOLOGIES

Smoke alarms

It is possible to calculate from data on reported fires, the percentage reduction in deaths, injuries and property damage when smoke alarms are present versus when they are absent, for electric ranges and separately for gas ranges. Calculated in this way, the statistics incorporate less than perfect reliability. The percentage reduction is a combination of the likelihood that smoke alarms will operate (for a fire large enough to activate an operational smoke alarm) and the average reduction in loss when smoke alarms do operate, which we assume results from the actions taken by occupants – escape, fire control – with the earlier notice of fire.

These calculations assume that any strategy operating after ignition, such as smoke alarms, automatic suppression equipment, or an automatic containment device, would have no effect on losses associated with ignitions of clothing on a person. Therefore, we first calculated the percentage reduction in fires and losses using a data set excluding clothing-ignition fires, then translated that percentage reduction into quantities of fires and losses prevented. Finally, we express that quantity of fires and losses prevented as a percentage reduction using the base of total fires and losses, including clothing-ignition fires and losses.

The results were as follows:

Percentage reduction in losses associated with smoke alarm presence, for electric ranges:

- 9% reduction in civilian fire deaths,
- 9% reduction in civilian fire injuries, and
- 30% reduction in direct property damage.

Percentage reduction in losses associated with smoke alarm presence, for gas ranges:

- 32% reduction in civilian fire deaths,
- 35% reduction in civilian fire injuries, and

- 2% reduction in direct property damage.

NFPA analyses of the effects of home smoke alarms usually do not include reductions in injuries or damages, because estimates based on all home fires usually do not show statistical reductions in those losses associated with the presence of smoke alarms. For example, calculations for all causes shown injuries per 100 fires and direct property damage per fire to be slightly higher when a smoke alarm is present than when one is not. This suggests that, at least as a sensitivity analysis, one might exclude effects on injuries and damages from the benefit calculation for smoke alarms.

Note that these statistics are for a conventional home fire detection device used to detect fires, nearly all of which will be ionization type smoke alarms. Estimates of the impact of other types of fire detection or smoke detection devices – or devices intended to detect hazardous conditions before ignition, such as vapors from pyrolosis – would need to be developed using other data or other approaches.

Automatic containment devices

Impact is estimated based on the reduction in losses if all fires were confined to object of origin. With this approach, these are the calculated impact percentages:

Percentage reduction in losses associated with confinement of all fires to object of origin, for electric ranges:

- 78% reduction in civilian fire deaths,
- 12% reduction in civilian fire injuries, and
- 70% reduction in direct property damage.

Percentage reduction in losses associated confinement of all fires to object of origin, for gas ranges:

- 60% reduction in civilian fire deaths,
- 19% reduction in civilian fire injuries, and
- 87% reduction in direct property damage.

These estimates probably overstate the impact of an automatic containment device. There is no basis, other than engineering judgment, to estimate how often the device will not work (reliability problems) or will not provide effective containment (effectiveness problems, in which the fire is able to spread past the barrier after the barrier is deployed) or will not operate in a timely manner (effectiveness problems, in which the fire has already spread outside the containment area before the barrier is deployed). Furthermore, the average size of a fire shown as confined to object of origin (but not shown as confined to cooking vessel), where the object of origin is something ignited by a range, is likely to be smaller than the containment area, which the containment device will permit to be covered by fire.

My suggestion for engineering judgment estimates would be a 10% reduction for each of the two following factors: (a) the likelihood that the device will not deploy for a fire that should activate the device (reliability problems) and (b) the likelihood that the average final size of a fire contained by the technology will be larger than the average final size of a fire reported as confined to object of origin (but not confined to a cooking vessel).

These two adjustments would mean the revised impact percentages would be as follows:

Percentage reduction in losses, for electric ranges:

- 63% (90% x 90% x 78%) reduction in civilian fire deaths,
- 10% (90% x 90% x 12%) reduction in civilian fire injuries, and
- 57% (90% x 90% x 70%) reduction in direct property damage.

Percentage reduction in losses, for gas ranges:

- 49% (90% x 90% x 60%) reduction in civilian fire deaths,
- 15% (90% x 90% x 19%) reduction in civilian fire injuries, and
- 70% (90% x 90% x 87%) reduction in direct property damage.

Sprinklers or wet/dry chemical extinguishing equipment

NFPA's most recent report on sprinklers shows that, when wet-pipe sprinklers are present in any type of home, excluding buildings under construction and sprinkler installations without sprinklers in the area of the fire, the death rate per 100 fires was 85% lower (than with no automatic extinguishing equipment present) and the rate of direct property damage per 100 fires was 71% lower. NFPA usually uses the rounder numbers of 80% and 70% so that the many materials citing impact statistics do not have to revised every time there is a new statistical report, which would also make the constantly changing numbers harder to remember. NFPA also does not claim reductions in civilian injuries; as with smoke alarms, the statistics often do not show any such impact.

For wet or dry chemical systems, there are not enough home fires with this equipment present to support any calculations, but statistics can be developed using all structure fires where wet or dry chemical extinguishing equipment was reported present. The most relevant such statistics are estimates specifically for range fires, which showed an 81% reliability percentage (likelihood that extinguishing equipment will operate for a fire large enough to activate operational equipment) and an 89% effectiveness percentage (likelihood of performing effectively if it operates) producing a 72% likelihood of effective operation.

Of course, these are not the same types of devices used or proposed for the home environment.

This is a likelihood of effective operation, which is not the same as a predicted percentage reduction in loss. There are not enough fire deaths in the properties that have used these devices to date to support direct estimates of percentage reduction in fire losses. Instead, a rough estimate may be developed by relating the impact percentages for sprinklers to the likelihood of effective

operation for sprinklers, and then applying this relationship to the likelihood of effective operation for wet or dry chemical extinguishing equipment, producing an estimate of impact percentages for wet or dry chemical extinguishing equipment.

As noted above, sprinklers were associated with an estimated 85% reduction in death rate and a 71% reduction in damage rate. In the same NFPA annual report, sprinklers had an estimated likelihood of effective operation of about 92%. Suppose we argue that ratio of sprinkler death rate reduction (85%) to sprinkler likelihood of effective operation (92%) will be the same as the ratio of wet/dry chemical death rate reduction (what we want to solve for) to wet/dry chemical device likelihood of effective operation (72%).

Then the estimated death rate reduction percentage for wet/dry chemical extinguishing equipment would be (85%/92%) x 72% = 67%.

In the same way, the property damage rate reduction for wet/dry chemical extinguishing equipment would be estimated as (71%/92%) x 72% = 56%.

Sensor-based stovetop (range burner) fire prevention technology

These estimates assume perfect reliability and perfect effectiveness if the device operates. The latter may be a reasonable assumption, but the former probably is not. Applying engineering judgment in a consistent manner, one might apply a 90% factor to the estimate of impact of these devices, reducing the across-the-board 100% impact estimates to 90% impact estimates.

SECTION 3. LOCATION AND CIRCUMSTANCES OF COOK

The goal of this task is to develop a basis for quantifying relative likelihood of cook locations, a critical part of the occupant behavioral scenarios needed as a partial basis for assessing the predicted impact of stovetop fire prevention or mitigation technologies. One technology involves detection of elevated temperature of a cooking vessel or food in a cooking vessel on a stovetop burner. A second technology involves detection of the presence of a cook and is therefore focused on fires beginning during cooking activities.

Both technologies could theoretically be designed to react to a detected hazardous condition by either (a) acting directly to remove the hazard (i.e., turning off the power to the burner) or (b) sounding an alarm to alert the cook to a hazardous condition. Evaluation of the latter approach requires the development of a timeline. The behavioral part of that timeline includes estimating whether and when the cook will hear the alarm, whether and when the cook will react to the alarm, and whether and when the cook will be back at the range and able to take action. (This is a simplification. Even if fire begins before the cook returns, there may be an opportunity to extinguish the fire in its earliest stages. Also, the cook's reaction to the alarm could involve escape rather than firefighting, and that could be deemed a type of success.)

The protocol uses data from 18 relevant coded incidents with narratives and the results of published studies, particularly 51 incidents in the 1998 New Zealand Fire Service, Bay-Waikato Fire Region Kitchen Fire Research study. (Key Research, 1998) Results from a CPSC range fire study are also used. (Smith, 1999)

Of the 51 New Zealand cooking fires, seven involved baking or roasting, 33 involved shallow or deep frying, and 18 involved boiling. Another three fires involved grilling or toasting. This totals 61 and indicates that several incidents involved multiple types of cooking. The New Zealand study showed seven fires in the oven, 40 fires on the stovetop, and five fires involving a bench-top cooker or barbecue. These results suggest that the 40 stovetop fires involved frying or boiling. Similarly, the CPSC range study found that baking-related fires were "generally" in the oven, while frying and boiling-related fires were "generally" on the stove top.

The published report on the New Zealand cooking fires provides some cook-location breakdowns but does not provide breakdowns limited to the 40 stovetop fires, which is what we would ideally have wanted. Of the 51 fires, one had cook location unknown and eight involved cooks located in the kitchen. The other 42 fires are the only fires considered by the study authors to involve unattended cooking. They divided as follows:

1. 22 fires occurred while the cook was in another room in the house
    a. provided no additional details
    b. forgot something was left on
    c. had unintentionally turned cooking on before leaving the room
    d. indicated the cooking was not stovetop cooking – one oven and one toaster
    e. 11 left to address a distraction – 7 to deal with people in person (3 to deal with children, 2 to deal with adults, 2 to deal with unspecified visitors), 1 to answer the phone, 2 to watch television, and 1 to stoke a fire
    f. 1 went to the bedroom for 10 minutes with no other details provided
2. 20 fires occurred while the cook was outside the building
    a. 7 who were still on the yard or property though not in the house
    b. 13 who were away from the property as well as the house (including 2 whose cooking was not stovetop cooking)

Analysis can be done by removing the four incidents that did not involve stovetop cooking and allocating the two incidents with cooks in the house but no details on circumstances. This suggests the following splitting factors:

- 0.474 for cooks outside the building, where they could not be expected to hear an alarm, based on dividing the outside-building total of 18, excluding the two non-stovetop incidents, by the combined total of 38, excluding the four non-stovetop incidents
- 0.292 for cooks in another room in the house who are involved in an activity involving competing sounds (e.g., conversation in person or on phone, television), based on 10 incidents with competing sounds, allocation of two incidents without details over the 18 other incidents (excluding non-stovetop incidents) with cooks in another room, all divided by the combined total of 38

- 0.234 for cooks in another room in the house who are not known to be involved in an activity involving competing sounds (i.e., the four who forgot something was left on, the two who unintentionally turned cooking on, and the two who were either stoking a fire or going to a bedroom for no known purpose), based on those 8 incidents, allocation of two incidents without details over the 18 other incidents (excluding non-stovetop incidents) with cooks in another room, all divided by the combined total of 38.

In the current study, of the 25 unattended cooking, cooking-material stovetop fires, there was information on cook location for 9 incidents, excluding one incident where the cook was reported to be at the range even though the factor contributing to ignition was unattended. These 9 incidents divided as two outside the house and seven in another room, but four of the seven were asleep, which would be a different form of activity competitive with successful alerting by an alarm.

If you combine these 9 incidents with the 38 New Zealand incidents, then the splitting factors are modified as follows:

- 0.426 for cooks outside the building
- 0.321 for cooks in another room in a condition or activity that makes successful alerting by alarm less likely
- 0.253 for cooks in another room with no condition or activity that would make successful alerting by alarm less likely

In the current study, there were a total of 30 incidents with information on the location and circumstances of the cook, excluding incidents where the cook was reported to be at the range – 12 with cook outside the building and 18 with cook in another room (8 with cook asleep, 1 with cook distracted by a child, and 9 with no information on distractions). If you combine these 30 incidents with the 38 New Zealand incidents, then the splitting factors are modified as follows:

- 0.441 for cooks outside the building
- 0.296 for cooks in another room in a condition or activity that makes successful alerting by alarm less likely (distracted or asleep)
- 0.263 for cooks in another room with no condition or activity that would make successful alerting by alarm less likely

The CPSC range fire study provides 186 additional cases (excluding 32 cases where the cook was in the kitchen) for consideration. As with the New Zealand study, stovetop fires are not characterized separately from other range fires. The CPSC “not at home” category may not include all the fires where the cook is at home, but physically located outside the building. The CPSC category of outside kitchen but not known to be dealing with an interruption may not include all the fires where the cook is outside the kitchen but in a condition or activity that makes successful alerting by alarm less likely.

The splitting factors for the CPSC range fire study alone are as follows:

- 0.194 for cooks outside the building [specifically, cook not at home]
- 0.269 for cooks in another room in a condition or activity that makes successful alerting by alarm less likely (distracted or asleep) [specifically, cook outside kitchen with interruption]
- 0.538 for cooks in another room with no condition or activity that would make successful alerting by alarm less likely [specifically, cook outside kitchen without interruption]

These factors are quite different from the factors calculated from the New Zealand study and the narratives of the current study. Also, they are different in the direction one would expect if the CPSC range study is defining "not at home" and "with interruption" more narrowly than the corresponding categories of "outside the building" and "condition or activity that makes successful alerting by alarm less likely" used in this protocol.

These two sets of factors can be separately applied to the food in pan on burner portion of the section on fire location, with the results providing a sensitivity analysis of the effects of varying the cook-location distribution.

If the two datasets are to be pooled, I recommend that they not be simply combined, because if they are, the CPSC range study data set, being nearly three times the size of the other data set, will dominate.

If the data sets are combined but given equal weight (that is, the 186 CPSC range study fires count the same as the 68 fires from New Zealand and the current study's narratives), then the resulting splitting factors would be as follows:

- 0.318 for cooks outside the building
- 0.282 for cooks in another room in a condition or activity that makes successful alerting by alarm less likely (distracted or asleep)
- 0.400 for cooks in another room with no condition or activity that would make successful alerting by alarm less likely

If this is further simplified, the baseline calculation might be done with splitting factors of 0.4 for cooks in another room with no condition or activity that makes successful alerting by alarm less likely, and 0.3 for both cooks outside the building and cooks in another room in a condition or activity that makes successful alerting by alarm less likely.

The CPSC range fire study provides the best available basis for estimating time from initiation of cooking to fire ignition. Results are provided for frying, boiling, baking, and other (including grilling and broiling). Baking is said to be "generally" an issue for oven fires, while frying and boiling are said to be "generally" an issue for stovetop fires.

If frying alone is compared with boiling alone, then the frying percentage is 78% (based on 138 frying incidents and 40 boiling incidents). If frying is combined with other (including grilling and broiling), then the frying percentage is 80% (based on 138 frying incidents, 19 other incidents, and 40 boiling incidents).

Table G shows the cooking time until fire ignition for cooking fires associated with boiling, frying, and baking, with baking excluded because it is assumed to involve the oven and incidents with unknown cooking time until fire ignition also excluded.

Table G. Cooking Time Prior to Fire Ignition for Stovetop Cooking
Based on Results from CPSC Range Fire Study

Cooking time before fire ignition	Boiling	Frying	Other (including grilling and broiling)	Frying and Other
0 to 14 minutes	6%	83%	76%	82%
15 to 29 minutes	31%	5%	0%	4%
30 to 60 minutes	20%	12%	12%	12%
61 or more minutes	43%	0%	12%	2%

If one makes a bold assumption that incidents are distributed evenly across each interval, then the median cooking time to fire ignition would be 50 minutes for boiling, 9 minutes for frying, 10 minutes for other, and 9 minutes for frying combined with other. Even if the distributions are far from even across any interval, the median for boiling would have to be greater than 30 minutes and the median for frying would have to be less than 15 minutes.

The time distributions for frying and for "other" cooking resemble each other much more than either resembles the distribution for boiling. Because of that fact and the fact that there are so few fires involving cooking other than boiling or frying, the distribution of cooking time before fire ignition for frying is nearly identical to the time distribution for frying and "other" cooking combined.

Note that the actual time to ignition will vary, depending on various factors such as the type and quantity of cooking oil, grease, or food, and possibly the size, configuration and type of pan. The studies and data available to us did not indicate how large the variation is, by type of cooking, but it seems unlikely that this variation would change the general conclusion that times to ignition are quite short for frying and generally longer for other types of cooking.

Therefore, the concern for evaluation of a technology will be with frying. The technology will need to operate quickly enough to deal effectively with frying-related fires.

If the technology uses direct reduction of heat to the pan rather than an alarm, then the question will be how reliably the detector works to identify an overheat condition, how much more heat is required at that point to cause fire ignition, and how quickly heat is reduced after overheat is detected. In this context, effective fire prevention will push for earlier declaration of an overheat condition, while minimal interference with cooking operations will likely push for later declaration of an overheat condition.

If the technology uses an alarm rather than direct reduction of heat to the pan, then there will be at most 15 minutes – and possibly only 5-10 minutes for most fires – to fit in the various time components. These could be either of the following:

- If the technology checks the heat of the pan, then the time from detected overheating of pan to fire ignition would have to be less than the time needed by a cook to hear the alarm, react to the alarm (if occupant is still in the building and if alarm can break through distractions or sleep), return to the range, and address the hazard, which might involve moving the pan or turning off the heat.
- If the technology checks the presence of the cook, then the time from determination of no cook in the area (which may be set based on an elapsed period of time with no detection of a cook in the area) to fire ignition would have to be less than the time needed by a cook to hear the alarm, react to the alarm (if occupant is still in the building and if alarm can break through distractions or sleep), return to the range, and address the hazard, which might involve moving the pan or turning off the heat.

REFERENCES

Key Research and Marketing, Ltd., *New Zealand Fire Service, Bay-Waikato Fire Region, Kitchen Fire Research, Summary of Findings*, October 1998, accessed at http://baywaikato.fire.org.nz/research/pdf/kitchen.pdf.

Linda Smith, Ron Monticone, and Brenda Gillum, *Range Fires, Characteristics Reported in National Fire Data and a CPSC Special Study*, Washington: U.S. Consumer Product Safety Commission, Division of Hazard Analysis, Directorate of Epidemiology, 1999, accessed at http://www.cpsc.gov/LIBRARY/FOIA/Foia99/os/range.pdf.

APPENDIX D – WORKSHOP REPORT

Technology Assessment: Home Cooking Fire Mitigation
Workshop Summary and Key Action Items
Background

Cooking related fires are a leading cause of U.S. fire loss. Beginning in the mid 1980's, the National Institute of Standards and Technology, Consumer Product Safety Commission, and the home appliance industry undertook a comprehensive review[4] of strategies to mitigate death, injury and property loss from cooking fires with a focus on cooking range technologies. In February of 2010, a Vision 20/20 workshop on this topic was convened in Washington D.C. Participants recommended that an additional study be undertaken to identify the barriers to the utilization of these technologies and to develop an action plan towards improving cooking fire safety.

The Fire Protection Research Foundation has been asked by the National Institute of Standards and Technology to develop an action plan to mitigate loss from home cooking fires by investigating safety technologies related to home cooking. Elements of the study include an in-depth assessment of cooking fire scenarios, a review of current and emerging technologies, and development of an assessment methodology to consider the utility and effectiveness of mitigation technologies against a range of fire and use scenarios and other criteria. On July 14, leaders in the fire safety community met together in Baltimore Maryland to review the results of the Foundation study.

Workshop Goal

The goal of the workshop was to develop an action plan for research, product development and technology transfer to address the goal of mitigating fire loss from home cooking through technology.

Overview of Workshop Agenda

Approximately 30 leaders from the fire safety community participated in the workshop. Kathleen Almand, Executive Director of the Foundation, provided an overview of the study, which is sponsored by the National Institute of Standards and Technology. John Hall, Director of NFPA's Fire Analysis and Research Division, presented an in-depth analysis of cooking fire incidents which was designed to inform the study. Hughes Associates, who conducted the technology assessment portion of the Foundation's study, presented a review of cooking fire mitigation technologies in the marketplace. Tom Fabian, Underwriters Laboratories, John Donovan, State Farm Insurance, and Andrew Trotta, Consumer Product Safety Commission, presented

[4] CPSC Study (with AHAM Support): "Technical, Practical, and Manufacturing Feasibility of Technologies to Address Surface Cooking Fires." May 22, 2001. Arthur D. Little

overviews of related research activities at their organizations. Hughes Associates then presented a methodology to evaluate the performance of cooking fire mitigation technologies against a range of parameters including fire protection effectiveness, usability, and cost. They then presented the application of this methodology to cooking fire mitigation technology classes, including detection of imminent or occurring fires with warning, control/containment technologies, suppression technologies, and fire prevention technologies.

Participants provided feedback on the method and its limitations and suggested enhancements, including: separating the assessment of technologies for gas and electric ranges; providing more weight in the method on cooking performance by breaking that out as a separate factor and combining other issues like cleaning/maintenance into the cost section; reviewing the statistics to determine if there is a way to place at least a judgment value on the effectiveness of various technologies (i.e. instead of assuming that they are always effective if they are present); adjusting the work to focus on stove top fires only; and refining the unattended fire analysis. It was noted that the assessments presented were preliminary; assessments used for decision making should be carried out by a broad group of individuals using a Delphi or other process.

Participants then divided into three breakout groups to discuss elements of an action plan. Each group was asked to address needed improvements in the assessment method, needed research, and needed technology transfer programs that would address the goal. The results of each breakout group are appended. Each group reported their action item recommendations to the plenary. The workshop concluded with a commitment from participants to continue to participate in activities to achieve the goal of reducing cooking fire loss through technology solutions.

Summary of Key Action Items

Research

- Develop standard fire scenarios and create test methods and performance criteria which can feed into standards development
- Improve understanding of pre-ignition detection
    - Research time to detection vs. time to ignition
    - Further research on pre-ignition indicators
- Conduct a societal cost/benefit study
- Long term scientifically based assessment of field performance of Safe-T element and other technologies
- Continue to refine the technology assessment methodology

Considerations for Product Development

- Pursue a multi-sensor or multi-threshold approach (i.e. warning then cooking control)
- Product development should have a specific design focus:
    - Type of range (gas, electric, flat top, or induction)

- Specific population (elderly, low income, students)
- Items first ignited (oil, clothing(control placement))
- High risk cooking such as deep fat fryers, high heat Asian cooking, blackening

Technology Transfer

- Develop standard performance criteria and integrate into UL 858(electric) and CSA/ANSI Z21.1(gas) as supplemental requirements for fire mitigation which would receive a special listing (gold star)
- Consider formation of a new Cooking Fires Task Group under the purview of UL STP 858
- Market as an option for consumer choice

Appendices

Workshop Agenda

Workshop Attendance

Breakout Group Notes

List of Action Items

THE FIRE PROTECTION RESEARCH FOUNDATION

Technology Assessment: Home Cooking Fire Mitigation
Development of an Action Plan

9:30 a.m. – 3:30 p.m.
Thursday, July 14th, 2011, BWI Airport Marriott

AGENDA

1.	Welcome/Background/Workshop Objective	Dan Madrzykowski, NIST
2.	Overview – Fire Protection Research Foundation Project	Kathleen Almand, FPRF
3.	Analysis of Cooking Fire Incidents	John Hall, NFPA
4.	Technologies for Cooking Fire Mitigation	Josh Dinaburg, Hughes Associates
5.	Recent Research:	
	a. Stove Top Retrofit Technology Performance	John Donovan, State Farm
	b. Prototype Stovetop Technology Assessment	Andrew Trotta. CPSC
	c. Smoke Characterization Applied to Cooking Fire Mitigation	Tom Fabian, UL

LUNCH

6.	Technology Assessment and Gap Analysis	Josh Dinaburg
7.	Elements of an Action Plan:	Discussion/Breakouts
	a. Cooking Fire Mitigation Technology Research and Development	
	b. Assessment Methodology Next Steps	
	c. Technology Transfer	
8.	Conclusion	

ATTENDEES

Mike Love, representing Vision 20/20

Andrew Trotta, CPSC

Tom Fabian, Underwriters Laboratories Inc.

Wayne Morris, AHAM

Dan Madrzykowski, NIST Engineering Laboratory

John Donovan, State Farm Insurance

Brian Merrifield, FPRF

Kathleen Almand, FPRF

John Hall, NFPA

Dan Gottuk, Hughes Associates, Inc.

Joshua Dinaburg, Hughes Associates, Inc.

Candace Ahwah-Gonzalez, Safe Kids Worldwide

Meri-K Appy, Safe Kids Worldwide

Jason Averill, NIST

Larry Bell, BSH Home Appliances

Debra Carlin, Dallas Fire Rescue Department

Amy Carpenter, WRT Design

Doug Crawford, Ontario Deputy Fire Marshal

Jim Crawford, Vision 20/20

Bob DellaValle, Underwriters Laboratories Inc.

William Downing, Baltimore City Fire Department

Sandy Facinoli, US Fire Administration

Mike Gerdes, BSH Home Appliances

Anthony Hamins, NIST Engineering Laboratory

Meredith Hawes, Grand Traverse (MI) Metro FD

David Kerr, Plano (TX) Fire Rescue

Dave Kinney, GE

David Klein, Veterans Affairs

Lawrence McKenna, U.S. Fire Administration

Kevin McSweeney, Center for Campus Fire Safety

Joseph Musso, Underwriters Laboratories Inc.

George Morgan, U.S. Navy

Steve Polinski, Miele

Amanda Robbins, BRANZ

Wayne Senter, South Kitsap (WA) Fire & Rescue

Marty Walsh, BSH Home Appliances

Maggie Wilson, FEMA

BREAKOUT GROUP NOTES

BLUE GROUP:

Research:

- Any further research must be sure to include a diverse constituency (i.e. manufacturers, consumer testing, etc)
- Strongly support a multi-sensor or multi-threshold approach. Consider a sequence of events such as warning of immanent hazard first, then as time and the situation continues: automatically shut-off source, automatically suppress, and consider notifying the Fire Department or other authorities to check in on the situation.
    - Ex: computer – power save mode, sleep mode, turn off
    - Ex: Pre-action sprinkler system: smoke detector sounds the alarm and charges the system but the extinguishment requires a secondary confirmation (heat) to prevent accidental discharges
- Investigate current high hazard protection such as the UK Potato Chip fire incidents
- Research should have a specific design focus such as a product specifically designed for the:
    - Type of range (gas, electric, flat top, or induction)
    - Specific population (elderly, low income, students)
    - Items first ignited (clothing, oil)
- Consider either one product for all types of ranges (which will work for all but not be as effective for some) vs. a specific product for each niche market (much more effective for each, but not uniform across industry)
- Continue CPSC's current research
- Product design must be inexpensive, easy to install, and easy to use to make jump into larger market.

Method:

- Consider incorporating TFPG goals into method to mesh common ideas easier
- Refine method to apply to specific range types (gas, electric, flat top, induction)
- "Reliability Internationally"
- "Drill further into fire statistics"
- Elaborate further to quantify cost, effectiveness, and reliability.
- Change the way information is displayed in graphs to show % change in loss measures, preferably with uncertainty bars.
    - Consider using John Hall's chart with percentage of events that occur in each category to easily quantify the % impact of the results.

- Perhaps use the current method created to "triage" the mass amount of products to narrow the field to those most likely to make the largest impact then dig deeper quantifying for the fewer options.
- "Use Delphi panels at least for a use scale where you can't get data"
- Current method does not take product effectiveness in specific niches into account, only general applicability.
- Very subjective guesses were made, consider using a very large sampling group to evaluate parameter importance.

Technology Transfer

- Focus technology on high fire risk areas and styles of cooking (i.e. deep fryers and high heat Asian cooking).
- Strengthen links between research and standards.
- Consider developing performance criteria for specific niche types of ranges rather than product specifications (i.e. Performance Based Design style where a design criteria is established for certain types of ranges where so long as a product meets that classification, it is considered usable for that type of range)
- Market first then mandate after experience (similar to airbags)
    - Put options on the market to introduce idea. "You can get a regular stove, but with your higher risk with children around, can I suggest a "safer" option." Make it a desired safety item and consumers will adapt.
    - Market focused approaches:
        - i.e. AARP focusing on importance to baby boomers getting older
- Instead of mandating a specific technology, consider allowing substitutions to meet intent such as allowing a non-regulated stove top to be installed only if a sprinkler system is installed in the kitchen. (Allowed to cook with larger flames if passive or active protection is added in place of regulated temperature or type of stove).
- Electric seems easier to input control unit, gas and induction should be researched more
- Further define parameters (i.e. timers – specific lengths of time, ignore button)
- Change standard design criteria such as having single deep widths rather than double to prevent users from reaching over active burners.
    - Similar debate to where the knobs should be (on front of stove allows access for kids to play with but behind the store encourages users reaching over burners, which is more dangerous?)

RED GROUP:

Research and Development

- Pre-ignition detection and control
    - Research time to detection vs. time to ignition
- More work on promising technologies that are currently available
- Consumer research on available technologies
- Create and test methods and performance criteria based on standard fire scenarios
- Further research pre-ignition indicators
- # of nuisance alarm evaluation and correction
- NFIRS
    - Deeper diving into cooking fire stats
    - Special studies
    - CPSC
    - Reliability?

Action Implementation

- CPSC action
    - Expand beyond temperature control
- Clear regulatory/approval/standards/listing paths for retrofit technology.
- Drivers for new product entry:
    - Regulation
    - Consumer education
    - Develop case for society – cost benefit analysis
    - Market for high risk groups initially
- Barriers:
    - Legal issues – Optional safety features
    - Life safety code provisions
        - Extra safety features for high risk groups
- Not in product standard

GREEN GROUP:

In general the discussion focused upon setting performance goals for the implementation of devices. The need for standards to identify a level for acceptable products was emphasized.

The group recommends that fire mitigation is included in UL 858 and CSA/ANSI Z21.1 (gas ranges) to identify performance requirements for temperature limiting devices (burner control).

The fire mitigation would be included in the standard as a supplemental requirement. Any device meeting the additional requirement would get a "gold star" or other special listing. It was noted that this is how coffee makers can be listed for "hospitality" use as an example.

In order to begin work on this process a new STP would need to be organized and beginning working off the single performance goal of "Prevent ignition of a pot of 100% corn oil." It was felt that prevention of this single fire would indicate an ability to prevent numerous other fire scenarios due to the ease of ignition of this test.

It was also discussed that the consumer performance goals should be dictated by the customers. We also noted that when the consumer is a property manager or similar, the allowable impact to cooking is not as important as the need to prevent fires. The opposite may be true when the consumer is the person who will be using such a device.

With regard to the presentations, it was generally felt that more statistical data is necessary to fully carry through such an analysis.

ACTION ITEMS

I Performance Assessment Method Enhancements

- Refine method to apply to specific range types (gas, electric, flat top, induction)
- Elaborate further to quantify cost, effectiveness, and reliability using for example international data sources, deeper exploration of NFIRS and other studies, etc.
- To remove subjectivity, consider using a very large sampling group to evaluate parameter importance or use Delphi Panels.
- Consider incorporating TFPG goals into method to mesh common ideas easier
- Change the way information is displayed in graphs to show % change in loss measures, preferably with uncertainty bars.
- Perhaps use the current method to "triage" the mass amount of products to narrow the field to those most likely to make the largest impact; then dig deeper into quantification of a smaller number of more promising options.
- *Provide more weight in the method on cooking performance by breaking that out as a separate factor and combining other issues like cleaning/maintenance into the cost section;

- *Review the statistics to determine if there is a way to place at least a judgment value on the effectiveness of various technologies (ie instead of assuming that they are always effective if they are present);
- *Adjust the work to focus on stove top fires only
- *Refine the unattended fire analysis.
- *Provide a written description of the input, identifying the limitations in input values.

* Identified in the general session, not the breakout sessions

II Research

Test Methods and Performance Criteria

- Develop standard fire scenarios and create test methods and performance criteria which can feed into standards development

Detection

- Improve understanding of pre-ignition detection
    - Research time to detection vs. time to ignition
    - Further research on pre-ignition indicators

Consumer Studies

- Research consumer attitudes/reaction to available technologies
- Conduct societal cost/benefit study

General Studies

- Study the number of nuisance alarms, their causes and strategies to reduce them
- Study reliability over time measures
- Explore tamper resistance (identified in general session, not breakout)
- Continue to monitor and enrich understanding of cooking fire incidents through deeper dives into NFIRS, conduct of special studies either through CPSC or through fire departments
- Any further research must be sure to include a diverse constituency (i.e. manufacturers, consumer testing, etc)

III Product Development

- Pursue a multi-sensor or multi-threshold approach. Consider a sequence of events such as warning of imminent hazard first, then as time and the situation continues: automatically shut-off source, automatically suppress, and consider notifying the Fire Department or other authorities to check in on the situation.

- Investigate analogous strategies such as current high hazard protection - UK Potato Chip fire incidents
- Product development should have a specific design focus such as a product specifically designed for the:
    - Type of range (gas, electric, flat top, or induction)
    - Specific population (elderly, low income, students)
    - Items first ignited (clothing, oil)
    - High risk cooking such as deep fat fryers, high heat Asian cooking
- Continue CPSC's current research and extend beyond temperature control technologies
- Focus product development on these characteristics to speed market entry: inexpensive, easy to install
- Focus product development on promising technologies that are currently available
- Focus on gas and induction as most focus to date has been on electric
- Further define parameters (i.e. timers – specific lengths of time, ignore button)
- Consider other product development approaches such as depth of range to prevent users reaching over active burners; timers, ignore buttons

IV Technology Transfer

Standards Development

- Strengthen links between research and standards.
- Develop performance classes for niches (cooking, high risk groups)
- Develop a code approach which would explore detection, passive, suppression options
- Standard performance criteria should be developed and integrated in to UL 858(electric) and CSA/ANSI Z21.1(gas) as supplemental requirements for fire mitigation which would receive a special listing (gold star)
- Form a new Cooking Fires Task Group with a single performance goal of "Prevent ignition of a pot of 100% corn oil." It was felt that prevention of this single fire would indicate an ability to prevent numerous other fire scenarios due to the ease of ignition of this test.
- Consumer performance goals should be dictated by the customer
- Clear regulatory/approval/standards/listing paths for retrofit technology.

Marketing and Consumer Education

- Market first then mandate after experience (similar to airbags)

- Market as an option for consumer choice
- Consumer education
- Educate on societal cost/benefit
- Market for high risk groups initially

SAFE-T-ELEMENT ACCELERATED LIFE TEST PROCEDURE AND PRELIMINARY RESULTS

(This material was not developed or reviewed as part of the Research Foundation project but was developed independently by State Farm and provided as a supplemental write-up for the verbal presentation made at the workshop.)

An Accelerated Life Test on the Safe-T-Element (STE) is in progress to evaluate its ability (during the life of the range) to prevent ignition of a pan of cooking oil that has been left heating unattended.

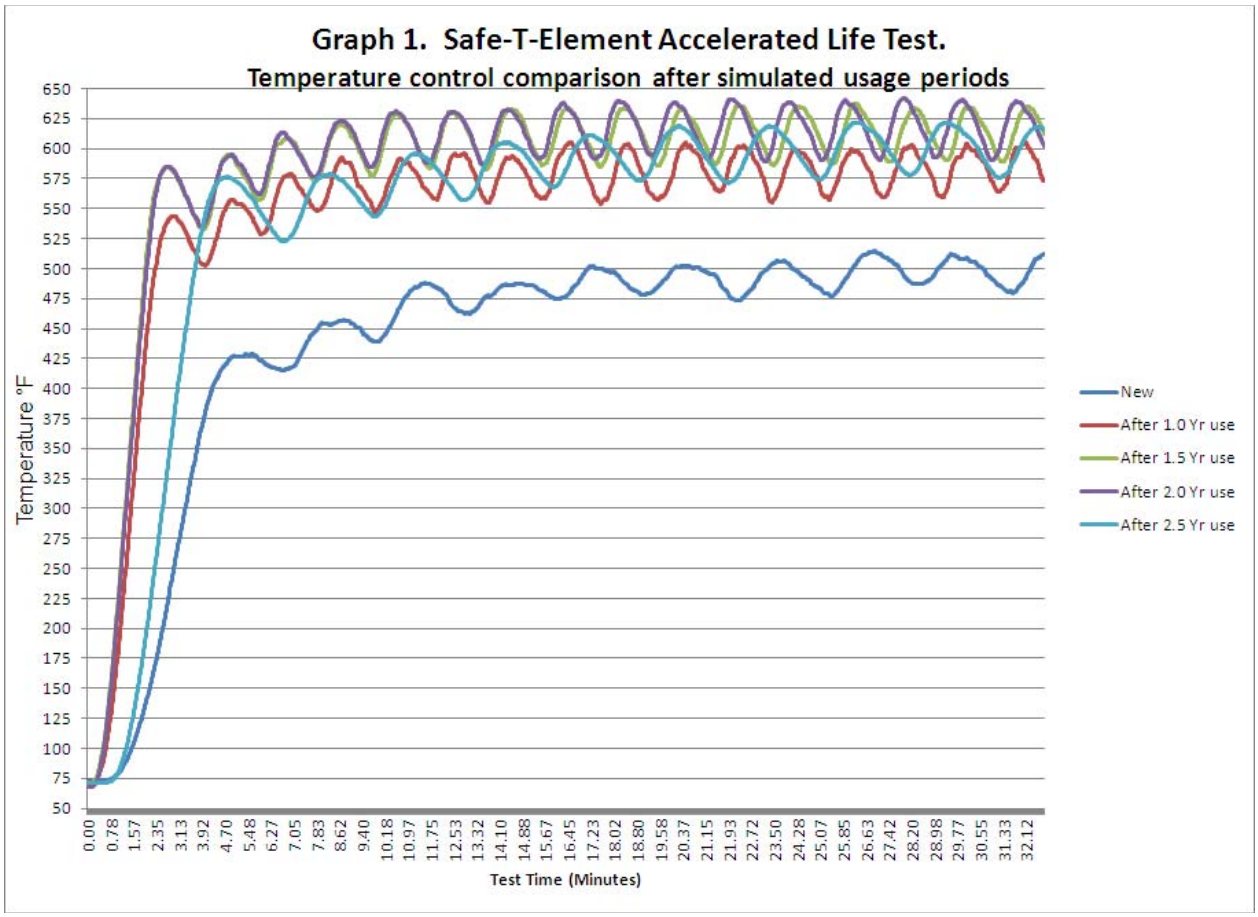
One sample of STE was installed on a 2600 watt burner of a new electric range. The thermocouple and burner plate of the STE were attached to the burner per the instructions; however, the STE's burner control relay was wired to the input of a microcontroller circuit so that the microcontroller could sense when the STE system had reached its set-point temperature. Heating of the burner was also controlled by the microcontroller through a solid state relay.

Each cycle of test operation consists of the microcontroller energizing the range's burner until the STE's power control relay opens, indicating that the burner has reached its set-point temperature, as sensed by the STE's thermocouple. The microcontroller then de-energizes the burner and applies fan-cooling for a fixed 8 minutes, allowing the burner to return to room temperature. Thus, each cycle of operation approximately simulates one session of cooking. An oil-ignition evaluation was conducted prior to beginning the Life Cycle Test by heating 16 oz of peanut oil in a 10" diameter stainless steel frying pan on the STE-controlled burner for a period of 30 minutes and observing whether or not the oil ignites.

Three cooking sessions per day was arbitrarily assumed to be "common use" for the purposes of this test (3 cycles of test operation equating to 1 day's cooking). Based upon accumulated cycles, the test was interrupted after 1, 1.5, 2, and 2.5 years of simulated cooking use, the STE power relay re-installed per instructions, and a temperature rise test conducted, the results of which are shown in Graph 1. The oil-ignition test was also repeated during each interruption.

Results to date indicate that the temperature set-point maintained by the STE has increased substantially after the 1st year of simulated use, but ceased to continue rising after 2 years. It should be noted that the STE temperature control rise did not allow the oil to ignite during the oil-ignition tests.

No explanation for the change in STE behavior has been determined at this time; the installation of the STE's thermocouple and burner plate has not been disturbed during the tests. The test will be continued until 10 years of simulated use have been reached, and is currently scheduled to be complete by April 2012.


Graph 1. Safe-T-Element Accelerated Life Test.
Temperature control comparison after simulated usage periods
Temperature °F
650
625
600
575
550
525
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
0.00
0.78
1.57
2.35
3.13
3.92
4.70
5.48
6.27
7.05
7.83
8.62
9.40
10.18
10.97
11.75
12.53
13.32
14.10
14.88
15.67
16.45
17.23
18.02
18.80
19.58
20.37
21.15
21.93
22.72
23.50
24.28
25.07
25.85
26.63
27.42
28.20
28.98
29.77
30.55
31.33
32.12
Test Time (Minutes)
New
After 1.0 Yr use
After 1.5 Yr use
After 2.0 Yr use
After 2.5 Yr use

Technology Assessment: Home Cooking Fire Mitigation

Development of an Action Plan

July 14, 2011

Workshop Goal

Develop an **action plan** to mitigate loss from home cooking fires by furthering the implementation of proven effective safety technologies related to home cooking.

Foundation Background

- Independent not for profit formed by NFPA in 1983
- Mission – to plan, manage and communicate research in support of the NFPA fire safety mission
- Major research programs in sprinkler protection, smoke alarms, hazardous materials protection and electrical safety

All Reports Available on Foundation Website

www.nfpa.org/Foundation

Project Background

- Cooking-equipment related fires are a leading cause of U.S. fire loss.
- 1980’s CPSC study on attributes of cook top mitigation technologies
- Voluntary standards development activities initiated
- TPFG developed by UL STP – focus on cooking performance
- Since the 1980’s no advances in applied technology

Project Background

- February 2010 Vision 20/20 Workshop
- Recommendation to study barriers to implementation and develop an action plan
- Key Element – assessment of technologies – reference 1980s A.D. Little Study

Project Tasks

- Define major cooking fire scenarios based on fire incident data
- Identify new and existing promising technologies
- Develop an assessment methodology
- Assess technologies
- Identify gaps – action plan

Action Plan

- Research and technology development
- Performance criteria and conformity assessment methodologies
- Standards development
- Other actions

Agenda

- Analysis of Cooking Fire Incidents
- Technologies for Cooking Fire Mitigation
- Recent Research
- **LUNCH**
- Technology Assessment and Gap Analysis
- Breakout Discussion: Elements of an Action Plan

Action Plan Items

- Research and Development related to promising technologies – e.g. field testing, new sensors, etc
- Further refinement of the technology assessment method –
- Needed technology transfer – items that will lead to/remove barriers – standards, performance criteria, market focused approaches…..

Technologies for Cooking Fire Mitigation

Joshua Dinaburg, Hughes Associates Inc.
Dan Gottuk, Ph.D., Hughes Associates Inc.

HUGHES ASSOCIATES, INC
FIRE SCIENCE & ENGINEERING

The Fire Protection Research Foundation
Baltimore, MD
July 14, 2011

Objective

- Identify technological options for reducing the threat of cooking fires started by household range tops
- Identify the current developmental status of existing and potential technologies
  - Existing products
  - Laboratory scale experiments
  - Potential concepts

Approach

- Conduct literature and patent review
- Identify technologies capable of reducing losses from home range top fires
  - Potential losses include deaths, injuries, and property damages
  - Any device or system that could prevent these losses were considered, but none requiring a user to actively fight fires after ignition
  - Technologies sorted according to method of mitigating fire threats (i.e. warning, suppression, prevention, etc.)

Methods of Mitigating Fire Losses

- *Group 1*: Detect an occurring fire and provide a warning
  - May prevent deaths and injuries by alerting occupants to danger and increasing the likelihood of escape
- *Group 2:* Detect an imminent fire condition and provide a warning
  - Occupants may intervene prior to ignition if within range of the warning alarm
- *Group 3*: Control fire/prevent fire spread
  - Contain a fire to the range top and prevent fire spread and growth, may prevent fire from reaching a state capable of inflicting injuries or death

Methods of Mitigating Fire Losses (cont.)

- *Group 4*: Provide automatic suppression
  - Detect an occurring fire and take automatic actions to suppress the flames
- *Group 5*: Prevent fire from occurring
  - Imminent fire conditions are detected and the system is capable of eliminating the ignition hazard
  - Also includes devices that inherently do not allow certain ignition scenarios to occur rather than through detection and control

Group 1: Detect Occurring Fire and Provide Warning

- Detect flames or heat on or around the range
- Provide an audible and/or visual warning
- Intended to alert the occupants to evacuate and contact the fire department
  - Active fire fighting should not be recommended
  - Effective use dependent upon cooking fire education
- Potential detection methods include:
  - Fusible link placed over range top (i.e. hood installation)
  - Non-optical temperature sensor placed over range top
  - Optical temperature sensor observing range top
  - Video Image Detection (VID) observing range top
  - Optical Flame Detector (OFD) observing range top
  - Thermal imaging of range top

Group 2: Detect Imminent Fire and Provide Warning

- Detect potential ignition conditions on or around range top
- Provide an audible and/or visual warning
- Should provide adequate warning to allow occupants to take steps to safely prevent the ignition
  - Actions may include turn off/lower burner, remove combustibles from burner, etc.
- Potential detection methods include:
  - Air temperature sensor (lower threshold than Group 1)
    - Optical or Non-optical
  - Smoke detector
  - Pan/Burner temperature sensor
    - Contact or Non-contact
  - Unattended range detection
    - Motion sensor
    - Timer
    - Can combine operation with range power or temperature sensor

Group 3: Contain Fire/Prevent Fire Spread

- Prevent fires on range top from spreading beyond range and increasing hazards and damage
- Does not reduce the number of fire incidents, only the resulting losses through control
- Not intended to provide users additional opportunity to fight fires (education)
- Potential containment methods include:
  - Passive containment: fire resistive materials surrounding range top do not allow fires to spread to surrounding cabinets, walls, or other combustibles
  - Active containment: moveable exhaust chamber that detects the presence of a fire and physically moves to prevent spreading of flames

Group 4: Provide Automatic Suppression

- Requires a sensor to detect a fire and a system to initiate a fire suppressant
- Detection technologies for occurring fires same as Group 1
  - Include heat and flame sensing options
- Suppressants include sprinklers, wet and dry chemical suppressants
- Does not reduce the number of fire incidents, only the resulting losses through suppression
  - Property damages costs may be greater in some cases than the fire due to release of suppressant

Group 5: Prevent Fire

- Prevent ignition of fires regardless of user actions
- May be limited in types of fires prevented
- Detection technologies for imminent fire conditions same as Group 2
  - Prevent unattended cooking through motion sensors or timers, may include temperature or power level sensors
  - Prevent food ignitions through temperature detection
    - Pan contact sensor or optical sensor
    - Burner temperature sensor (only for electric stovetops)
    - Mechanically actuated sensor – bi-metallic strip or expandable liquid
    - Applicable to overheat conditions through fixed temperatures, gradients (boil over/dry), or user defined cooking settings

Group 5: Prevent Fire

- Once an ignition condition is detected, the system takes steps to prevent the ignition automatically
  - Reduce or eliminate power supply to the burners
- Other prevention options may simply eliminate ignition scenarios without detection
  - Induction range does not allow for ignition of clothing due to cool burner surface temperature, also does not operate if pot not detected on surface

Market Status and Existing Products

- Home Kitchen Suppression Systems
  - Various temperature detectors, sprinklers, wet and dry chemical agents already in market
  - UL 300A – Proposed method for testing such devices
  - ***StoveTop Fire Stop*** – small canister of sodium bicarbonate mounted above range top and releases through gravity when heated
- Motion Detection to Prevent Unattended Cooking
  - ***HomeSenser*** – alarm after 6 minutes of unattended cooking, shutdown after 8 minutes, only for electric ranges
  - ***StoveGuard*** – Automatic shutoff after user defined time sensing no motion, 1 minute is default time
- Contact Burner Temperature with Control
  - ***Safe-T-Element*** – Solid cast iron plate with TC fits over top of an electric coil, prevents burner surface from overheating by controlling burner surface temperature

Market Status and Existing Products

- Optical Temperature with Control
  - ***Innohome Stove Alarm*** – Sensor mounts over range top and alerts to overheat condition, an additional controller can use the sensor to cutoff power to electric ranges
- Smoke Detection with range power control
  - ***Fidepro Intelligent Smoke Alarm*** – Smoke alarm that can cutoff power to entire rooms, areas, or individual devices, applicable to electric range tops
- Induction Range
  - Magnetic field induces heating in ferrous utensils, can eliminate clothing ignitions or accidental heating without a pan on the burner

Evaluated Technologies

Detect occurring fire and provide warning	Fusible link	
	Non-optical temperature sensor	
	Optical temperature sensor	
	Video image detection	
	Optical flame detector	
	Thermal imaging	
Detect imminent fire condition and provide warning	Non-optical temperature sensor	
	Optical temperature sensor	
	Smoke detector	
	Pan temperature sensor - Contact Sensor	
	Pan temperature sensor - Non-contact sensor	
	Burner surface temperature sensor	
	Unattended Cooking Warning Alarm	Motion Sensor
		Motion Sensor + Temperature Sensor
		Motion Sensor + Power Sensor
		Timer
		Timer + Temperature Sensor
		Timer + Power Sensor
Control fire/prevent fire spread	Passive 3 wall system	
	Active drop down hood	

Evaluated Technologies (cont)

Provide Automatic Suppression	Fusible link		
	Non-optical temperature sensor		
	Optical temperature sensor		
	Video image detection		
	Optical flame detector		
	Thermal imaging		
Prevent Fire	Prevent unattended cooking through burner control	Motion Sensor	
		Motion Sensor + Temperature Sensor	
		Motion Sensor + Power Sensor	
		Timer	
		Timer + Temperature Sensor	
		Timer + Power Sensor	
	Prevent ignition through burner temperature control	Fixed Temperature Control	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
			Mechanical actuation
		Temperature Gradient for boil over/ spills	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
		User selected cook-type or temperature option with microprocessor control	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
		Smoke Detection	
	Induction range		


Questions?

Technology Assessment and Gap Analysis

Part II

Joshua Dinaburg, Hughes Associates Inc.
Dan Gottuk, Ph.D., Hughes Associates Inc.

HUGHES ASSOCIATES, INC
FIRE SCIENCE & ENGINEERING

The Fire Protection Research Foundation
Baltimore, MD
July 14, 2011

Objective & Approach

- Develop a methodology for comparing potential range cooking fire mitigation technologies
- Compare the potential impact of technologies utilizing statistical fire incident data (John Hall)
- Analyze each concept based upon non-fire characteristics, including use of the product and costs involved
- Determine which protection options could provide the highest reduction in fire losses while limiting influence on user behavior and cost
- Determine where gaps exist with regard to product evaluation and the current developmental design status

Scoring System Overview

- Each technology given a score from 1-10 in each of three general criteria
  - Fire Protection Effectiveness
    - Assuming technology is always 100% operational and successful, score represents the percentage of potential fire scenarios that could be addressed by total adoption of the technology
  - Overall Effect upon the Use of the Cooking Range
    - Includes contributions of effects upon cooking, functional and operational considerations, and user responsibilities
  - Total Cost
    - Includes contributions of purchasing, installation, maintenance, and operation

Fire Protection Effectiveness

- The final fire protection effectiveness score
  - Represents the maximum possible reduction in losses if:
    - The technology is immediately installed on all applicable devices
    - The technology operates ideally in each installation with no failures
  - Scored from 1-10 representing the percentage of potential fire loss reductions (10=100%)
  - A sum of the contribution of the technology to reducing fire losses on gas and electric range tops
  - Based upon statistical fire incident data (Hall)
    - Includes contributions of ignition factors, fire locations, clothing ignitions, and gas and electric range tops
  - Calculated independently for each fire loss category
    - Fire Incidents
    - Deaths
    - Injuries
    - Property Damages

Effect Upon Use of the Cooking Range

- A representation of the effect of the product in a real installation
- Represents the state of the technology in its current design stage
  - Future advancements in improving product functionality and use could improve overall scoring
- Includes
  - Cooking Performance
    - Cooking Time
    - Cooking Quality
  - Consumer Responsibilities
    - Cook behavioral modifications
    - Cleaning/maintenance required for proper operation
    - Additional safety risks to users
  - Functional Considerations and Reliability
    - Restoration of range after actuation
    - Potential for and consequences of false actuation
    - Fail-safe operation
    - Operate with reasonable user error or misuse
- Criteria scored as 1, 5 or 9

Total Cost

- A representation of all the costs involved in installing the technology in a real kitchen
- Represents the state of the technology in its current design stage
  - Future advancements in improving product costs could improve overall scoring
- Includes
  - Initial Purchasing Cost
  - Installation Cost
  - Product Life-cycle Costs
    - Serviceability
    - Durability
  - Cookware applicability
- A high score in cost is reflective of low total costs
- Criteria scored as 1, 5 or 9

Scoring

- Effect upon the use of the range and total cost criteria each scored:
  - 1 – Low product performance or high impact of technology
  - 5 – Medium performance or some impact
  - 9 – High performance or no impact
- Scores from each sub-criteria are calculated as the geometric mean
  - The product of the scores is taken to the root of the number of scores
  - A score of one in any category will have a greater impact upon the overall score for the technology
- Example (Scores = 1,9,9)
  - Geometric mean = $(1x9x9)^{1/3} = 4.3$
  - Average = (1+9+9)/3 = 6.3

Technologies to be Evaluated

Detect occurring fire and provide warning	Fusible link	
	Non-optical temperature sensor	
	Optical temperature sensor	
	Video image detection	
	Optical flame detector	
	Thermal imaging	
Detect imminent fire condition and provide warning	Non-optical temperature sensor	
	Optical temperature sensor	
	Smoke detector	
	Pan temperature sensor - Contact Sensor	
	Pan temperature sensor - Non-contact sensor	
	Burner surface temperature sensor	
	Unattended Cooking Warning Alarm	Motion Sensor
		Motion Sensor + Temperature Sensor
		Motion Sensor + Power Sensor
		Timer
		Timer + Temperature Sensor
		Timer + Power Sensor
Control fire/prevent fire spread	Passive 3 wall system	
	Active drop down hood	

Technologies to be Evaluated

Provide Automatic Suppression	Fusible link		
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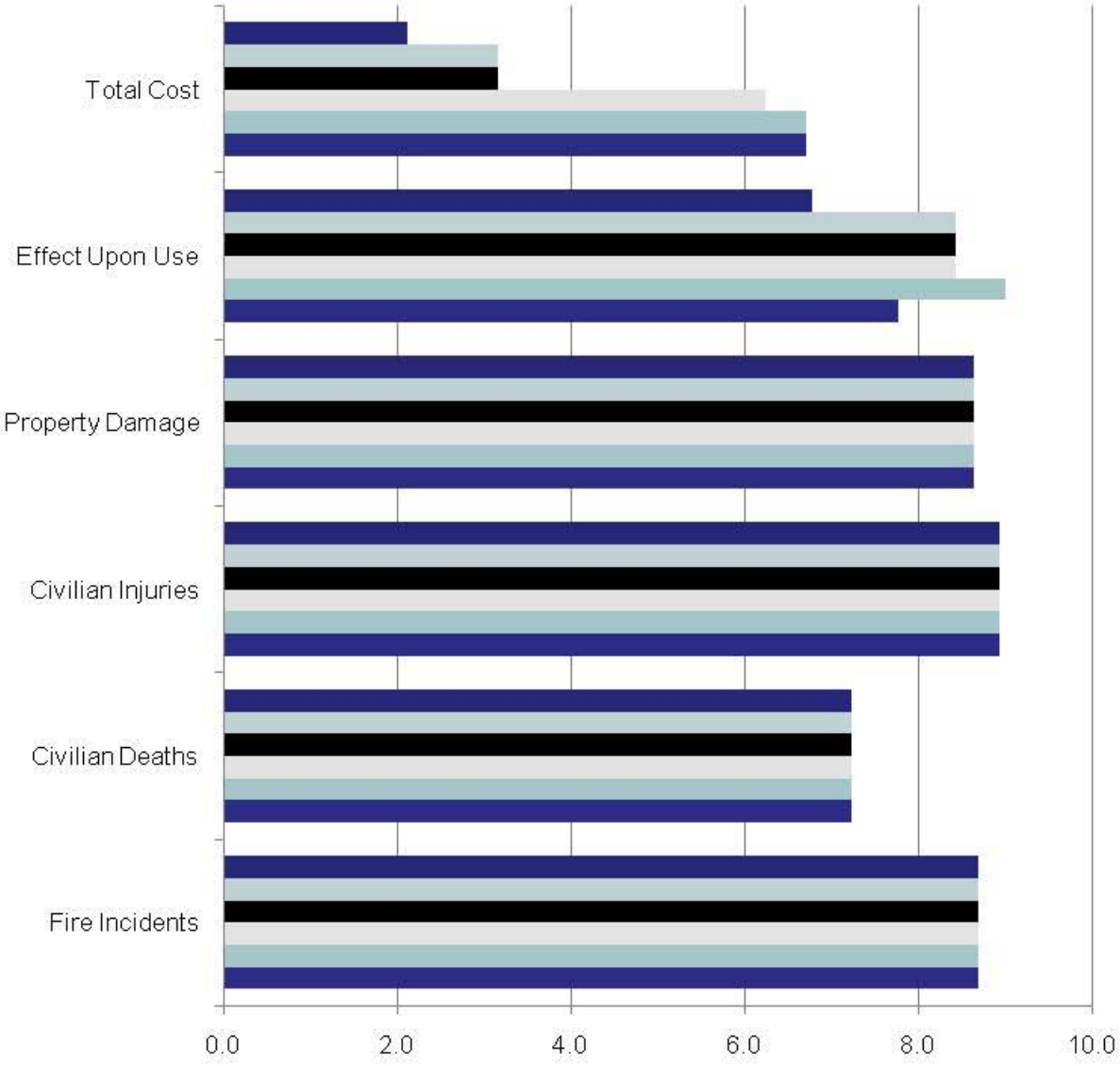
	Optical temperature sensor		
	Video image detection		
	Optical flame detector		
	Thermal imaging		
Prevent Fire	Prevent unattended cooking through burner control	Motion Sensor	
		Motion Sensor + Temperature Sensor	
		Motion Sensor + Power Sensor	
		Timer	
		Timer + Temperature Sensor	
		Timer + Power Sensor	
	Prevent ignition through burner temperature control	Fixed Temperature Control	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
			Mechanical actuation
		Temperature Gradient for boil over/ spills	Utensil contact temperature
			Burner temperature
			Non-contact temperature sensor
		User selected cook-type or temperature option with microprocessor control	Utensil contact temperature
			Burner temperature
			Non-contact utensil temperature sensor
	Smoke Detection		
	Induction range		

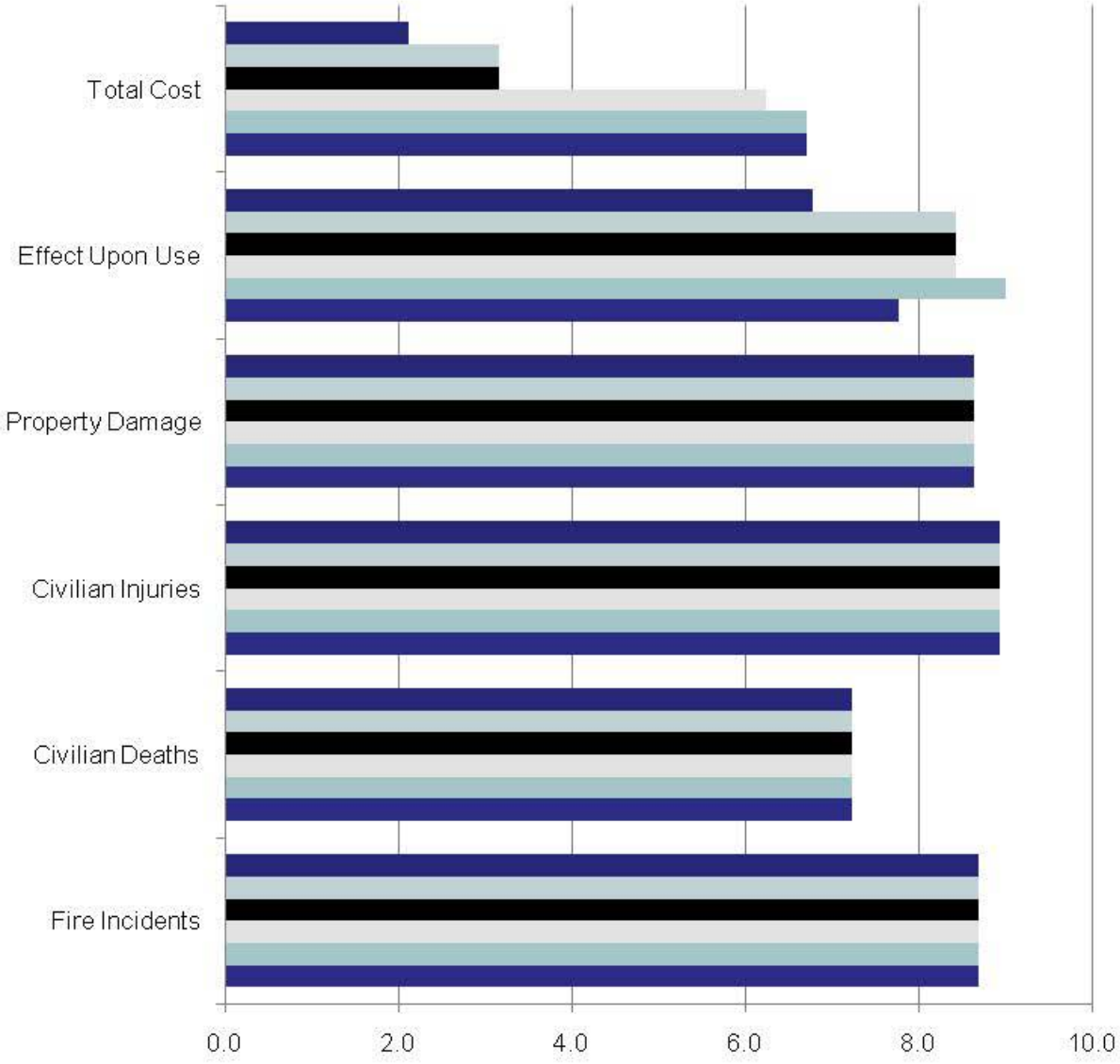
Mitigation Group 1: Detect Occurring Fire and Provide Warning



Total Costs

- TI, OFD, and VID score poorly due to high purchasing cost
- Fusible link and non-optical temperature sensors have lowest total costs
- Optical temperature sensor slightly more expensive than non-optical due to potential product life-cycle costs

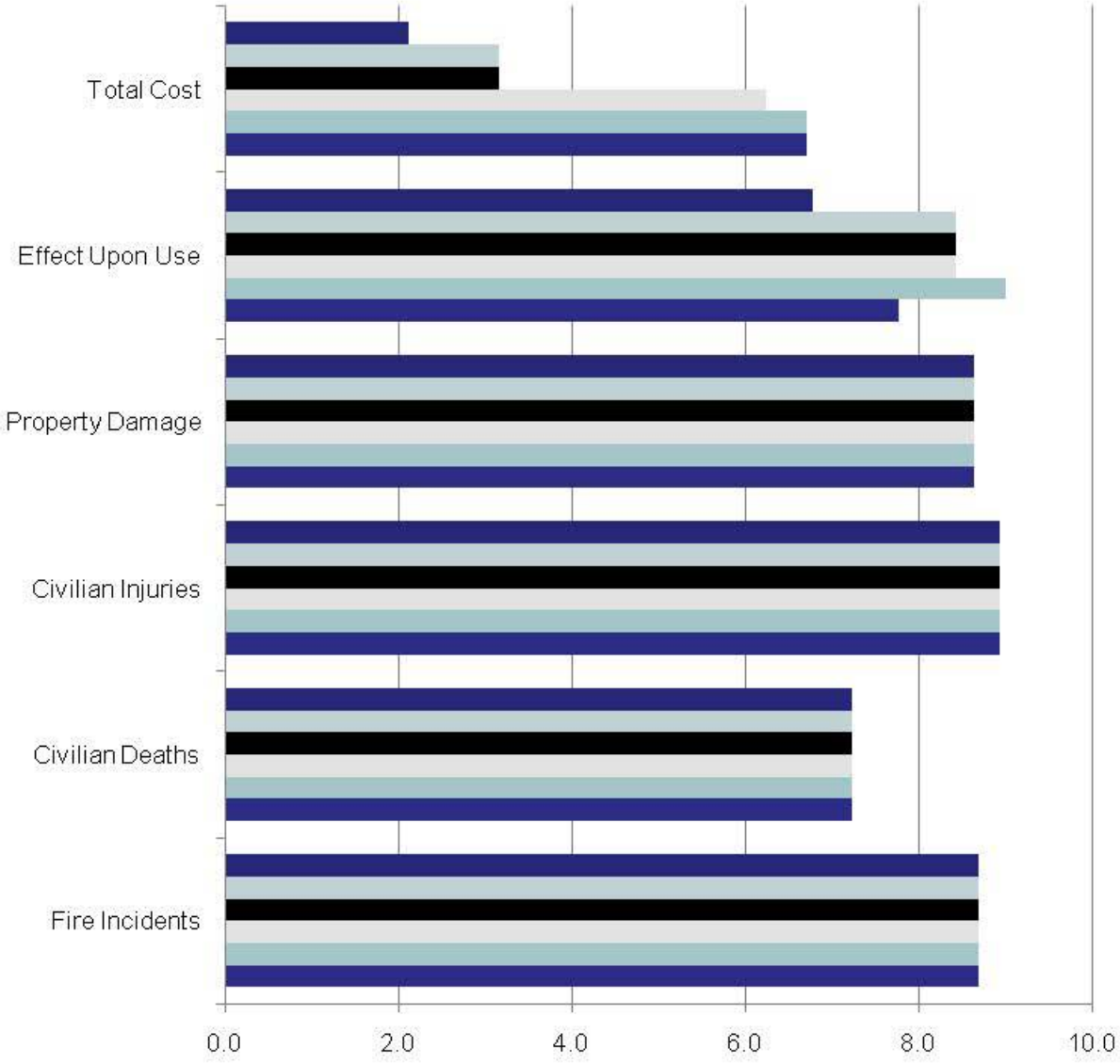
Mitigation Group 1: Detect Occurring Fire and Provide Warning



Effect Upon Use of the Cooking Range

- Non-optical temperature sensor has least effect due to reduced overall maintenance
- The fusible link has reduced score due to required replacement after actuation
- Thermal imaging requires high level of cleaning and maintenance

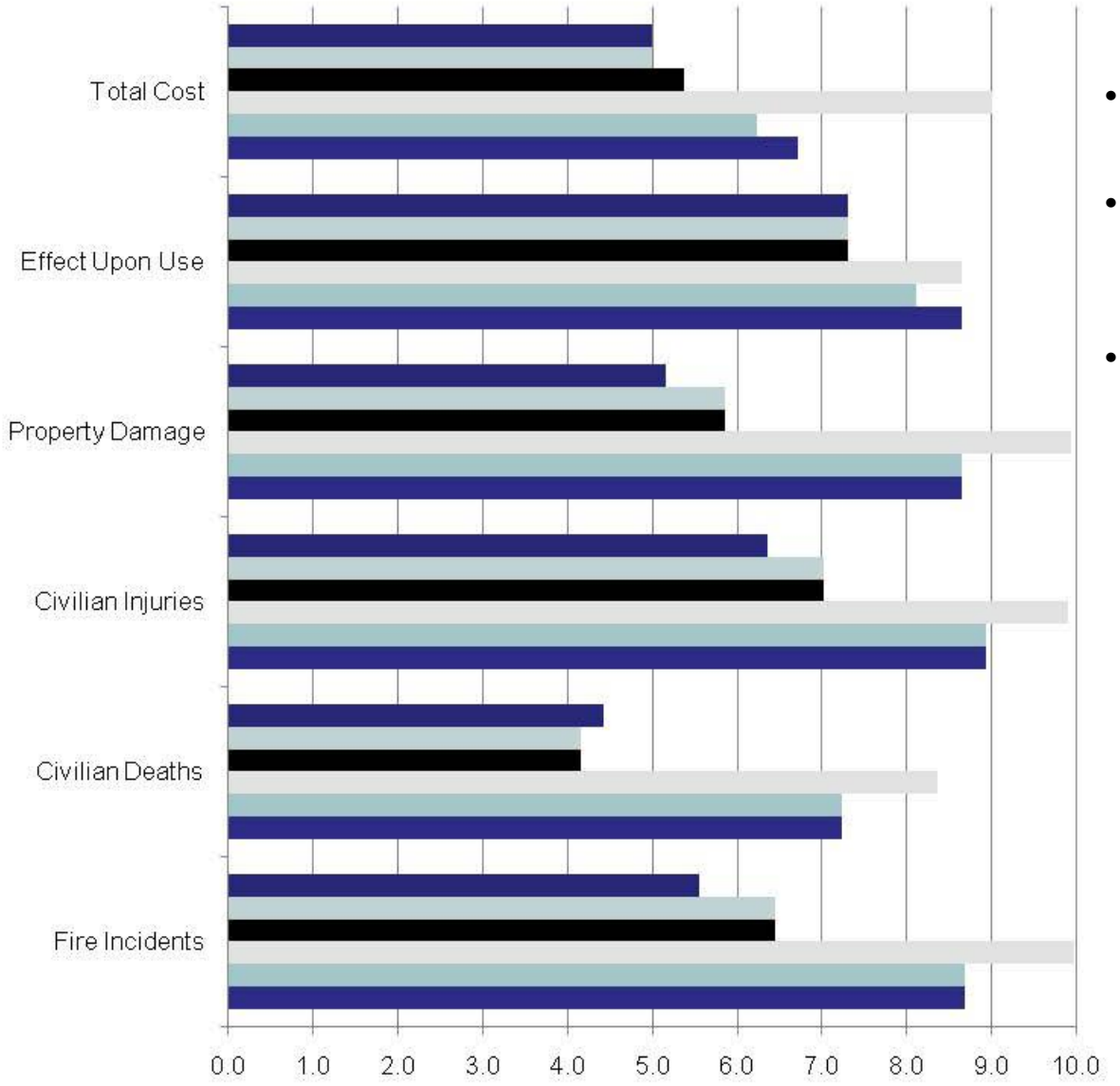
Mitigation Group 1: Detect Occurring Fire and Provide Warning



Fire Protection Effectiveness

- All sensors types are applicable to same fire scenarios
- Include all fires occurring on the range top regardless of ignition scenarios
- Reduces scores for prevention of death a result of failure to prevent clothing ignitions

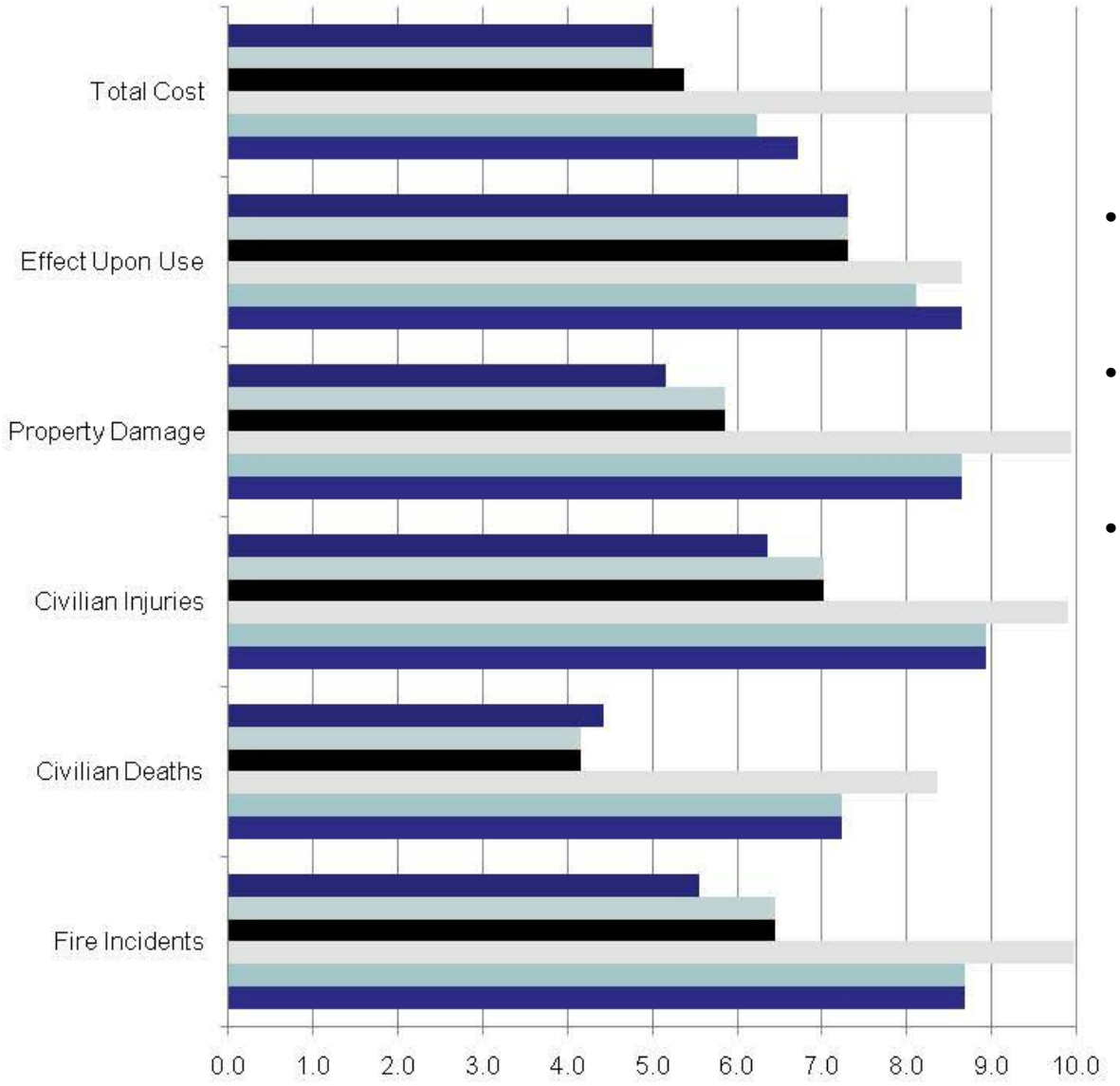
Mitigation Group 2-a: Detect Imminent Fire from Pre-ignition Conditions and Provide Warning



Total Costs

- Smoke detector is cheapest of all detection options
- Over range temperature sensors score as cheaper options than pan or burner contact temperatures
- Pan and burner temperature sensors reduced in cost score due to service and durability concerns

Mitigation Group 2-a: Detect Imminent Fire from Pre-ignition Conditions and Provide Warning

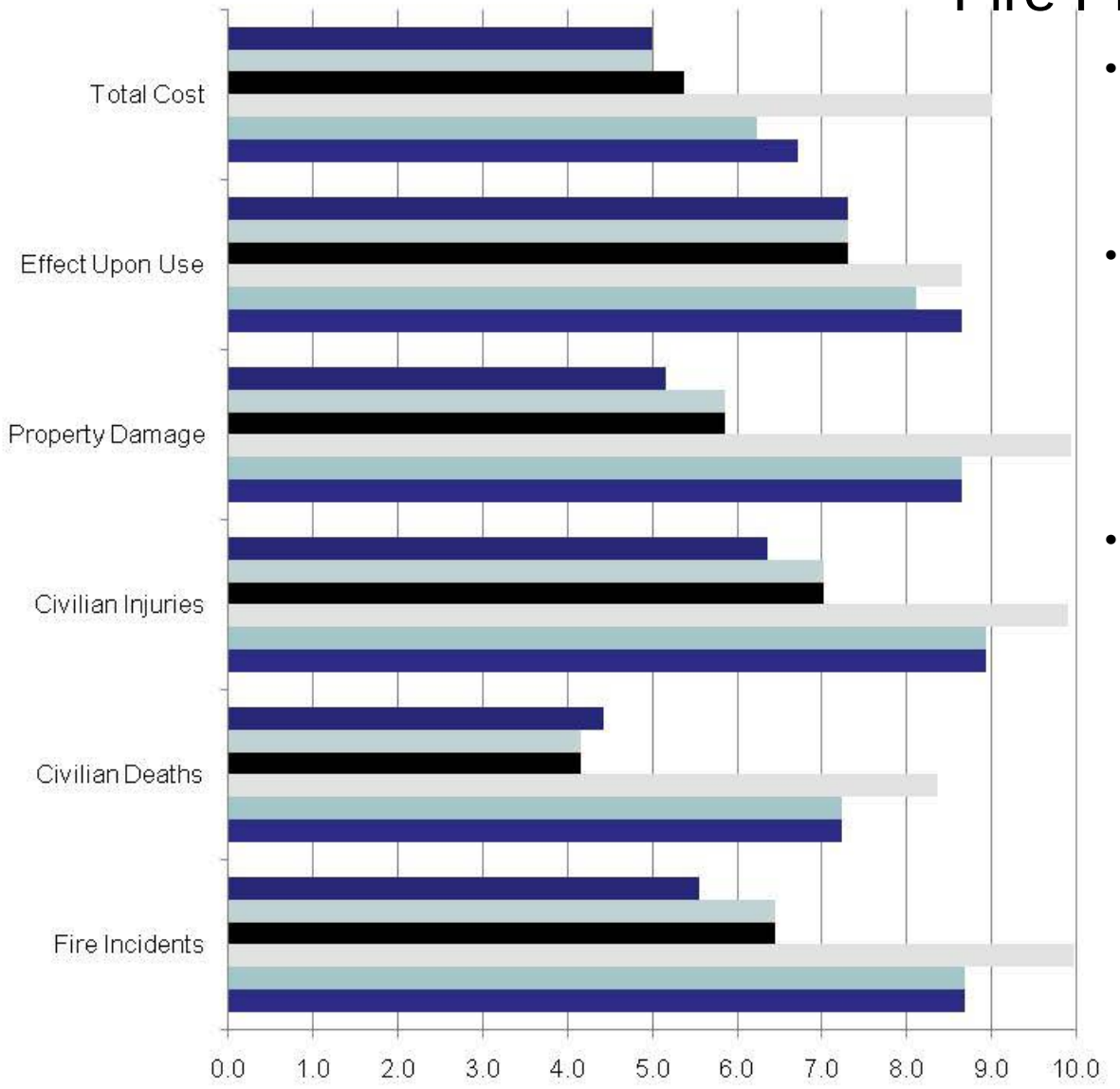


Effect Upon the Use of the Cooking Range

- Smoke detector rates as least effect upon use of range in a tie with a non-optical temperature sensor
- Optical temperature sensor reduced use score from non-optical due to potential cleaning requirements
- All pan and burner temperature sensors require user to constantly interact with the sensor, rather than being hidden in the hood

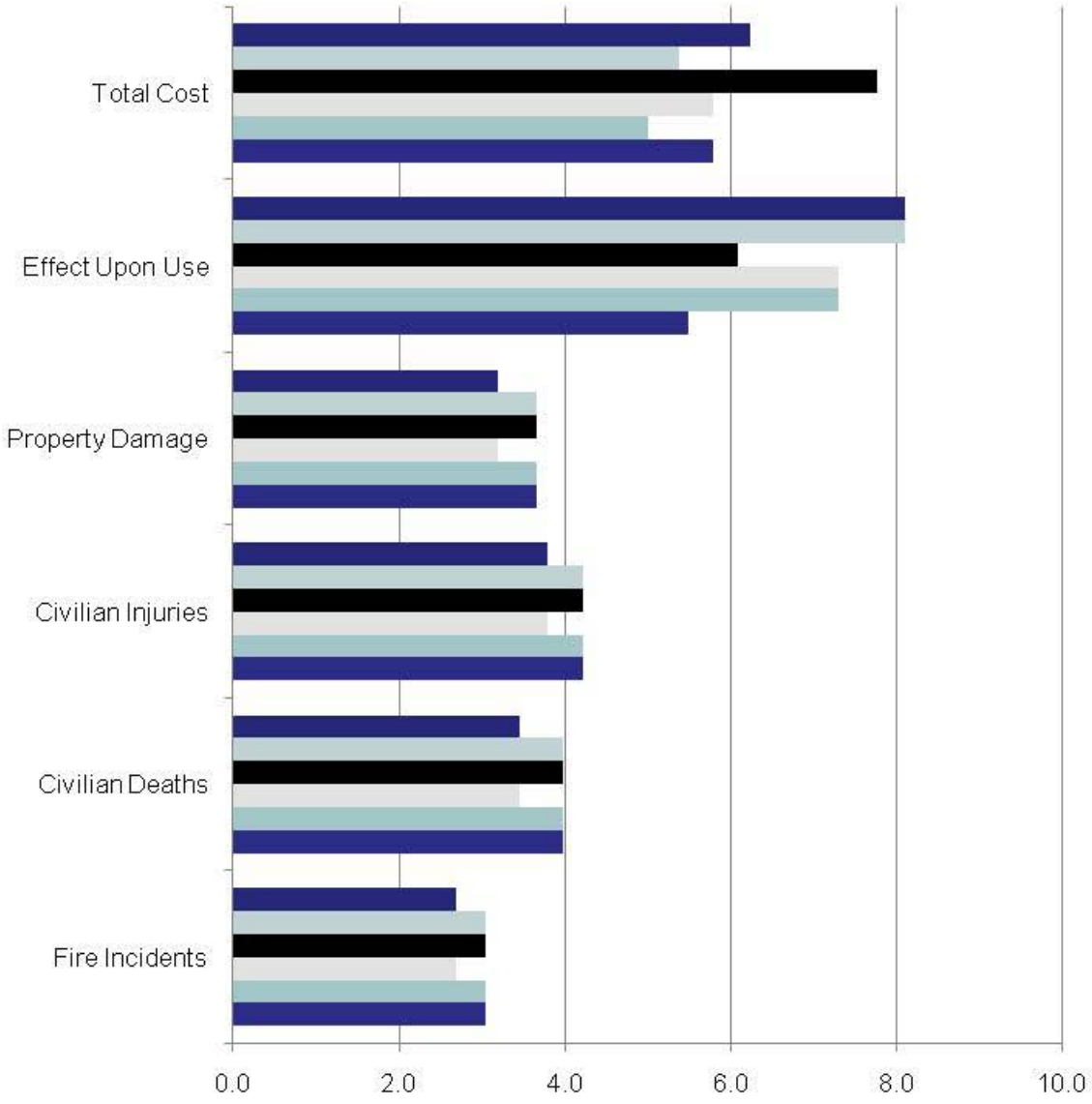
Mitigation Group 2-a: Detect Imminent Fire from Pre-ignition Conditions and Provide Warning

Fire Protection Effectiveness



- Smoke detector capable of addressing all range fire scenarios
  - Can not prevent the ignition of clothing, thus reducing the FPE for civilian deaths
- Burner surface temperature scores reduced from other pan temperatures by eliminating influence on gas ranges
  - Only slight decrease, electric range fires are more prevalent
- Over range temperature sensors capable of addressing more ignition scenarios than pan or burner sensors

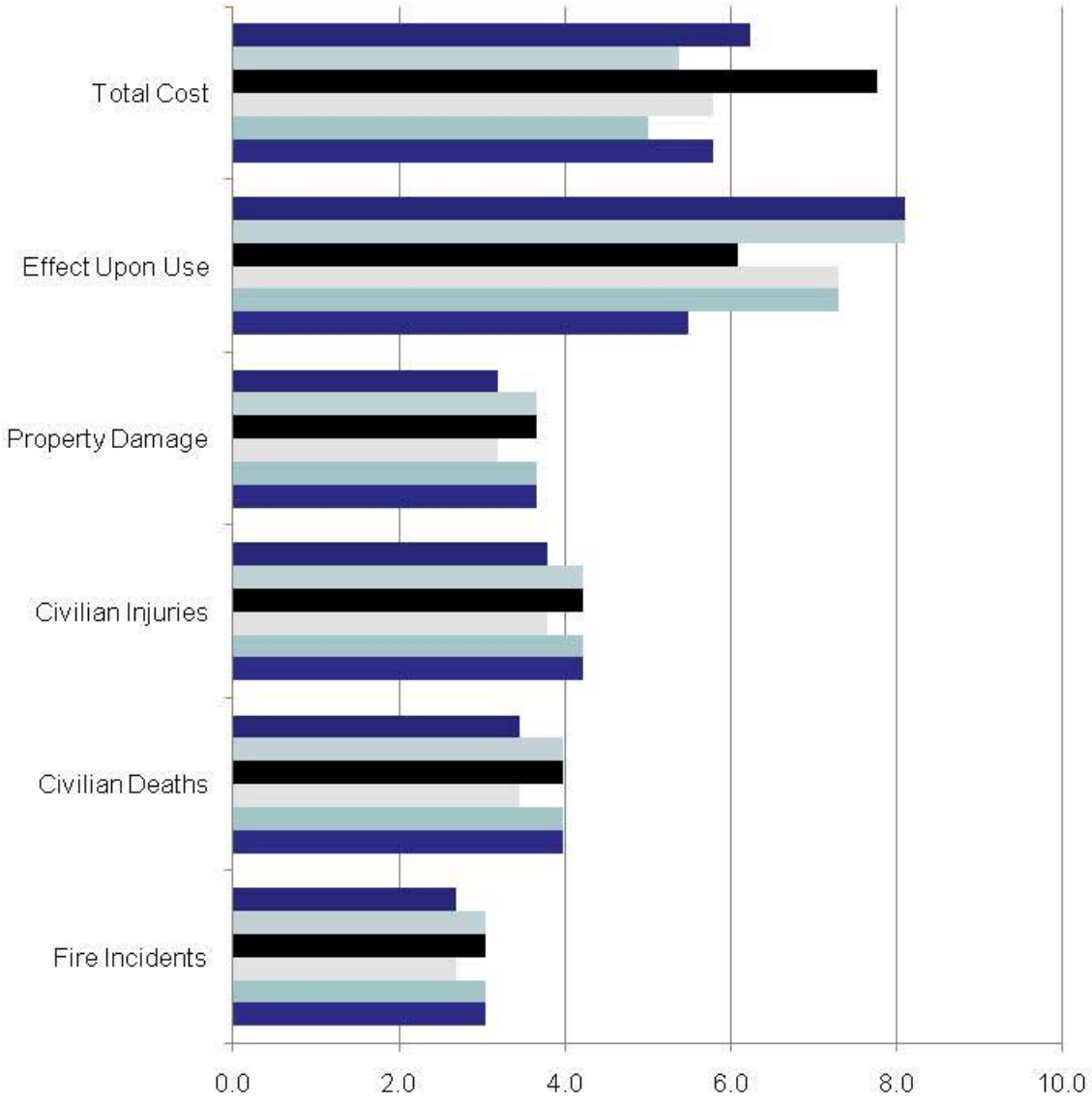
Mitigation Group 2-b: Detect Unattended Cooking and Provide Warning



Total Costs

- Simpler and more robust designs result in improved cost scores vs. pan and burner temperature sensors
- Motion sensors more costly than simple timer devices
- Adding temperature sensors and power sensors to the timer or motion sensor increases overall cost
- Less cost effect for measuring system power than for measuring temperature

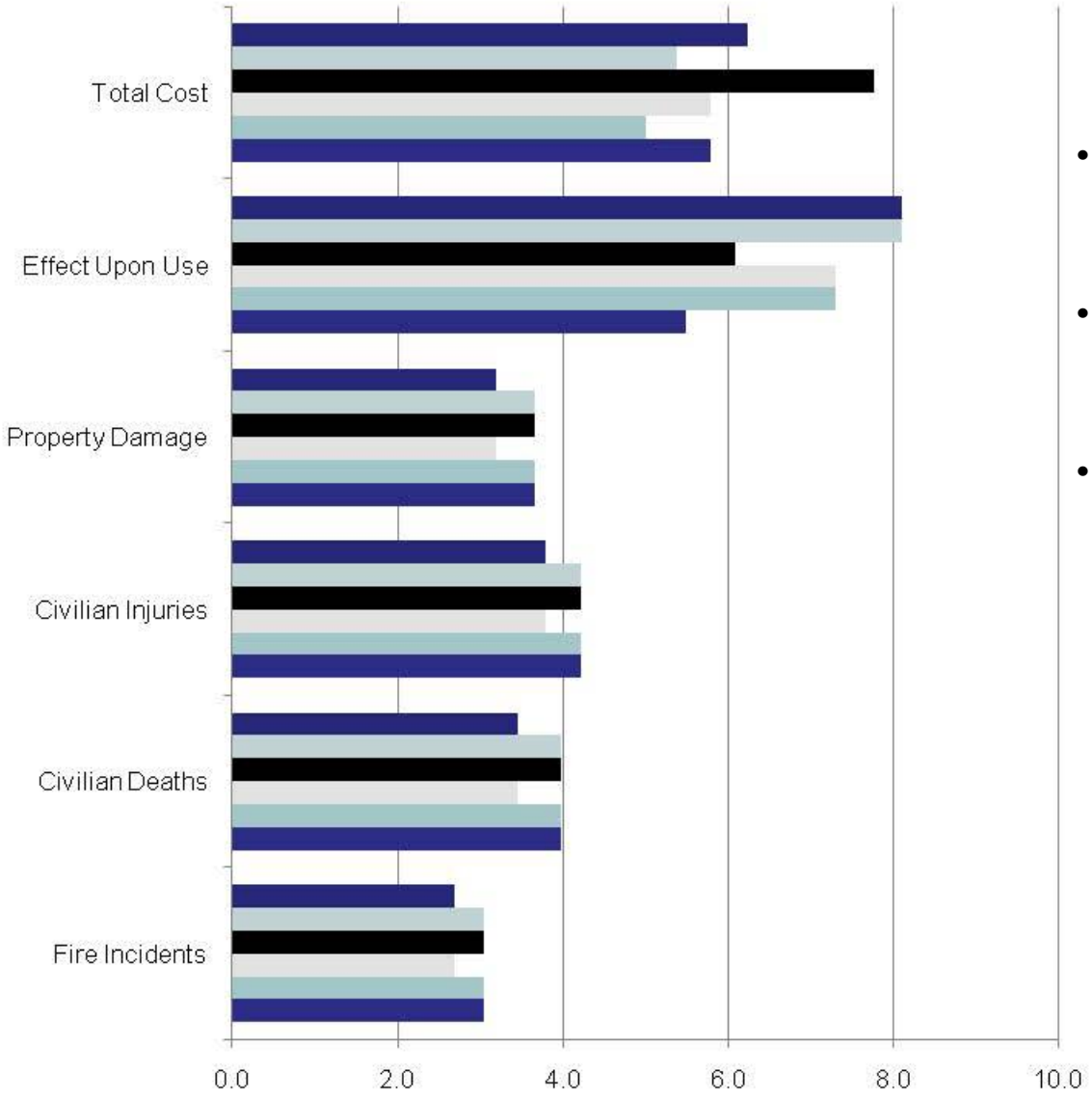
Mitigation Group 2-b: Detect Unattended Cooking and Provide Warning



Effect Upon the Use of the Cooking Range

- Adding temperature sensors or power sensors reduces the overall effect upon the range
  - Simmering or low temperature/power cooking will not initiate an alarm
- The systems utilizing the timer have a lower overall impact on the use of the range than devices with motion sensors
  - The timer is less prone to false positives than a motion sensor

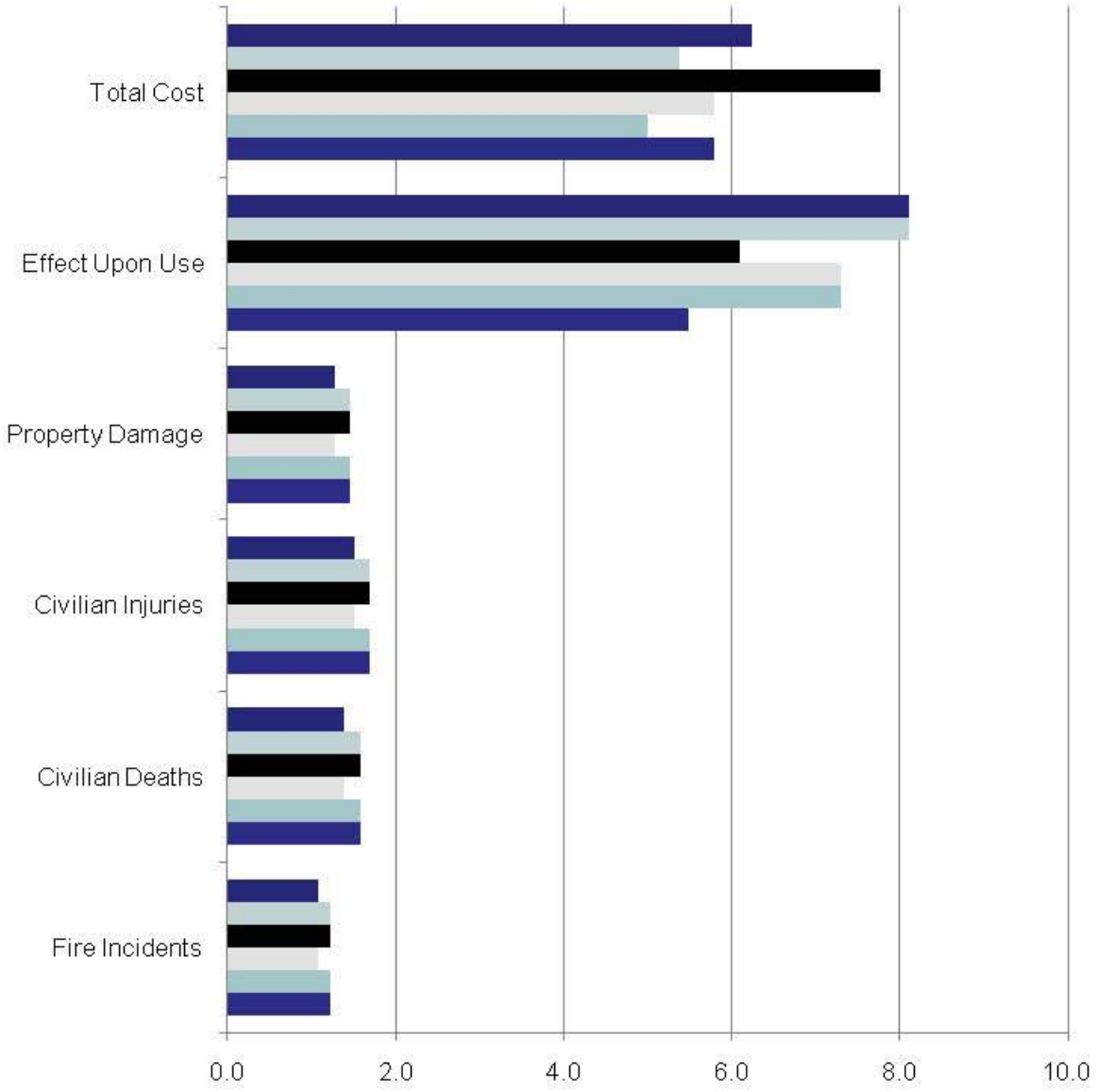
Mitigation Group 2-b: Detect Unattended Cooking and Provide Warning



Fire Protection Effectiveness

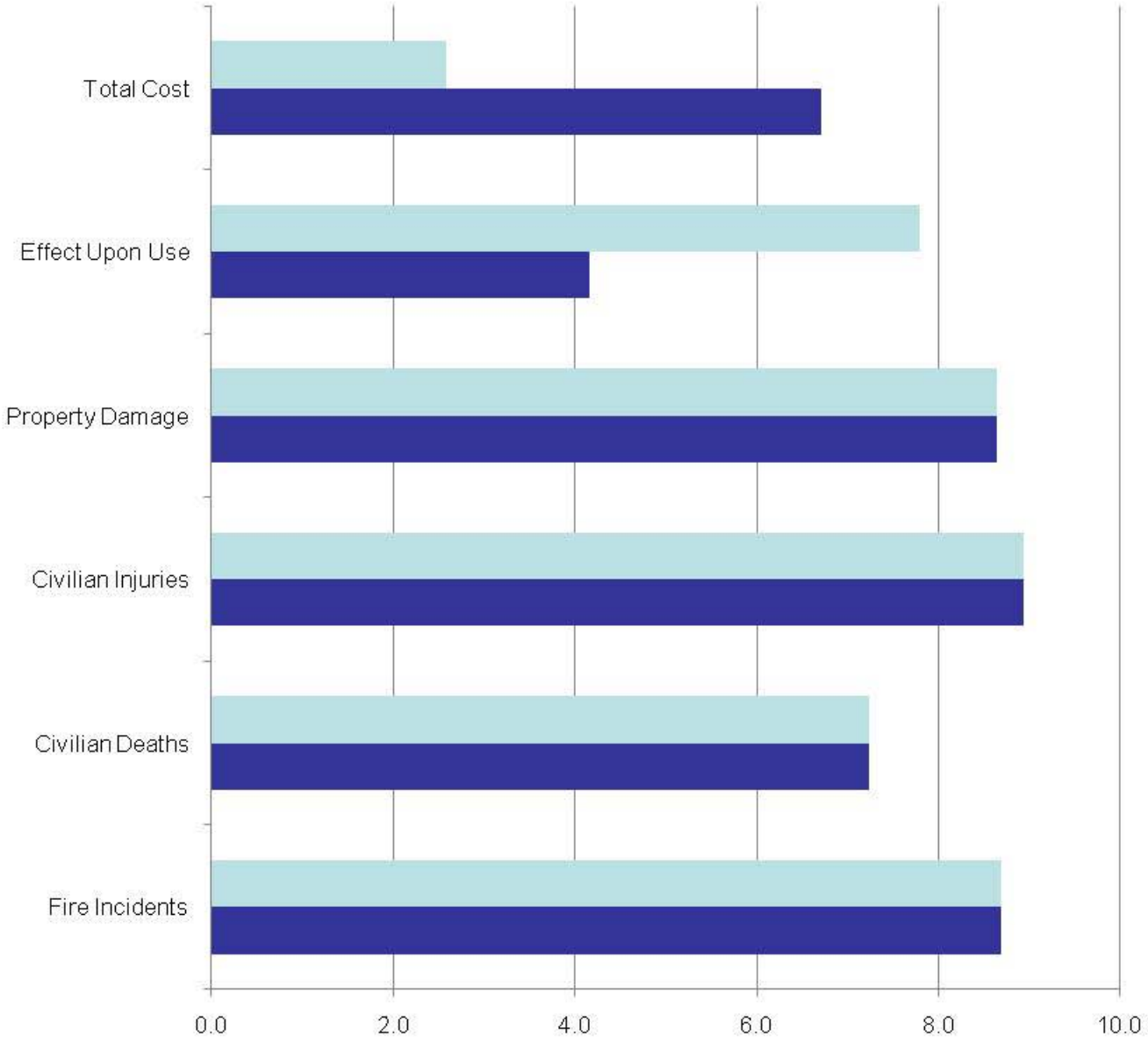
- Represent the statistical contribution of fires resulting from unattended cooking
- Systems utilizing a power sensor are not applicable to gas ranges, and thus a reduced overall FPE is calculated
- Score reflects the assumption that producing an alarm will alert the cook to respond with 100% effectiveness
  - Statistical data is available to refute such an assumption

Mitigation Group 2-b: Detect Unattended Cooking and Provide Warning – Adjusted for Cook Location



- Warning of unattended cooking shown to be effective due to cook location in approximately 40% of cases (Hall)
- Adjusting FPE scores for warning devices to account for potential response reduces effectiveness to approximately 10-15% of incidents
- Should be noted, that even 10% represents approximately 9000 fires, 33 deaths, 370 injuries, and $54 million in property damages

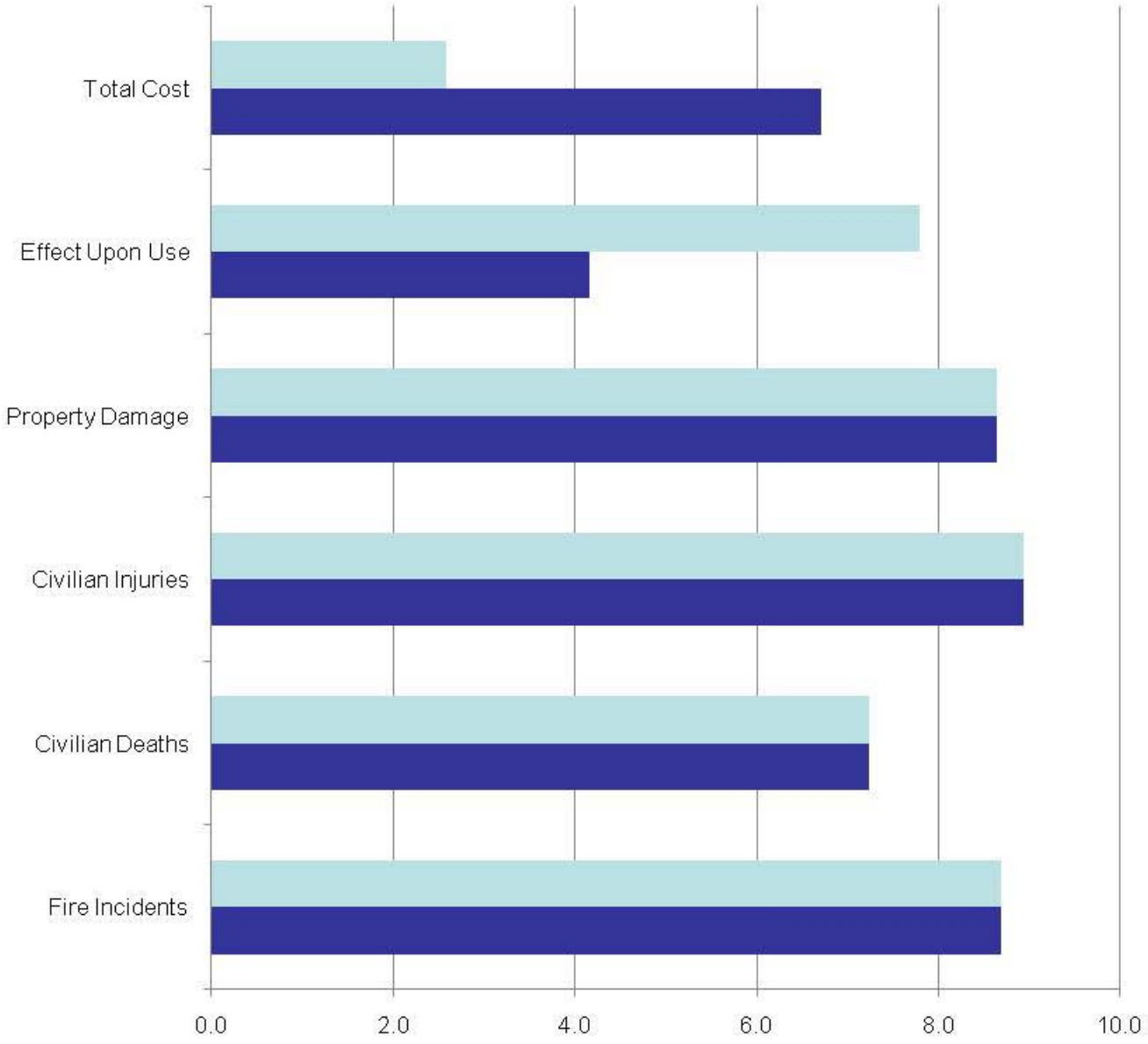
Mitigation Group 3: Contain Fire/Prevent Fire Spread



Total Costs

- An active hood entails significant cost increases over a passive fire resistive wall
- Additional costs include purchasing and installation in addition to service and upkeep costs

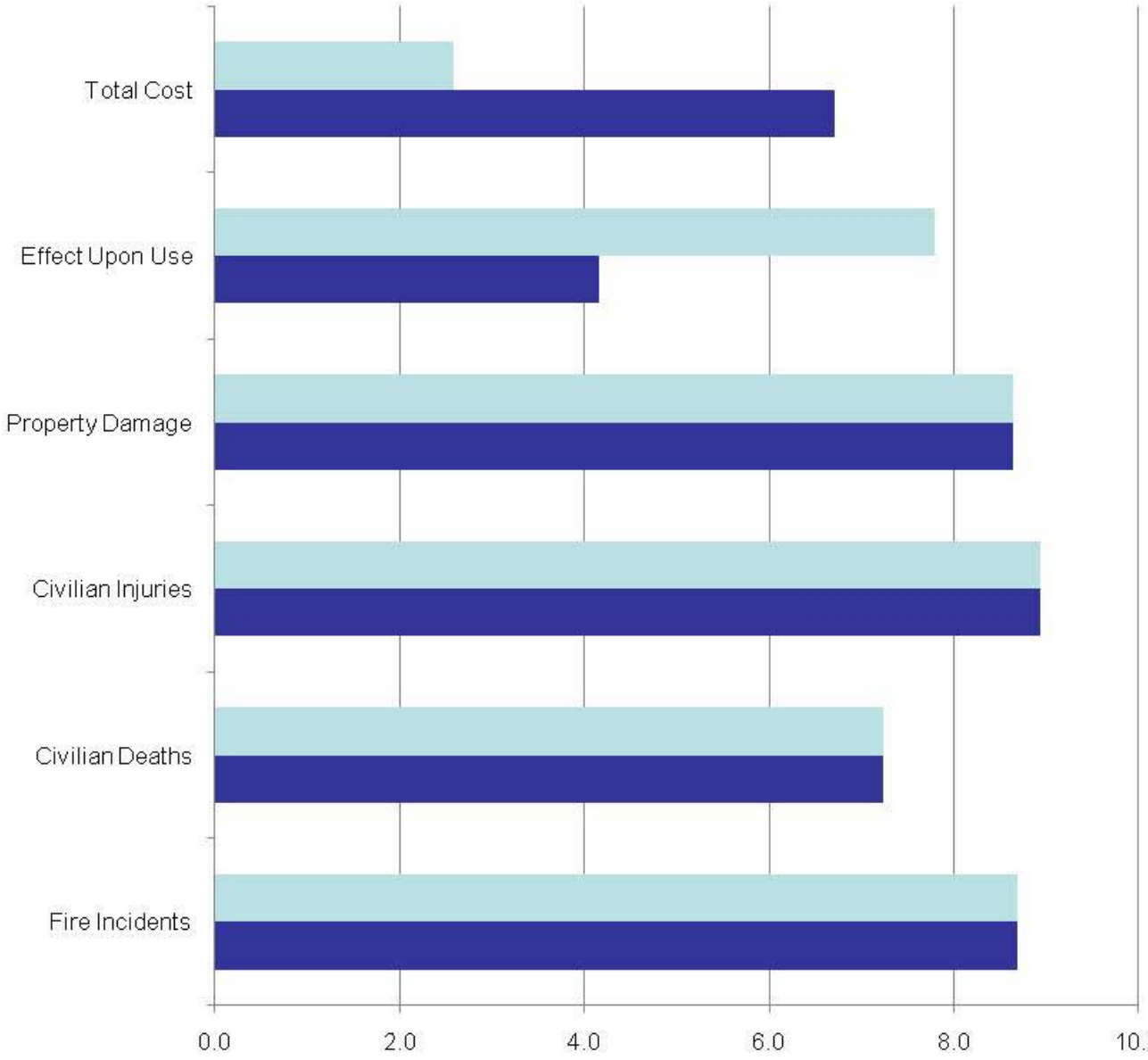
Mitigation Group 3: Contain Fire/Prevent Fire Spread



Effect Upon Use of the Cooking Range

- The active hood should be essentially invisible to the user and only require actions after actuation
- A passive wall system may restrict use of back burners as well as increase risk of burns while reaching for pans around the walls
- The effect upon use of the range is in direct opposition to the cost scores

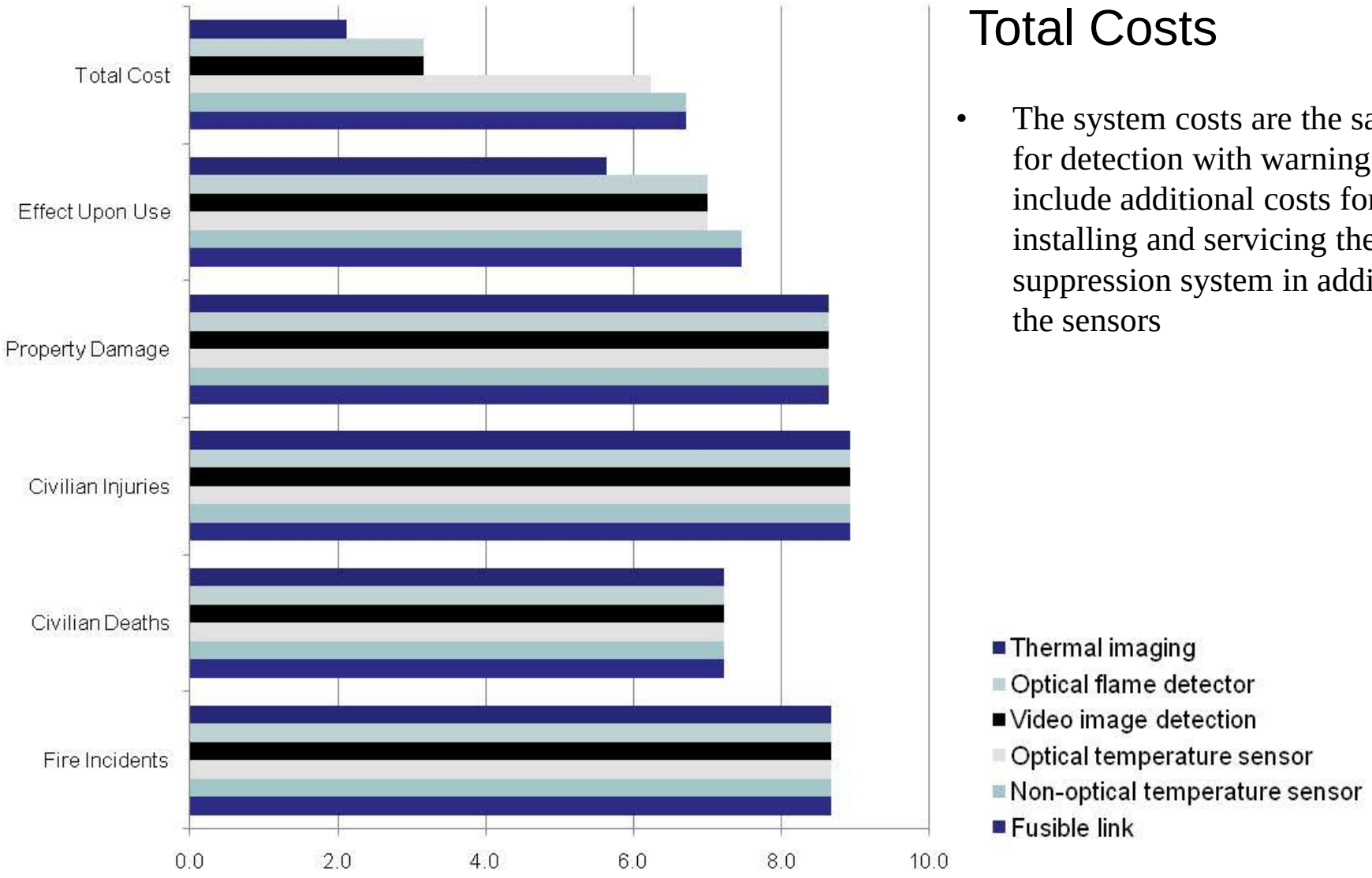
Mitigation Group 3: Contain Fire/Prevent Fire Spread



Fire Protection Effectiveness

- Both technologies would address the same fire scenarios and are thus given the same scores
- Reduced scores for civilian deaths are a result of failure to prevent clothing ignitions
- Numerous fire scenarios are addressed by containment to the range top (70-90% of fire losses)

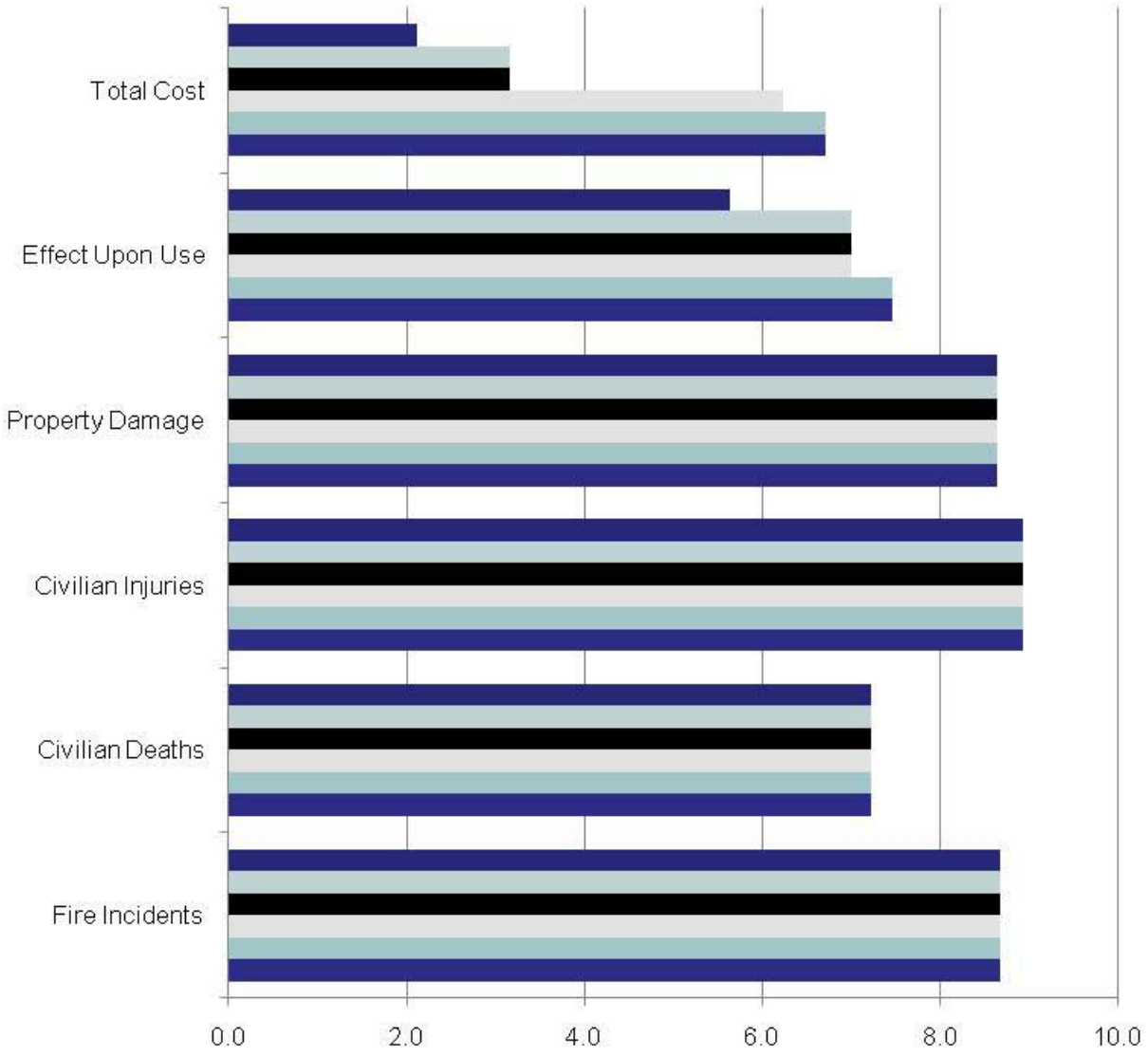
Mitigation Group 4: Detect Occurring Fire and Provide Automatic Suppression



Total Costs

- The system costs are the same as for detection with warning but include additional costs for installing and servicing the suppression system in addition to the sensors

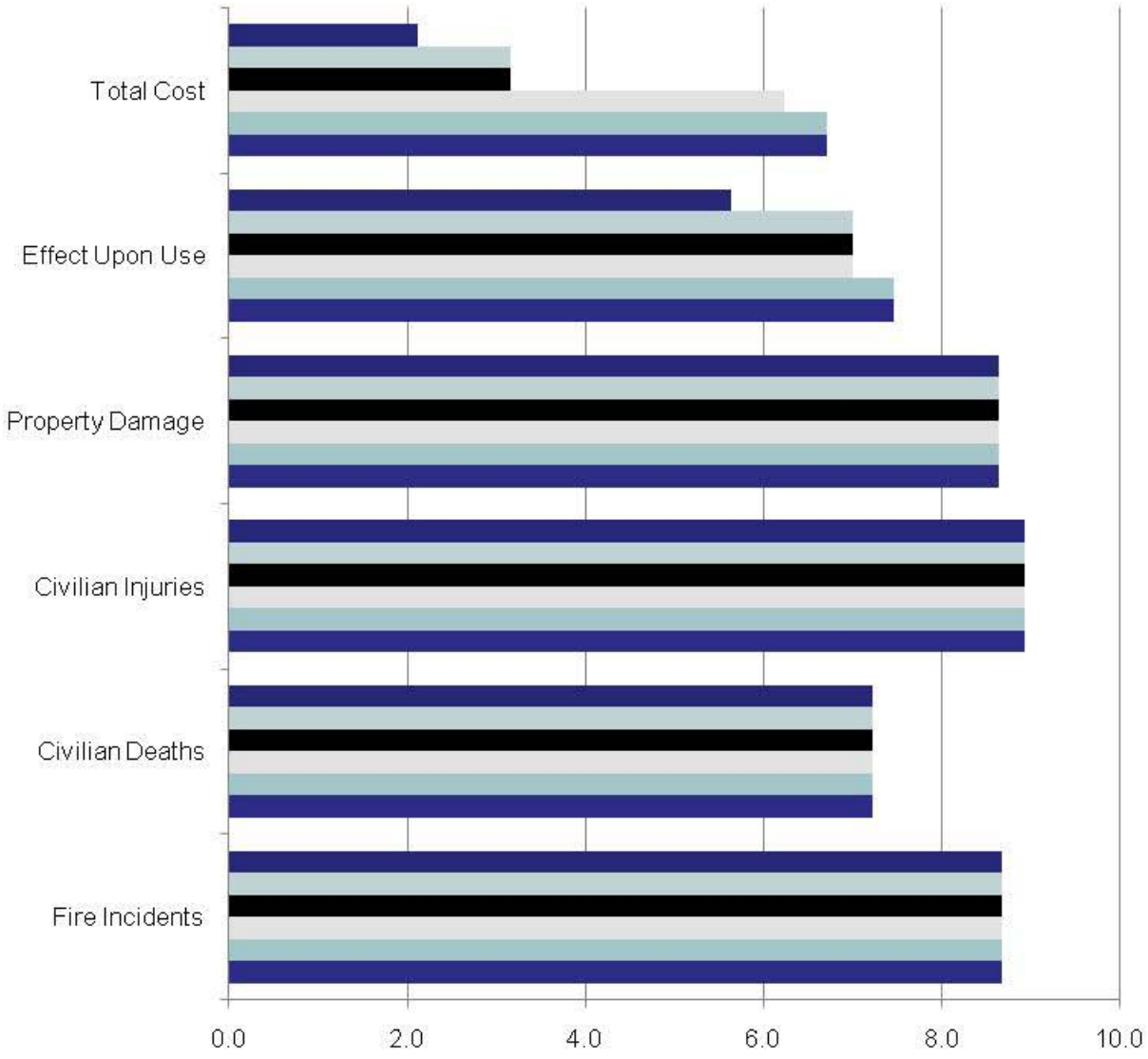
Mitigation Group 4: Detect Occurring Fire and Provide Automatic Suppression



Effect Upon Use of the Cooking Range

- All use scores same as for detection and warning only systems but are reduced uniformly due to the need for cleanup and replacement after suppression actuation

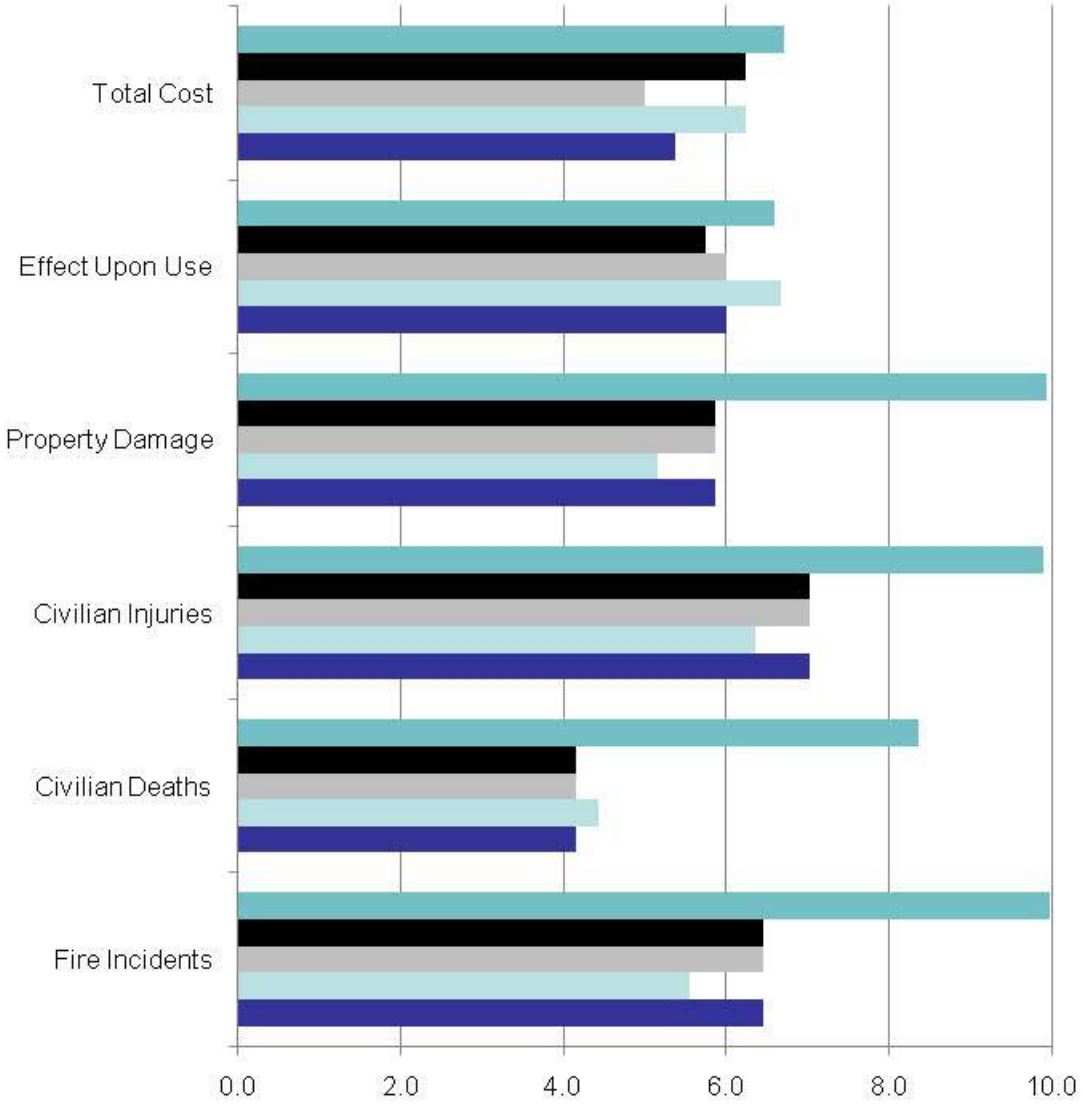
Mitigation Group 4: Detect Occurring Fire and Provide Automatic Suppression



Fire Protection Effectiveness

- Same fire scenarios addressed as when used only for detection
- Each detection method addresses same fire ignition scenarios, including all flaming ignitions on the range top
- Does not address clothing ignitions

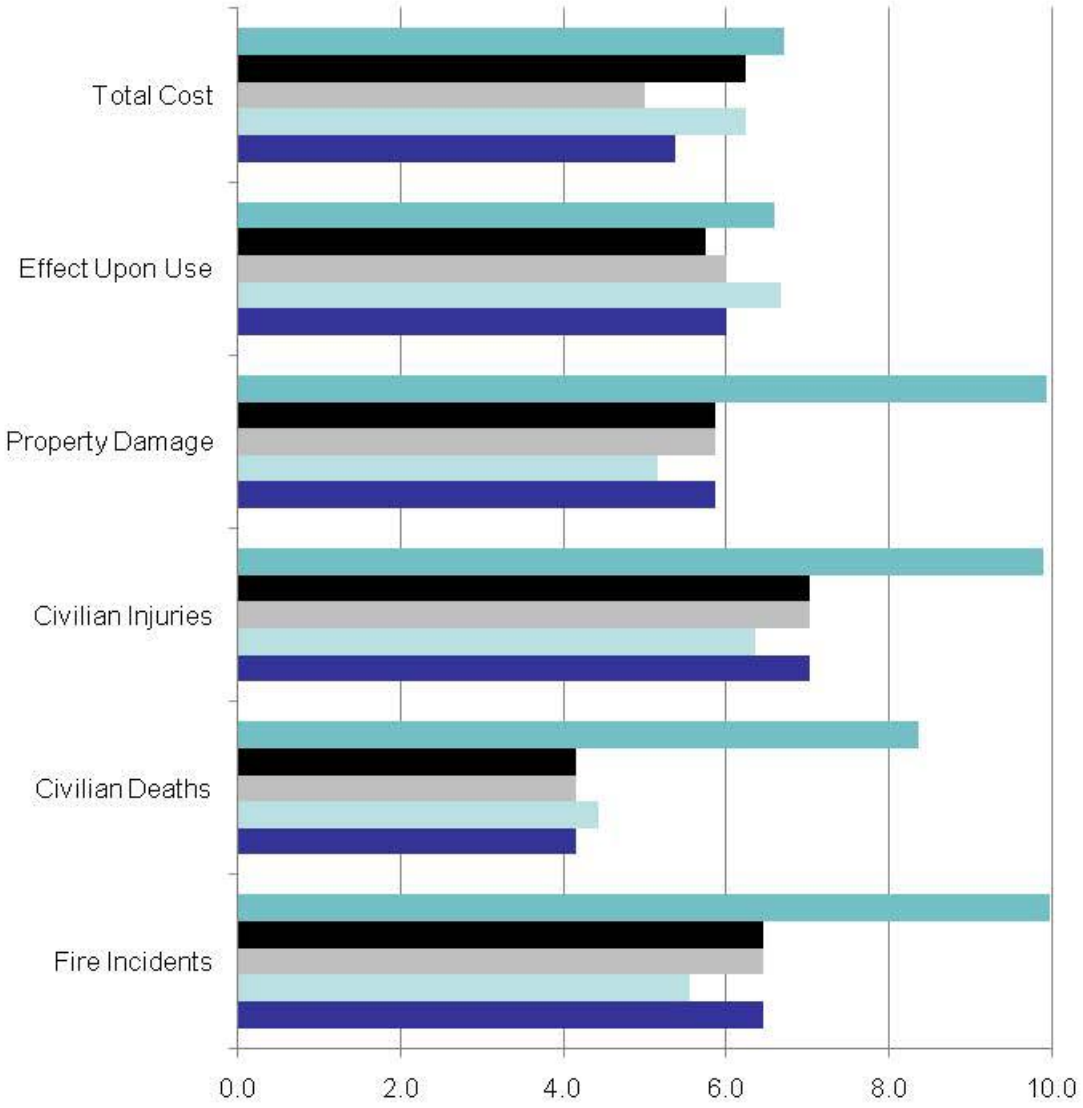
Mitigation Group 5-a: Detect Imminent Fire – Fixed Temp or Smoke Pre-ignition Conditions and Control Burner



Total Costs

- Smoke detector with control is lowest cost of pre-ignition sensor options
- The burner surface temperature has improved cost score due to increased durability vs. utensil temperature sensors
- The mechanically actuated switch is a cheap and durable option
- The non-contact utensil temperature measurement is the most sophisticated detection and thus the most expensive

Mitigation Group 5-a: Detect Imminent Fire – Fixed Temp or Smoke Pre-ignition Conditions and Control Burner

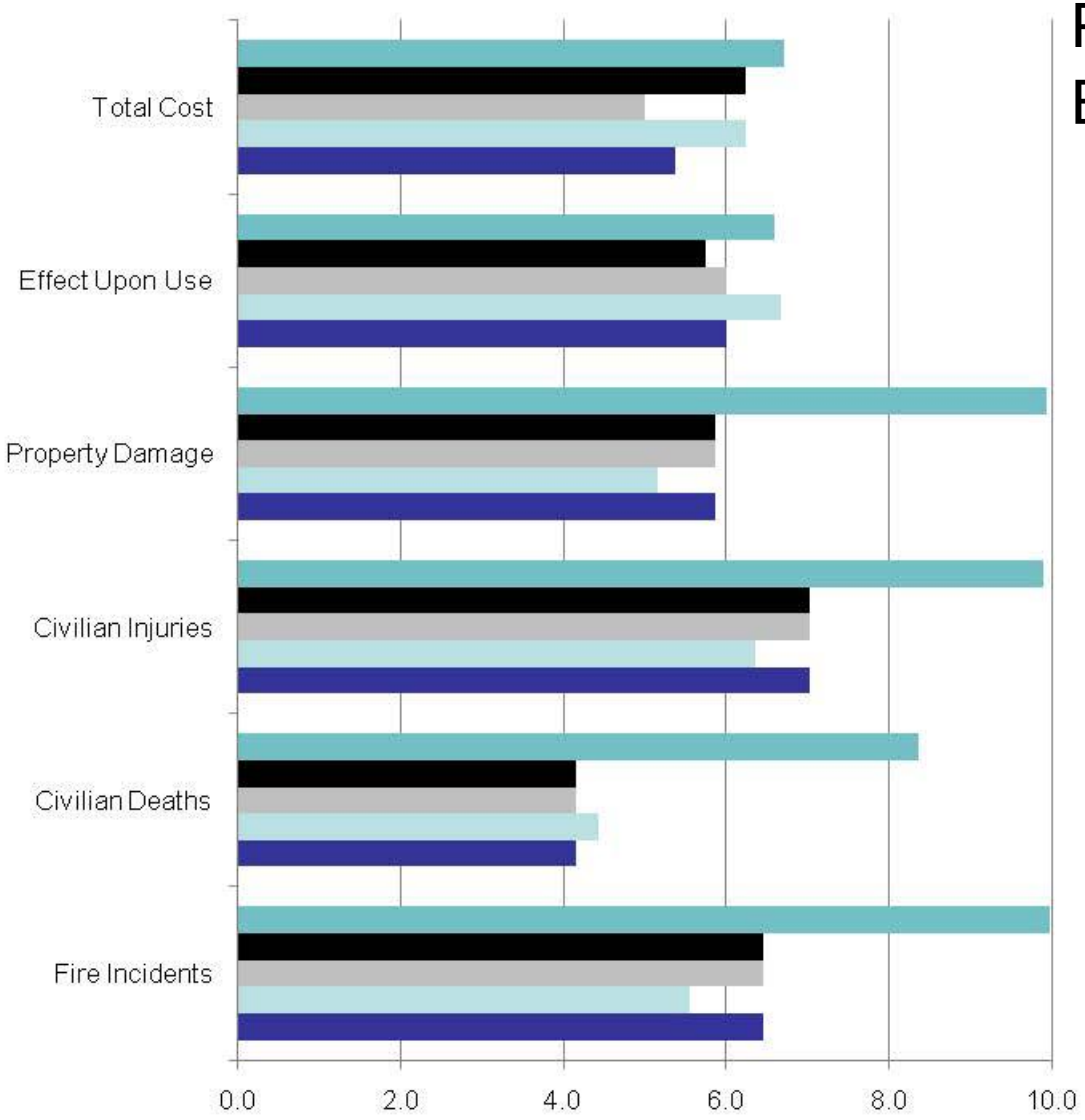


Effect Upon Use of the Cooking Range

- Most devices are comparable in the effect upon the use of the cooking range
  - They all have some affect upon the ability to cook on the range by controlling the burners
- The smoke detection score reflects complete burner shutdown and its potential for nuisance alarms
- Also analyzed gradient control for boil over and user controlled temperature settings
  - Fixed temperature applicable to more fires than gradient
  - Fixed temperature produced less effect upon the use of the range than user controlled

Smoke Detection
Mechanical actuation
Non-contact utensil temperature sensor
Burner temperature
Utensil contact temperature

Mitigation Group 5-a: Detect Imminent Fire – Fixed Temp or Smoke Pre-ignition Conditions and Control Burner

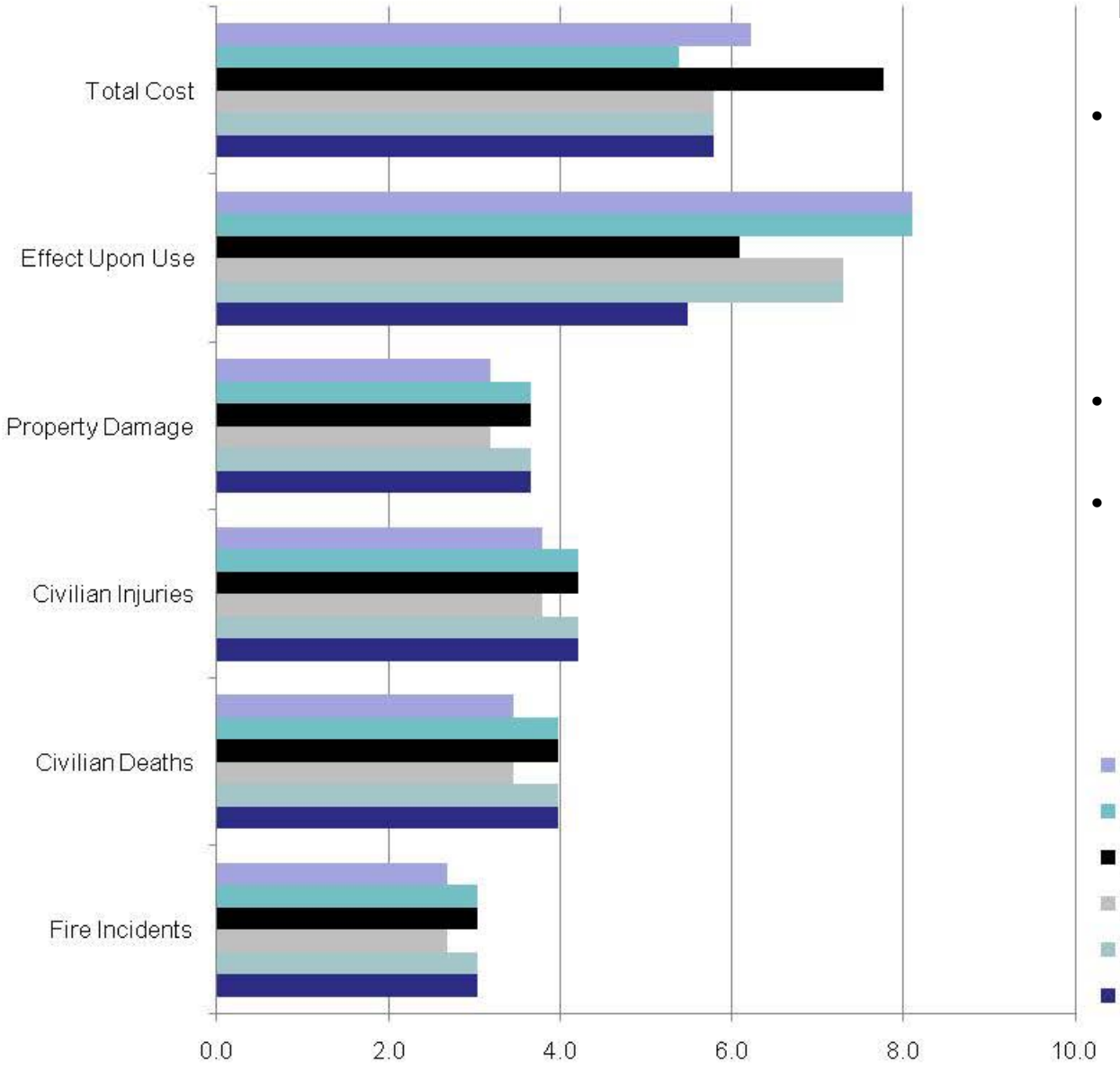


Fire Protection Effectiveness

- Smoke detection addresses the highest number of fires, only neglects clothing ignitions
- Burner temperature FPE reduced due to electric range only operation
- Burner temperature device has increased FPE for death losses due to demonstrated ability to prevent clothing ignitions
- Utensil/ burner temperatures represent only specific in pan cooking fires, and this is represented by the FPE vs. smoke

Smoke Detection
Mechanical actuation
Non-contact utensil temperature sensor
Burner temperature
Utensil contact temperature

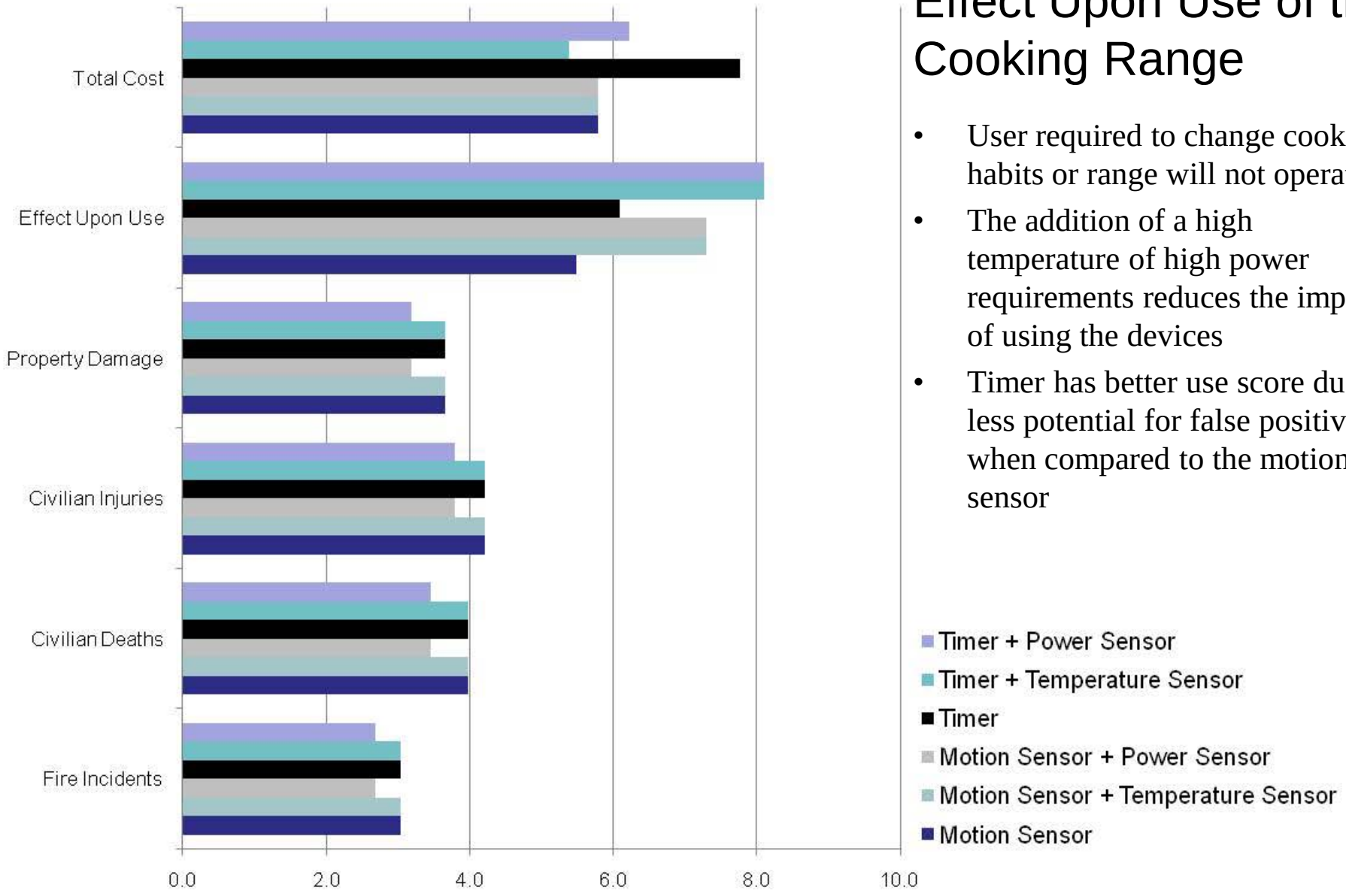
Mitigation Group 5-b: Detect Unattended Cooking with Control



Total Costs

- Prevention is a higher level mitigation method than providing warning, but does require the inclusion of additional devices, increasing costs and decreasing the reliability
- Timer is least expensive unattended control device
- The primary cost driving factor for the motion sensor is the sensor itself, costs of additional control systems not reflected by this scoring method (still medium)

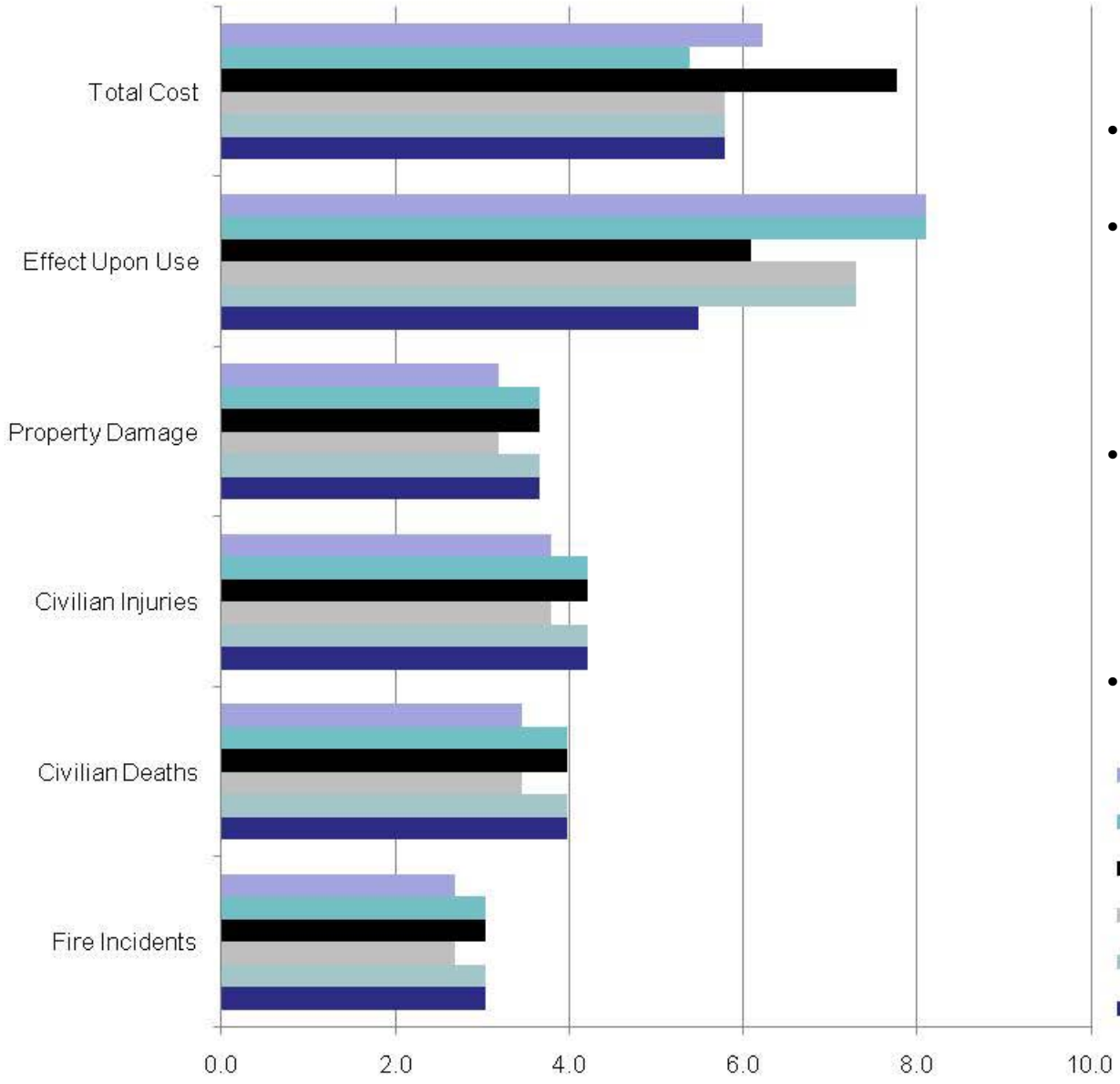
Mitigation Group 5-b: Detect Unattended Cooking with Control



Effect Upon Use of the Cooking Range

- User required to change cooking habits or range will not operate
- The addition of a high temperature of high power requirements reduces the impact of using the devices
- Timer has better use score due to less potential for false positives when compared to the motion sensor

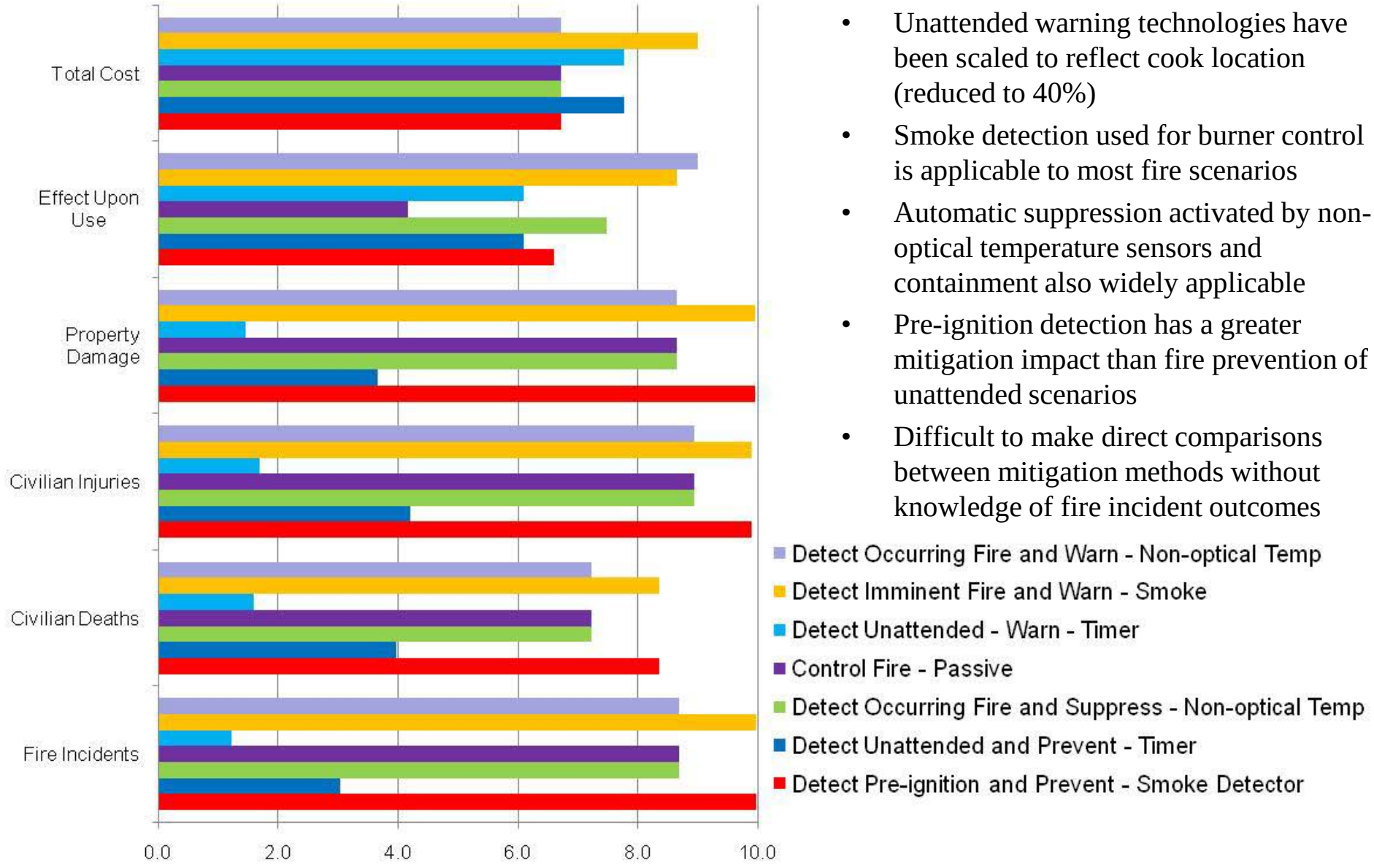
Mitigation Group 5-b: Detect Unattended Cooking with Control



Fire Protection Effectiveness

- Results same as unattended sensors used for warning
- By eliminating the warning and directly preventing ignition, the technologies become applicable to 30-40% of fire losses vs. 10-15% for warning only devices
- Unattended cooking fires represent lower number of addressed fires when compared to detection of pre-ignition conditions (30-40% vs. 40-100%)
- Devices with power sensors only applicable to electric ranges

Comparison in Scoring Between Various Mitigation Groups



- Unattended warning technologies have been scaled to reflect cook location (reduced to 40%)
- Smoke detection used for burner control is applicable to most fire scenarios
- Automatic suppression activated by non-optical temperature sensors and containment also widely applicable
- Pre-ignition detection has a greater mitigation impact than fire prevention of unattended scenarios
- Difficult to make direct comparisons between mitigation methods without knowledge of fire incident outcomes

Technologies Compared Between Groups

Technology			Mean Score	Overall Rank
Detect Occurring Fire and Provide Warning	Non-Optical Temperature Sensor		7.6	2
	Optical Temperature Sensor		7.2	4
Detect Imminent Fire and Provide Warning	Pre-ignition Conditions	Smoke Detector	8.7	1
		Non-optical Temperature Sensor	7.5	3
	Unattended Cooking	Timer	4.2	38
		Timer + Power Sensor	4.1	39
Control Fire/Prevent Fire Spread	Passive		5.9	11
	Active		5.3	28
Provide Automatic Suppression	Fusible Link		7.1	8
	Non-Optical Temperature Sensor		7.1	8
Prevent Fire	Pre-ignition Conditions	Smoke Detector	7.2	6
		Fixed Temperature Burner Temp	5.7	15
	Unattended Cooking	Timer	5.7	14
		Timer + Power Sensor	5.6	16

Mean score is the geometric mean of **(FPE_{DEATH}), Use, and Cost Scores**
Ranking of technologies as compared to all 44 evaluated technologies

Conclusions

- Smoke detection provides most universally applicable detection method
  - Smoke detection is still one of the most reliable and universally applicable methods of detecting pre-ignition conditions
  - Rate of nuisance alarms key difficulty in using smoke detection for prevention rather than warning
- Significant Fire Loss Reductions
  - Detect Fire and Provide Automatic Suppression
  - Control Fire/Prevent Fire Spread
- Warning systems are not as effective options as prevention technologies
  - Cook locations and activities
  - Products requiring less intervention and onus on consumers is preferred
  - Focus of product development should be in automatic fire prevention
- Prevention of clothing ignitions is a key factor for prevention of deaths in cooking fires (35% of fatalities only 0.5% of incidents)

Conclusions

- Technology Scoring Considerations
  - Scoring system is a snapshot of the current status of technologies
  - Product development status could significantly change scores
  - In some cases, a low score does not imply a technology does not have potential value, but rather that additional work is required to bring the technology to a marketable state
- Many prevention options are tailored to specific ignition scenarios and/or range types
  - Differentiating all these details not possible in assessment methodology
  - Niche options can be considered (only applicable to gas or electric, only for ranges with hoods, etc.)
  - Scoring could change dramatically if evaluated for niche applications (e.g. electric coil ranges)

Information Gaps and Future Work

- Implementation
  - How quickly could a product penetrate into existing homes? Retro-fit v. new install?
  - Marketing of existing products generally focused on infirmed and group homes, what steps to move to more universal acceptance?
  - Criteria constituting mandating use of technologies? Cost benefit analysis?
- What aspects of ranking constitute real value?
  - Scoring not intended to eliminate technologies from future consideration
  - Statistical data needed to fully differentiate warning vs. control technologies (e.g. impairments, response of occupants, etc.).
- International work driving product development
  - Most existing cooking fire mitigation products are international
  - Introduction of actual products lagging in U.S. markets, still most work in theoretical stages or niche markets
  - Scientific evaluations have shown numerous viable solutions
- Potential product reliability and durability still unclear in most cases, especially for technologies existing in concept only
- Assigning numeric values to expected costs rather than rough low, medium, high assignments could give more accurate picture


Questions?

Home Stovetop Fires: Specifying Scenarios for Use in Evaluation Method

John R. Hall, Jr., Ph.D.
National Fire Protection Association
November 2010

Restating the assignment

- Assignment: Develop a fire scenario structure with quantification, showing the number (or share) of fires and losses per year associated with each selected scenario.
- For any fire prevention or mitigation technology or strategy, this will provide a comprehensive set of fire challenges.
- Each technology or strategy will need to be evaluated for its expected percent reduction in fires and losses for each identified strategy.

Restating the assignment (continued)

- One step is to separate stovetop fires from other reported range fires.
- A second step is to separate stovetop fires beginning during cooking activities from other stovetop fires.
- A third step is to separate stovetop fires associated with cooking activities where the cook is absent (unattended cooking) from stovetop cooking-activity fires with cook present.

Restating the assignment (continued)

- A technology that detects overheated food might prevent stovetop cooking fires but not other stovetop fires
- A technology that detects overheated heating elements might prevent all stovetop fires
- A technology that detects presence or absence of cooks might prevent all unattended cooking fires but not other stovetop fires

Restating the assignment (continued)

- An educational program might lower the likelihood of unattended cooking and so lower the likelihood of unattended cooking fires
- And so on.

Approach taken to the assignment

- First, we see what scenario structures are possible that are also consistent with the coding of fires reported to the NFIRS system.
- Then, we see what special databases may exist that can be used to convert an NFIRS-based scenario structure to a scenario structure useful for the assignment.

What can you get from NFIRS?

- You cannot isolate fires on the stovetop.
- You can only isolate fires in, on, or around the range
- Special databases will be needed to separate the stovetop fires from the other range fires.

What can you get from NFIRS?

- You cannot isolate fires beginning during cooking activities.
- You can identify fires by Factor Contributing to Ignition and by Item First Ignited
- Some of the codes for Item First Ignited make the connection to cooking clear (e.g., cooking materials). Others do not (e.g., flammable or combustible liquid with properties that could mean cooking oil or something else).

NFIRS-based categories

- Factor Contributing to Ignition can be reported with multiple factors identified.
- These categories are based on a hierarchical sorting.
- That means that each fire in Category X had no reported characteristics that would have assigned it to a Category numbered lower than X (e.g., Category 3 fires have no fires that would have qualified for Category 1A, 1B, or 2).

NFIRS-based categories (continued)

- Category 1A: Unattended (Factor Contributing) and Cooking materials (Item First Ignited)
- Category 1B: Not Unattended (Factor Contributing) and Cooking materials (Item First Ignited)
- Category 2: Unattended (Factor Contributing) and Not cooking materials (Item First Ignited)

NFIRS-based categories (continued)

- Category 3: Mechanical or electrical failure or malfunction; or design, manufacturing or installation deficiency (Factor Contributing)
- Category 4: Various behavioral errors possibly related to kitchen activity (Factor Contributing), such as heat source too close to combustible, which could refer to spilled food or an abandoned dishcloth too close to a burner.

NFIRS-based categories (continued)

- Category 5: Various behavioral errors clearly not related to kitchen activity (Factor Contributing), such as cutting or welding too close to combustibles.
- Category 6: Unknown, unclassified or none (Factor Contributing)

Groups we would like to have

- We would like to link fires more closely to the stovetop and to cooking activities
- Group 1: Fire beginning in food in a cooking vessel on a burner
- Group 2: Fire beginning on stovetop during cooking activities but not food in a cooking vessel on a burner
- Group 3: Fire beginning on stovetop but not during cooking activities

Groups we would like to have

- Group 4: Fire beginning in the oven part of the range and not on the stovetop
- Group 5: Fire beginning in or on or beside the range but not on the stovetop or in the oven

One more key limitation of the method we used

- We had enough data to set up mapping factors to indicate what fraction of Category X fires were estimated to belong to Group Y, where X goes from 1A to 6 (7 categories) and Y goes from 1 to 5 (5 groups).
- We did not have enough data to set up separate mapping factors for deaths, injuries, or property damage, or to set up separate mapping factors for gas vs. electric ranges (let alone more specific different types of ranges).

Mapping factors for Categories 1A and 1B

	Group 1: Fire begins in a cooking vessel on a burner	Group 2: Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	Group 3: Fire begins on stovetop but not during cooking activities	Group 4: Fire begins in oven	Group 5: Fire begins in or on range but not on stovetop or in oven
Category 1A (cooking materials and unattended; item first ignited = 76; factor contributing to ignition = 53)	1.000	0.000	0.000	0.000	0.000
Category 1B (cooking materials and not unattended; item first ignited = 76; factor contributing to ignition ≠ 53)	0.806	0.097	0.000	0.065	0.032

Mapping factors for Categories 2, 3 and 4

	Group 1: Fire begins in a cooking vessel on a burner	Group 2: Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	Group 3: Fire begins on stovetop but not during cooking activities	Group 4: Fire begins in oven	Group 5: Fire begins in or on range but not on stovetop or in oven
Category 2 (unattended but not cooking materials: item first ignited ≠ 76; factor contributing to ignition = 53)	0.400	0.200	0.200	0.200	0.000
Category 3 (mechanical or electrical failure or malfunction or design, manufacturing, or installation error and not cooking materials: item first ignited ≠ 76; factor contributing to ignition ≠ 53; factor contributing to ignition 20-44)	0.000	0.055	0.111	0.111	0.722
Category 4 (not cooking materials and behavioral errors: item first ignited ≠ 76; factor contributing to ignition ≠ 20-44, 53; factor contributing to ignition 10-12,14,17, 19,51-52,54-58)	0.000	0.000	0.794	0.147	0.059

Mapping factors for Categories 5 and 6

	Group 1: Fire begins in a cooking vessel on a burner	Group 2: Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	Group 3: Fire begins on stovetop but not during cooking activities	Group 4: Fire begins in oven	Group 5: Fire begins in or on range but not on stovetop or in oven
Category 5 (not cooking materials and factors not related to cooking behaviors: item first ignited ≠ 76; factor contributing to ignition ≠ 10-12,14,17,19,20-58; factor contributing to ignition 13,15-16,18,60-75)	0.000	0.000	0.000	0.000	1.000
Category 6 (not cooking materials and unclassified or unknown factors: item first ignited ≠ 76; factor contributing to ignition ≠ 01-99; factor contributing to ignition 00,NN,UU, blank)	0.000	0.259	0.646	0.095	0.000

Range fires, 2005-09 average, by type of fuel or power

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Gas	15,200	84	500	$86
Electric	74,640	247	3,187	$461
Other	280	0	10	$1
Total	90,120	330	3,697	$548

Gas range fires, 2005-09 average, by Category

Type of Fuel or Power	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Category 1A	2,730 (17.9%)	22 (26.8%)	127 (25.5%)	$17 (19.9%)
Category 1B	6,370 (41.9%)	3 (4.0%)	160 (32.1%)	$24 (27.5%)
Category 2	520 (3.4%)	3 (4.0%)	34 (6.8%)	$8 (9.3%)
Category 3	1,300 (8.6%)	3 (4.0%)	31 (6.2%)	$6 (7.1%)
Category 4	2,470 (16.3%)	27 (31.7%)	86 (17.1%)	$16 (18.4%)
Category 5	350 (2.3%)	0 (0.0%)	10 (2.0%)	$1 (1.0%)
Category 6	1,460 (9.6%)	25 (29.5%)	51 (10.2%)	$14 (16.7%)
Total	15,200 (100.0%)	84 (100.0%)	500 (100.0%)	$86 (100.0%)

Electric range fires, 2005-09 average, by Category

Type of Fuel or Power	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Category 1A	21,050	(28.2%)	96	(38.9%)	1,221	(38.3%)	$135	(29.2%)
Category 1B	34,490	(46.2%)	31	(12.7%)	1,303	(40.9%)	$163	(35.4%)
Category 2	3,110	(4.2%)	32	(12.9%)	185	(5.8%)	$41	(8.9%)
Category 3	2,700	(3.6%)	12	(5.1%)	42	(1.3%)	$16	(3.5%)
Category 4	6,910	(9.3%)	54	(22.0%)	277	(8.7%)	$64	(13.8%)
Category 5	570	(0.8%)	0	(0.0%)	8	(0.3%)	$3	(0.6%)
Category 6	5,820	(7.8%)	21	(8.5%)	149	(4.7%)	$39	(8.5%)
Total	74,640	(100.0%)	247	(100.0%)	3,187	(100.0%)	$461	(100.0%)

Gas range fires, 2005-09 average, by Group

Group	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Group 1. Fire begins in a cooking vessel on a burner	8,070 (53.1%)	26 (31.6%)	270 (54.1%)	$39 (45.8%)
Group 2. Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	1,170 (7.7%)	8 (9.1%)	37 (7.5%)	$8 (9.2%)
Group 3. Fire begins on stovetop but not during cooking activities	3,150 (20.8%)	38 (45.5%)	111 (22.2%)	$24 (28.1%)
Group 4. Fire begins in oven	1,160 (7.7%)	7 (9.0%)	38 (7.6%)	$8 (8.7%)
Group 5. Fire begins in or on but not on stovetop or in oven	1,640 (10.8%)	4 (4.9%)	43 (8.6%)	$7 (8.1%)
Total	15,200 (100.0%)	84 (100.0%)	500 (100.0%)	$86 (100.0%)

Electric range fires, 2005-09 average, by Group

Group	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage (in Millions)
Group 1. Fire begins in a cooking vessel on a burner	50,090 (67.1%)	134 (54.3%)	2,345 (73.6%)	$282 (61.3%)
Group 2. Fire begins on stovetop during cooking activities but not in a cooking vessel on a burner	5,630 (7.5%)	16 (6.3%)	205 (6.4%)	$35 (7.6%)
Group 3. Fire begins on stovetop but not during cooking activities	10,160 (13.6%)	64 (26.0%)	359 (11.3%)	$86 (18.7%)
Group 4. Fire begins in oven	4,730 (6.3%)	20 (8.0%)	181 (5.7%)	$34 (7.3%)
Group 5. Fire begins in or on but not on stovetop or in oven	4,030 (5.4%)	13 (5.4%)	97 (3.0%)	$24 (5.1%)
Total	74,640 (100.0%)	247 (100.0%)	3,187 (100.0%)	$461 (100.0%)

Other analyses done & useful in elaborations of method

- We developed statistics by Group for civilian fire deaths due to ignitions of clothing on a person.
- They accounted for one-third of deaths for gas ranges and about one-tenth of deaths for electric ranges.
- Some technologies that can prevent ignition of food may not prevent ignition of fabric, and clothing ignitions are a major category of non-food fatal ignitions.

Other analyses done & useful in elaborations of method

- We developed statistics on where the absent cooks were and what they were doing.
- Using all databases combined, weighting each study equally but not each case equally, we get 32% of cooks outside building, 28% inside building but distracted or asleep, and 40% inside building and not distracted or asleep.
- This could be useful in estimating audibility and alerting effectiveness of an alarm triggered by a sensor detecting absence of cook.

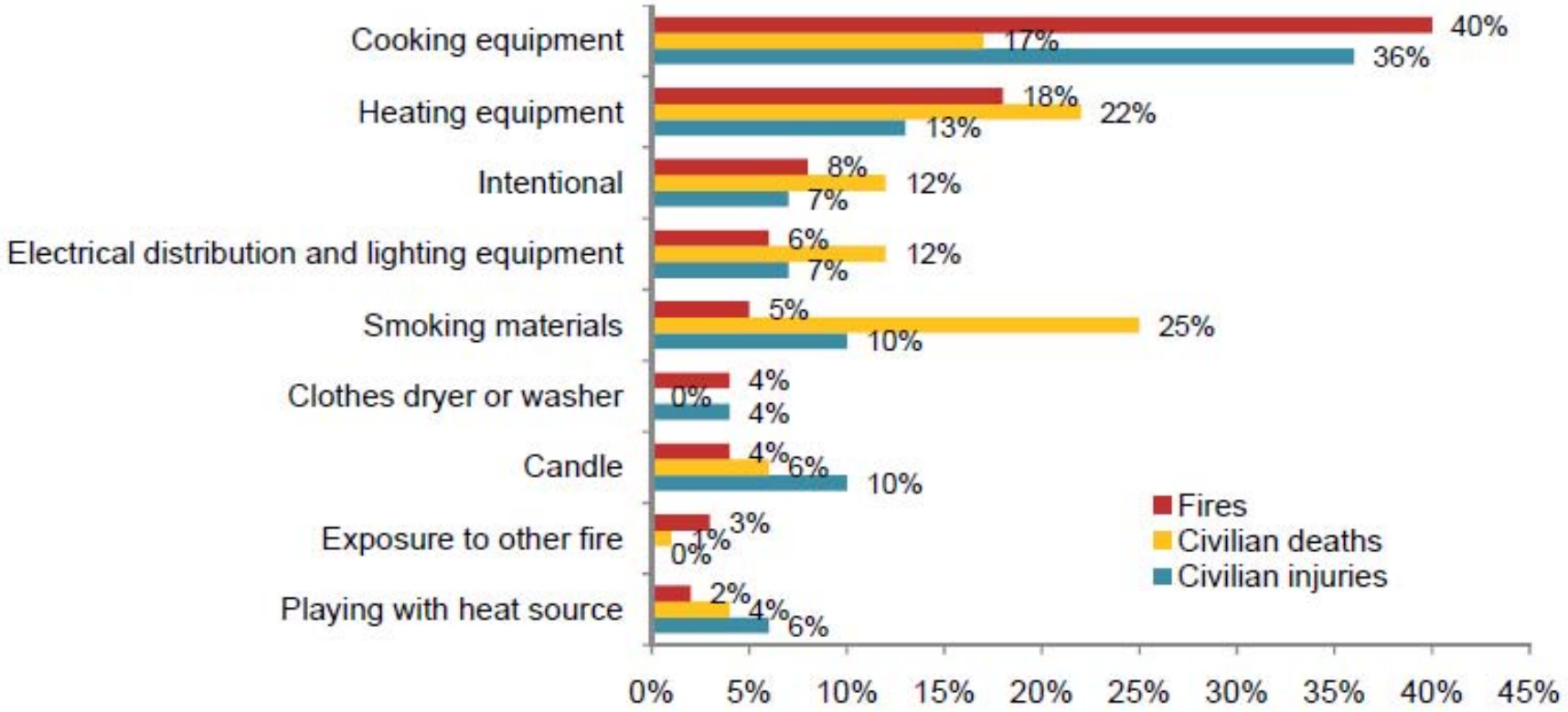
Other analyses done & useful in elaborations of method

- We referenced statistics developed elsewhere on cooking time prior to ignition, by type of cooking.
- For example, ignition took place in 14 minutes or less for 83% of frying fires but only 6% of boiling fires.
- This could be useful in estimating how often prevention technologies will activate before ignition and how long before ignition they will activate.

Cooking Fire Prevention

Tom Fabian, Ph.D.
Underwriters Laboratories

Leading Causes of Reported Home Structure Fires between 2003-2007



- M Ahrens, “Home Structure Fires”, NFPA (March 2010)

CPSC Sponsored Research on Detection of Cooking Fires

- Temperature, smoke particulate, and hydrocarbon gases are strong indicators for impending ignition.
- No single sensor technology performed faultlessly for predicting impending ignition; a combination of a gas sensor on the range hood and a thermocouple contacting the bottom of the pan were found to be most effective.
- Standard household smoke alarms identify pre-ignition conditions well but generate a significant number of false alarms.

- E.L. Johnsson, “Study of Technology for Detecting Pre-Ignition Conditions of Cooking-Related Fires Associated with Electric and Gas Ranges and Cooktops, Phase I Report”, NISTIR 5729, October 1995.
- E.L. Johnsson, “Study of Technology for Detecting Pre-Ignition Conditions of Cooking-Related Fires Associated with Electric and Gas Ranges and Cooktops, Final Report”, NISTIR 5950, January 1998.

CPSC Sponsored Research on Detection of Cooking Fires while Ventilating

Cooking experiments in conjunction with range hoods and ceiling fans:

- Pan bottom temperatures provided a good indication of pre-ignition condition.
- Gas sensors had generally low and variable responses until near ignition.
- Smoke detectors did not respond consistently.
- Range hoods and ceiling fans substantially depressed gas sensor and smoke detector responses.

- U.S. Consumer Product Safety Commission, “ Study of Technology for Detecting Pre-Ignition Conditions of Cooking Related Fires Associated with Electric and Gas Ranges: Phase III”, February 23, 1998.

UL Research on Prevention of Cooking Fires

Investigated if a common Japanese cooktop with a pan contact temperature sensor could reduce the risk of ignition:

- Effective but may interfere with certain types of cooking such as blackening
- Efficacy was found to depend on the Interaction between cookware and sensor

- D.G. Dubiel, S.K. Maltas, “Report of Research on Cooking Fires and Pan Contact Temperature Sensor”, Underwriters Laboratories Inc., August 11, 2003.
- D.A. Dini, S.K. Maltas, “Report of Research on Cooktop Pan Contact Temperature Sensor – Technical Feasibility and Performance Goals”, Underwriters Laboratories Inc., August 12, 2004.

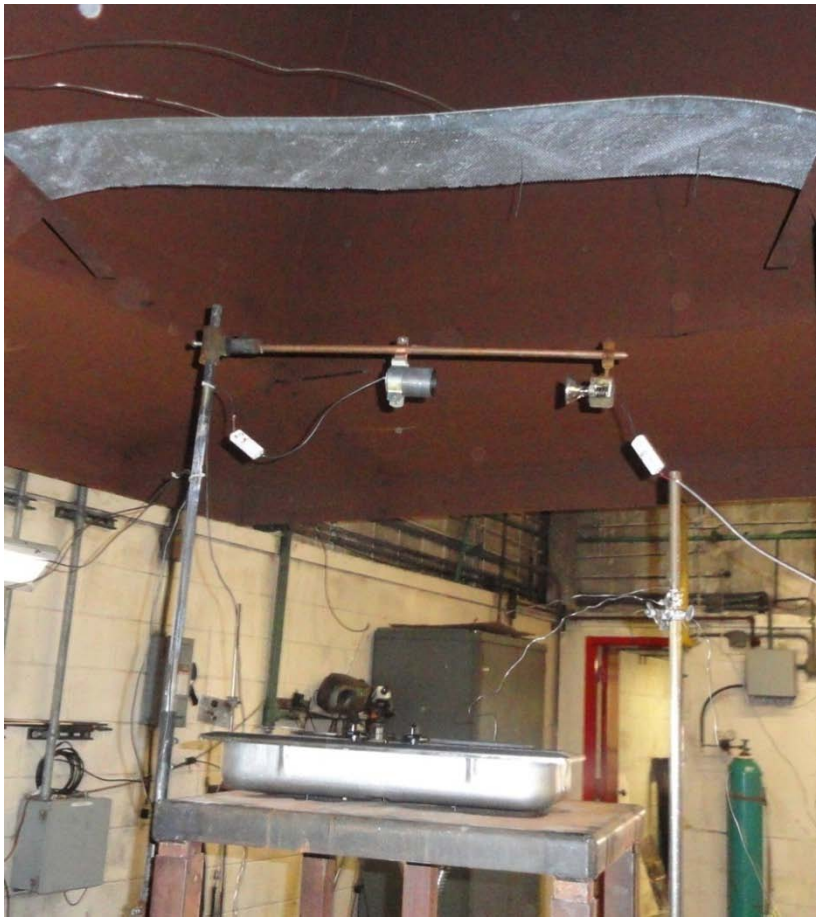
UL-IIT Research into Cooking Fire Precursor Conditions

Visiting IIT student project
- Adnan Ansari
- Anchit Guarav
- Vivek Yadav

½” oil (canola, corn, or peanut) in a 12” diameter cast iron pan

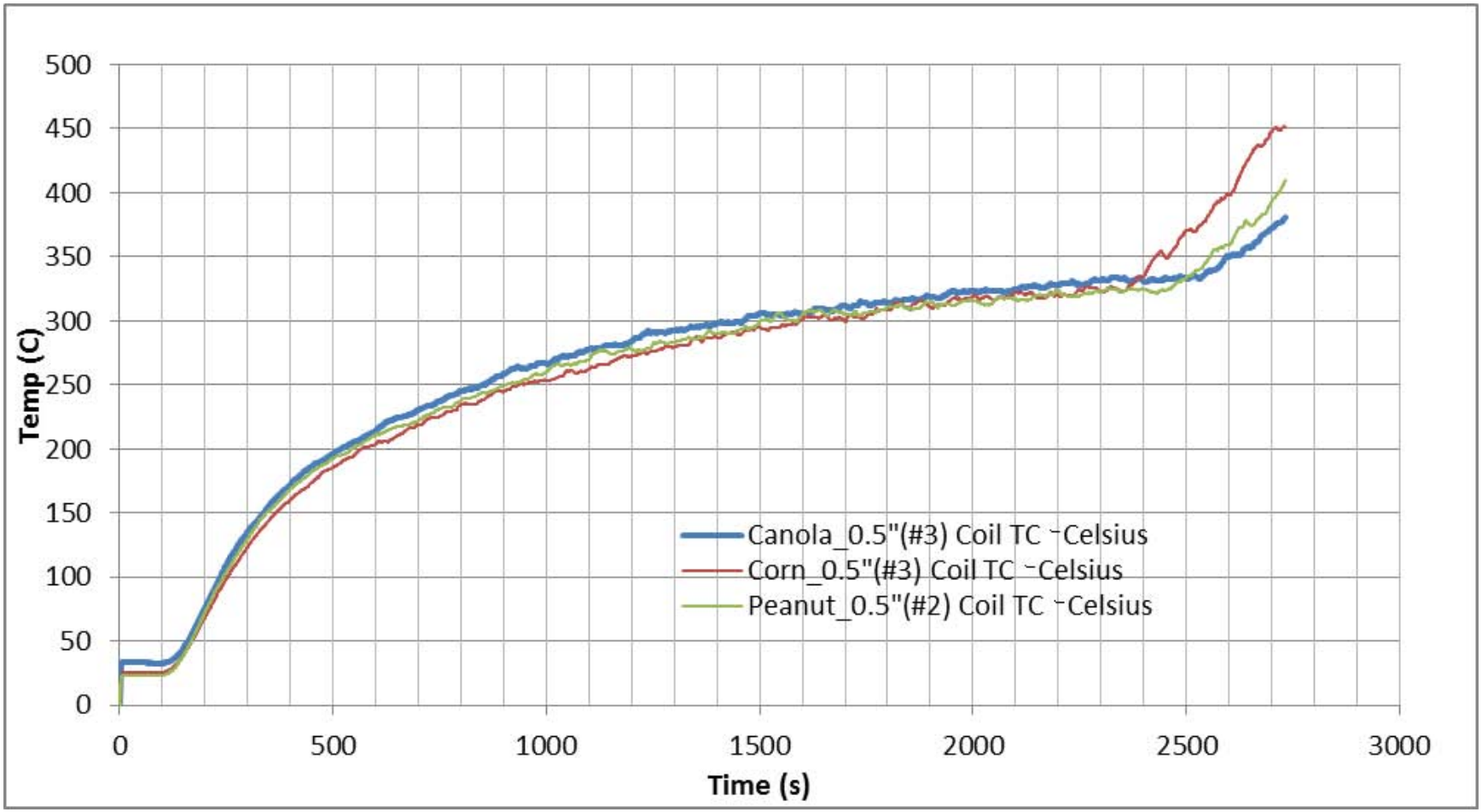
Electric coil cooktop

<u>Metrics</u>
- Temperature
- Smoke concentration

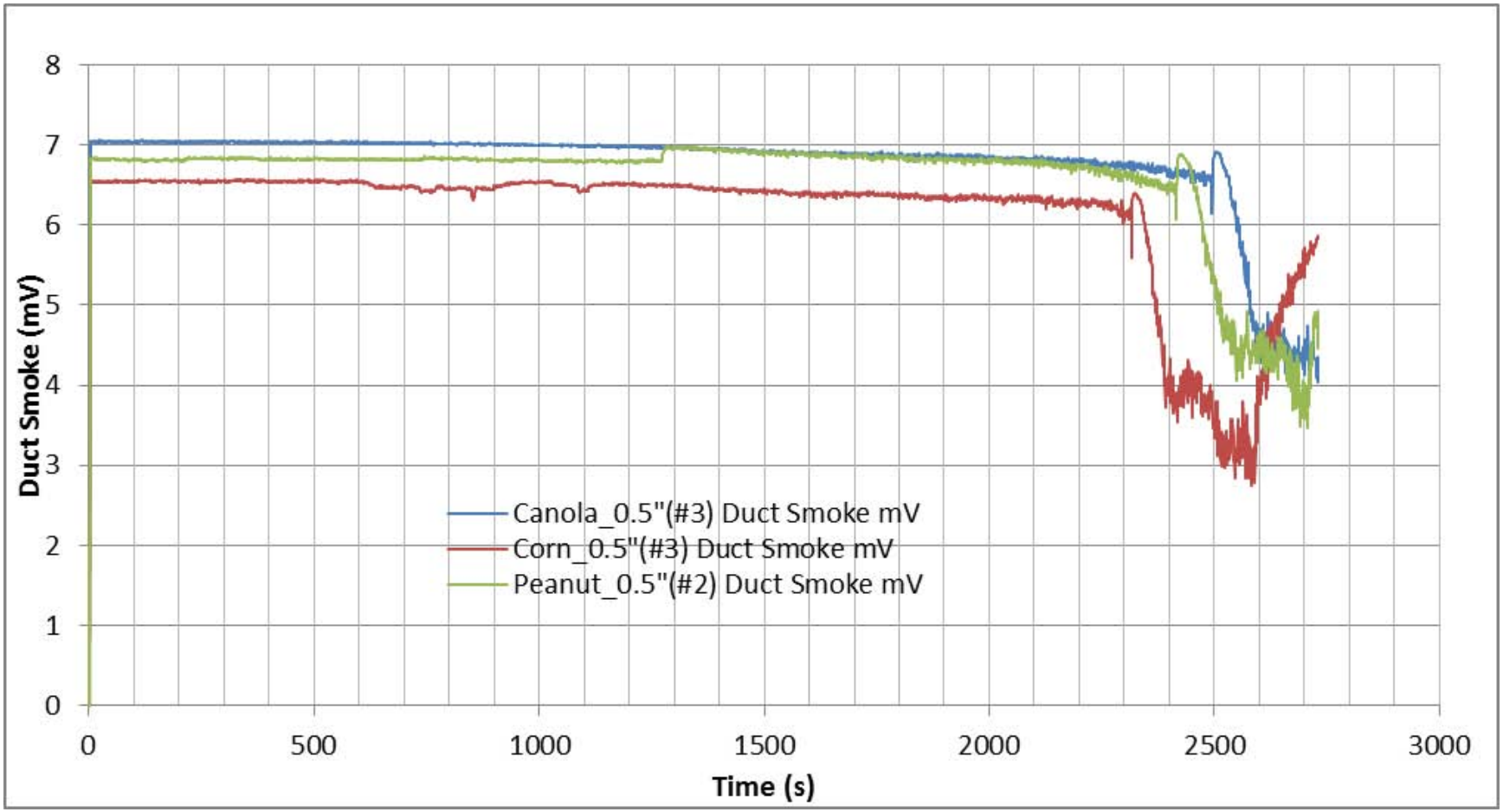


Imminent Cooking Fire Conditions

Coil Temperature for Different Oils

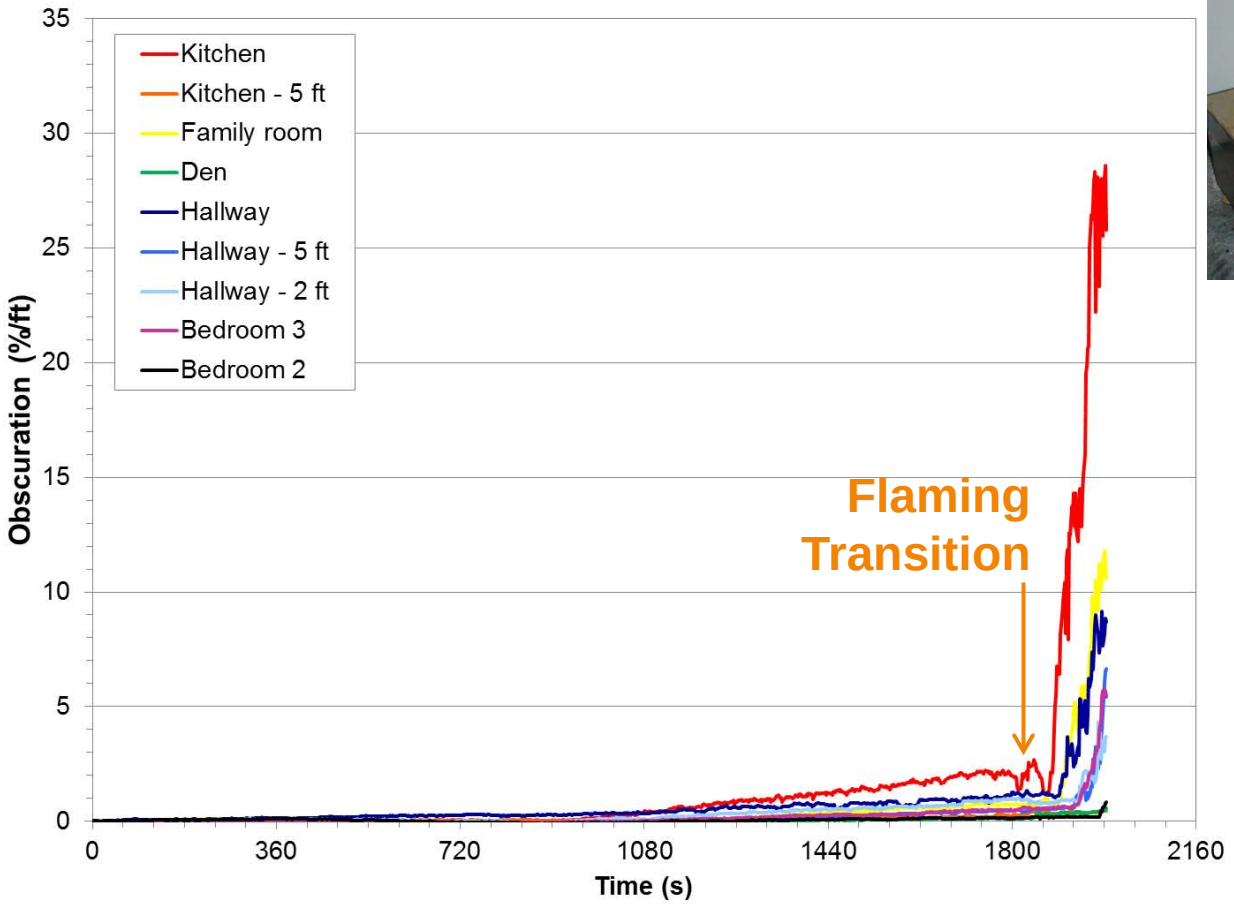


Smoke Density for Different Oils

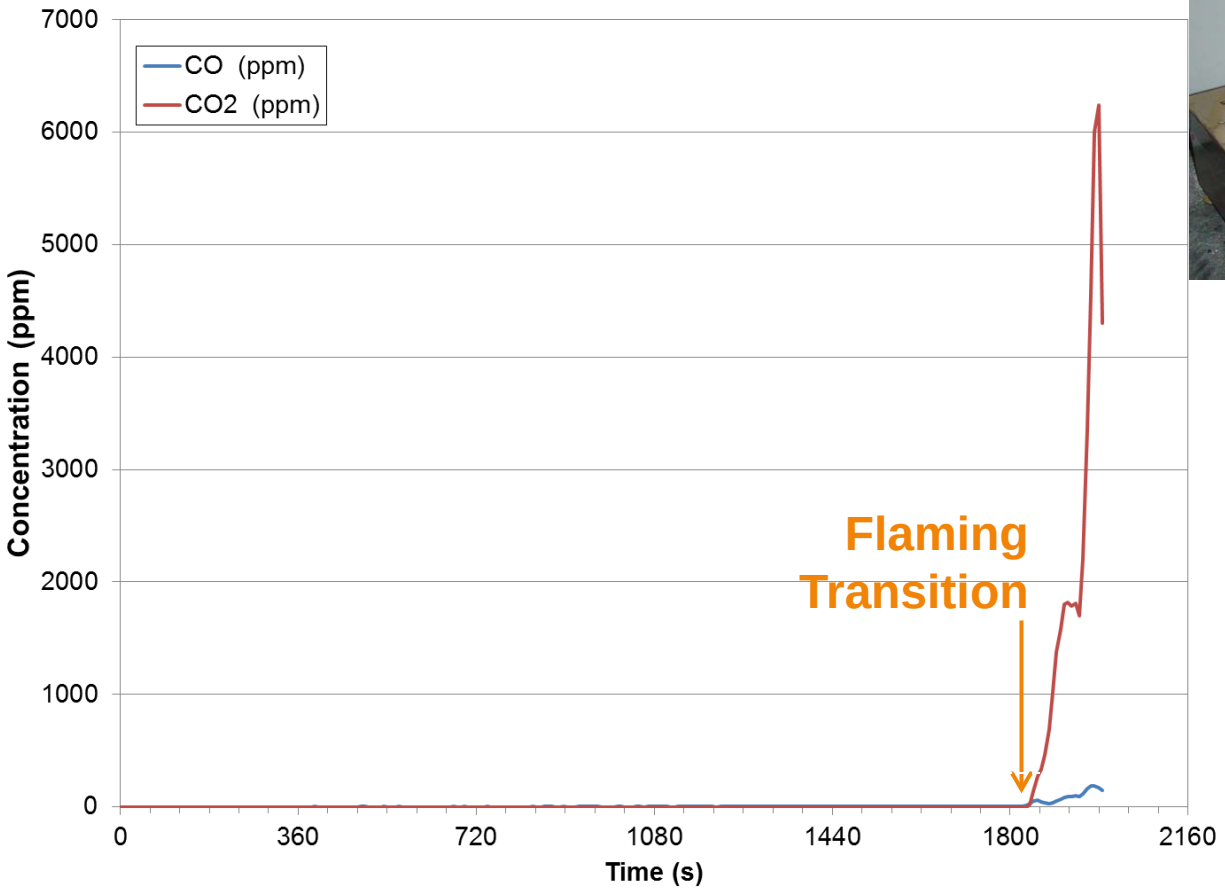


UL 2 Story, Open Floor Plan House Fire Tests

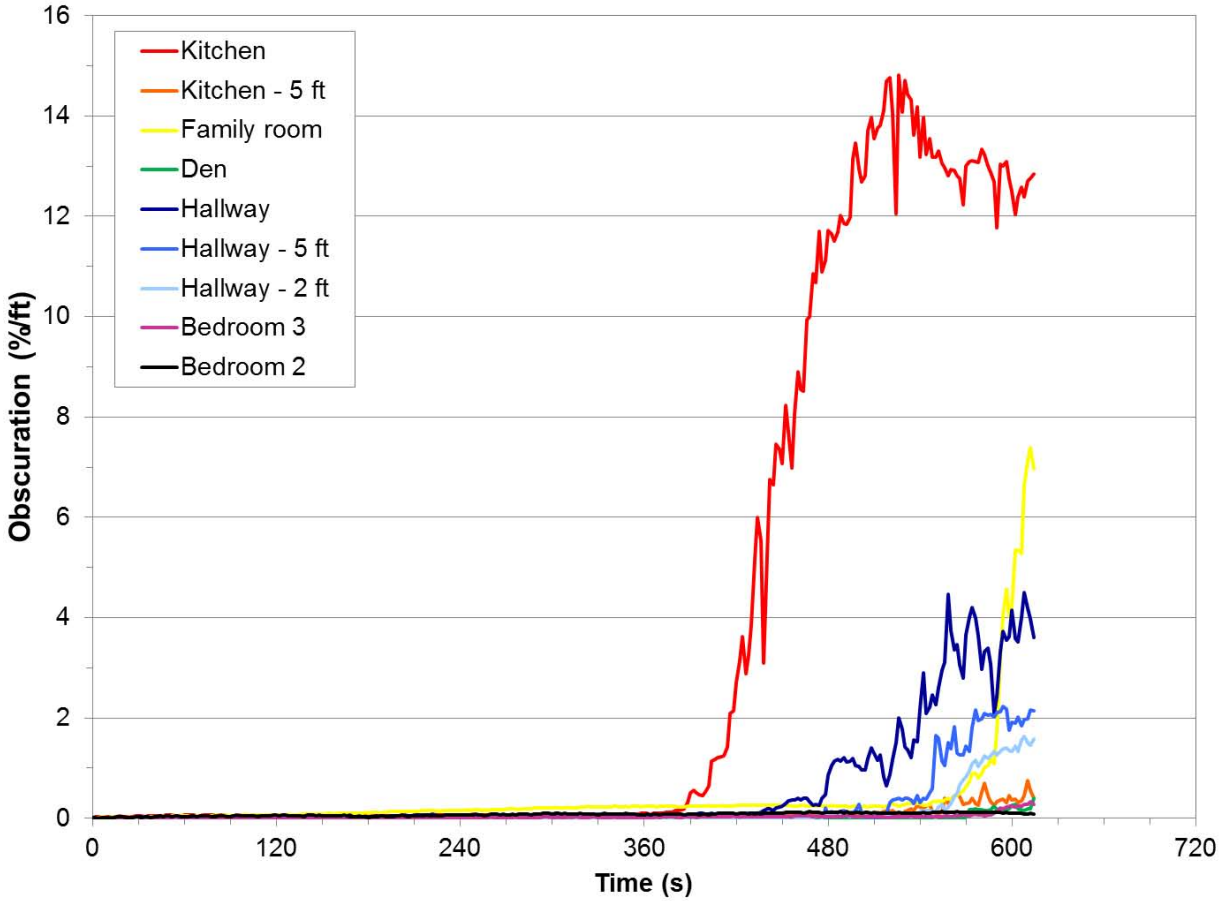
Corn Oil Cooking Scenario



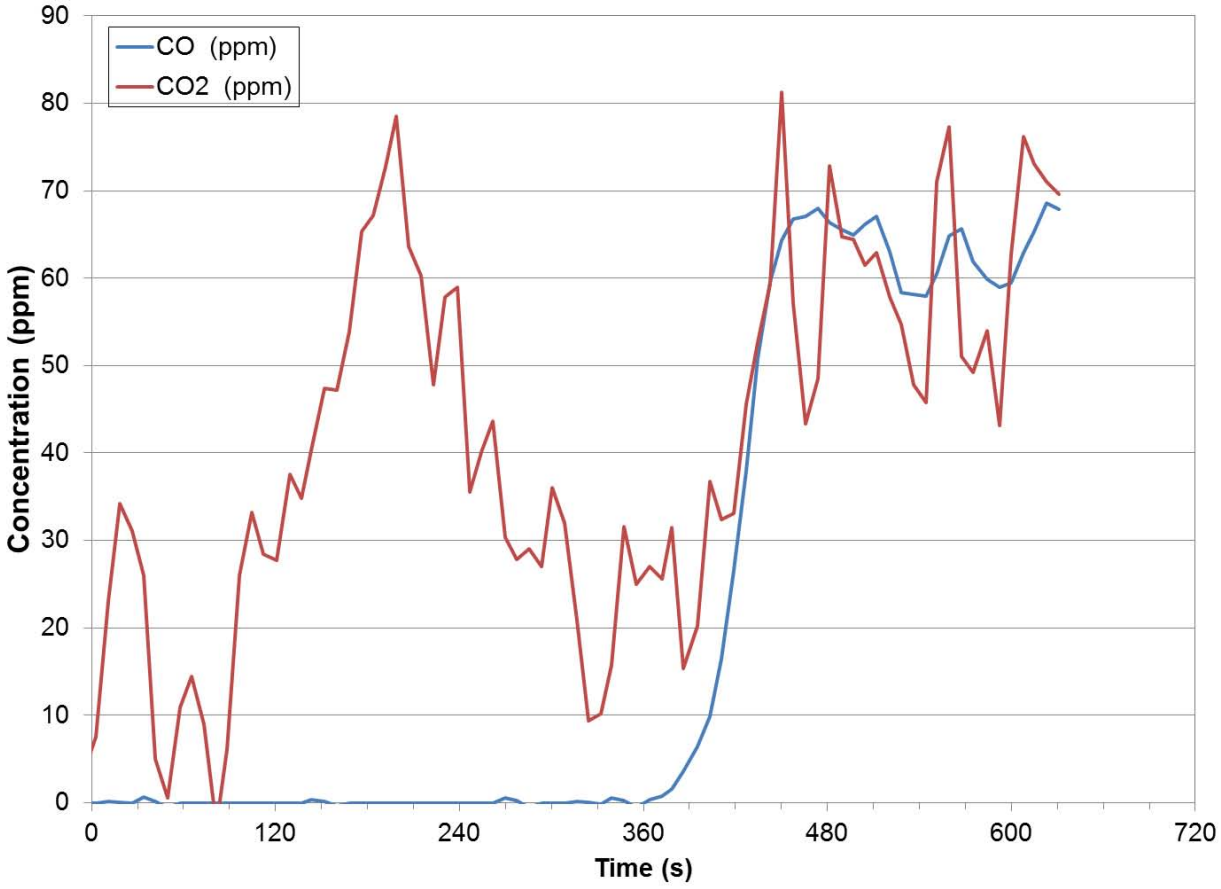
Corn Oil Cooking Scenario



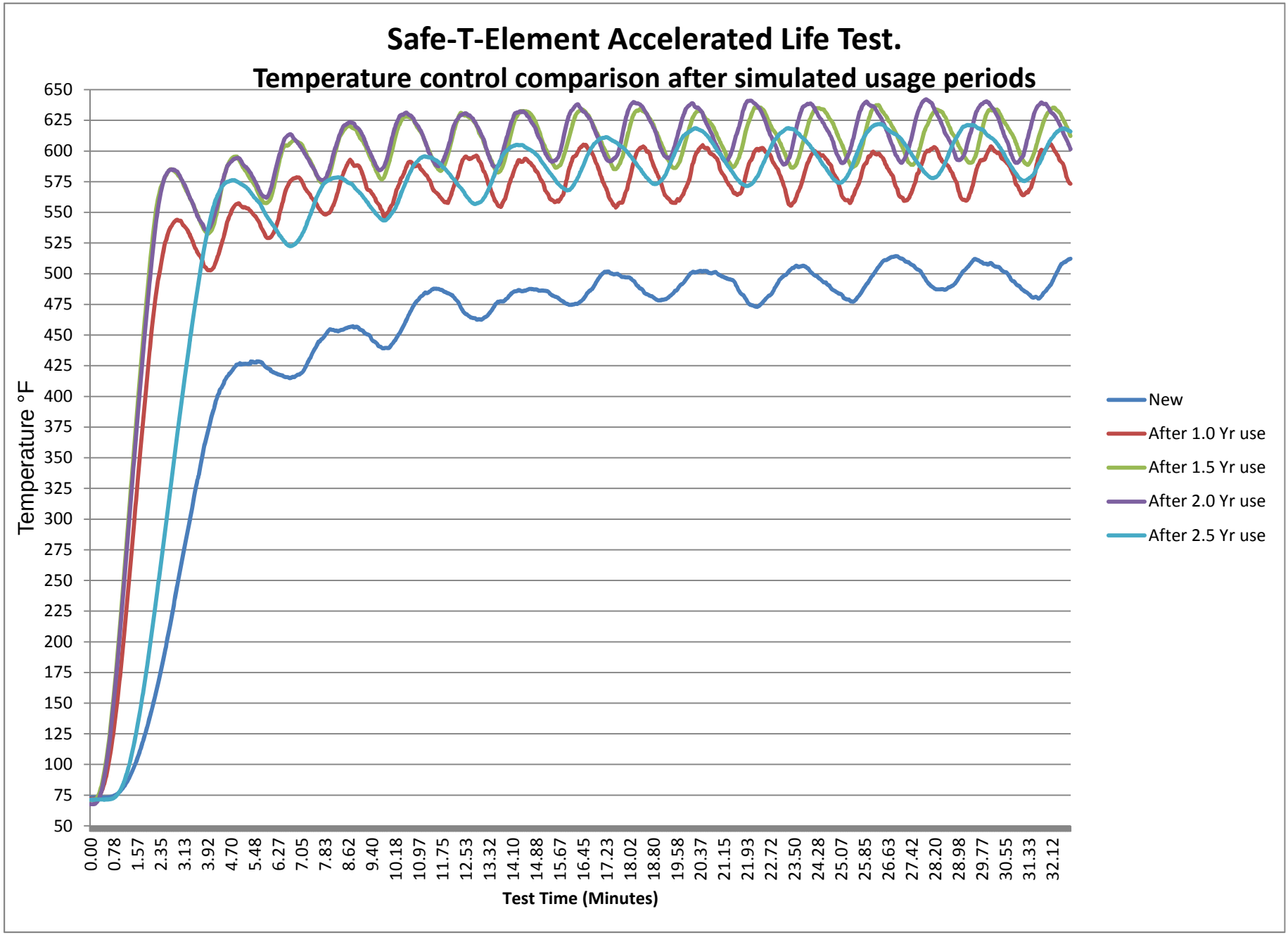
Overactive Toaster Scenario



Overactive Toaster Scenario



THANK YOU.


Safe-T-Element Accelerated Life Test.
Temperature control comparison after simulated usage periods
Temperature °F
650
625
600
575
550
525
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
0.00
0.78
1.57
2.35
3.13
3.92
4.70
5.48
6.27
7.05
7.83
8.62
9.40
10.18
10.97
11.75
12.53
13.32
14.10
14.88
15.67
16.45
17.23
18.02
18.80
19.58
20.37
21.15
21.93
22.72
23.50
24.28
25.07
25.85
26.63
27.42
28.20
28.98
29.77
30.55
31.33
32.12
Test Time (Minutes)
New
After 1.0 Yr use
After 1.5 Yr use
After 2.0 Yr use
After 2.5 Yr use