Carbon Monoxide Detection and Alarm Requirements: Literature Review

Final Report by:

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Foreword

New requirements for installation of Carbon Monoxide (CO) detection into several types of occupancies, both new and existing occupancies, are being addressed in the latest editions of NFPA 101*, Life Safety Code® and* NFPA 5000*, Building Construction and Safety Code®*. During the most recent revision cycle process (2021 edition of the new codes), an underlying concern has arisen if the requirements (of when and how CO detection is required) are adequate, and if the requirements need to be extended to other types of occupancies. Although this project originated with the Technical Committee on Residential Occupancies, the need to look at other occupancies has been suggested. See Table 1 for a summary of current provisions.

The overall goal of this project is to summarize the current set of requirements for installation of Carbon Monoxide (CO) detectors in various occupancies through a literature review of applicable Codes and Standards, and State Fire Code regulations. The study will also focus to collect and summarize non-fire CO incident injury and death data from available sources.

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The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

NFPA's membership totals more than 65,000 individuals around the world.

Keywords: **carbon monoxide, carbon monoxide detector, carbon monoxide alarm, NFPA 5000, NFPA 101, NFPA 72, IFC, IBC, IEBC, IRC, IPMC, carbon monoxide health effects**

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Table of Contents

List of Figures

List of Tables

Executive Summary

Carbon monoxide (CO) poisoning incidents have been occurring in the United States and globally at a fairly consistent rate. CO is a colorless and odorless gas and therefore impossible to detect without an alarm or some other air sampling system. It is a byproduct a of combustion reaction, so it is not uncommon for this toxic and fatal gas to leak from appliances, equipment, and vehicles. Incidents resulting from these leaks can and will happen almost anywhere, which is why it is imperative to have adequate regulations to eliminate these occurrences. Regulations for CO detection are provided by various codes from both the National Fire Protection Association (NFPA) and International Codes Council (ICC). As the 2024 editions are being developed, it is the goal of this report to provide the necessary information to the technical committees to allow them to determine if the current CO detection requirements are adequate and consistent across the range of occupancies (both new and existing) that the codes regulate.

The relevant codes include NFPA 101: *Life Safety Code*, NFPA 5000: *Building Construction and Safety Code*, International Fire Code (IFC), International Building Code (IBC), International Existing Building Code (IEBC), International Residential Code (IRC), and the International Property Maintenance Code (IMPC). NFPA 1: *Fire* Code is also relevant to the project; however, its requirements are derived through the NFPA extract policy and the NFPA 1 requirements are identical to those found in the NFPA 101 with respect to CO detection. This project summarizes the CO detection requirements of all these codes for all applicable occupancy types. In addition, NFPA 72, *National Fire Alarm and Signaling Code* contains the specific installation requirements regarding CO detection in chapter 17. The requirements of NFPA 72 relate more to the performance and "how to" provisions rather than the "when required" type of rules.

States and local jurisdictions regulate CO detection through the incorporation by reference of codes and standards. They incorporate by reference either the NFPA 101, the IFC, or have specific statewide or local codes. In states where there is there is no statewide use of any code—the editions of the codes used and the means of enforcement vary, resulting in differing regulations across the US. This report summarized CO detector requirements based on state fire codes by occupancy type, the code that they have used, and the respective edition year. Further information about state regulations can be found in the Appendix.

A data collection effort on CO non-fire incidents was conducted in this report, and all available data from various sources has been consolidated and analyzed. These sources include but are not limited to the Centers for Disease Control and Prevention (CDC), the NFPA, the National Fire Incident Reporting System (NFIRS), the Consumer Product Safety Commission (CPSC), the Jenkins Foundation and others. While a significant amount of data was found, there are still several limitations to the available data. To complement the available data and account for its shortcomings, a case study review was also conducted of news stories. These data sources and news stories were analyzed to identify trends in CO incidents and the various factors that contribute to the CO problem.

Lastly, a limited set of literature on the health effects of CO poisoning was reviewed. It has been shown that CO poisoning has both short term and long-term effects. The short-term effects are hard to identity in the moment and quickly escalate from vague, trivial symptoms to severe and fatal symptoms. In the long-term, studies indicate that there are serious and permanent consequences to CO poisoning such as neuropsychological and cardiovascular complications.

1: Introduction

Carbon monoxide (CO) is a colorless and odorless gas that is a byproduct of combustion. CO intoxication can adversely affect health and even cause death. CO poisoning symptoms range from general fatigue or illness to death. Its early mild symptoms are often mistaken for other issues, making its detection difficult until victims become too impaired to help themselves or others which results in over 400 unintentional[5] deaths and over 50,000 hospitalizations[14] each year in the United States. Most of these CO incidents could be considered preventable through public education, warning labels on consumer products, and CO alarms; despite this problem's preventability, it persists in the US and around the world.

Requirements for installation of carbon monoxide (CO) detection into several types of occupancies (both new and existing) were first introduced in the 2012 editions of NFPA 101 *Life Safety Code* and NFPA 5000 *Building Construction and Safety Code*. Those requirements have since been expanded to include other occupancies for the subsequent editions, including the 2021 codes. For these codes, there is an underlying concern that questions if these requirements (both when and how required) are adequate, and if these regulations need to extend to other types of occupancies. The extent to which the requirements also need to expand into existing buildings (this would be applicable to NFPA 101 only) is also under discussion. The overall objective of this literature review effort is to provide insight on these concerns for the technical committees.

The research goal is to summarize the existing requirements for installation of CO detection devices through a literature review and a consolidation of all available and pertinent non-fire CO incident data. This is achieved through a summary of CO installation requirements from the 2021 editions of NFPA 101, NFPA 5000, and the 2018 editions of International Building Code (IBC), International Fire Code (IFC), the International Existing Building Code (IEBC), International Residence Code (IRC), and the International Property Maintenance Code (IPMC); a summary of the state fire codes for CO detection; consolidation of non-fire CO injury and death data; and lastly a review of the health effects of carbon monoxide poisoning.

This report is intended to assist the NFPA 101 and NFPA 5000 technical committees as they develop proposed changes for the 2024 editions. Additionally, this report will be helpful for 2024 editions of the International Code Council (ICC) codes.

This project involves the following tasks:

Task 1. Literature review of Codes & Standards: Conduct a literature review to summarize current requirements (when and how required) of installation of CO detectors for various occupancies in the 2021 editions of NFPA 101 and NFPA 5000; and 2018 editions of IBC, IFC and IEBC. Prepare a comparison chart of the requirements based on occupancy type or any other appropriate format. Identify occupancies that do not have CO requirements.

Task 2. Literature review of State regulations: Identify and summarize State fire codes for CO detection requirements in various occupancies. This should also include the amendment being proposed for the Federal Hotel and Motel Fire Safety Act.

Task 3. Data collection: Compile and consolidate non-fire CO incident injury and death data from publicly available sources such as NFPA, CDC, OSHA, CPSC and news articles into one place.

Task 4. Final report: Prepare a final report and finalize the report after reviewing with the project panel.

2: Review of NFPA and International Codes

Model Codes published by NFPA and the International Code Council (ICC) aim to provide guidelines to ensure public health and safety. The International Fire Code (IFC) addresses fire and fire-related hazards to life and property. The IFC provides the minimum regulations for fire, explosion, handling of hazardous materials and the use of occupancies. NFPA 101 (which coordinates with NFPA 1: *Fire Code*) addresses the minimum features of construction, protection and occupancy features necessary to protect people from dangers of fires. The Life Safety Code also considers other hazards due to non-fire emergencies. NFPA 5000 addresses the dangers to life and property by providing minimum regulations for permitting, design, construction, material quality, occupancy use and location, maintenance, and specific equipment. These three codes, all address carbon monoxide detection requirements.

This section provides a summary of the CO detection installation requirements for the various occupancies. Below, in table 1, the different model codes are listed at the top, while different occupancies are listed on the side to provide an easy comparison between the different codes. It is important to note that, the IBC, IEBC, and the IPMC refer to the IFC regarding CO requirements. Further, the NFPA codes have varying requirements for different occupancies while the IFC either applies its general requirement or it does not, which is why the table only displays it once.

Additionally, on table 1, a "^" symbol indicates that a requirement for an existing structure is the same requirement for a new structure; a "/" indicates that code does not mention a requirement for that occupancy.

The term "Fuel-Burning Appliance," (FBA) is a term often used in these codes and is clarified by the NFPA glossary definition: A device that burns solid, liquid, or gaseous fuel or a combination thereof. However, this is an NFPA-defined term and is not used in the international codes.

Table 1: Code CO Requirement Summary

Occupancy		NFPA 5000 (2021)	NFPA 101 (2021)	IFC (2021)
Assembly	New	Rooms containing fuel burning appliances/fireplaces, occupiable spaces served by fuel burning HVAC systems, spaces adjacent to garages; NOT required in in garages, spaces next to open/mechanically ventilated garages.	Rooms containing fuel burning appliances/fireplaces, occupiable spaces served by fuel burning HVAC systems, spaces adjacent to garages; NOT required in in garages, spaces next to open/mechanically ventilated garages.	/
	Existing	/	/	/
Educational	New	Rooms with fuel-burning sources, served by fuel burning HVAC system, or next to garage; NOT required in garage, spaces next to open parking structure, or mechanically ventilated garage	Rooms with fuel-burning sources, served by fuel burning HVAC system, or next to garage; NOT required in garage, spaces next to open parking structure, or mechanically ventilated garage	915.1-2
	Existing	/	/	^
Daycare	New	Sleeping units that are next to fuel burning equipment or enclosed parking structure	Sleeping units that are next to fuel burning equipment or enclosed parking structure	915.1-2
	Existing	/	/	^
Healthcare	New	Rooms containing fireplace	Rooms containing fireplace	915.1-2
	Existing	/	^	^
Detached One- and Two-Family Dwellings	New	Dwelling units with attached garage, or contains fuel burning equipment; detector shall be placed outside each sleeping room, each occupiable level; NOT required in garage, space next to open or mechanically ventilated garage	Dwelling units with attached garage, or contains fuel burning equipment; detector shall be placed outside each sleeping room, each occupiable level; NOT required in garage, space next to open or mechanically ventilated garage	R315.2 IRC
	Existing	/	/	^

Occupancy		NFPA 5000 (2021)	NFPA 101 (2021)	IFC (2021)
Lodging/Rooming	New	Any lodging/room that has attached garage or contains fuel burning equipment; detector outside each sleeping room, every occupiable level; NOT required in garage, in rooms attached to open/mechanically ventilated parking structure	Any lodging/room that has attached garage or contains fuel burning equipment; detector outside each sleeping room, every occupiable level; NOT required in garage, in rooms attached to open/mechanically ventilated parking structure	915.1-2
	Existing	/	/	^
Hotels/Dormitories	New	Guest rooms with attached garage, or containing fuel burning equipment; detector outside each sleeping area, every occupiable level; any room containing fuel burning equipment, spaces served by fuel burning HVAC system, space next to garage; NOT required in garage or space next to open/mechanically ventilated parking structure	Guest rooms with attached garage, or containing fuel burning equipment; detector outside each sleeping area, every occupiable level; any room containing fuel burning equipment, spaces served by fuel burning HVAC system, space next to garage; NOT required in garage or space next to open/mechanically ventilated parking structure	915.1-2
	Existing	/	^	^
Apartment Buildings	New	Units with attached garage or contains fuel burning equipment, detector for each sleeping area, every occupiable level, in the rooms containing fuel-burning equipment, served by fuel burning HVAC system, or space next to garage; NOT required in garage, space next open/mechanically ventilated	Units with attached garage or contains fuel burning equipment, detector for each sleeping area, every occupiable level, in the rooms containing fuel-burning equipment, served by fuel burning HVAC system, or space next to garage; NOT required in garage, space next open/mechanically ventilated	915.1-2
	Existing	/	/	^

Occupancy		NFPA 5000 (2021)	NFPA 101 (2021)	IFC (2021)
Residential Board and Care	New	With attached garage or contains fuel burning equipment, detector for each sleeping area, every occupiable level, in the rooms containing fuel-burning equipment, served by fuel burning HVAC system, or space next to garage; NOT required in garage, space next open/mechanically ventilated	With attached garage or contains fuel burning equipment, detector for each sleeping area, every occupiable level, in the rooms containing fuel-burning equipment, served by fuel burning HVAC system, or space next to garage; NOT required in garage, space next open/mechanically ventilated	915.1-2
	Existing	/	/	^
Mercantile	New	/	/	/
	Existing	/	/	/
Business Operations	New	/	/	/
	Existing	/	/	/
Industrial	New	/	/	/
	Existing	/	/	/
Detention/Correctional	New	/	/	/
	Existing	/	/	/
Ambulatory Healthcare	New	/	/	/
	Existing	/	/	/

**915.1-2*	*CO Detection required if:* 1. *dwelling/sleeping unit or classroom contains fuel burning equipment, is served by fuel burning HVAC system (unless alarm is present in first room served).* 2. *If fuel burning equipment is outside dwelling/sleeping unit or classroom; NOT required if there is no communicating opening, detector is already in approved location between equipment and unit, or if detector already in the room containing the equipment.* 3. *If there is attached garage, NOT required if no communicating garage, garage is one story away, connection is made via open-ended corridor, if detector is already present in garage, if garage is open/mechanically ventilated. - LOCATIONS OF DETECTOR: Outside each sleeping area, in sleeping area if contains fuel burning equipment, inside classrooms.*

Aside from the fact that NFPA 5000 only regulates new construction, the two NFPA codes and the IFC reviewed in the study have similar requirements. It can be noted that all three documents have regulations for the same occupancies, except assembly types, where IFC does not have any requirements. It can also be seen that all three tend to often not have requirements for garages, especially residential types. While the IBC, IEBC, IRC, and IPMC all reference the IFC for carbon monoxide detection requirements, there are some code specific exceptions that pertain to how CO detectors shall be installed and maintained. For example, the IEBC has a few exceptions for CO detection:

"**307.1 Carbon monoxide detection.** Where an addition, alteration, change of occupancy or relocation of a building is made to Group I-1, I-2, I-4 and R occupancies and classrooms of Group E occupancies, the existing building shall be provided with carbon monoxide detection in accordance with Section 1103.9 of the International Fire Code or Section R315 of the International Residential Code.

Exceptions:

1. Work involving the exterior surfaces of buildings, such as the replacement of roofing or siding, the addition or replacement of windows or doors, or the addition of porches or decks.
2. Installation, alteration, or repairs of plumbing or mechanical systems, other than fuel-burning appliances.
3. Work classified as Level 1 Alterations in accordance with Chapter 7."[22]

3: Review of State Fire CodeRegulations

Table 2 provides a summary of state fire code regulations regarding CO alarm installation. The table lists all the states and includes Washington D.C. on the left column, with the different occupancy types along the top. An “x” indicated that state has regulation to some degree for that occupancy. There are occupancy types that are not included in Table 2 as they aren’t regulated by any state, and certain occupancy types, such as assembly occupancies, that have had documented incidents and deaths, are shown to have very little regulation. The state fire code used, and their respective editions are also provided. States have one of the four conditions: IFC use, NFPA 1/101 use, state specific use, or no statewide use at all. States also have different editions of the respective codes, some as recent as 2018, and some being as dated as 2006, such as Hawaii. There is also an important caveat that while some states have a statewide fire code use, it does not necessarily mean it’s enforced statewide; some states allow local jurisdictions to make amendments or have their own regulations to be enforced. Also, it is important to note is that a majority of states have an incorporation by reference of some edition of the IFC. The Occupational Safety and Health Administration (OSHA) has their own CO limitation for workplaces (50 ppm over eight hours); however, they do not regulate the installation of CO detectors. The Federal Hotel and Motel Fire Safety Act of 1990 was an amendment to the Federal Fire Prevention and Control Act of 1974 to expand safety regulations for hotels and motels. There is another amendment currently being proposed to this to include CO detection requirements. It would require the installation of CO detectors and alarms in every hotel and motel room[48]. Table 2 provides a summary of the CO detector requirements based on the referenced state fire codes. It is important to note that CO detector requirements may be required by other state statutes and mandates which are not included in Table 2. In addition, Table 2 does not reference local amendments to the enforced fire codes.

During this review process, multiple online resources were identified that summarize CO detector requirements in state statutes. For additional information, we are providing a reference to the National Conference of State Legislatures (NCSL) as an online resource that can be utilized in addition to Table 2, to determine CO detector requirements from state statutes. This NCSL CO detector information was last updated in March 2018.

Table 2: State Fire Code CO Regulations by Occupancy

<u>Table labels:</u> N – New occupancy; E – Existing occupancy

				Assembly		Education		Daycare		Healthcare		Residential Home		Lodging/ Rooming		Hotels/ Dormitories		Apartment Buildings		Residential Board & Care	
State	**Incorporation by Reference**	**Edition**	**Enforcement/ Notes**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**
Alabama	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Alaska	International Fire Code (IFC)	2012	Statewide incorporation by reference, Local Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Arizona	International Fire Code (IFC)	2012 Statewide, 2018 (Most recent edition incorporated by reference by any jurisdiction)	*Local* incorporation by reference/*Enforcement*					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Arkansas	International Fire Code (IFC)	2012	Statewide incorporation by reference/Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X
California	International Fire Code (IFC)	2018	Statewide incorporation by reference, with possible local amendments that are more stringent; *local enforcement*			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Colorado	International Fire Code (IFC)	2018 (Most recent edition incorporated by reference by any jurisdiction)	*Statewide incorporation by reference, Local Enforcement*			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Connecticut	NFPA 101 - Life Safety Code	2015	Statewide incorporation by reference/Enforcement			X		X		X	X	X	X	X		X		X			
Delaware	NFPA 1 - Fire Code NFPA 101 - Life Safety Code	2015	*Local incorporation by reference/Enforcement*			X		X		X	X	X	X	X		X		X			
Florida	Florida Fire Prevention Code/ NFPA 1/101	2015	Statewide incorporation by reference and Enforcement			X		X		X	X	X	X	X		X		X			

				Assembly		Education		Daycare		Healthcare		Residential Home		Lodging/ Rooming		Hotels/ Dormitories		Apartment Buildings		Residential Board & Care	
State	**Incorporation by Reference**	**Edition**	**Enforcement/ Notes**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**
Georgia	International Fire Code (IFC)	2018	Statewide incorporation by reference, *Local Enforcement*			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hawaii	Hawaii Fire Code/NFPA 1	2006	*Local incorporation by reference/Enforcement*																		
Idaho	International Fire Code (IFC)	2015	Statewide incorporation by reference/Enforcement; possible local amendments that more stringent			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Illinois	NFPA 101 - Life Safety Code	2015	*Local incorporation by reference/Enforcement*			X		X		X	X	X	X	X		X		X			
Indiana	International Fire Code (IFC)	2012	Statewide incorporation by reference					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Iowa	International Fire Code (IFC)	2015	Statewide incorporation by reference/Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kansas	International Fire Code (IFC)	2006	*Statewide incorporation by reference/Enforcement; Local Jurisdiction Make own incorporation by reference/Enforcement*																		
Kentucky	International Fire Code (IFC)	2015	Statewide incorporation by reference/Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Louisiana	NFPA 101 - Life Safety Code	2015	Statewide incorporation by reference/Enforcement			X		X		X	X	X	X	X		X		X			
Maine	NFPA 1/101	2018	Statewide incorporation by reference, Local Enforcement	X		X		X		X	X	X	X	X		X		X		X	
Maryland	NFPA 1/101	2018	*Statewide incorporation by reference, Local jurisdictions can choose to incorporate by reference/enforce their own codes*	X		X		X		X	X	X	X	X		X		X		X	
Massachusetts	Massachusetts Fire Code 2017/NFPA 1/101	2015	Statewide incorporation by reference/Enforcement			X		X		X	X	X	X	X		X		X			
Michigan	International Fire Code (IFC)	2015	Statewide incorporation by reference; Local incorporation by reference/Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Minnesota	2020 Minnesota Fire Code/International Fire Code (IFC)	2018	Statewide incorporation by reference/Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mississippi	International Fire Code (IFC)	2015	Statewide incorporation by reference/Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Missouri	International Fire Code (IFC)	2015	Local incorporation by reference																		
Montana	International Fire Code (IFC) International Building Code (IBC)	2012	Statewide incorporation by reference /Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Nebraska	NFPA 101 - Life Safety Code	2000	Statewide incorporation by reference /Enforcement									X						X			
Nevada	International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
New Hampshire	NFPA 1	2015	Statewide incorporation by reference /Enforcement					X		X	X	X	X	X		X		X		X	
New Jersey	International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
New Mexico	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement; possible local amendments that more stringent			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
New York	2020 New York Fire Code/International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
North Carolina	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
North Dakota	International Fire Code (IFC)	2018	Statewide incorporation by reference ,Local amendments permitted			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X

				Assembly		Education		Daycare		Healthcare		Residential Home		Lodging/ Rooming		Hotels/ Dormitories		Apartment Buildings		Residential Board & Care	
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Ohio	2017 Ohio Fire Code/International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oklahoma	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oregon	Oregon Fire Code 2019/International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pennsylvania	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement; possible local amendments that more stringent			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rhode Island	NFPA 1	2015	Statewide incorporation by reference /Enforcement			X		X		X	X	X	X	X		X		X			
South Carolina	International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement; local amendments permitted			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
South Dakota	2018 South Carolina Fire Code/ International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement; local amendments permitted			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tennessee	International Fire Code (IFC)	2012	Statewide incorporation by reference /Enforcement, local incorporation by reference permitted					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Texas			*Local* incorporation by reference																		
Utah	International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vermont	NFPA 1/101	2015	Statewide incorporation by reference /Enforcement			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Virginia	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X
Washington	International Fire Code (IFC)	2018	Statewide incorporation by reference /Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X

				Assembly		Education		Daycare		Healthcare		Residential Home		Lodging/ Rooming		Hotels/ Dormitories		Apartment Buildings		Residential Board & Care	
State	**Incorporation by Reference**	**Edition**	**Enforcement/ Notes**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**	**N**	**E**
West Virginia	NFPA 1, NFPA 101 and International Building Code	2015	*Statewide* incorporation by reference, *up to local jurisdiction to enforce*			X		X		X	X	X	X	X		X		X			
Wisconsin	International Fire Code (IFC)	2015	Statewide incorporation by reference /Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Wyoming	International Fire Code (IFC)	2018	Statewide incorporation by reference, Local Enforcement			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
District of Columbia	International Fire Code (IFC)	2012	Statewide incorporation by reference /Enforcement					X	X	X	X	X	X	X	X	X	X	X	X	X	X

4: Review of Carbon Monoxide Non-Fire Incident Data

4.1: Centers for Disease Control and Prevention (CDC)

The CDC tracks carbon monoxide incident data through the National Environment Public Health Tracking Network. This resource tracks various public health data on a state-by-state basis. This report shows the information on non-fire, unintentional incident data. Maps show CO poisoning death rates, as well as annual average fatalities over two different time periods. Two death rates are displayed: crude death rate (CDR) and age-adjusted death rate (ADR). CDR is simply the number of deaths divided by the midyear population. The ADR is derived by multiplying age-specific death rates with their respective standard population shares. The purpose of utilizing an ADR is to account for the effects that age has on populations. These results are then summed and divided by the total population to produce an age adjusted death rate. The CDC also tracks non-fatal data, such as hospitalizations; however, these data sets are not included in this report as far too many states had an incomplete data collection, rendering the non-fatal statistics not useful for analysis.

There are a few details about this data that alters the context of the data. First, the numbers as they related to mortality are obtained from the National Vital Statistics System which collects mortality data from the US for any and all causes, which is then filtered to carbon monoxide poisoning. CO poisoning deaths were then filtered again to non-fire related and unintentional. There is data that pertains to fire related as well as unknown mechanism or intent. The fact there is data associated with unknown details that are filtered out implies that the numbers are actually larger. Lastly, there are some states that are labeled as “suppressed,” this simply refers to the fact the number is small enough that it is hidden to help ensure the confidentiality of the people that are a part of that statistic.

Not shown:
Alaska-0.57,
Hawaii-Suppressed

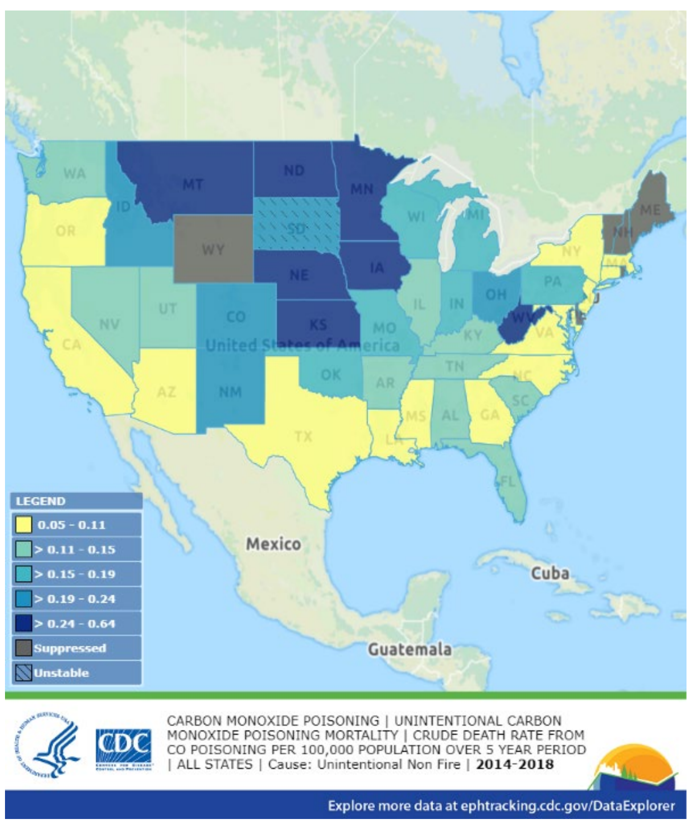

Figure 1: Crude Death Rate per 100,000 (2014-2018)[5] - Data Courtesy: CDC 2020

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Alaska-0.57,
Hawaii-Suppressed

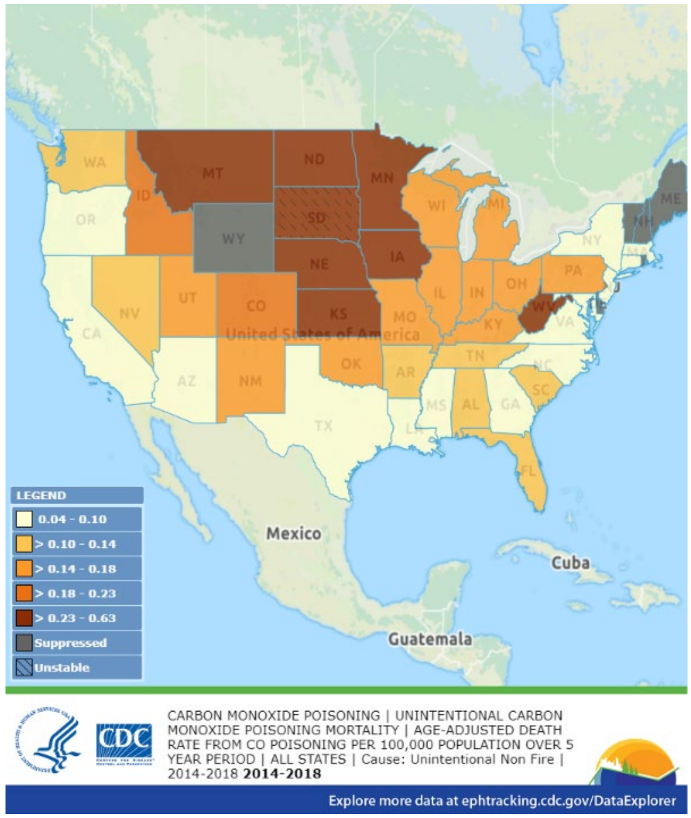

Figure 2: Age Adjusted Death Rate per 100,000 (2014-2018)[5] – Data Courtesy: CDC 2020

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Hawaii-Suppressed

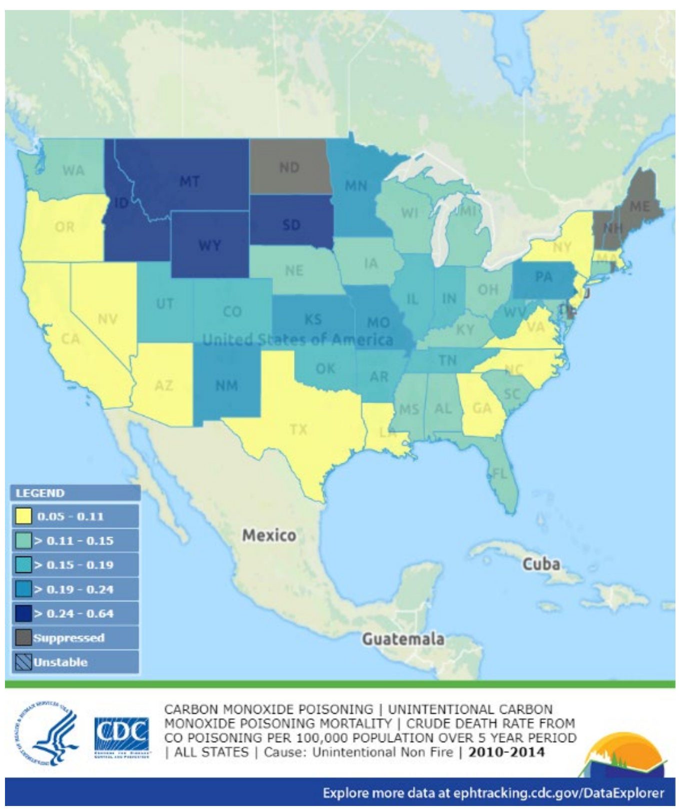

Figure 3: Crude Death Rate per 100,000 (2010-2014)[5] - Data Courtesy: CDC 2020

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Alaska-0.45,
Hawaii-Suppressed

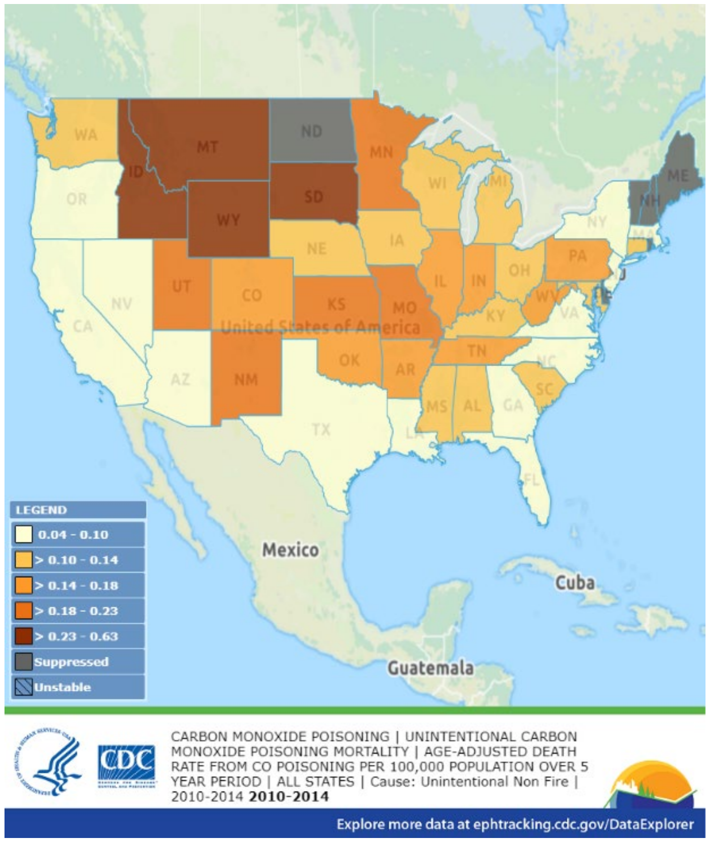

Figure 4: Age Adjusted Death Rate per 100,00 (2010-2014) [5] - Data Courtesy: CDC 2020

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Alaska-4, Hawaii-
Suppressed

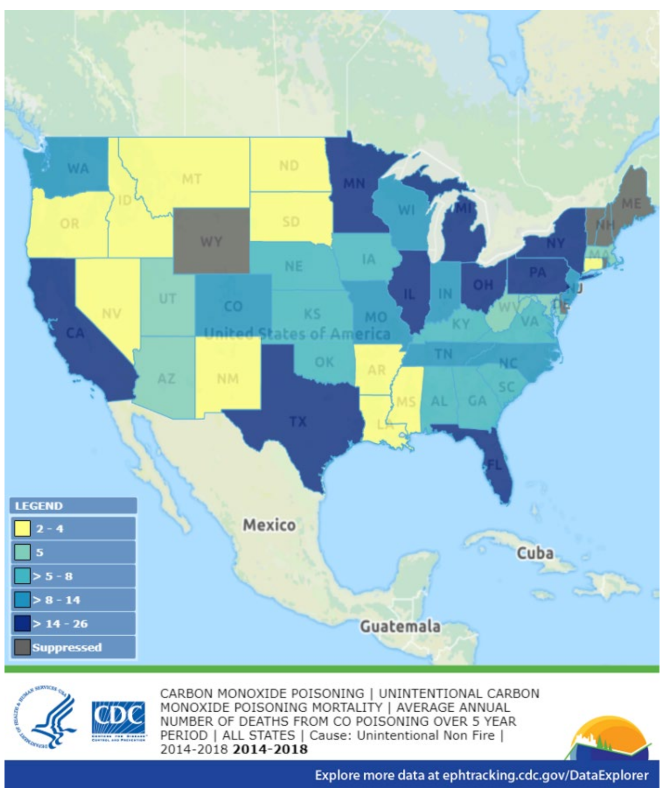

Figure 5: Average Annual Deaths (2014-2018) [5] - Data Courtesy: CDC 2020

Not shown:
Alaska-0.3, Hawaii-Suppressed

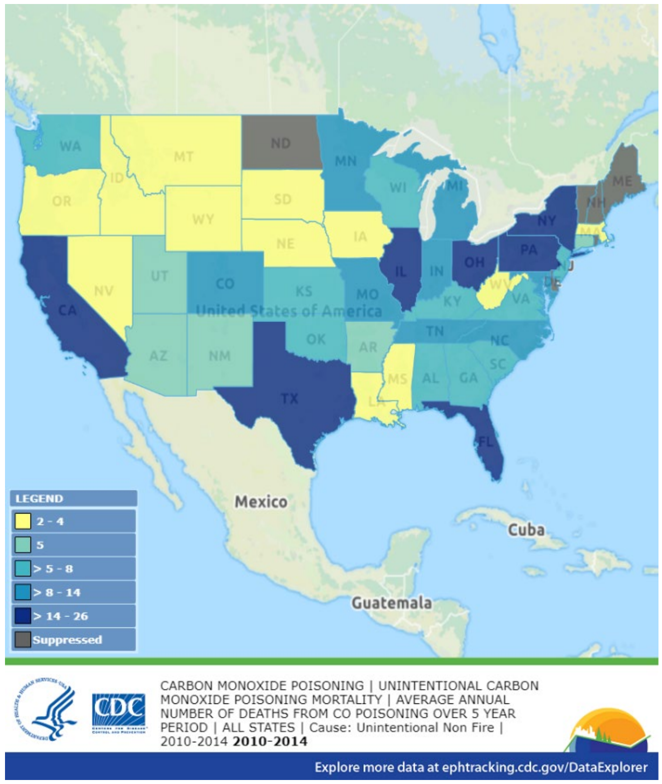

Figure 6: Average Annual Death Rate (2010-2014)[5] - Data Courtesy: CDC 2020

From these maps, it appears that generally midwestern states and states with higher populations tend to have more issues with carbon monoxide incidents. Across the entire United States, there are more than 400 unintentional, non-fire CO poisoning deaths[5], and more than 50,000 hospitalizations each year[14].

4.2: National Fire Protection Association (NFPA)

The NFPA prepares a variety of data reports for public health purposes, one[1] of which summarizes unintentional non-fire CO poisoning deaths in the US. The data referenced in figures 7 and 8 are compiled from the Centers for Disease Control and Prevention, National Center for Health Statistics, which upkeeps the CDC WONDER database. The specific database titled *Multiple Cause of Death, 1999-2017*, comprises of population and mortality counts for all US counties. The deaths are based off the death certificates of US residents. This data set was filtered for carbon monoxide poisoning.

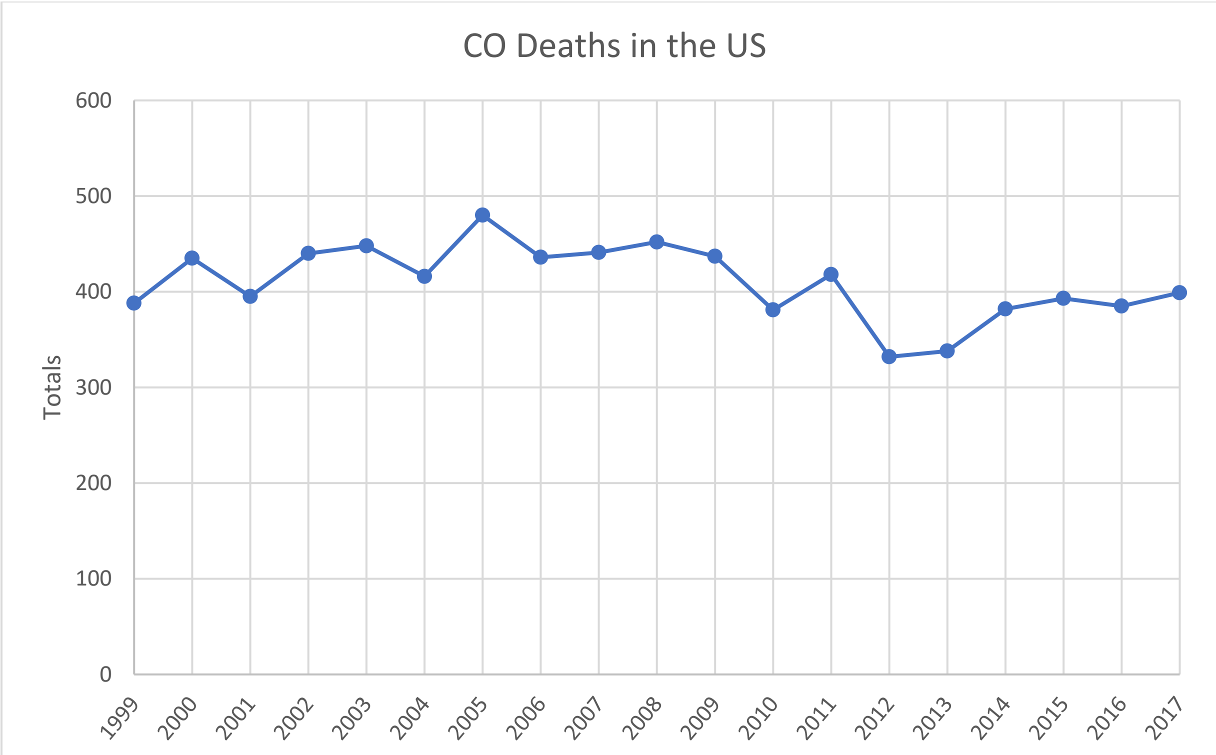

Figure 7: US CO Poisoning Deaths by Year[1] - Data Courtesy: Ahrens 2020

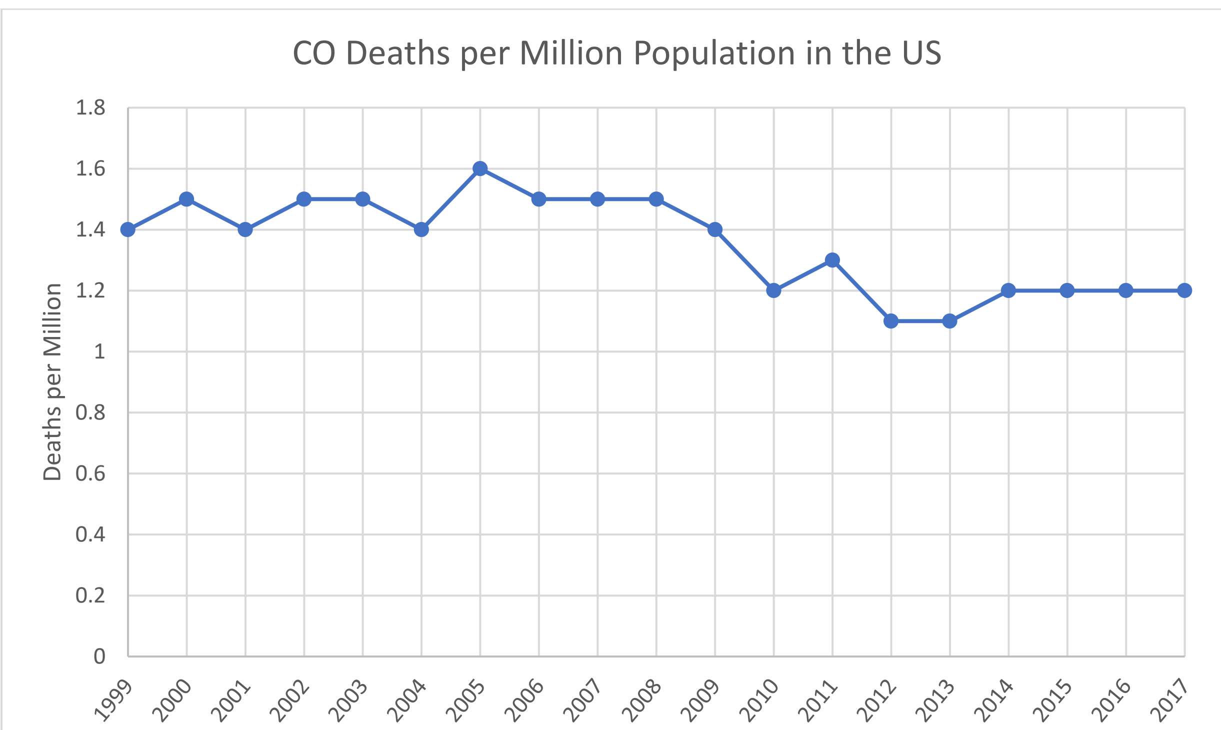

Figure 8: US CO Age Adjusted Death Rate per Million by Year[1] - Data Courtesy: Ahrens 2020

It is seen that the fatality totals have remained fairly consistent over the past two decades, however, considering the continual rising population in the US, this is a positive sign. This can be seen in figure 8 as the death rate per million has been on a gradual decline since the late 2000s. However, the death rate drop is not very dramatic; this could be attributed to the fact that although safety codes have continually included new and safer regulations, it takes considerable time for them to become incorporated by reference and used in state laws. While some states have incorporations by reference of 2018 editions of either the NFPA or International codes, there are also many states still using older versions, and then some states do not have state-wide mandates at all.

4.3: National Fire Incident Reporting System (NFIRS)

NFIRS collects information from first responders to document their response. This is accomplished through a NFIRS report (see Appendix) that is completed after the event. NFIRS separates different types of incidents through a section on the NFIRS report titled "Incident type". The following data was retrieved by filtering for incident type 424 – "Carbon Monoxide Incident. Excludes incidents with nothing found (736 or 746)."[10] An incident pertains to non-fire case where injuries or death were the result of carbon monoxide, or a CO event where first responders were needed.

It should be noted that NFIRS reports are typically related to fire-related incidents, when the incident is non-fire related, responders use the "basic module," which captures mostly dispatch information and actions taken by the first responders. The civilian casualty field is only utilized when fires are involved. Further valuable information involving CO incidents such as the source, parts per million levels, the number of people with symptoms and injuries (and the extent of those symptoms and injuries) or killed are not submitted to NFIRS. Collecting any such information is left up to the local departments should they choose to record it, thus, this data source that is typically reliable and extensive for incident data is very limited. Lastly, it is important to understand that the 424-incident code is also sometimes mistakenly used for CO false alarm incidents; it is known that some of the CO incidents in this data set contains events where nothing was found. This is the result of a discrepancy between the NFIRS Complete Reference Guide (CRG), and the Data Dictionary. The data dictionary is one of the excerpts from the CRG that contains incident-type codes and made to be more easily searchable than the CRG. The Data Dictionary does not mention the exclusion of incidents when no CO is found. [31]

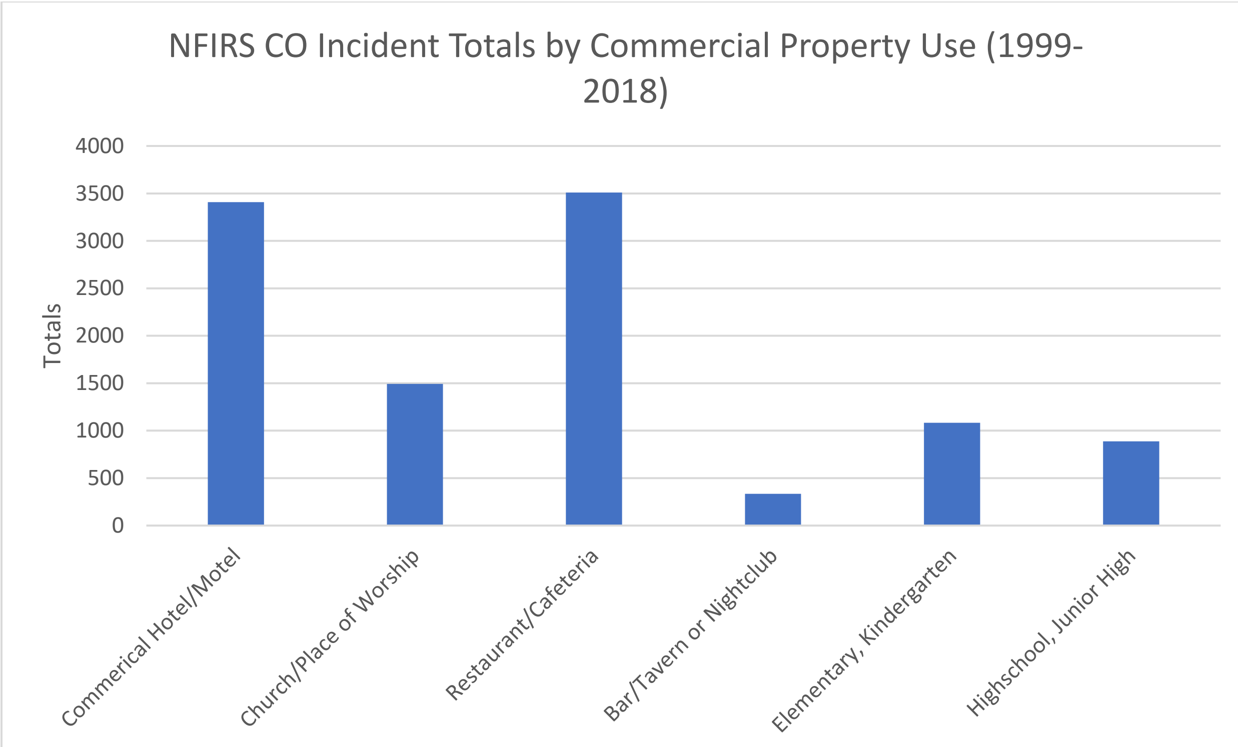

Figure 9: NFIRS CO Incident Totals in Commercial Occupancies (1999-2018)[34]- Data Courtesy: NFIRS 2020

Figure 9 demonstrates how CO incidents can occur in a variety of occupancies. Codes tend to focus on residential, institutional and educational occupancies. Restaurants and cafeterias have the most incidents and they would fall under the assembly occupancy type, which the IFC does not regulate, unlike the NFPA codes. However, this data compares just the totals from the different occupancies, without considering the number of buildings within each occupancy type, therefore not comparing the respective frequencies of CO incidents.

4.4: Hotel Residential Occupancies

The Jenkins Foundation[50] is a nonprofit organization that is dedicated to prevention of death and injury resulting from CO poisoning. This organization tracks and records all CO incidents in commercial hotels and motels. The first incident was recorded in this database in 1967 and has been kept up to date ever since. Below is an analysis of this data.

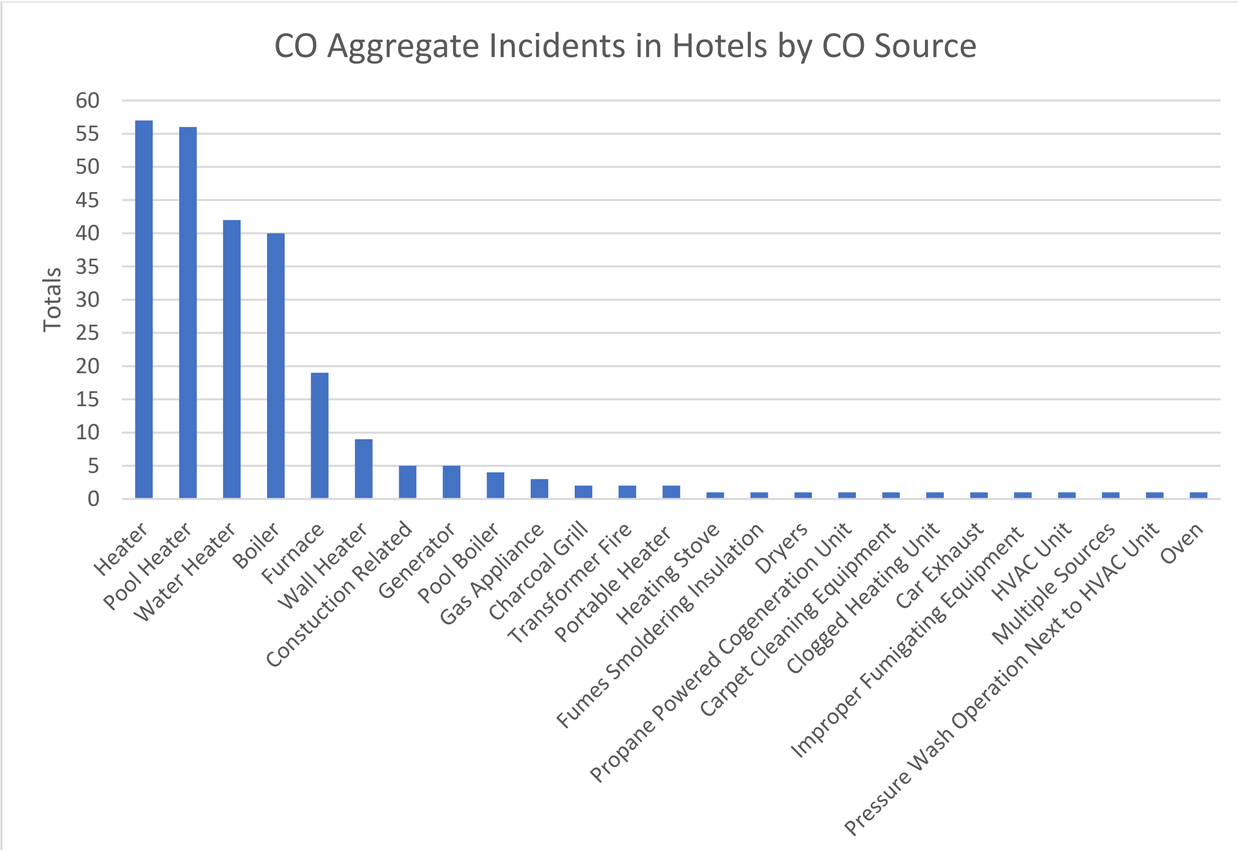

Figure 10: CO Aggregate Incidents in Hotels by Source[12,50,54]- Data Courtesy: The Jenkins Foundation 2020

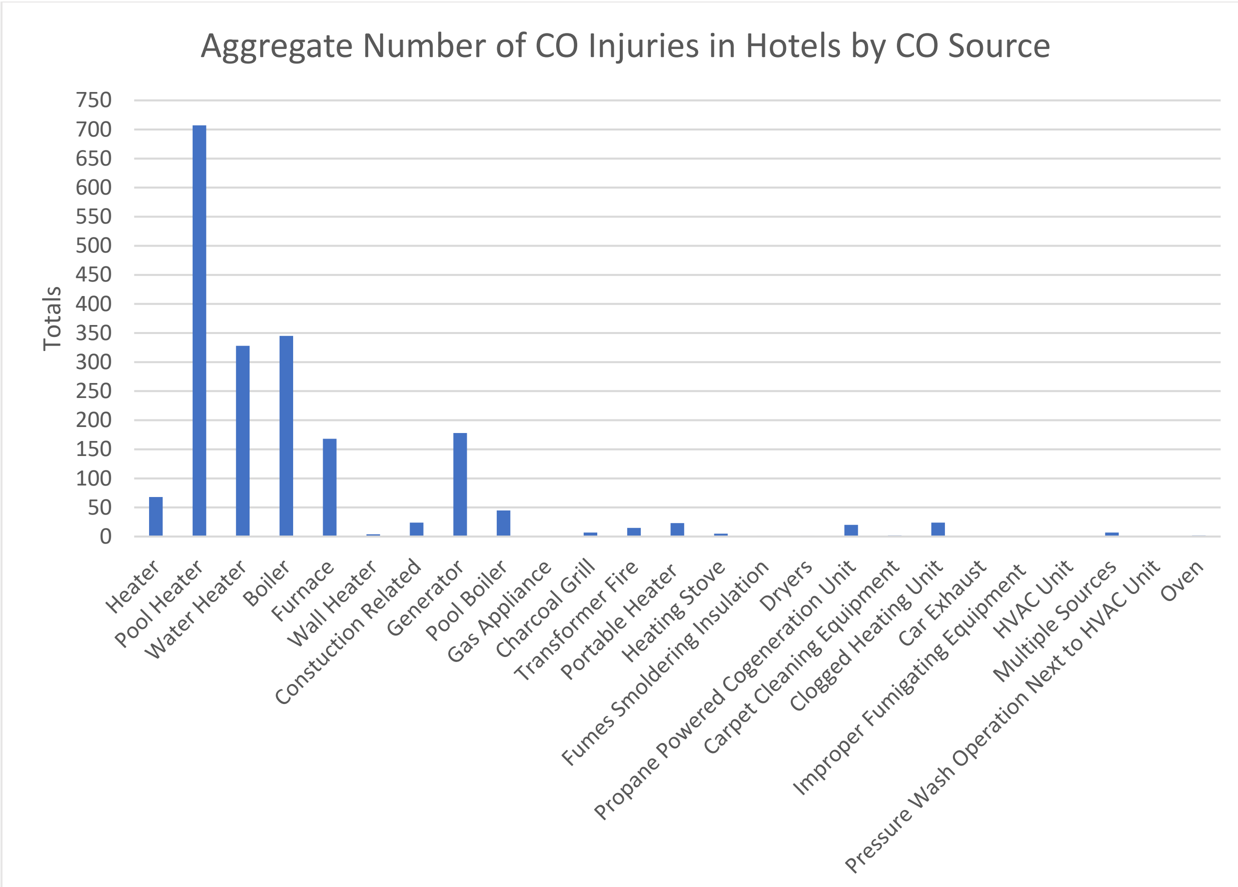

Figure 11: Aggregate Number of CO Injuries in Hotels by Source[12,50,54]- Data Courtesy: The Jenkins Foundation 2020

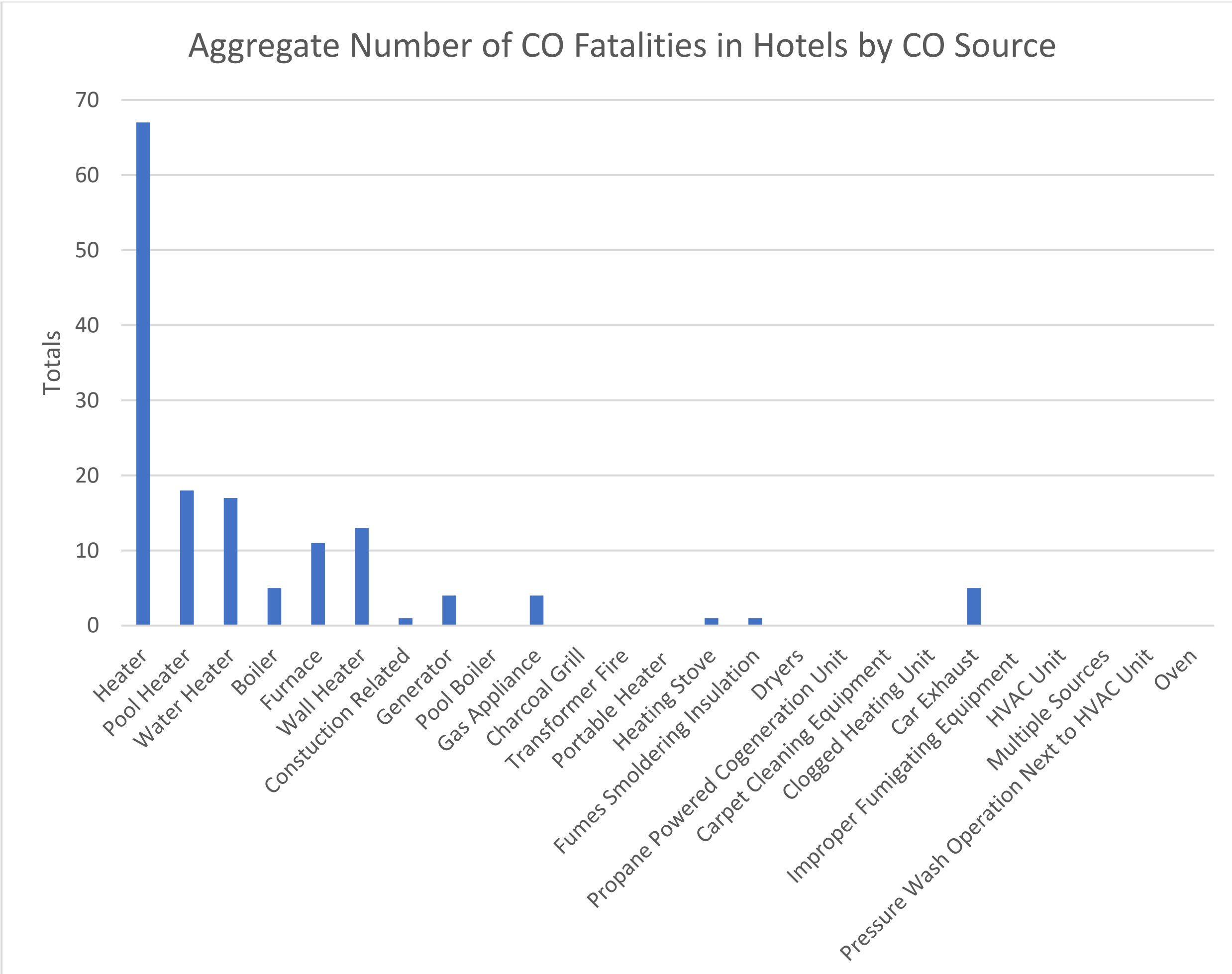

Figure 12: Aggregate Number of CO Fatalities in Hotels by CO Source[12,50,54]- Data Courtesy: The Jenkins Foundation 2020

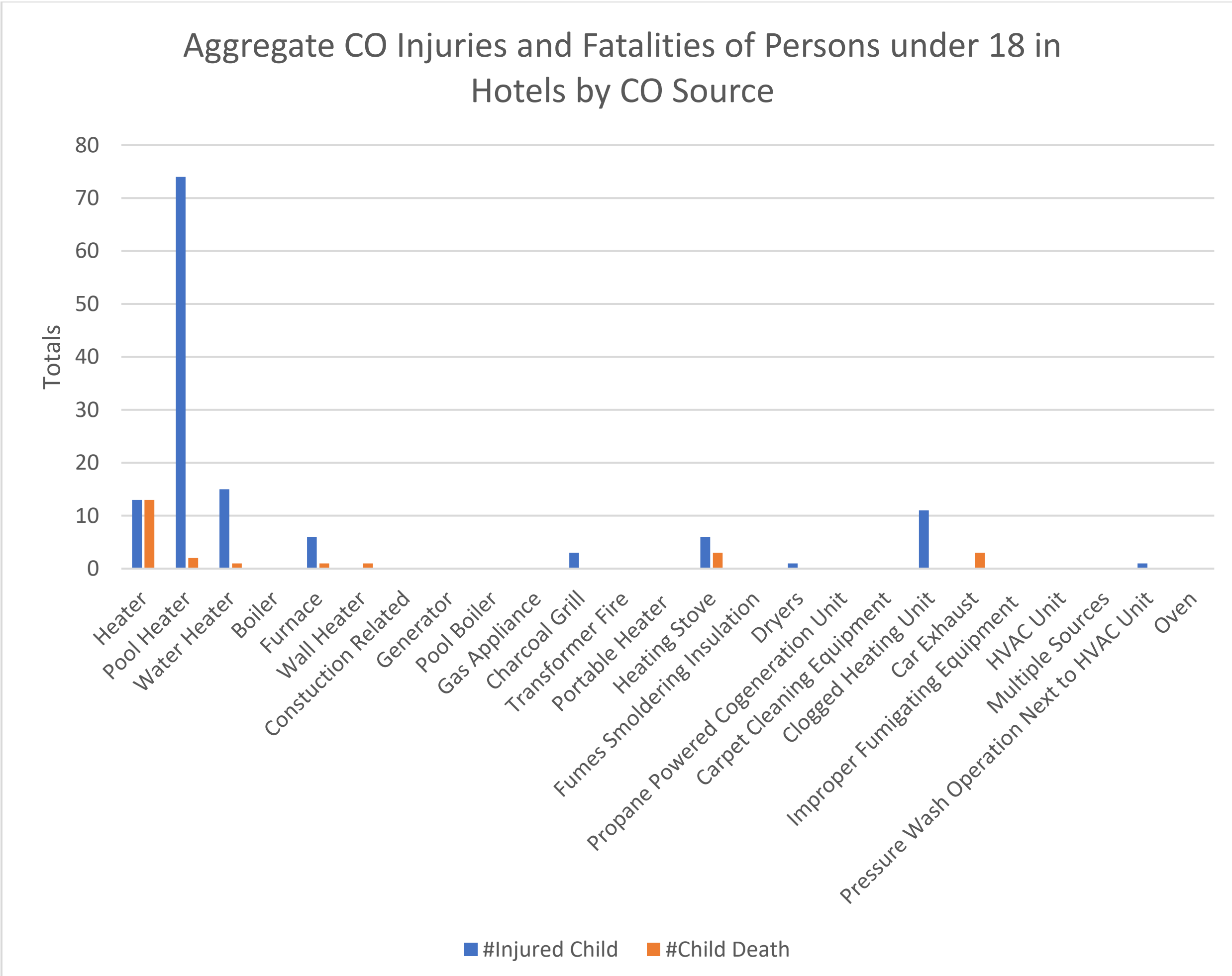

Figure 13: Aggregate CO Injuries and Fatalities of Person under 18 in Hotels[12,50,54]- Data Courtesy: The Jenkins Foundation 2020

Since 1967, it is clear that there have been a variety of CO sources responsible for incidents; however, CO sources that fall under the permanent FBA definition are found to be the main problem. Portable heaters are not included in the permanent FBA definition. Also, faulty exhaust system ductwork and equipment plays a role. This can result in CO leaks that affect areas far from the fuel burning CO source. Aside from the sources that cause a lot of incidents, it is important to note that some sources can have few incident totals, but then have disproportionate injury/fatality numbers.

4.4: Consumer Product Safety Commission (CPSC)

The following data that is analyzed below is extracted from reports prepared by the CPSC. This data refers to CO incidents as a result of consumer products, of which the vast majority of these incidents occurred in residential occupancies. As this is from CPSC reports, no data that falls outside of the CPSC's jurisdiction was collected, such as incidents that are related to vehicle exhaust, or occupational hazards. Further, incidents that are related to integral generators are also excluded, such as an RV or boat generator that was built into the vehicle by the manufacturer. As with previous data, these CO incidents are non-fire, and unintentional.

4.4.1: CO Incidents associated with all Consumer Products

The analysis in this subsection is based off of a report done in 2019[19], which collected data starting in 2006 and continuing until 2016. It should be noted that this report indicated that its 2016 data was not complete, so the numbers related to that year are likely larger. When CO sources are listed, incidents related specifically to generators will not be shown. This is a result of generator incidents being compiled into the umbrella category of "engine-driven tools" (EDTs). Generators make up the majority of the EDT incidents. Generators and other EDTs are further analyzed in the subsection, 4.4.2. It should be noted that while this data collection spanned the years of 2006-2016, annual averages were calculated with data only from the years of 2014-2016.

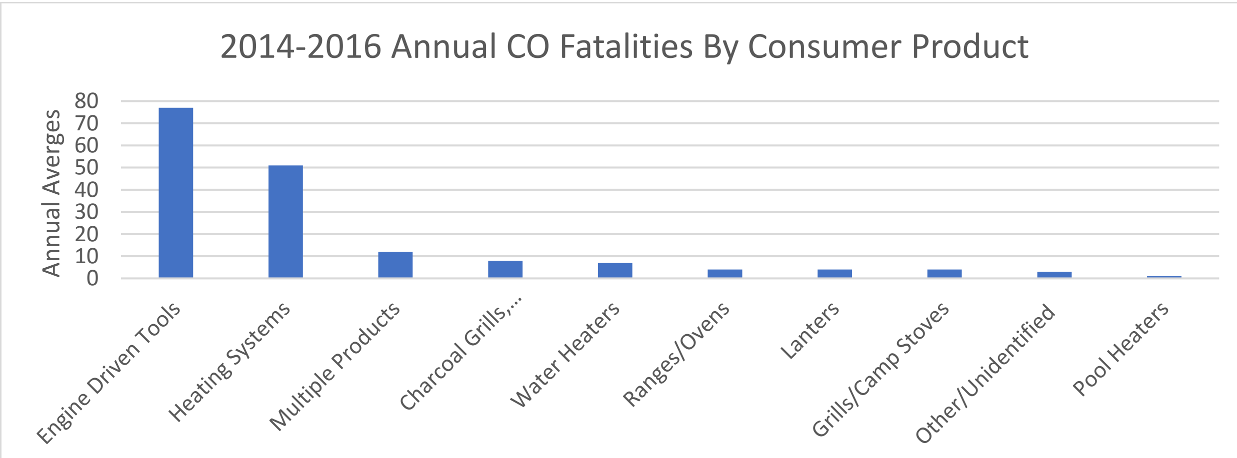

Figure 14: 2014-2016 Annual CO Fatalities by Consumer Product[19] - Data Courtesy: Hnatov 2019

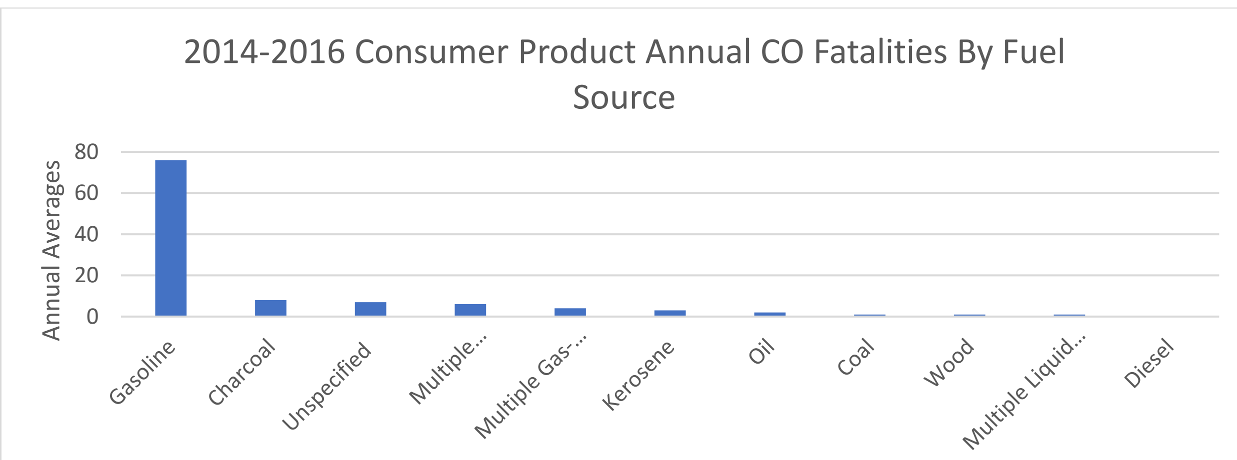

Figure 15: 2014-2016 Consumer Product Annual CO Fatalities by Fuel Source[19] - Data Courtesy: Hnatov 2019

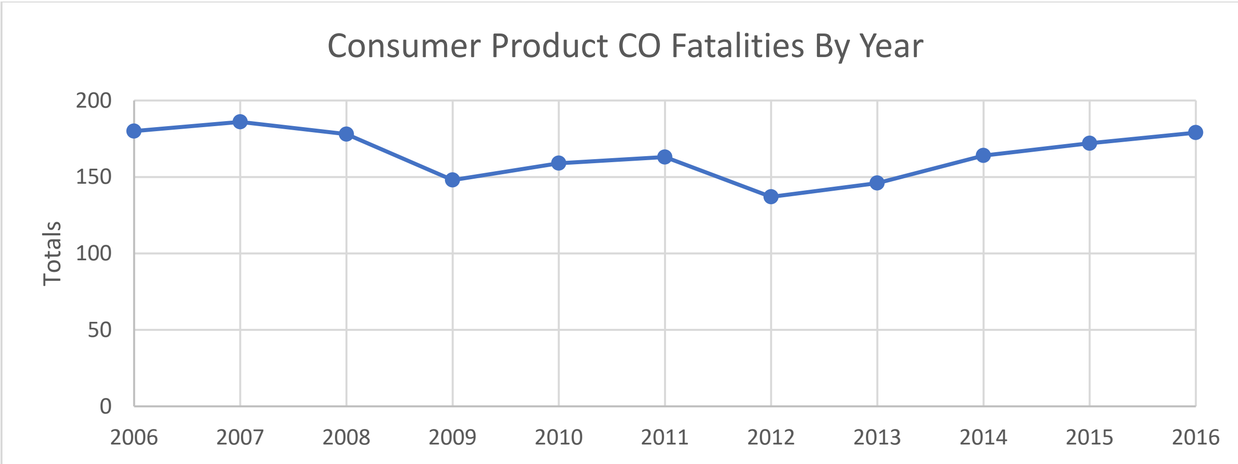

Figure 16: Consumer Product CO Fatalities by Year[19] - Data Courtesy: Hnatov 2019

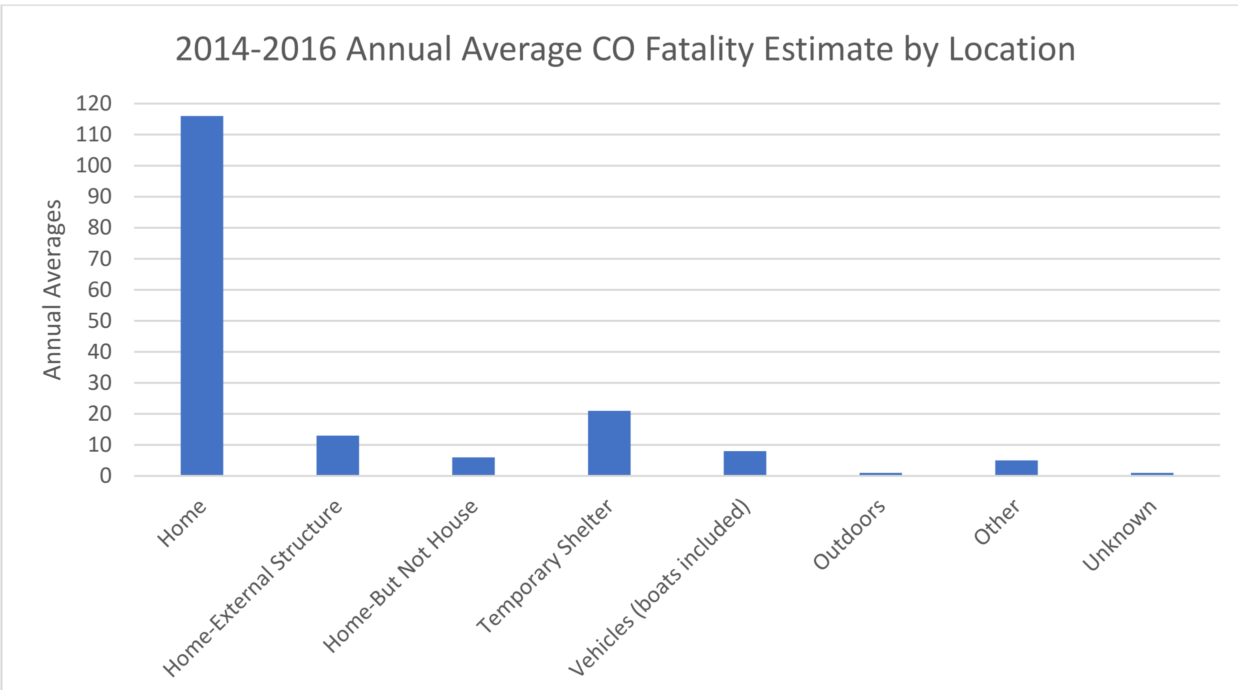

Figure 17: 2014-2016 Annual Average CO Fatality Estimate by Location[19] - Data Courtesy: Hnatov 2019

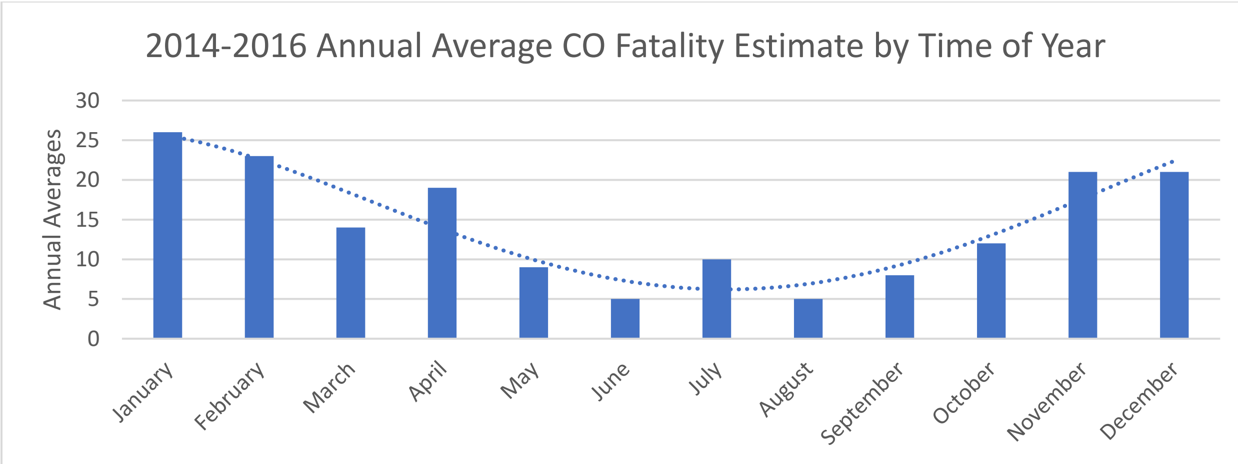

Figure 18: 2014-2016 Annual Average Fatality Estimate by Time of Year[19] - *Data Courtesy: Hnatov 2019*

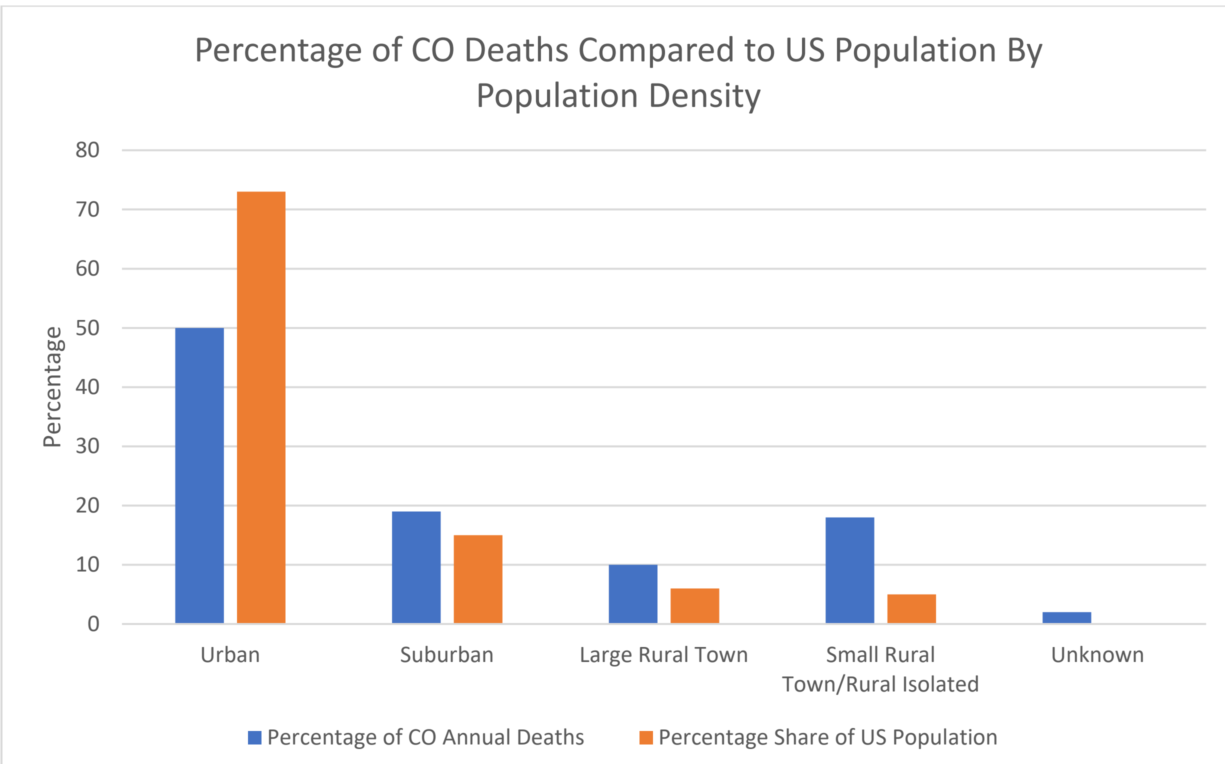

Figure 19: Percentage of CO Deaths Compared to US Population by Population Density [19] *- Data Courtesy: Hnatov 2019*

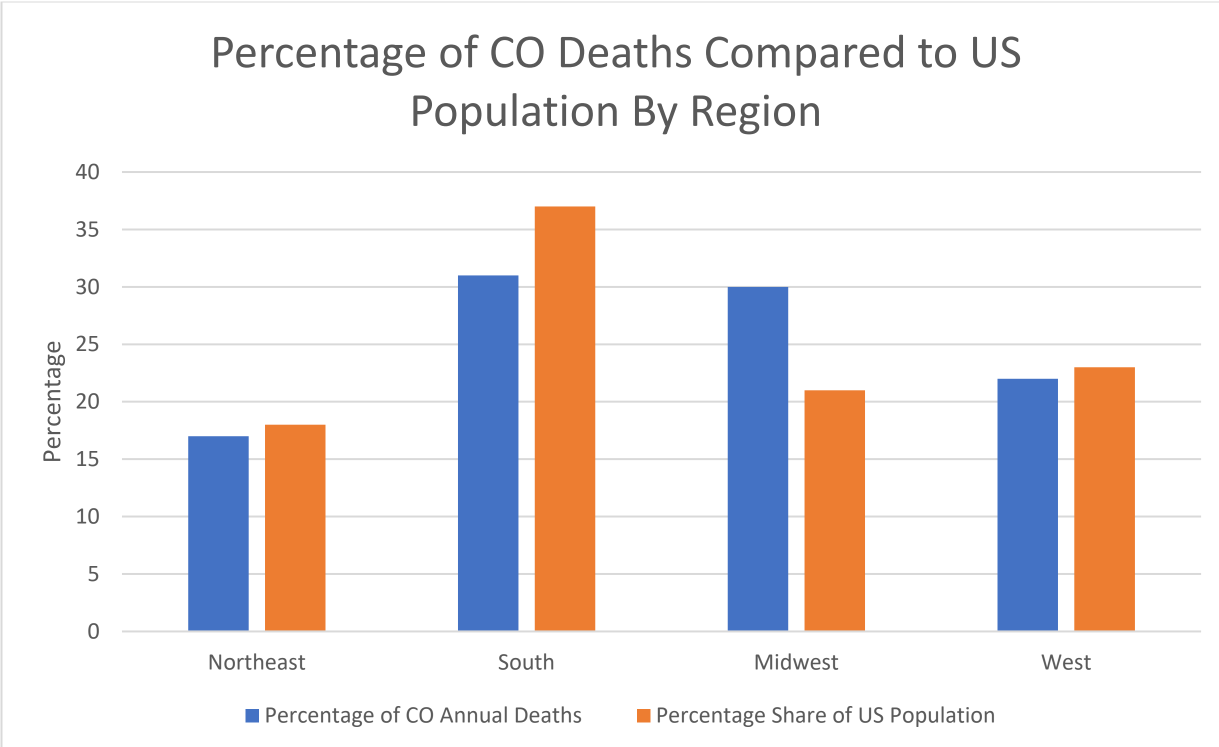

Figure 20: Percentage of CO Deaths Compared to US Population by Region[19] - Data Courtesy: Hnatov 2019

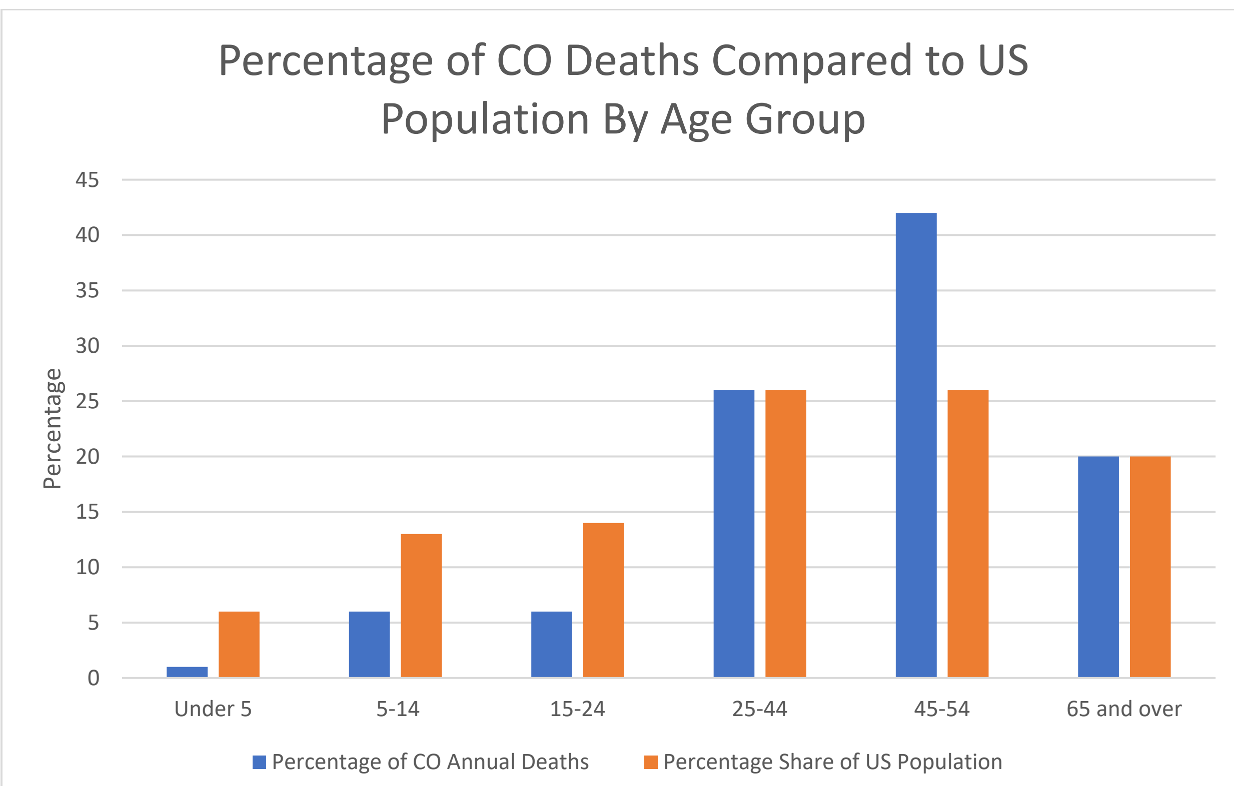

Figure 21: Percentage of CO Deaths Compared to US Population by Age Group[19] - Data Courtesy: Hnatov 2019

Although EDTs are the largest contributor to consumer product incidents, which is explained in the next section, from figures 14-21, the following conclusions can also be made. Aside from EDTs, heating systems are also a major factor in this problem. Gasoline as a fuel source has the most associated CO incidents by a significant margin. CO poisoning fatalities from consumer products have been very consistent over the past decade, with most incidents occurring in the colder months of the year. This is likely due to the increased use of heating systems during the winter. Lastly, when comparing against the US population shares, non-urban areas, the Midwest, and 45-54-year-olds have disproportionately large fatality numbers.

A significant portion of these incidents involve fuel burning appliances, particularly heating systems, that utilize ductwork and exhaust systems. These incidents are important to note as faulty ductwork and equipment can be the cause of CO build-up or be the means of travel for CO to affect many areas of a building that are not necessarily close to original CO source. These systems have several different failure modes, including disconnected vents, (partially) blocked vents, over-fired appliances, and inadequate combustion air. The CPSC has investigated these types of CO incidents, and in 2015, they have proposed regulations to the American National Standards Institute (ANSI) to minimize these types of incidents. The CPSC proposes that for gas furnaces and boilers:

1. Limit CO emissions to 0.04% or limit combustion conditions that result in CO emissions at or more than 0.04%
2. Shut off appliance in response to CO emissions hit 0.04% or combustions conditions that result in CO emissions at or more than 0.04%
3. Modulate appliance to reduce CO emissions in response to CO emissions hit 0.04% or combustions conditions that result in CO emissions at or more than 0.04%.

While improvement in this standard is helpful, these standards, and any further changes to them are still voluntary standards, making them recommendations rather than rules[6].

4.4.2 CO Incidents Associated with Engine Driven Tools

This section contains a similar data analysis[18] as the previous subsection but focuses strictly on generators and other EDTs. However, the timeline for the following data ranges from 2008 to 2018. The CPSC indicated that their data collection for the years of 2017 and 2018 is incomplete, so it is likely that actual incident numbers for these years are larger.

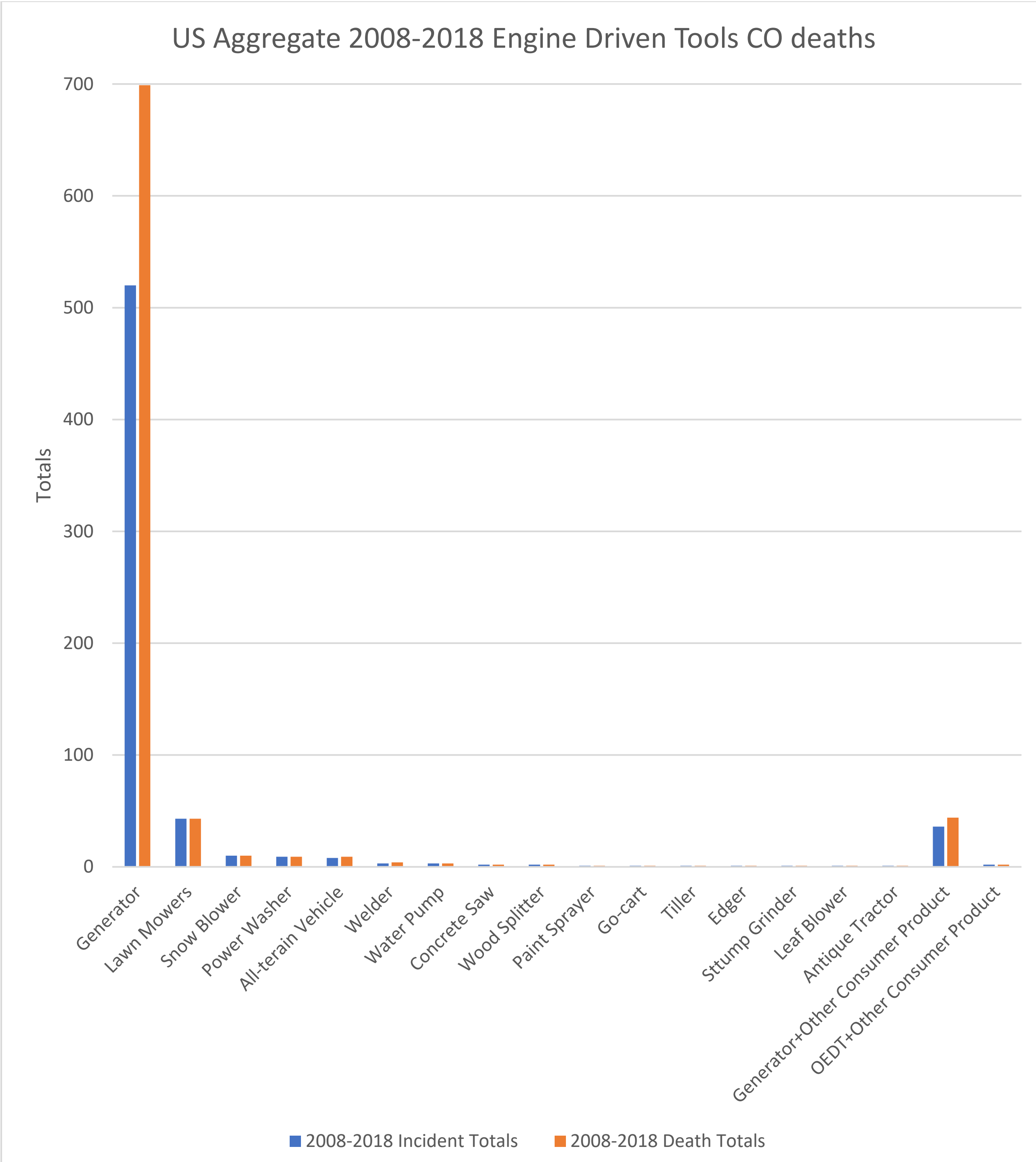

Figure 22: US Aggregate 2008-2018 Engine Driven Tools CO deaths[18] - Data Courtesy: Hnatov 2019

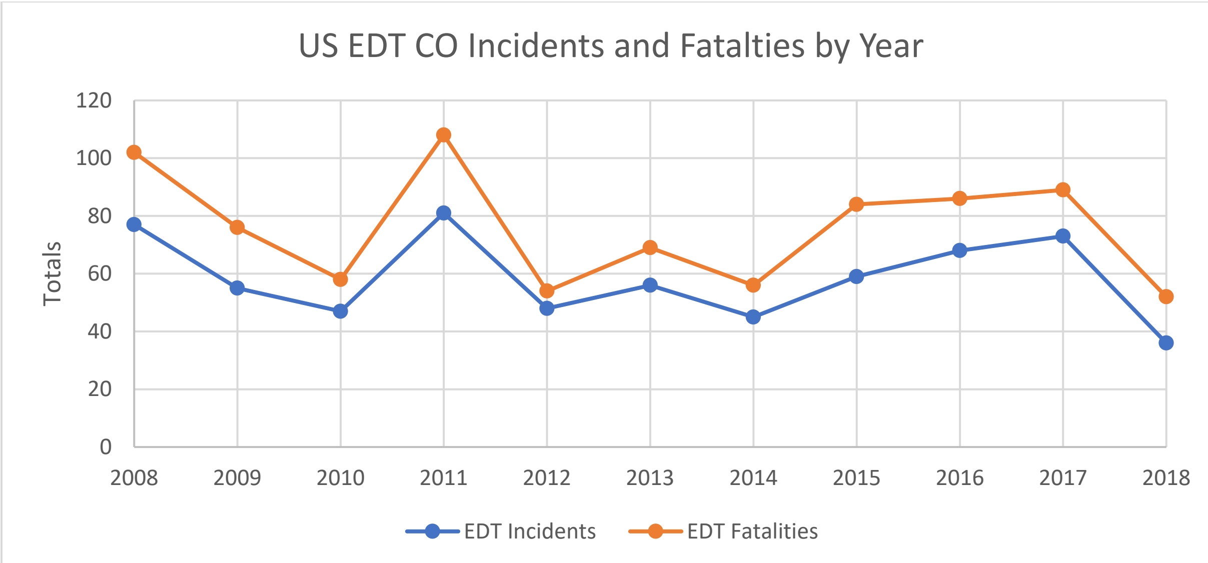

Figure 23: US EDT Incidents and Fatalities by Year[18] - Data Courtesy Hnatov 2019

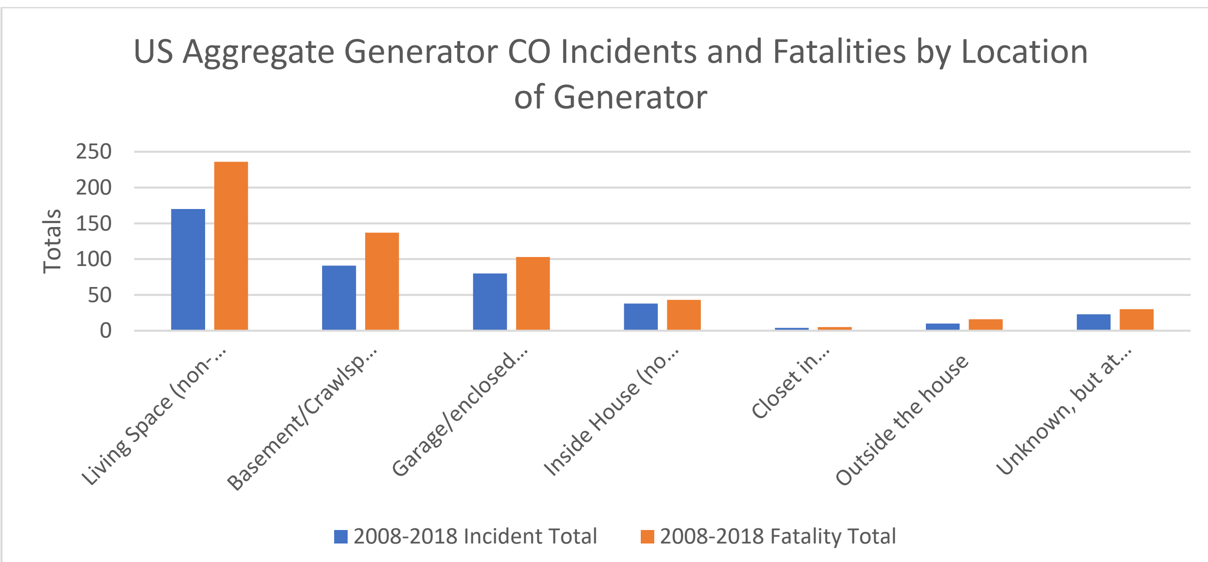

Figure 24: US Aggregate Generator CO Incidents and Fatalities by Location of Generator[18] - Data Courtesy: Hnatov 2019

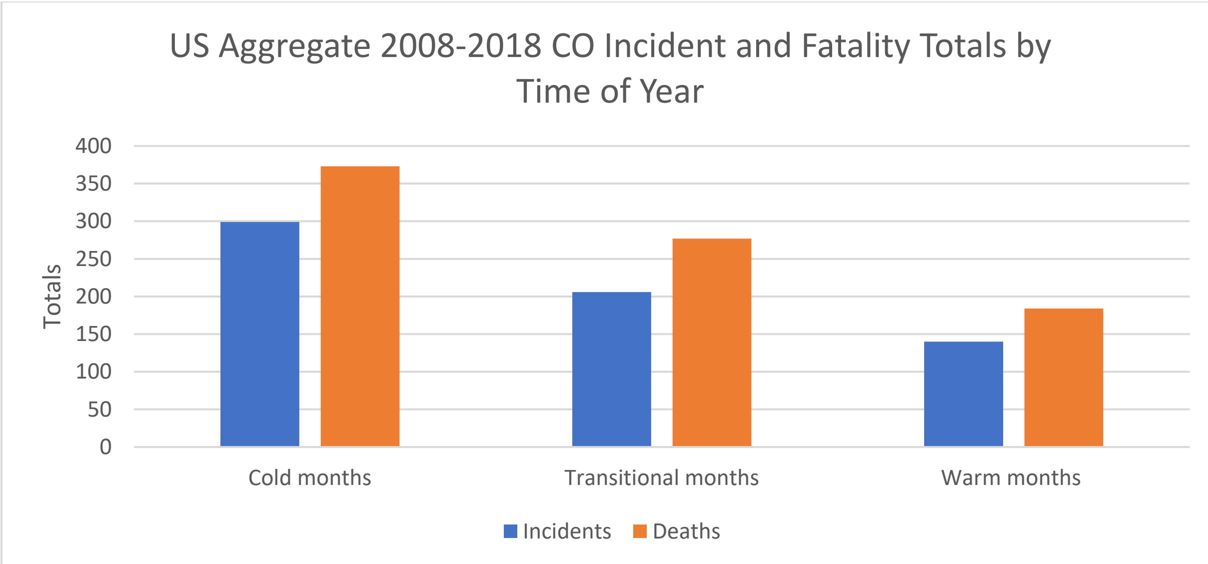

Figure 25: US Aggregate 2008-2018 CO Incident and Fatality Totals by Time of Year[18] - Data Courtesy: Hnatov 2019

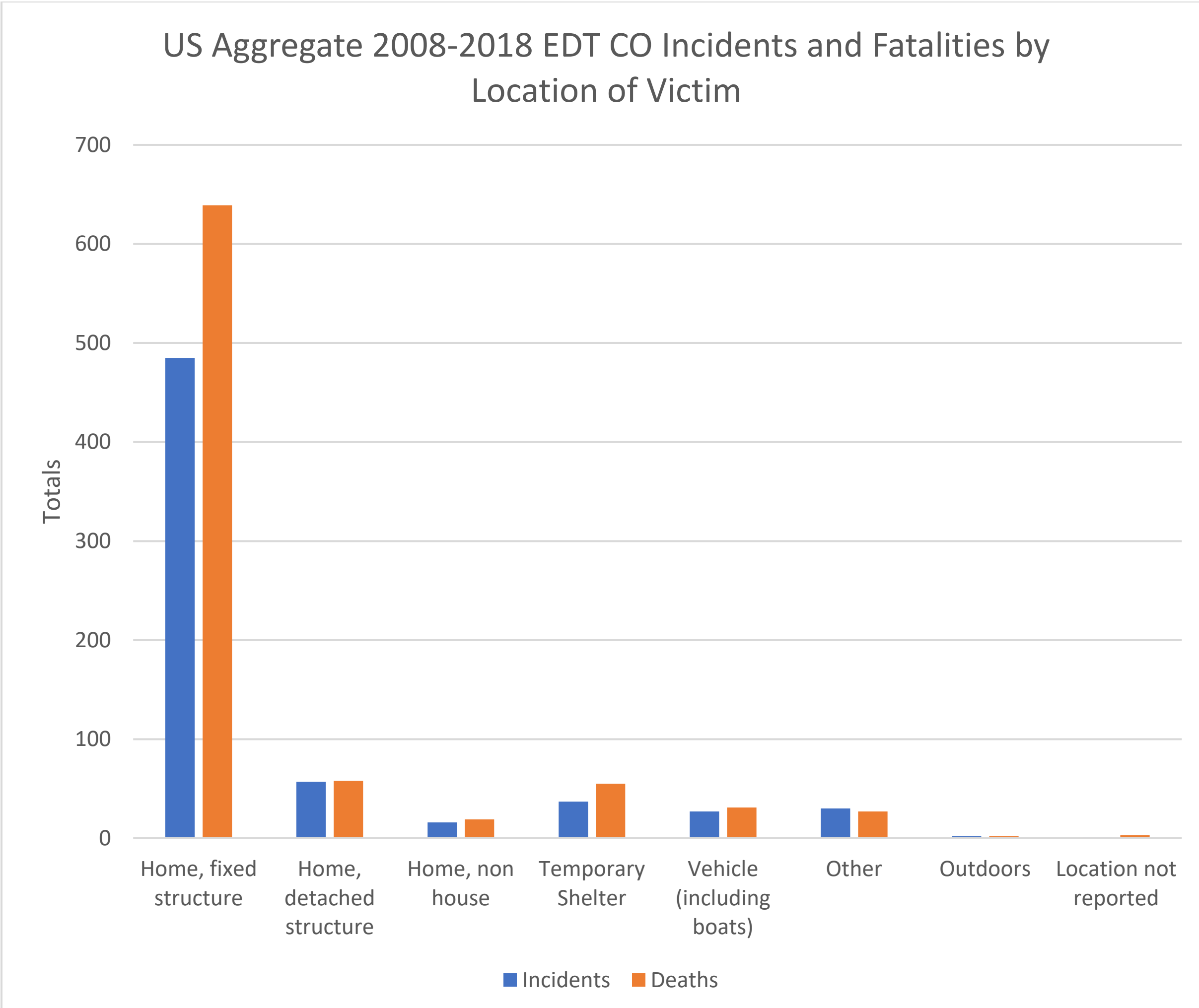

Figure 26: US Aggregate 2008-2018 EDT CO Incidents and Fatalities by Location of Victim[18] *- Data Courtesy: Hnatov 2019*

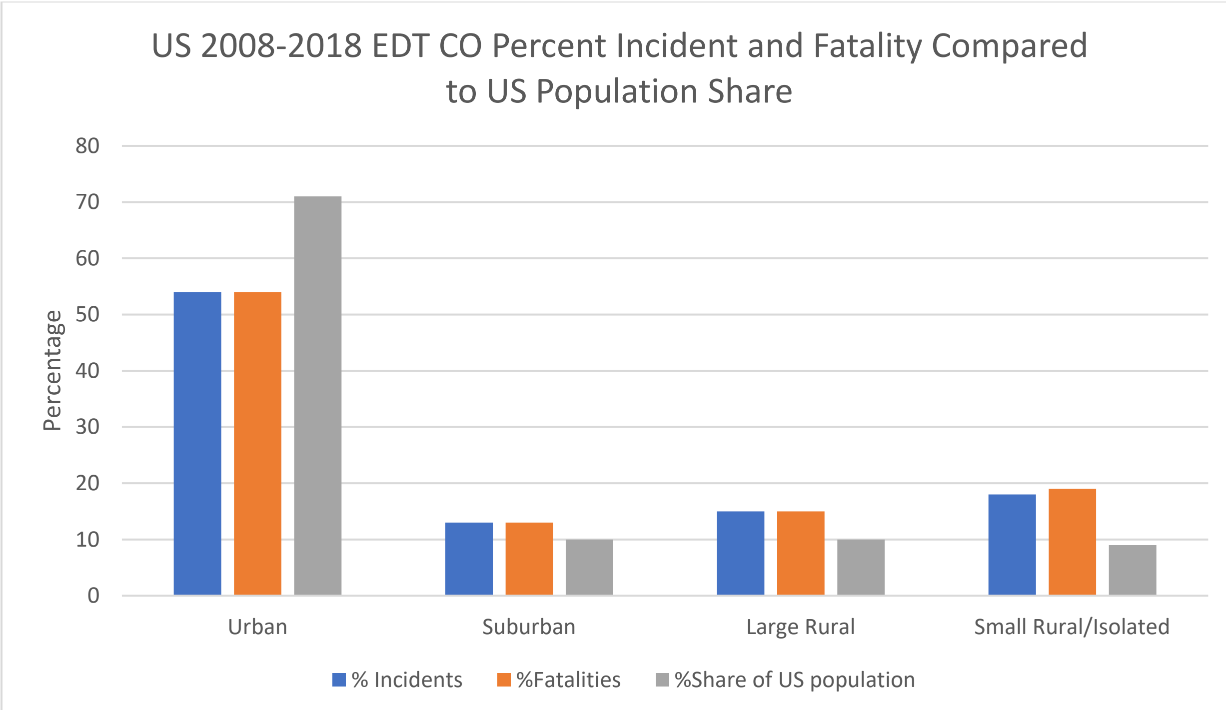

Figure 27: US 2008-2018 EDT CO Percent Incident and Fatality Compared to US Population Share[18] - Data Courtesy: Hnatov 2019

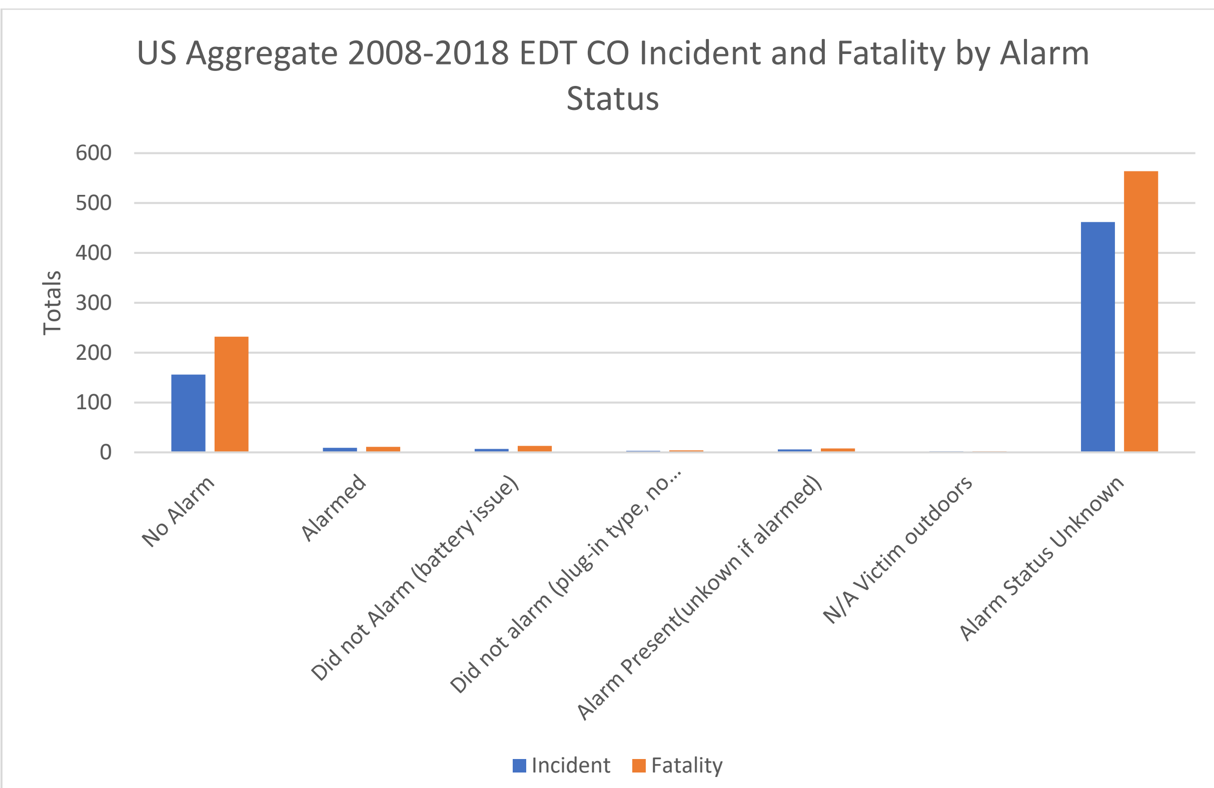

Figure 28: US Aggregate 2008-2018 EDT CO Incident and Fatality by Alarm Status[18]- Data Courtesy: Hnatov 2019

Looking at figures 22-28, it is observed that of all the EDTs, generators (vast majority are portable generators) are associated with the most incidents by a large margin. The fact that generator incidents are occurring with generators being used inside the home is problematic; it demonstrates a clear negligence to the dangers of CO (along with other products in fuel exhaust). Non-urban areas are again to be seen with disproportionately large numbers; more incidents occurring in colder months is also a repeated trend. EDT incidents have a less consistent pattern over the decade, but no clear trend is present. Lastly, when the CO alarm status is known—even though it is usually not—there is a correlation with incident occurrence and lack of alarm use.

4.4 Financial Loss Associated with CO incidents.

Aside from the loss of life and injuries from CO, there is a substantial financial loss in the US. One study[17] that aims to address this topic was conducted in 2015 to estimate total financial loss each year in the US. Approximately 6600 people per year are subject to long-term cognitive sequela, which results in a total loss in personal earnings of $925 million. 400 plus people die from accidental, non-fire CO poisoning, with an average loss of 26 years of productivity, which results for $355 million in forgone earnings. Lastly, 2800 people are hospitalized with a total of $33 million in medical care costs. These figures combine to a total of roughly $1.3 billion annually[17].

In figure 29, one clarification should be explained. Nonfatal accidental non-fire incidents are divided into two categories: NBO2 and HBO2. This refers to the two general types of CO poisoning treatments, which are called hyperbaric oxygen therapy (HBO2) and normobaric (NBO2) oxygen therapy.

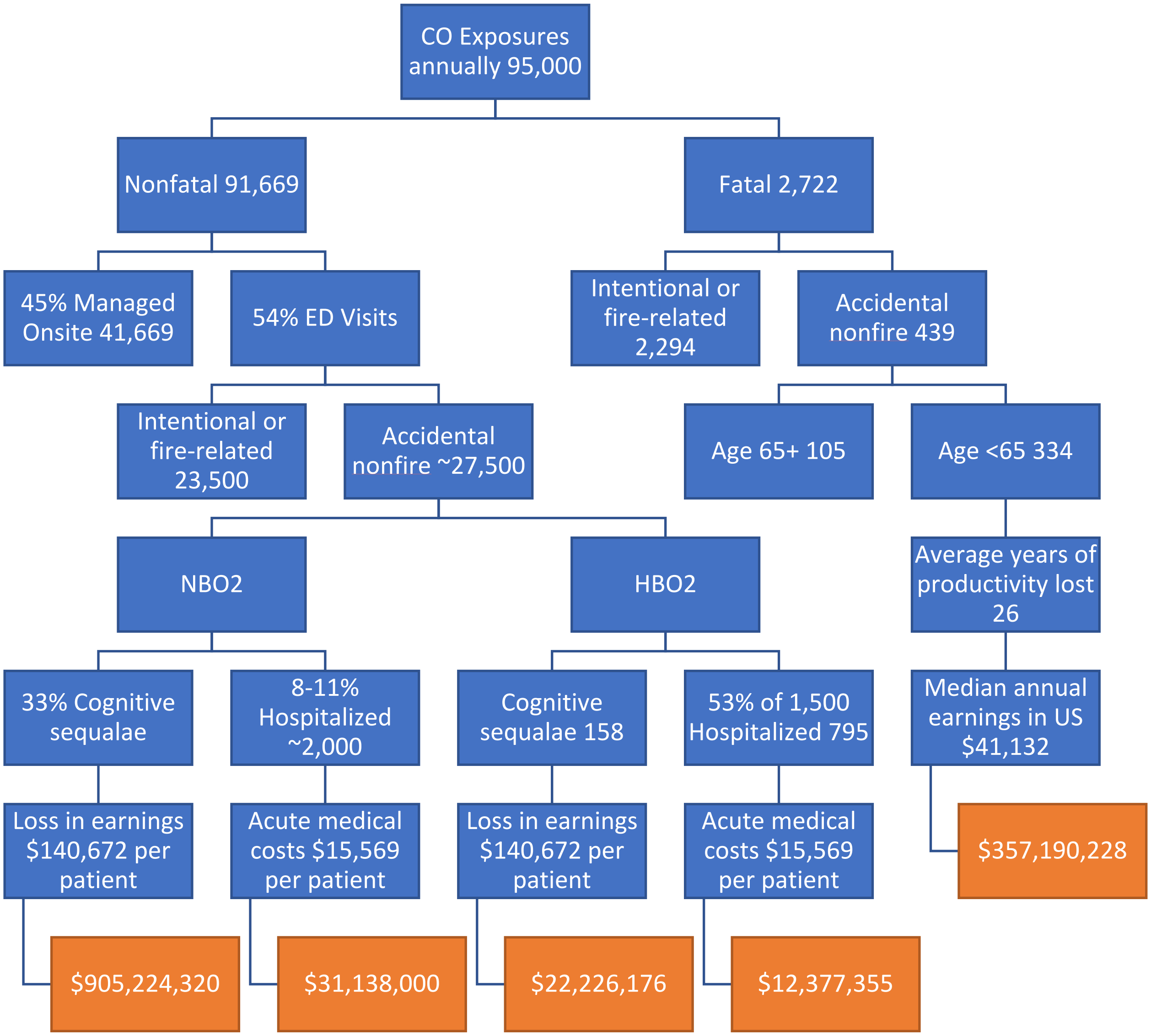

Figure 29: Annual US cost of accidental CO poisoning[17]. Image Courtesy: Reproduced from Hampson 2015

4.5 CO Diffusion through Drywall

A Fire Protection Research Foundation (FPRF) report[53] was published in 2015 which investigated the ability of CO to diffuse through drywall, another mechanism for CO to spread through a building. It was concluded that CO diffusion through drywall is possible and does happen. There have been at least five reported incidents where CO diffusion was a factor. The diffusion coefficient of CO through gypsum board drywall has been found to be within the range of $1.6 \cdot 10^{-6}$ to $4 \cdot 10^{-6}$ m^2/s. This coefficient value range allows for relatively fast diffusion when compared to other compounds that have been studied.[13] Figure 30 graphically compares mean diffusivity values for carbon monoxide from 12 experiments and values other studied compounds.

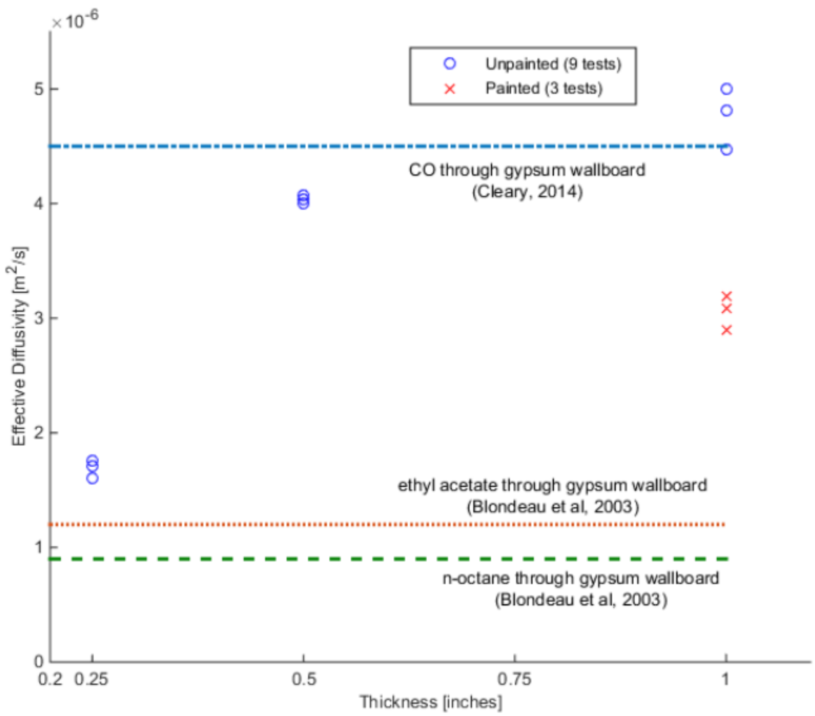

Figure 30: Comparison of Diffusivities[53] - Image Courtesy: Vermesi et al 2015

Figure 31 shows the CO concentration level in parts per million over time in the initial chamber and the control chamber through 4 experiments, with only the wall separating the chambers varied. It is shown that the thickness of the wall and the paint on the wall doesn't provide any significant differences in dispersion, so dispersion through drywall should be considered to be a common factor in CO dispersion throughout a building.

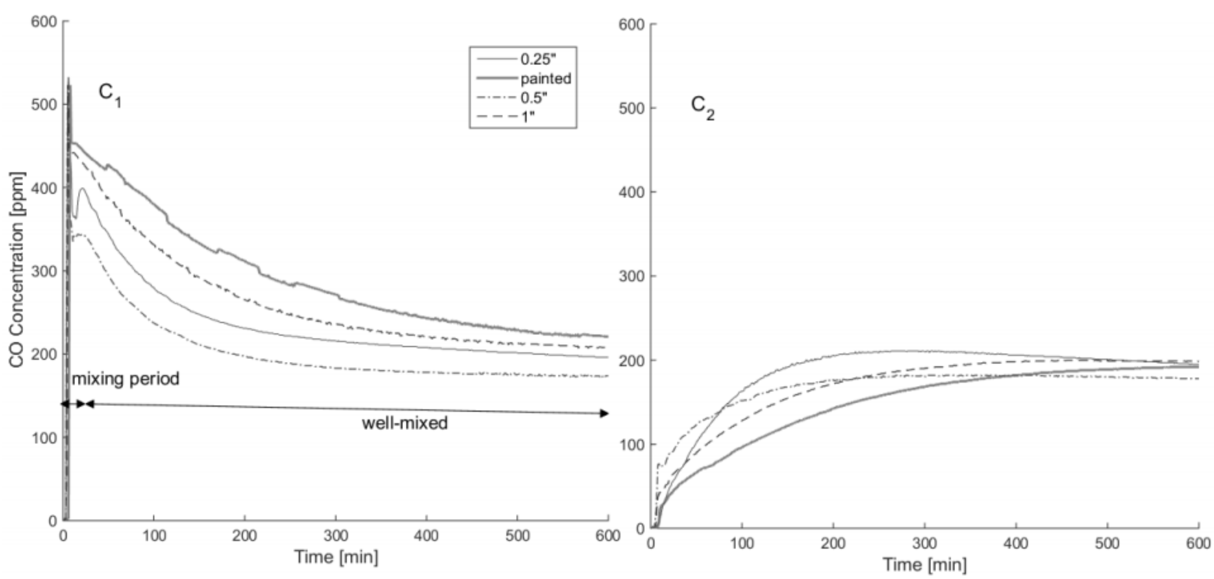

Figure 31: CO Diffusion Experiment Summary; C1-Initial Chamber; C2-Control Chamber[53] Image Courtesy: Vermesi et al 2015

4.6 CO Detector Siting

A Fire Protection Research Foundation report[3] completed in 2007 investigated the non-fire CO problem and sought to provide general guidelines on the siting of CO detectors. This was accomplished by several tasks. It first provided an overview of the CO incident data that was available at the time. This report also identified the sources of CO in buildings along with the respective rates of emission of different kinds of sources. Carbon monoxide dispersion through buildings was researched and reported. Lastly, there was a review of the available literature that pertained to CO detector siting.

The literature review and analysis suggest a two-prong approach to CO detection:

1. CO detectors in all rooms containing a combustion source to serve in the role of combustion safety devices (CSD)
2. CO detectors located in occupied areas to provide monitoring of the indoor air quality (IAQ) with respect to CO, to provide protection from mobile sources, and to provide backup protection with respect to fixed sources.

Since the publication of this 2007 research report, a better understanding related to CO hazards continues to drive additional studies and has led to a better understanding related to CO hazards and many advances in technology. However, before determining additional device siting guidelines, further research is needed.

4.7 Data Limitations

When it comes to non-fire carbon monoxide poisoning incidents, the available data does not describe the full picture. There are many details that if collected would be very valuable, as seen with NFIRS. Common items that are not recorded are duration of CO leaks and exposures, injury extent, parts per million levels, onsite CO detection type (if any), and if negligence was at play. A data source that is a good example of not having enough details is the Occupation Safety and Health Administration (OSHA). OSHA keeps a database[45] of work-place incidents, which can be filtered for CO poisoning; even though there are more than 300 incidents recorded, the available details of the cases vary too much. Some cases will provide the when, where, and how, while others have no details recorded at all. While OSHA reports could be used for narrative purposes, it would be difficult to put together quantifiable data to be analyzed. There are some data reports that exist that are extensive, however they are much too dated to be used as an analysis at the time of this published report.

5: Case Study Review

Table 3 displays a variety of CO incidents that were collected by reviewing various news articles, that demonstrate issues that the available data struggles to capture. These stories reflect the importance of working CO alarms and emphasize a general negligence of the CO problem. Additionally, they demonstrate how many people can be affected by one CO leak, and how CO leaks can occur in areas that are not addressed in fire/building codes. And lastly, they show the kinds of injuries that people can fall victim to. It should be noted that the reliability of the details described are dependent on the news source. Verification of these articles and their respective details has not been conducted as part of this current literature review effort.

Table 3 shows incidents involving deaths and injuries to children. Incidents also demonstrate the potential for mass casualty from any one leak, some examples show incidents where ten or more people were affected. One incident resulted in injuries to 40 people including two pregnant women, one of whom had to deal with serious medical and financial consequences with a premature birth.

Table 3: CO Incidents Case Study Review from News Articles - Deaths of Children & Potential for Mass Casualty Incident

Incident	**Details**
1) 1 Dead, at Least 11 Poisoned in Michigan Hotel Carbon Monoxide Leak: Police News Ref: https://www.nbcnews.com/news/us-news/1-dead-least-11-poisoned-michigan-hotel-carbon-monoxide-leak-n741586	Michigan hotel CO leak, 13-year-old boy died, 11 others injured. Victims found unconscious near pool, one in a 1st floor guest room. CO level at 800ppm.
2) Partygoers felt weak, woozy before detecting monoxide poisoning. News Ref: https://billingsgazette.com/news/state-and-regional/montana/partygoers-felt-weak-woozy-before-detecting-monoxide-poisoning/article_f196fa49-7669-5acb-a394-50b4bb2c8cbf.html	Montana, Hotel hosted function for Marines. CO Leak led to 40 people sent to hospital. Boilers were leaking, no CO alarm in boiler room. No serious injuries reported at the time. Victims were sick and some did pass out. One woman was pregnant, and had serious consequences, described in story#3 below
3) Preemie, young parents struggle with aftereffects of carbon monoxide poisoning. News Ref: https://mtstandard.com/news/state-and-regional/preemie-young-parents-struggle-with-aftereffects-of-carbon-monoxide-poisoning/article_ae5e9eaa-e30e-5797-b8cd-ddc1ef2d005f.html https://billingsgazette.com/news/state-and-regional/montana/red-lodge-carbon-monoxide-poisoning-leads-to-death-of-child/article_dbe36c0d-2a1a-548e-bf5b-e4f75c2de9aa.html	The couple had premature birth. Baby weighed just under 2 pounds. Huge medical costs and surgeries/treatments, with several serious complications. Infant died within two months of birth.

The incidents described below in Table 4 show widespread ignorance, misdiagnosis at scene and at hospital, and negligence of care. These incidents highlight how easily a controllable circumstance can become out of control and quickly lead to deaths and injuries.

Table 4: CO Incidents Case Study Review from News Articles - Ignorance/Misdiagnosis/Negligence

Incident	**Details**
1) Victims of Carbon Monoxide Illnesses Call on Hotels, Motels to Step Up Safety Procedures News Ref: https://www.nbcchicago.com/news/local/mysterious-deaths-and-injuries-in-hotels-and-motels-nationwide/2222836/	Chicago, Illinois, in 2019 couple became sick hours after checking into 5-star hotel. Detector ended up going off at 3 am. They alerted the staff of the problem. The building engineer said it "happens every night," downplayed the situation, called it normal.
2) North Carolina incident News Ref: https://www.charlotteobserver.com/news/special-reports/nc-medical-examiners/article9093218.html	In Boone, North Carolina, in 2013, a couple was found unconscious inside their hotel room and were later pronounced dead. Another family checked into same room after, their 11-year-old died. Pool heater was leaking into room.
3) Other 911 Calls Preceded Ocean City, Maryland Deaths News Ref: https://www.emsworld.com/news/10410934/other-911-calls-preceded-ocean-city-maryland-deaths	Ocean City, Maryland. At least one case to identify and potentially save lives from CO poisoning was missed by town emergency crews and Atlantic General Hospital. Family called 911 at 1am after being sick. Husband and daughter later died. They were staying at hotel, which had a CO leak. 9:27am another group called 911, from adjacent hotel rooms. Paramedics did recognize CO symptoms, and the victim died. Emergency crews later found the CO leak, but it was too late.
4) Investigator: CO victims treated day earlier News Ref: https://rapidcityjournal.com/investigator-co-victims-treated-day-earlier/article_d03eedd4-3b80-5a83-a2fe-054c4d4e7faf.html https://billingsgazette.com/news/state-and-regional/wyoming/cheyenne-jury-awards-million-in-vail-resorts-carbon-monoxide-case/article_3ee1373b-1bb4-5dbc-abb4-807423b4ac0c.html	Jackson, Wyoming. Couple poisoned by CO at a resort, were taken to ER a day earlier for dehydration. They returned to hotel and were found unconscious the next day. The husband died and the wife had brain damage. There was a faulty boiler beneath their room. A safety switch was disconnected that was supposed to shut off the boiler if too much CO was emitted.

Table 5 displays incidents that relate to CO poisoning injuries that are result of the inability to self-rescue, or the inability to help others. Aside from direct CO poisoning injuries, people were further injured from blunt trauma as they fell when they became unconscious. It was also observed that a wife did not help herself or husband due to CO poisoning effects.

Table 5: CO Incidents Case Study Review from News Articles – Victim Inability to Self-Rescue

Incident	**Details**
1) Alleghany County family survives after poisonous gas fills home News Ref: https://www.wsls.com/news/2019/04/22/alleghany-county-family-survives-after-poisonous-gas-fills-home/	In Virginia, 7 family members are CO poisoned in their own home. First symptoms showed at 11:30pm, severe. Several people passed out, and hit their head furthering injuries. Home boiler malfunction was reported as the cause.
2) Couple treated in Toledo for carbon monoxide poisoning give thanks News Ref: https://www.toledoblade.com/local/2017/11/22/Couple-treated-in-Toledo-for-carbon-monoxide-poisoning-give-thanks.html	Ann Arbor, Michigan, couple in their 50s collapse in their home due to CO. One fell down the stairs while collapsing. Wife heard husband fall but didn't do anything right away due to CO effects. They did not have a CO alarm.
3) Partner of man who died in Legal Sea Foods CO leak on Long Island fights for safety law News Ref: https://abc7ny.com/steve-nelson-legal-sea-foods-carbon-monoxide-leak-fatal-gar-long-island-huntington-station-co2/233688/	Legal Sea Foods, New York, manager dies in basement of restaurant, assistant manager found unconscious due to faulty pipe in water heater. No CO alarms. Manager had been suffering from CO poisoning for several weeks prior, misdiagnosed by doctor as having a "blood disorder."

The lack of an operating alarm can be seen in several of these case studies. Carbon monoxide is colorless and odorless. Its early onset symptoms are not unique or severe, which leads to mistaking them for something else or thinking there is not a serious problem. These symptoms can quickly escalate to severe symptoms, which usually revolves around the victim becoming unconscious. People do not self-rescue when they are able, because they do not realize that they should. If someone does realize there is problem, it is most likely too late. This common sequence combined with CO's toxicity, and a general negligence, makes CO a very dangerous problem that can happen almost anywhere. Detection is the only safeguard against this problem.

6: Health Effects of Carbon Monoxide

Having proper CO detection can help mitigate and reduce exposure to CO, however when one is exposed, the health effects, both short and long term, can be complicated. It is often assumed that there is a direct correlation between blood carboxyhemoglobin (COHb) levels, and the symptoms or injuries a person would endure. This is due to the fact while COHb is the common mechanism for CO poisoning and it is correlated with the amount of CO in the bloodstream; there are several other modes of CO poisoning that can occur once it is in the body. Some of these include myoglobin, oxidative stress, fatty acid degradation in nerve cells, and apoptosis (programmed cell death). It has also been shown that CO symptoms become more intense at higher altitudes due to lower levels of oxygen[46]. For this reason, tables and figures that compare COHb levels and symptoms should be considered unreliable and not be used unless these factors are understood and considered. Considering COHb is not the only mechanism for CO exposure level limits, it isn't clear what a "safe" level of CO truly is, as ppm levels are not directly related to COHb levels. Section 8 of this report provides different permissible CO exposure levels that are recommended by various organizations. Table 6 displays common acute CO poisoning symptoms grouped by severity, and Table 7 displays all acute symptoms that have been reported by patients, grouped by organ group.

Table 6: Acute CO Poisoning Symptoms[30]

Reprinted from Emergency Medicine Clinics of North America, Volume 22, Issue 4, November 2004, Carbon Monoxide Poisoning, Page 990, Copyright © 2004 Elsevier Inc., with permission from Elsevier.

Mild	**Moderate**	**Severe**
Headache	Confusion	Palpitations
Nausea	Syncope	Dysrhythmias
Vomiting	Chest Pain	Hypotension
Dizziness	Dyspnea	Myocardial Ischemia
Blurred Vision	Weakness	Cardiac Arrest
	Tachycardia	Respiratory Arrest
	Tachypnea	Noncardiogenic Pulmonary edema
	Rhabdomyolysis	Seizures
		Coma

Table 7: All Acute CO poisoning Symptoms by Organ System[16]

Reprinted from, Undersea & Hyperbaric Medicine, Volume 39, Issue 2, Mar/Apr 2012, Symptoms of carbon monoxide poisoning do not correlate with the initial carboxyhemoglobin level, Page 660, Copyright © 2012 Undersea & Hyperbaric Medical society, with permission.

Cardiac	Chest pain, heaviness, fullness, tightness Left arm pain Palpitations
Gastrointestinal	Abdominal pain Diarrhea Fecal incontinence Hematemesis Nausea Vomiting Xerostomia
Neurological	Aphasia Confusion Coordination problems Dysarthria Facial droop Gait disturbance, ataxia, balance problems Headache Hemiparesis "Jerky" Movements Loss of consciousness Memory complaints Numbness (focal, diffuse) Pain (numerous sites) Paraparesis Paresthesia Seizure Tremor Twitching
Ophthalmologic	Ocular burning or pain Vision disturbance (blindness, blurring, diplopia, scotomata) blurring, diplopia, scotomata)
Otologic	Dizziness Hearing loss Tinnitus Vertigo
Psychiatric	Anxiety
Respiratory	Cough Dyspnea
Urologic	Flank pain Urinary incontinence
Miscellaneous	Chilling Diaphoresis Drowsiness Fatigue Fussiness Giddy Hot flashes Irritability Lethargy Lightheadedness Muscle cramps Myalgias Rash

It can be understood from symptoms illustrated in Table 6 why people do not suspect that they, or the people around them, could be experiencing the symptoms of CO poisoning. Initial symptoms are general and could easily be mistaken for other causes. Most commonly, people with the initial symptoms think they are flu-like and do not think it is a serious issue. Further, CO impacts everyone differently due to age and other health conditions. These symptoms can quickly escalate, as victims are often unable to help themselves, or call for help. Without early detection and notification, it is often too late by the time someone realizes something is seriously wrong.

Acute CO exposure levels can also result in long term health effects. Some that are fairly common across CO poisoning victims include:

- 30-50% of patients having permanent neuropsychological sequalae[55]
- increased rate of death due to heart attack[57]
- increased rate of fatal accidents[15]
- increased rates of parkinsonism[32]
- dementia[56]
- stroke[33]

7: Summary Observations

Carbon monoxide poisoning incidents have been a persistent problem for decades. While there has been an increase in prevention and detection efforts, there is still room for improvement. Considering most CO poisoning incidents can be mitigated, codes and standards continue to improve provisions to reduce CO incidents. New editions of these codes are being developed for the 2024 revision cycle, and the goal of this project is to assist the technical committees in their determination if the CO detection requirements are adequate. This was done through a literature review and summary of the following:

- Codes such as NFPA 101, NFPA 5000, IBC, IEBC, IFC, IRC, and IPMC
- State regulations
- Available consolidated and analyzed data pertaining to CO incidents
- The short- and long-term health effects

Regarding CO detection, the IFC and NFPA codes generally address attached garages, rooms containing fuel burning appliances, and spaces served by fuel-burning HVAC systems. There are several cases of CO incidents that have occurred outside of these areas. For example, incidents that relate to leaks from exhaust system ductwork and equipment (including failure of exhaust fans), which would be outside where the fuel burning appliance is located, yet its CO emission are carried elsewhere. These are the kind of CO migration details that are not recorded, making it difficult to fix this problem.

Regulations on CO detection differ significantly state to state. States typically incorporate by reference IFC or NFPA 101, and may have state-specific amendments. In some cases, states do not have a statewide incorporation by reference of any code. The most impactful details, however, are the edition year of the respective codes that are incorporated by reference, and the means of enforcement. Provisions in codes generally become more stringent with more recent editions, but many states are using 2012 or 2015 editions, and some are using editions as old as 2006. Further, many states let their local jurisdictions make amendments or even completely let them handle code incorporation by reference. Additionally, local jurisdictions are also often seen to be responsible for enforcement of these codes. This leads to inconsistent CO regulation across the US—which can be observed from New York having CO detection requirements for all buildings, while some states do not regulate any buildings.

Out of the various issues that are associated with CO poisoning, one prominent issue is a lack of comprehensive, concise, and coordinated data for these kinds of incidents, and data is required to substantiate regulatory changes. While fire related incidents are well documented, data collection on CO poisoning incidents is limited. For example, injuries and deaths of non-fire CO incidents are not recorded within NFIRS, only incident totals are reported. Similarly, the CPSC does thorough work in their data collection, yet their jurisdiction is limited, and therefore their data is also limited. Despite shortcomings in available data, there is still enough information to draw some conclusions.

While CO incidents have been occurring across the US, the Midwest region disproportionately has more issues with CO incidents. Fuel burning appliances and engine-driven tools (particularly generators) are consistently associated with the most CO incidents. These appliances and tools are also typically powered by gasoline. The lack of awareness of the problem at any level is also prevalent. This is demonstrated by reoccurring incidents of people running generators inside or near window and door openings to the structure. It could be suggested that increased awareness of CO could help reduce CO incidents. This could be accomplished through increased public education and more effective warning labels on products. To partially make up for these shortcomings in the data, a case study review of news stories was also conducted. These stories demonstrated the potential of CO to result in significant loss in any one incident, the various kinds of injuries and medical complications victims endure, and a general negligence of the problem.

8: Future Research Considerations

Current unknowns are primarily associated with data collection. While there is thorough and relevant data available, it is not consolidated in an effective way. Data collection efforts have varying jurisdictions with varying levels of detail. This results in the inability to obtain a full understanding of the CO problem, instead of the currently collected data that is comprised of different data sets that have limited perspectives. Total injuries and fatalities cannot be divided into their associated occupancy types. Case studies are presented to assist in describing the full picture, however this project does not serve as a running database of these news stories, so there are likely other insights that have been missed.

The FPRF report regarding CO detector siting and CO diffusion through drywall also suggest some future work is needed. Since buildings utilize a variety of materials, not just drywall, it is recommended that the permeability for CO should be investigated for these different building materials so that CO diffusion could be more accurately predicted. For CO dispersion in a building, the available data is not sufficient for large open floor areas with minimum closed door; similarly, non-HVAC fluid mechanical forces are not well addressed. Further research in CO dispersion through buildings should focus on these concepts.

There is also further research needed regarding CO levels. Considering COHb is not the only mechanism for measuring CO poisoning severity and ppm levels are not directly related to COHb levels, it is not clear what constitutes a "safe" level of CO exposure. The current permissible exposure limit/recommended exposure limit/threshold limit value for carbon monoxide exposure from various sources are as follows:

- Occupational Safety and Health Administration (OSHA): OSHA's permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air as an 8-hour time-weighted average (TWA) concentration[52].
- National Institute for Occupational Safety and Health (NIOSH): NIOSH recommended exposure limit (REL) for carbon monoxide of 35 ppm as an 8-hour TWA. The NIOSH limit is based on the risk of cardiovascular effects[35].
- American Conference of Government Industrial Hygienists (ACGIH): ACGIH recommend a threshold limit value (TLV) of 25 ppm as a TWA for a normal 8-hour workday and a 40-hour workweek [ACGIH 1994, p. 15]. The ACGIH limit is based on the risk of elevated carboxyhemoglobin levels [ACGIH 1991, p. 229][1].
- World Health Organization (WHO): WHO recommended limits are 9-10 ppm for no more than 8 hours, 25-35 ppm for no more than 1 hour, 90-100 ppm for no more than 15 minutes[47].
- US Environmental Protection Agency (EPA): EPA sets national ambient air quality standard for carbon monoxide in outdoor air and recommended exposure limit is 9 ppm over 8 hours, 35 ppm over 1 hour[9].
- The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): Recommended limit is consistent with WHO and EPA limits at 9 ppm over an 8-hour exposure under ASHRAE Standard 62.1-2016 "Ventilation for Acceptable Indoor Air Quality"[49].

It also is not specifically determined when initial "flu-like" symptoms transition into unconsciousness. Especially as CO affects everyone differently, and the duration of exposure is also a factor. Current understandings of COHb levels are also based off of models that assume sea-level; since it has been shown altitude is a factor in COHb levels, further investigation into the development of COHb models that incorporate altitude is needed. It should be noted that actual ppm levels for CO alarms/detectors are not specified in NFPA or ICC codes. Instead, NFPA or ICC codes specify that CO alarms/detectors shall be listed as complying with either UL 2034 or UL 2075. The lower CO ppm levels are also important while considering evacuation protocols. Understanding the long-term health effects from CO exposure could benefit by further compilation of the medical research literature that is available. Only a high-level overview of the limited literature pertaining to the long-term health effects has been presented in the current report. While it is known that there are long-term complications, the associated data is seldom compiled as compared to the acute effects of CO exposure.

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10: Appendix

10.1 NFIRS Reporting Form

A

FDID ☆ | State ☆ | Incident Date (MM DD YYYY) ☆ | Station | Incident Number ☆ | Exposure ☆

☐ Delete ☐ Change ☐ No Activity

NFIRS–1 Basic

B Location Type ☆

☐ Check this box to indicate that the address for this incident is provided on the Wildland Fire Module in Section B, "Alternative Location Specification." Use only for wildland fires.

☐ Street address
☐ Intersection
☐ In front of
☐ Rear of
☐ Adjacent to
☐ Directions
☐ U.S. National Grid

Census Tract

Number/Milepost | Prefix | Street or Highway | Street Type | Suffix

Apt./Suite/Room | City | State | ZIP Code

Cross Street, Directions or National Grid, as applicable

C Incident Type ☆

Incident Type

D Aid Given or Received ☆ ☐ None

1 ☐ Mutual aid received
2 ☐ Auto. aid received
3 ☐ Mutual aid given
4 ☐ Auto. aid given
5 ☐ Other aid given

Their FDID | Their State

Their Incident Number

E1 Dates and Times

Midnight is 0000

Check boxes if dates are the same as Alarm Date.

Month Day Year Hour Min

ALARM always required

Alarm ☆

ARRIVAL required, unless canceled or did not arrive

☐ Arrival ☆

CONTROLLED optional, except for wildland fires

☐ Controlled

LAST UNIT CLEARED, required except for wildland fires

☐ Last Unit Cleared

E2 Shifts and Alarms

Local Option

Shift or Platoon | Alarms | District

E3 Special Studies

Local Option

Special Study ID# | Special Study Value

F Actions Taken ☆

Primary Action Taken (1)

Additional Action Taken (2)

Additional Action Taken (3)

G1 Resources ☆

☐ Check this box and skip this block if an Apparatus or Personnel Module is used.

	Apparatus	Personnel
Suppression		
EMS		
Other		

☐ Check box if resource counts include aid received resources.

G2 Estimated Dollar Losses and Values

LOSSES: Required for all fires if known. Optional for non-fires.

		None
Property	$, ,	☐
Contents	$, ,	☐

PRE-INCIDENT VALUE: Optional

Property	$, ,	☐
Contents	$, ,	☐

Completed Modules

☐ Fire–2
☐ Structure Fire–3
☐ Civilian Fire Cas.–4
☐ Fire Service Cas.–5
☐ EMS–6
☐ HazMat–7
☐ Wildland Fire–8
☐ Apparatus–9
☐ Personnel–10
☐ Arson–11

H1 ☆ Casualties ☐ None

	Deaths	Injuries
Fire Service		
Civilian		

H2 Detector

Required for confined fires.

1 ☐ Detector alerted occupants
2 ☐ Detector did not alert them
U ☐ Unknown

H3 Hazardous Materials Release ☐ None

1 ☐ **Natural gas:** slow leak, no evacuation or HazMat actions
2 ☐ **Propane gas:** <21-lb tank (as in home BBQ grill)
3 ☐ **Gasoline:** vehicle fuel tank or portable container
4 ☐ **Kerosene:** fuel burning equipment or portable storage
5 ☐ **Diesel fuel/fuel oil:** vehicle fuel tank or portable storage
6 ☐ **Household solvents:** home/office spill, cleanup only
7 ☐ **Motor oil:** from engine or portable container
8 ☐ **Paint:** from paint cans totaling <55 gallons
0 ☐ **Other:** special HazMat actions required or spill > 55 gal (Please complete the HazMat form.)

I Mixed Use Property ☐ Not mixed

10 ☐ Assembly use
20 ☐ Education use
33 ☐ Medical use
40 ☐ Residential use
51 ☐ Row of stores
53 ☐ Enclosed mall
58 ☐ Business & residential
59 ☐ Office use
60 ☐ Industrial use
63 ☐ Military use
65 ☐ Farm use
00 ☐ Other mixed use

J Property Use ☆ ☐ None

Structures

131 ☐ Church, place of worship
161 ☐ Restaurant or cafeteria
162 ☐ Bar/Tavern or nightclub
213 ☐ Elementary school, kindergarten
215 ☐ High school, junior high
241 ☐ College, adult education
311 ☐ Nursing home
331 ☐ Hospital
341 ☐ Clinic, clinic-type infirmary
342 ☐ Doctor/Dentist office
361 ☐ Prison or jail, not juvenile
419 ☐ 1- or 2-family dwelling
429 ☐ Multifamily dwelling
439 ☐ Rooming/Boarding house
449 ☐ Commercial hotel or motel
459 ☐ Residential, board and care
464 ☐ Dormitory/Barracks
519 ☐ Food and beverage sales
539 ☐ Household goods, sales, repairs
571 ☐ Gas or service station
579 ☐ Motor vehicle/boat sales/repairs
599 ☐ Business office
615 ☐ Electric-generating plant
629 ☐ Laboratory/Science laboratory
700 ☐ Manufacturing plant
819 ☐ Livestock/Poultry storage (barn)
882 ☐ Non-residential parking garage
891 ☐ Warehouse

Outside

124 ☐ Playground or park
655 ☐ Crops or orchard
669 ☐ Forest (timberland)
807 ☐ Outdoor storage area
919 ☐ Dump or sanitary landfill
931 ☐ Open land or field
936 ☐ Vacant lot
938 ☐ Graded/Cared for plot of land
946 ☐ Lake, river, stream
951 ☐ Railroad right-of-way
960 ☐ Other street
961 ☐ Highway/Divided highway
962 ☐ Residential street/driveway
981 ☐ Construction site
984 ☐ Industrial plant yard

Look up and enter a Property Use code and description only if you have NOT checked a Property Use box.

Property Use: Code

Property Use Description

NFIRS–1 Revision 01/01/05

The ☆ denotes a required field. 3-2 NFIRS 5.0 COMPLETE REFERENCE GUIDE

K1 Person/Entity Involved

Local Option

Business Name (if applicable) | Area Code | Phone Number

☐ Check this box if same address as incident location (Section B). Then skip the three duplicate address lines.

Mr., Ms., Mrs. | First Name | MI | Last Name | Suffix

Number | Prefix | Street or Highway | Street Type | Suffix

Post Office Box | Apt./Suite/Room | City

State | ZIP Code

☐ **More people involved? Check this box and attach Supplemental Forms (NFIRS–1S) as necessary.**

K2 Owner

☐ Same as person involved? Then check this box and skip the rest of this block.

Local Option

Business Name (if applicable) | Area Code | Phone Number

☐ Check this box if same address as incident location (Section B). Then skip the three duplicate address lines.

Mr., Ms., Mrs. | First Name | MI | Last Name | Suffix

Number | Prefix | Street or Highway | Street Type | Suffix

Post Office Box | Apt./Suite/Room | City

State | ZIP Code

L Remarks:

Local Option

Fire Module Required?

Check the box that applies and then complete the Fire Module based on Incident Type, as follows:

☐ Buildings 111	Complete Fire & Structure Modules
☐ Special structure 112	Complete Fire Module & Section I, Structure Module
☐ Confined 113–118	Basic Module Only
☐ Mobile property 120–123	Complete Fire & Structure Modules
☐ Vehicle 130–138	Complete Fire Module
☐ Vegetation 140–143	Complete Fire or Wildland Module
☐ Outside rubbish fire 150–155	Basic Module Only
☐ Special outside fire 160	Complete Fire or Wildland Module
☐ Special outside fire 161–164	Complete Fire Module
☐ Crop fire 170–173	Complete Fire or Wildland Module

ITEMS WITH A ☆ MUST **ALWAYS** BE COMPLETED!

☐ **More remarks? Check this box and attach Supplemental Forms (NFIRS–1S) as necessary.**

M Authorization

Officer in charge ID | Signature | Position or rank | Assignment | Month | Day | Year

Check box if same as Officer in charge. ⇨ ☐

Member making report ID | Signature | Position or rank | Assignment | Month | Day | Year

10.2 Additional State Regulations Information

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
Alabama	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement	https://www.firemarshal.alabama.gov/Codes.aspx
Alaska	International Fire Code (IFC)	2012	Statewide incorporation by reference, Local Enforcement	https://dps.alaska.gov/getmedia/5b0d3e53-e7b8-432c-a870-6c66b009a284/13-AAC-50-55b;.aspx
Arizona	International Fire Code (IFC)	2012 Statewide, 2018 (Most recent edition incorporated by reference by any jurisdiction)	*Local incorporation by reference/ Enforcement*	https://www.dfbls.az.gov/userfiles/files/ofm/Amendments%20to%202012%20IFC.pdf
Arkansas	International Fire Code (IFC)	2012	Statewide incorporation by reference/ Enforcement	https://codes.iccsafe.org/content/ARFPCVIIB2012/chapter-9-fire-protection-systems
California	International Fire Code (IFC)	2018	Statewide incorporation by reference, with possible local amendments that are more stringent; *local enforcement*	https://codes.iccsafe.org/content/CFC2019P3
Colorado	International Fire Code (IFC)	2018 (Most recent edition incorporated by reference by any jurisdiction);	*Local incorporation by reference/ Enforcement, Statewide Enforcement for schools only*	https://www.iccsafe.org/advocacy/adoptions-map/colorado/#:~:text=The%20Division%20of%20Fire%20Prevention,the%20state%20minimum%20plumbing%20code. NOTE: CO Division of Fire Prevention and Control will use the 2021 IFC Effective July 1, 2021

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
Connecticut	NFPA 101 - Life Safety Code	2015	Statewide incorporation by reference/Enforcement	https://portal.ct.gov/DAS/Office-of-State-Fire-Marshal/CT-Fire-Safety-and-Prevention-Codes
Delaware	NFPA 1 - Fire Code NFPA 101 - Life Safety Code	2015	*Local incorporation by reference/Enforcement*	https://regulations.delaware.gov/AdminCode/title1/700/701.shtml
Florida	Florida Fire Prevention Code/ NFPA1/101	2018	Statewide incorporation by reference and Enforcement	https://www.myfloridacfo.com/division/sfm/bfp/floridafirepreventioncodepage.htm
Georgia	International Fire Code (IFC)	2018	Statewide incorporation by reference, *Local Enforcement*	https://www.dca.ga.gov/local-government-assistance/construction-codes-industrialized-buildings/construction-codes
Hawaii	Hawaii Fire Code/NFPA 1	2018	*Local incorporation by reference/ Enforcement*	http://labor.hawaii.gov/wp-content/uploads/2013/02/State-Fire-Code-1-1-10-w-signatures.pdf
Idaho	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement; possible local amendments that more stringent	https://doi.idaho.gov/sfm/Prevention/Statutes
Illinois	NFPA 101 - Life Safety Code	2015	*Local incorporation by reference/ Enforcement*	https://www2.illinois.gov/sites/sfm/Resources/Pages/Life-Safety-Code.aspx NOTE: The 2015 edition of NFPA 101 is incorporated by reference in our rules is applicable across the state except: • Chicago is exempted. • If the local is a Home Rule unit of government they can utilize unique provisions, but if they do not have specific requirements, the statewide incorporation by reference applies. • If the local is non-Home Rule they can incorporate by reference standards that are equal to or higher than the statewide code. • The statewide incorporation by reference also applies in all state owned, leased or licensed occupancies anywhere in the state including Chicago and Home Rule communities.
Indiana	International Fire Code (IFC)	2012	Statewide incorporation by reference	http://www.in.gov/legislative/iac/20140827-IR-675130341FRA.xml.pdf

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
Iowa	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement	https://dps.iowa.gov/divisions/state-fire-marshal/building-code NOTE: Iowa writes their own chapter on CO in the Public Safety Administrative Code 661 – Chapter 211, section 661, 211.1 is: https://www.legis.iowa.gov/docs/iac/chapter/04-21-2021.661.211.pdf
Kansas	International Fire Code (IFC)	2006	*Statewide incorporation by reference, Local Jurisdiction Make own incorporation by reference/ Enforcement*	https://www.sos.ks.gov/publications/pubs_kar_Regs.aspx?KAR=22-1-3
Kentucky	2018 Kentucky Building Code/ International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement	https://dhbc.ky.gov/Documents/KHBC_BuildingCode.pdf
Louisiana	NFPA 101 - Life Safety Code	2015	Statewide incorporation by reference/ Enforcement	http://sfm.dps.louisiana.gov/insp_crl.htm
Maine	NFPA 1/101	2018	Statewide incorporation by reference, Local Enforcement	https://www.maine.gov/dps/fmo/fire-service-laws/rules
Maryland	NFPA 1/101	2018	*Statewide incorporation by reference, Local jurisdictions can choose to incorporate by reference/ enforce their own codes*	https://mdsp.maryland.gov/firemarshal/Pages/CodeEnforcementLicensingRegulation.aspx
Massachusetts	NFPA 1/101	2015	Statewide incorporation by reference/ Enforcement	https://www.mass.gov/service-details/massachusetts-fire-code
Michigan	International Building Code (IBC)	2015	Statewide incorporation by reference; Local incorporation by reference/ Enforcement	https://www.michigan.gov/lara/0,4601,7-154-89334_10575_17550-234789--,00.html

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource	
Minnesota	2020 Minnesota Fire Code/International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://codes.iccsafe.org/content/MNFC2020P1/chapter-9-fire-protection-and-life-safety-systems	
Mississippi	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement; possible local amendments that more stringent	http://www.mid.ms.gov/legal/regulations/20171Reg.pdf	
Missouri			*Local incorporation by reference*	https://dfs.dps.mo.gov/safetytips/	
Montana	International Fire Code (IFC) International Building Code (IBC)	2012	Statewide incorporation by reference/ Enforcement	http://www.mtrules.org/gateway/ShowRuleFile.asp?RID=35846	
Nebraska	NFPA 101 - Life Safety Code	2012	Statewide incorporation by reference/ Enforcement	https://sfm.nebraska.gov/regulations	https://nebraskalegislature.gov/laws/statutes.php?statute=76-603
Nevada	International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://fire.nv.gov/bureaus/FPE/FPE_Main/	
New Hampshire	NFPA 1	2015	Statewide incorporation by reference/ Enforcement	https://www.nh.gov/safety/divisions/firesafety/legal/index.html	
New Jersey	International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://www.nj.gov/dca/divisions/codes/codreg/#2	https://codes.iccsafe.org/content/NJBC2018P2/chapter-9-fire-protection-and-life-safety-systems#NJBC2018P2_Ch09_Sec915
New Mexico	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement; possible local amendments that more stringent	http://www.nmprc.state.nm.us/state-firemarshal/code-enforcement/index.html#gsc.tab=0	

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
New York	2020 New York Fire Code/ International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://codes.iccsafe.org/content/NYSFC2020P1
North Carolina	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement	https://codes.iccsafe.org/content/NCFC2018/chapter-9-fire-protection-systems#NCFC2018_Pt03_Ch09_Sec915
North Dakota	International Fire Code (IFC)	2018	Statewide incorporation by reference, Local amendments permitted	https://www.communityservices.nd.gov/buildingcode/
Ohio	International Fire Code (IFC) / Ohio Fire Code (2017)	2015	Statewide incorporation by reference/Enforcement	https://codes.ohio.gov/ohio-administrative-code/chapter-1301:7-7
Oklahoma	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement local amendments permitted	https://www.ok.gov/oubcc/Codes_&_Rules/Adopted_Building_Codes/index.html
Oregon	International Fire Code (IFC)	2021	Statewide incorporation by reference/ Enforcement	https://www.oregon.gov/osp/programs/sfm/Pages/Fire_Codes.aspx
Pennsylvania	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement; possible local amendments that more stringent	https://www.dli.pa.gov/ucc/Pages/UCC-Codes.aspx
Rhode Island	NFPA 1	2015	Statewide incorporation by reference/ Enforcement	https://rules.sos.ri.gov/regulations/part/450-00-00-7
South Carolina	2018 South Carolina Fire Code/ International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement; local amendments permitted	https://codes.iccsafe.org/content/SCFC2018P1/chapter-5-fire-service-features#SCFC2018P1_Pt03_Ch05_Sec510

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
South Dakota	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement; local amendments permitted	https://sdlegislature.gov/#/Rules/Administrative/20319
Tennessee	International Fire Code (IFC)	2012	Statewide incorporation by reference/ Enforcement, local incorporation by reference permitted	https://www.tn.gov/commerce/fire/codes-enforcement.html
Texas			*Local* incorporation by reference	https://hhs.texas.gov/laws-regulations/handbooks/smccsp/chapter-1-basic-standards/1-8-6-local-fire-codes
Utah	International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://le.utah.gov/interim/2018/pdf/00004566.pdf NOTE: Additional amendments https://casetext.com/statute/utah-code/title-15a-state-construction-and-fire-codes-act/chapter-5-state-fire-code-act/section-15a-5-103-nationally-recognized-codes-incorporated-by-reference
Vermont	NFPA 1/101	2015	Statewide incorporation by reference/ Enforcement	https://firesafety.vermont.gov/sites/firesafety/files/files/rules/dfs_rules_firecode2015_current.pdf
Virginia	International Fire Code (IFC)	2015	Statewide incorporation by reference/ Enforcement	http://register.dls.virginia.gov/vol34/iss18/v34i18.pdf
Washington	International Fire Code (IFC)	2018	Statewide incorporation by reference/ Enforcement	https://sbcc.wa.gov/
West Virginia	NFPA 1, NFPA 101 and International Building Code	2015	*Statewide* incorporation by reference, *up to local jurisdiction to enforce*	https://firemarshal.wv.gov/about/Laws/Documents/87CSR4.pdf
Wisconsin	NFPA 1	2012	Statewide incorporation by reference/ Enforcement	https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/301_319/314

State	Incorporation by reference	Edition	Enforcement/ Notes	Resource
Wyoming	International Fire Code (IFC)	2018	Statewide incorporation by reference, Local Enforcement	http://wsfm.wyo.gov/electrical-safety/rules-statutes-and-jurisdictions
District of Columbia	International Fire Code (IFC)	2012	Statewide incorporation by reference/ Enforcement	https://codes.iccsafe.org/content/chapter/9220/