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The Invisible US Fire Problem

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The Invisible US Fire Problem

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Contents

1 Introduction

The primary narrative about safety to life from fire in the United States (US) is a success story. With the introduction of smoke alarms, social changes such as a reduction in smoking, improvements in building, fire and electrical codes and standards, introduction of other forms of safety protection technologies, and improved emergency response and healthcare for much of the population, fire deaths have reduced dramatically since 1980. [1]

But as with many headlines, this does not tell the whole story.

In the US, the demand for affordable housing often outstrips supply. In response to these gaps and other societal issues, people often find or create alternative living arrangements, which may fall outside the purview of state legal systems of land ownership and tenure, and of planning, land use, building, public health and safety regulations.

These housing problems contribute to hundreds of thousands of people in the US experiencing homelessness [2] and millions of people living in 'slum households', defined by UN-Habitat as an individual or a group of individuals living under the same roof who lack one or more of the following:

- Durable housing of a permanent nature that protects against extreme climate conditions.
- Sufficient living space, which means not more than three people sharing the same room.
- Easy access to safe water in sufficient amounts at an affordable price.
- Access to adequate sanitation in the form of a private or public toilet shared by a reasonable number of people.
- Security of tenure that prevents forced evictions.

Traditionally thought to be a feature of development in rapidly urbanizing Low- and Middle-Income Countries (LMICs), the phenomenon of fire among populations living in 'slum conditions' is a feature of American cities, and across the spectrum form urban areas to rural areas. [3] But news headlines don't tell the stories of people living in these conditions suffering disproportionately from fire. Reframing this issue through a regulatory lens can offer new perspectives – what are the stories of fire in under-regulated[1] construction and the fire challenges related to homelessness, especially in unregulated[2] and non-sheltered[3] conditions – the 'invisible' fire problem?

The perceived likelihood of encountering an informal settler inside a vacant or abandoned building remains a tenet of firefighting doctrine, leading firefighters to aggressively enter and search burning structures of compromised or uncertain integrity. [4] [5] Recent line of duty firefighter deaths under such circumstances in St. Louis and Baltimore illustrate the hazards posed by makeshift housing. [6] Fires in vacant buildings have also shown to be catastrophic for populations living in these settings, e.g., the deadliest fire in Oakland's history, the 2016 Ghost Ship fire, killed 36 people in an old warehouse with unpermitted living, working and performance space, occupied by local artists. This nexus between homelessness and fire risk was acknowledged by fire chiefs, elected officials, and the press following a series of fatal fires in January 2022.

In addition, large sectors of the US population live in unregulated and non-sheltered conditions, and experience high incidence rates of fire and severe fire consequences. Fires in unregulated

[1] See section 3 for definition
[2] See section 3 for definition
[3] See section 3 for definition

contexts consisting of tent encampments, recreational vehicles, and other improvised housing is widely reported in both large cities and smaller urban places across the US. These incidents cause casualties [7] [8], disruption of normal activity in larger urban centers [9], fire spread to adjacent infrastructure [10] [11] [12], fire spread to wildlands and adjacent communities [13], and other social and economic harm to include injuries, psychological trauma, and financial loss. Such unregulated encampments, often made of tents and makeshift dwellings, are growing in number and size in many American cities. The Los Angeles Fire Department reported that fires related to homelessness occurred at a rate of 24 fires per day, making up 54 percent of all fires the department responded to in the first quarter of 2021. [14]

The physical forms and typologies where persons experiencing homelessness seek shelter can challenge simple definitions or assumptions. In this report we consider under-regulated housing, where informal occupation of vacant and derelict buildings, and excess occupation of buildings (including illegal subdivisions) of all types remains an important component of the problem. A Los Angeles Times article from January 2022 expresses the complexity as follows:

> "*…in a city with homeless encampments popping up in parks, on sidewalks and under overpasses, a tiny and unnoticed community to hold here [a vacant office building], two blocks away from sleek Wilshire boulevard apartments, finding shelter within the derelict buildings dusty, wire-exposed walls. The main entrance is blocked, somewhat by planks of plywood leaning against the door frame, but it's easy to squeeze through"* [15].

Amid this burgeoning but poorly documented and understood element of the US fire problem, reliable statistics to enable a comprehensive analysis remains difficult to find. The complex nature of this fire problem, and its dynamic and informal nature challenges existing data systems, which are built around certainties such as street addresses, property ownership records, and formal registration with government agencies. Existing fire incident data systems do not capture or define the socioeconomic circumstances of the property owner, the maintenance or upkeep status of the property (beyond vacancy), or characteristics of the environment (tent fire on a campground versus under a highway bridge). Nonetheless, it is shown that the interactions between environmental, neighborhood, social, economic, demographic characteristics, and health can help explain discrepancies in fire losses.

Understanding the nature of insecure and vulnerable shelter is important for several reasons, most notably the ability to identify measures to improve fire safety across the range of existing shelter and housing in the US, and the need to situate these measures in the context of the prescriptive and complex US building regulatory system.

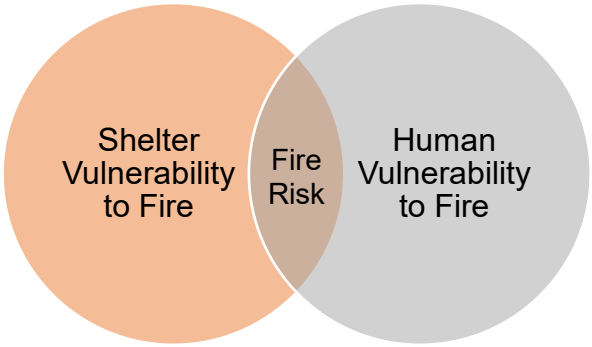
To address these systemic and widespread fire problems, this paper outlines what we know and do not yet know about the interactions between regulatory blind spots, ambiguous application of existing fire safety regulatory regimes and informality. By defining and framing these matters, this work aims to discover the breadth and depth of research and action needed to understand and ultimately address fire safety issues of insecurely and vulnerably sheltered populations[4] in the US – the invisible fire problem.

[4] i.e., populations living in under-regulated, unregulated, or non-sheltered conditions; see Section 2.

2 Definitions

Understanding a problem starts by understanding the language – the terminology, definitions, and concepts used to describe the problem. Some of the concepts in this paper may be new to some. Likewise, some of the terms used may have different definitions as applied in different sectors. This section includes definitions for key terms used throughout this paper.

- **Insecurely and vulnerably sheltered populations** – People living in unsafe conditions due to the combination of their own specific vulnerabilities and their shelter vulnerabilities caused by interrelated and often systemic issues, including people living in 'slum conditions'. For the purposes of this study, populations living in under-regulated, unregulated, or non-sheltered conditions are considered insecurely and vulnerably sheltered.



- **Shelter vulnerability to fire** – lack of capacity of shelter to provide protection from fire due to inappropriate or ill-maintained shelter materials and/or fire safety systems. In considering the shelter vulnerability to fire, the following typologies are defined:
  - **Vulnerability-Protected**: Goes beyond minimum aspect of building code and includes additional provisions / enhancements aimed at protecting shelters and their vulnerable populations more robustly from fire than minimally compliant shelters.
  - **Minimally Compliant**: Meets building code requirements at time of construction and are maintained to meet that level throughout their lifetime to provide a societally tolerated level of shelter vulnerability to fire.
  - **Under-Regulated**: May have met building code at time of construction, or not, and are inadequately maintained, have insufficient fire protection, may have illegal components, may be abandoned, etc. Also, persons may use the space for temporary or permanent shelter, legally or illegally.
  - **Unregulated**: Informal structure built outside of regulatory control; temporary materials and methods of construction may be used to provide minimal protection from some environmental effects; construction offers little or no fire protection; insecure tenure is common. Examples include tents, tarps, lean-to's, motor vehicles, shacks.

- **Non-sheltered**: No significant form of shelter, consisting of open sleeping, possibly with bedding or other cover (e.g., bridge, doorway, awning) for minimal protection against weather conditions. This is the lowest level of shelter / housing security.

- **Shelter insecurity** – lack of 'permanent' shelter, leading to the potential to move often, live in under-regulated, unregulated, or non-sheltered habitations, and so forth.

- **Human vulnerability to fire** – lack of capacity of person(s) to respond or recover from fire and its effects due to individual, household or community's circumstances, experiences, and capacities, shaped by demographic, physical, mental, social, cultural, institutional, environmental, and economic factors (or processes)

- **Risk** – the possibility of an unwanted outcome in an uncertain situation, where the possibility of the unwanted outcome is a function of three factors: loss or harm to something that is valued, the event or hazard that may occasion the loss or harm, and a judgement about the likelihood that the loss or harm will occur; see Section 3

- **Credible fire event** – a self-sustaining fire resulting from the confluence of a credible ignition source and available fuel; see Section 3.1

- **Fire risk** – a measure of the possibility of loss or harm resulting from a credible fire event

- **Risk to life from fire** – a measure of the possibility of harm to person(s) resulting from the occurrence of a credible fire event

- **Fire resilient shelter**[5] – a shelter that, when exposed to a credible fire event, has the ability to resist, absorb, accommodate and recover from the effects of that fire in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

- **Fire resilient occupants** – persons who, when exposed to a credible fire event, have the ability to resist, absorb, accommodate and recover from the effects of the fire in a timely and efficient manner, including physically, mentally, emotionally and financially.

3 Conceptualizing Risk

The concept of risk can be challenging due to the breadth of perceptions, conceptualizations, and definitions of risk. For many people, risk is related to the uncertainty around some future decision, action, or event, where all relevant knowledge and information that may impact the outcome is not known or available. This uncertainty necessitates considering the possibility or likelihood that different outcomes might occur. The framing of a risk is also dependent on how those involved perceive and value the potential positive and negative outcomes (e.g., those imposing the risk or those at risk). [16]

[5] Fire resilience terms are inspired by the United Nations Office for Disaster Risk Reduction resilience definitions. [15]

There are different types of risks which may be considered, such as health risks, safety risks, economic risks, political risks, and the interpretation and measurement of risk is often a function of the context of the risk problem that is being addressed. As a result, specific taxonomies and tools for discussing and assessing risk grew out of the context of the various problem areas for which risk analysis was being applied. [17] An example of the diversity of risk framing is illustrated in Table 1. [17] [18] Engineers idealize risk as a numerical value that is a function of probability and consequences. [18] By contrast, some social scientists view risk as a social construct, not dependent on numerical values, but dependent upon the social situation and conditional knowledge. [19] Another view is held by some psychologists who believe that "risk" does not exist outside of our minds, but that it is simply a concept humans developed to deal with uncertainties of life. [20] There are also some who have suggested that the selection of a definition of risk is a political one, chosen to express someone's views regarding the importance of different adverse effects in a particular situation. [21] In the latter case, a number of dimensions define the issue, including objectivity (objective versus subjective probability and/or risk), dimensionality (there are usually benefits as well as consequences), data, statistics and units of measure, time impacts, values and perceptions. Add to the mix various cultural and other viewpoints on risk, numerous definitions and classifications of risk can result. [17] The complexities of fire problems related to homelessness and insecurely and vulnerably sheltered populations is also fraught with uncertainty, which some have argued should be more explicitly included in formulations of risk. [22]

Although an ideal definition of risk may not be possible, and different views on the concept of probability exist, it is still helpful to aim for a definition of risk that encompasses the key aspects related to risk. Drawing from those who have considered what is needed in a well-rounded definition of risk, one can develop a list of key factors to be considered in any definition of risk [16]:

- The concept of hazard or hazard event,
- The consequences of the hazard event (including all relevant consequences and the valuation of the consequence, including off-setting benefits),
- Differences in risk perception,
- Social and cultural experience,
- Judgement(s) regarding the likelihood (probability) of the consequence occurring, and
- Consideration of uncertainty and variability.

One definition of risk that includes the above issues is (derived from [15] [16] [23]): the possibility of an unwanted outcome in an uncertain situation, where the possibility of the unwanted outcome is a function of three factors: loss or harm to something that is valued (consequence), the event or hazard that may occasion the loss or harm, and a judgement about the likelihood that the loss or harm will occur (probability).

In this definition, the valuation of loss or harm is intended to consider physical, technical, social, cultural, and psychological factors, and event or hazard is intended to consider any act or phenomenon that has the potential to produce loss or harm. Loss or harm to something that is valued includes such things as loss of life, injury, disease, reduced quality of life, inability to carry on economic activity (the inability of an individual to work, or the inability of a business to carry on operations), property damage, and damage to the environment.

Table 1: Systematic Classification of Risk Perspectives [17] [18]

	Integrated Approaches (e.g., Social Amplification of Risk)						
	Actuarial Approach	**Toxicology Epidemiology**	**Probabilistic Risk Analysis**	**Economics of Risk**	**Psychology of Risk**	**Social Theories of Risk**	**Cultural Theory of Risk**
Base Unit	Expected Value (EV)	Modelled Value	Synthesized Expected Value	Expected Utility (EU)	Subjective Expected Utility	Perceived Fairness and Competence	Shared Values
Predominant Method	Extrapolation	Experiments Health Surveys	Fault Tree and Event Tree Analysis	Risk Benefit Analysis	Psychometrics	Surveys Structured Analyses	Grid-Group Analysis
Scope of Risk Concept	Universal	Health & Environment	Safety	Universal	Individual Perceptions	Social Interests	Cultural Clusters
	One-dimensional	One-dimensional	One-dimensional	One-dimensional	Multi-dimensional	Multi-dimensional	Multi-dimensional
	Averaging over space, time, context			Preference Aggregation		Social Relativism	
Basic Problem Areas	Predictive Power	Transfer to Humans Intervening Variables	Common Mode Failure	Common Denominator	Social Relevance	Complexity	Empirical Validity
Major Application	Insurance	Health Environmental	Safety Engineering	Decision Making	Policy making and regulations Conflict resolution Risk communication		
Instrumental Function	Risk sharing	Early warning Standard setting	Improving systems	Resource allocation	Individual Assessment	Equity Fairness Political acceptance	Cultural identity
Social Function	Assessment	Risk reduction and policy setting (coping with uncertainty)					Political legitimization

3.1 Conceptualizing Fire Risk

Starting with the above conceptualization of risk and identifying a credible fire as presenting the hazard which could result in some potential loss or harm, one can define fire risk as **a measure of the possibility of loss or harm resulting from a credible fire event**. The term 'credible fire' is used to reflect a sustainable fire resulting from the confluence of a credible ignition source and available fuel. Here, sustainable simply means the fire can continue to burn without the presence of the ignition source. This is sometimes referred to as the stage of 'established burning' in the lifecycle of a fire (ignition, established burning, growth, steady-state, and decay).

The concept of credibility is important. Consider a campfire – what it takes to get it started, and what is required to keep it going. Assume you have one match and one large log. While a match is a credible source of ignition – if the fuel is a leaf or paper – it is nearly impossible to ignite a large log with a match. This is why some sort of easily ignitable material, such as paper, or dry leaves, is needed to establish a flame that will burn longer than the match. Even so, this may not be enough to ignite the log, as the duration of burning will be too short. However, if you have some kindling to place over the burning paper, the kindling may burn long enough to ignite the log. If there is sufficient kindling to adequately involve the log, you will get a nominal campfire. However, if you only have one log, the campfire will last only as long as the log is not fully burned.

The notion of a credible fire is also contextual and can cover a wide range of scenarios. For example, cigarette ashes can ignite clothing, and if the clothing is combustible and catches fire,

that is a credible fire. So too is the burning of a chair or sofa ignited by a cigarette, or the burning of a combustible blanket or covering that is ignited by the embers from a fire.

For each example of a credible fire, one can also conceptualize the possibility of loss or harm. A person can be severely burned if their clothing, bed covering, or furniture in which they are sitting catches fire. If a chair or sofa in a room catches fire, that can easily ignite other combustible materials in the room, and potentially spread to other rooms.

However, these are only possibilities, and the loss or harm can be avoided or minimized if action is taken or if protective measures are in place. If the ignited clothing is quickly smothered, the person may not be burned (but they might have a hole in their clothing). If sofa begins to burn, and the room in which it is located has a smoke alarm, the alarm will sound to warn occupants to escape. If the room also has fire sprinklers, the fire will likely be extinguished before it can spread to other items in the room or beyond.

The extent to which loss or harm can be avoided is in turn dependent upon the vulnerability of 'that which is valued', which includes people, property, and the like. A person who falls asleep while smoking or is otherwise not able to take action on their own, is more vulnerable to a smaller credible fire than an awake, alert person who has the ability to take life-saving action. Likewise, a shelter that is informally constructed of combustible materials that have no resistance to ignition or combustion is more vulnerable to a smaller credible fire than shelter constructed of fire-rated materials.

As such, when considering fire risk, it is important to consider the context and the confluence of credible ignition sources and fuels, the vulnerability of fuels that can be ignited, and the vulnerability of the persons or property (or other items that are that which are valued) in the analysis of the risk. When looking at a specific attribute of fire risk, such as safety to life from fire in a shelter, it can often be helpful to disaggregate the components to understand the vulnerabilities and exposures more clearly instead of trying to consider them all together; see also Section 3.4.

3.2 Shelter Vulnerabilities to Fire

At a basic level, a shelter can be considered a physical artifact that provides some measure of temporary protection from bad weather or danger. Shelter can range from a cave or lean-to created from tree branches to blankets or tarps draped over a support or free-standing tents, to enclosures constructed from discarded pallets or construction materials to more formally constructed buildings.

Because of the protection afforded, shelter is considered a basic human need. However, the range of shelter materials and construction afford widely ranging levels of protection to the occupant(s) from weather, illness, natural or man-made hazard, or physical attack. The level of protection afforded can be altered as modification is made to the shelter or its use, i.e., in the choice of technology. In formal construction, which is regulated by formal planning, zoning, building and fire regulation, a high level of protection, across many health and safety attributes, is afforded by the technologies that are used. At the other end of the spectrum (e.g., under-regulated, unregulated and for non-sheltered populations), little is provided in terms of protection, and the options to address the protection shortcomings are often limited.

One way of looking at the problem is through the lens of the causal sequence as outlined by Hohenemser, Kates and Slovic. [19] In this work, hazards, in particular technological hazards, are described as a sequence of causally connected events that result from human needs and wants,

to choice of technology, to initiating events, to possible release of energy or materials, to human exposure, to eventual harmful consequences. This is illustrated in Figure 1 (adapted from [19]).

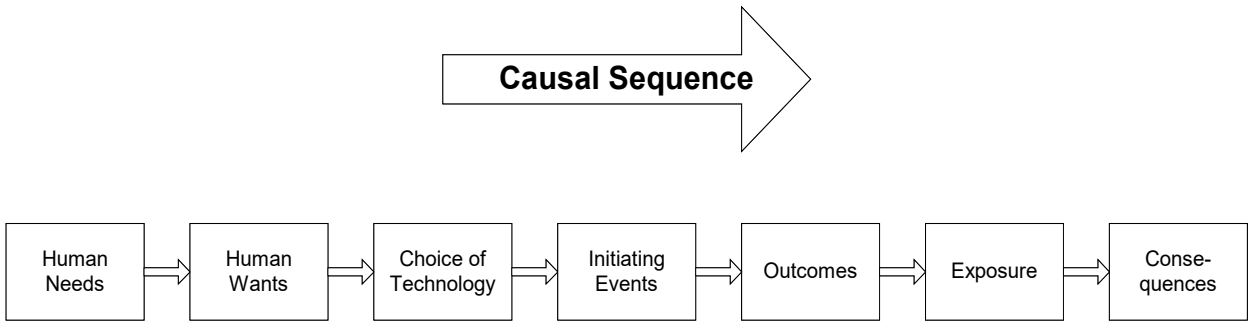


Figure 1: Casual Sequence for Technological Hazards (adapted from [19])

For each component of the causal sequence, there are opportunities to impact or alter the outcome of the hazard occurrence or consequences. This is illustrated in the following diagram (Figure 2) for a simplified case of fire as a means to provide heating in shelters.

In the top layer of Figure 2, a potential hazard sequence is laid out, where there is the human want for a heated shelter, which results in a choice of heating with an open fire. This choice could in turn create a hazard if smoke is not vented due to a blockage, and smoke becomes trapped in the space. The life safety impact(s) or outcome(s) can be measures in terms of intolerable temperatures, CO levels, smoke and so forth, with potential consequences being incapacitation or death.

However, at each step in the sequence, choices can be made to reduce or eliminate unwanted outcomes. Of course, not each choice is available to each person, so for some people the hazards are not able to be reduced. Fundamentally, the first choice is to move to a climate where heating is not required (although the hazard may remain for cooking). This is often not a viable choice. The next choice is related to the heating technology, which can be modified from open flame, to enclosed flame, to electric or other source. The event that results in a hazard and its extent can be changed by technology (e.g., automatic smoke vents, fire extinguishing system, …) or human action (e.g., open a door, extinguish the fire, …), and exposure can be blocked by technology or action (e.g., leave the space), which limit the potential consequences (which are difficult to reduce if no intervention occurs).

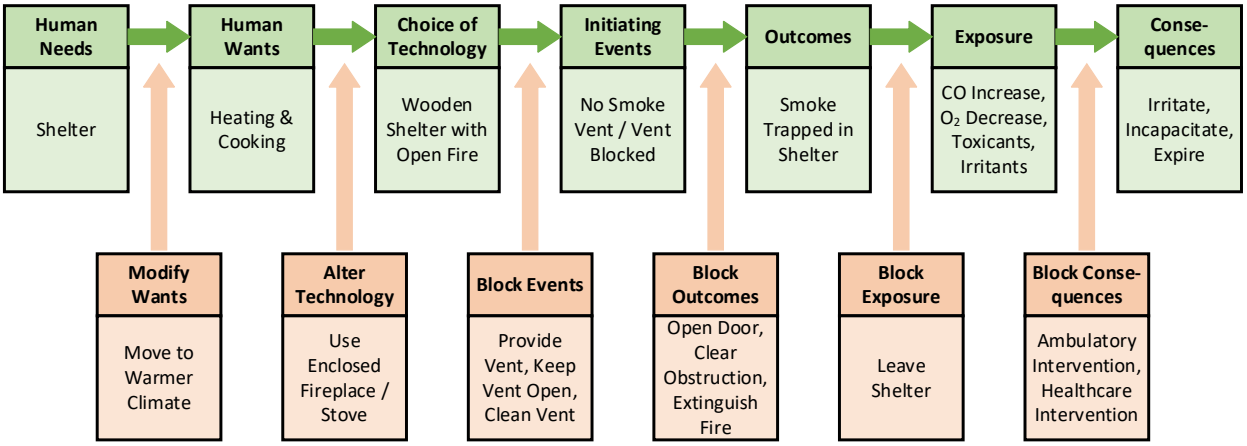


Figure 2: Casual Sequence for Fire Hazards in Shelter

With respect to shelter fire hazards, the more formal, regulated shelter that one has, generally the less opportunity there is for credible fires, the less vulnerable the shelter is to fire, and the less potential for producing hazardous conditions may exist, largely due to implementation of technological interventions.

Diagnostically the sequence can be used to understand what fire risk reduction interventions are missing for shelters that are less formally constructed and regulated, less substantial, and afford less protection. That is, as each intervention, which is present in formal, regulated shelters is removed, there is an increased vulnerability to fire for the shelter.

This framework lends itself to the formulation of shelter typologies that are reflective of the formality of construction and level of regulation (and enforcement) as means to (a) understand the vulnerabilities of the shelter typologies to fire events that are credible in the context of the typologies, and (b) understand the types and range of potential interventions and/or mitigation measures that could be taken to reduce both shelter vulnerability and associated fire risk.

3.2.1 Shelter Typologies

For the purposes of this work, shelter is considered in the following broad categories within which insecurely and vulnerably sheltered populations are likely to live. Here we build upon the terminology and definitions of Section 2 and provide additional considerations.

- **Vulnerability-Protected**: Goes beyond minimum aspect of building code and includes additional provisions / enhancements aimed at protecting shelters and their vulnerable populations more robustly from fire than minimally compliant shelters.

- **Minimally Compliant**: Meets building code requirements at time of construction and are maintained to meet that level throughout their lifetime to provide a societally tolerated level of shelter vulnerability to fire.

- **Under-Regulated**: May have met building code at time of construction, or not, and are inadequately maintained, have insufficient fire protection, may have illegal components, may be abandoned, etc. Also, persons may use the space for temporary or permanent shelter, legally or illegally.

  As buildings age, their fire safety performance tends to decrease, especially if not well maintained. The ability of building owners and occupants to properly maintain buildings and their fire safety systems tends to be lower in buildings and communities housing occupants that are economically and socially disadvantaged, thereby leading to higher fire risks in these settings.

  Examples include ***under-maintained, under-the-radar, and vacant / abandoned*** buildings.

  - ***Under-maintained:*** describes the situation of a regulated building falling into neglect due to an owner unwilling or unable to address maintenance issues. This can occur with owner occupied or rented housing. These buildings are typically considered occupied, even if the level of habitability is poor (see also discussion below regarding abandoned or vacant buildings).

    The reasons that this may happen are numerous, and the impacts can be significant. Harvard University's The State of the Nation's Housing 2021 [20] reflects some of the

challenges, noting that "more than a third of all occupied homes in 2017 had structural, plumbing, electrical, and heating problems."

One could suppose that similar challenges exist with fire safety features, including some type of problem with smoke alarms, door systems, and compartmentation. This concern is echoed by the National Center for Healthy Housing (NCHH), which notes that regulations and industry practices affecting existing owner-occupied and rental housing, the focus of their National Healthy Housing Standard, have not kept pace with our knowledge about housing-related disease and prevention of disease and injury through routine maintenance.

While not included in the Harvard study or that by the NCHH, National Fire Protection Association (NFPA) statistics suggest that at least for smoke alarms, installation and maintenance is a concern, ranging from whether smoke alarms are even present, to present but failed to operate. Even if smoke alarms and/or fire detection and alarm systems exist, they may be subject to nuisance alarms, leading occupants to ignore them. This 'cry wolf' syndrome, or 'learned irrelevance', can lead to occupant failure to act upon first indication of a fire, which can have dire consequences. Furthermore, other aspects of a building's fire safety system may be inadequately maintained or non-functioning, which can lead to increased fire safety risks. These other systems include fire and smoke resistive construction of structure, walls, and door systems, door closers, smoke and heat venting and exhaust systems, and more. When a combination of system failures occurs, the outcomes can be catastrophic.

Under-Maintained

Reporting by the New York Times regarding the tragic January 2022 [21] fire in the Twin Parks North West high-rise affordable housing apartment building in the Bronx, New York, indicates that inadequate maintenance likely played a role in the 17 fatalities. Constructed in 1972, the apartment building was constructed before sprinklers were required. The primary fire safety measures were therefore early detection and passive compartmentation. Reporting suggests that some type of fire alarm sounded in the building; however, residents "did not take them seriously, given the history of false alarms in the building." Reporting goes on to suggest that automatic door closers, which should have functioned to contain smoke spread, failed to work properly on the apartment of fire origin, allowing smoke to spread into the stairwells on the floor of fire origin, and onto upper-level floors. The 2017 Grenfell Tower fire in London, in which 72 people died, experienced a similar combination of fire safety systems failures, complicated by a combustible exterior façade, installed as part of building renovations for energy retrofits, which greatly facilitated fire spread. [22]

- ***Under the radar:*** in addition to inadequately maintained buildings, there is a collection of situations that can go 'under the radar'. Two significant concerns are insecure tenure and illegal conversion or subdivision of space.
    - Insecure tenure is used here to describe housing of persons within an otherwise legally permitted unit but characterized by owner- or user-driven mechanisms such as illegal sub-leases or extra occupancy beyond the legal framework of tenancy between owner and resident. This situation can happen in cases of best

intention, such as providing shelter for extended family. However, it can also be driven by opportunistic situations in which financial gain can be obtained through overcrowding and/or inappropriate/unregulated rental of space.

- Illegal conversion / subdivision refers to the conversion of commercial or industrial spaces to residential uses, as well as illegal subdivision of formal dwelling units into smaller spaces, again for the purpose of opportunistic financial gain. Such occupancies often reflect inadequate fire safety and egress, access to utilities, and living space. Included within this category are conversion of parts of regulated premises, such as basements, into housing units outside of any regulatory process. An example of inappropriate industrial conversion is the 2016 fire previously mentioned in a converted warehouse in Oakland that led to the deaths of thirty-six people. The building was an occupied structure divided into live / workspaces, which was also used for events. The evening of the fire, a music event being held on the second floor. Use of the warehouse building for housing and entertainment was illegal.

  In these types of situations, which would classify as 'change of use' of an existing building under the building code, there would be requirements to bring fire safety features in line with the new use. However, if no permit is applied for, it is very difficult for authorities to know that the situation exists.

Illegal Renovations/Subdivision

Otherwise, compliant structures can be modified by adding illegal or non-compliant rooms. Fires in what appear to be "typical" 3- or 4-bedroom houses can house many more people through illegal subdivision. In Hillcrest, NY, a single-family home was illegally converted to have 11 bedrooms, with an additional space being used as a sleeping area. The home was cited for illegal conversions in 2020, and after code enforcement action, was subsequently subdivided again. A fire there in 2022 injured three people. [23]

Similarly, a Washington, DC rowhouse was illegally converted to add multiple bedrooms. A fire resulting in 2 fatalities resulted in the owner being charged with murder. [24]

Overoccupancy

Pressure on the housing stock and the need to accommodate additional residents can result from displacement of relatives or friends due to economic insecurity, fire, or other causes. The result is temporary or semi-permanent "doubling up," couch surfing, or other improvised uses. A fire in a Philadelphia rowhouse apartment owned by the Philadelphia Housing Authority resulted in 12 fatalities among 18 residents living in the 4-bedroom apartment. The apartment was originally intended to house only six residents. [25]

- ***Vacant – abandoned:*** vacant and abandoned buildings pose different types of fire risks. Many of these buildings lack any type of fire protection measures, do not have active utilities connections (e.g., power, water), and may be filled in part with discarded

belongings, trash, or other combustibles. If people are using such buildings for shelter, they may be using open flame for cooking and heating, presenting significant fire ignition hazards. Likely the fire service will not know the building has occupants should a fire occur.

Saint Louis – A fire in a vacant building caused a structural collapse that killed one firefighter in January 2022. The problems of squatters living in vacant or abandoned buildings was well-illustrated by a 2018 piece in the Saint Louis Post-Dispatch newspaper that documented habitation in these buildings, some of which had already begun a process of structural collapse from abandonment. [26]

Baltimore – Three members of the Baltimore City Fire Department were killed and a fourth was seriously injured shortly after they entered a fire in an abandoned rowhouse [5]. The fire was subsequently determined to be arson. [27] The same building caught fire in 2015, injuring 3 firefighters. The property was marked as vacant for some 4 years before that. [28].

- **Unregulated**: Informal structure built outside of regulatory control; temporary materials and methods of construction may be used to provide minimal protection from some environmental effects; construction offers little or no fire protection; insecure tenure is common. Examples include tents, tarps, lean-to's, motor vehicles, shacks.

- **Non-sheltered**: No significant form of shelter, consisting of open sleeping, possibly with bedding or other cover (e.g., bridge, doorway, awning) for minimal protection against weather conditions. This is the lowest level of shelter / housing security.

Within the under- or unregulated accommodation, there are areas of considerable overlap and complexity. Enforcement mechanisms are largely market-driven, with property owners responsible for maintaining or bringing property up to legal minimum standards by the local Authority Having Jurisdiction (AHJ). Chronic, long-term problems of property maintenance and abandonment contribute to deterioration of housing quality. Housing regulation presumes a stable, legal pattern of ownership and tenancy. This regulatory system exists based on norms of conduct, and when these norms are breached, opportunities for proliferation of unsafe or less safe housing can be created, even within structures ostensibly subject to regulation.

Illegal conversion / subdivision is a gray area in most regulatory systems. The size of this market is not well known. Recent experience shows that this portion of the housing market is both tolerated by regulators, and a wide swathe of municipalities are in various stages of developing and implementing schemes for legalization of some of this housing stock. For example, New York City has a large stock of illegal basement apartments that exist outside any formal regulatory process. Estimates place as many as 100,000 informal units of all types within New York City. [21]

Reasons of housing scarcity and a desire to avoid making tenants homeless have occurred in multiple locales, creating a gray area where governments may tolerate non-code-compliant housing. The existence of such units creates a tension between tenants, landlords renting units without approval, and housing advocates who want to avoid creating more unsheltered people. In Los Angeles, enforcement of codes in unpermitted housing was relaxed during the covid-19 pandemic to protect health of inspectors. In New York City, plans to legalize basement apartments were questioned after 11 residents drowned in flooding following heavy rainfall from Hurricane Ida [22]. A subsequent report by the City calls for establishing a list of basement apartments (implying legal tolerance) and developing a comprehensive basement apartment conversion program. [23]

In the realm of illegally constructed dwelling units, a New York Times article describes a garage converted into a 1100 sq. ft. dwelling in the back yard of a more modest house. The article describes this portion of the housing market as a *"shadow inventory of unpermitted housing that has swelled across Los Angeles and other high-priced cities as affordable housing shriveled. Amateur developers build them for profit. Homeowners build them for family or to help with the mortgage."* [32]

Another share of regulated illegal conversion / subdivision housing includes use of non-residential structures for residential purposes. Often these units may not comply with egress and life safety requirements.

In the area of improvised housing, fire safety concerns dominate due to the lack of fire resistance, insecure tenure, and often, proximity to other improvised housing which increases risk of fire spread across multiple units, and heightened risks of crime, violence, unsafe or irregular heating or cooking operations. Such settlements can include collections of tents, vehicles used for shelter, informally constructed shelters, often with accumulations of storage and combustibles in close proximity. Parallels can be drawn to and lessons learned from fire issues in informal settlements in South Africa, India, and Mexico, among other Low- and Middle-Income countries where combustible materials of construction, high dwelling densities, inhabitants storing materials in and around homes, poor construction techniques, reliance on unsafe and potentially hazardous forms of energy for daily activities such as cooking, heating, and lighting, and other factors contribute to heightened fire risks in comparison to more formal areas.

Lastly, improvised temporary housing includes totally non-sheltered circumstances such as sleeping outside without a tent, use of rudimentary bedding, or crude shelters such as cardboard boxes or crates.

3.3 Human Vulnerabilities to Fire

Various social and individual, economic and demographic factors were identified and mapped onto a matrix (Table 2), to understand which aspects of human vulnerability have been identified in research in relation to fire risks, what those risks are, and what are the identified housing typologies that allow for the fire risk and human vulnerabilities to interact. These results were gathered from a range of literature: peer-reviewed papers focusing on human vulnerability and fire risks internationally, US government reports and fire safety organizations' reports. Across the reviewed literature, broadly 18 categories were found to indicate human social, demographic and economic vulnerability that contributes to general fire risks (see table below). Generally, individual habits (e.g., use of alcohol drugs, smoking), physical psychological fitness (e.g., mental or

physical health conditions), demographics (age and gender, family structure), economic status (identified as either poverty, household income, employment status, or education), and social belonging, often explored on the basis of individual background (e.g., ability to speak local language, ethnicity, inclusion in community) were the recurring predictors of general fire risks.

However, some of these predictors were shown to be ambiguous or contradictory across the geographically diverse studies. For example, while intoxication is often explored as a contributing factor to fire risks, one study by [24] showed that in 40% of the fatalities the, post-mortem examination identified traces of alcohol in the body fluids, while no alcohol was found in an equally large proportion. In addition, while the incidence of all fires decreased with rising rent [25], it also showed that for higher-rent strata, fire risks increase mainly due to smoking habit, overall showing that direct relationships between an individual vulnerability and fire risk could vary from context to context (e.g., across countries, states, neighborhoods, but also across socio-economic, demographic, and other groups and importantly, their intersections).

Indeed, some studies explored such intersectional relationships, indicating heightened fire risk to elderly females [26]; individuals with mental illness and habit of smoking [24]; people of retirement age and with smoking habits, as well as reduced cognitive abilities and reduced mobility [24]; higher-rent and smoking habit [27] being middle-aged, male and intoxicated [26]; being very young and male [28]; younger children in families with least favorable occupational status [29]; children under the age of 18 living with both parents. [30] While intersectional approach lacks validation across multiple studies, and may still require contextualization (e.g., specific country-based research) they may allow to draw more robust conclusions for specific vulnerability groups, facilitating risk mitigation efforts.

Table 2 shows the human vulnerability factors identified in the literature and their corresponding relationship to general fire risks. Those results that apply intersectionality across several vulnerabilities are shown in multiple rows.

Table 2: Human vulnerability factors identified in the literature and their corresponding relationship to general fire risks

Vulnerability factor	General fire risk relationship
Use of alcohol / intoxicating substances	− Alcohol, Drugs being contributing factors to fire incident [30]; [31] as well as reaction to fire event [32] − below retirement age the most conspicuous risk factors are known substance abuse (54%), alcoholic influence (59%), and smoking (36%) [24] − middle-aged (45–64 years old), (often) intoxicated men [26] − however in a study by [24] in 40% of the fatalities the post-mortem examination identified traces of alcohol in the body fluids, while no alcohol was found in an equally large proportion.
Smoking	− Residents who are smokers have increased risk due to the cigarette ignition [31]; [32]; [1] − below retirement age the most conspicuous risk factors are known substance abuse (54%), alcoholic influence (59%), and smoking (36%) [24] − For those who have reached retirement age four recurring risk factors were identified: reduced mobility (47%), impaired cognitive ability (the elderly with Alzheimer's or other forms of dementia) (33%), mental illness (34%) and smoking (33%) [24] − However, no recurring patterns of combinations of various risk factors were identified, except mental illness and smoking [24] − fires caused by cigarettes were responsible for a larger share of fires among the high-rent tracts [25]
Mental Health	− Mental disability as a contributing factor to fire incident [30]; [31] as well as residents' ability to react to the event [32] − For those who have reached retirement age we principally see four recurring risk factors: reduced mobility (47%), impaired cognitive ability (the elderly people who fell into this category often had Alzheimer's disease or other forms of dementia) (33%), mental illness (34%) and smoking (33%) [24]

Vulnerability factor	General fire risk relationship
	− However, no recurring patterns of combinations of various risk factors were identified, except mental illness and smoking [24]
Physical disability	− This is a risk factor because the nature of the disability may mean the resident could not evacuate safely or quickly in the event of a fire [31]; [32]; [30] − For those who have reached retirement age we principally see four recurring risk factors: reduced mobility (47%), impaired cognitive ability (the elderly people who fell into this category often had Alzheimer's disease or other forms of dementia) (33%), mental illness (34%) and smoking (33%) [24]
Being Male	− middle-aged (45–64 years old), (often) intoxicated men [26] − Proportion of young males. 6–18 years [28]
Being Female	− Elderly people, usually female at higher fire risk [26]
Any age	− below retirement age the most conspicuous risk factors are known substance abuse (54%), alcoholic influence (59%), and smoking (36%) [24] − fatalities are exponential across the age [24] − Claiming support from adult social care services [32] − expectations for the future of their neighborhoods [27]
Older Age	− Elderly people [31]; [33]; usually female at higher fire risk [26] − Residents aged over 65. This is a risk factor because older residents may suffer more from the effects of smoke or burns and may not be able to recover as quickly as a younger resident. [32] [34] − For those who have reached retirement age we principally see four recurring risk factors: reduced mobility (47%), impaired cognitive ability (the elderly people who fell into this category often had Alzheimer's disease or other forms of dementia) (33%), mental illness (34%) and smoking (33%) [24] − There has been little change in the death toll of older adults [1]
Younger Age	− Proportion of young males. 6–18 years [28] − Population of young people [35] − We have been successful in dramatically reducing the number of fire deaths of children under five, but there has been little change in the death toll of older adults. Several factors contribute to older adult fire death toll, including the increasing age of the population overall, older adults increasingly living alone, the increase in disabilities with age, and the tendency for older adults to live in older homes. [1] − In studies on children, younger children in families with least favorable occupational status have higher risks of burn injuries across UK, USA, Peru, South Africa [29]
Middle age	− Middle-aged (45–64 years old), (often) intoxicated men [26]
Family structure	− Percentage of children under the age of 18 living with both parents [36]
Poverty	− Poverty, defined as the percentage of persons whose incomes fell below the poverty line [36] − Claiming support from adult social care services [32] − Ethnicity has also been found to be associated with rates of fire although it has been argued that this is the result of collinearity with poverty and deprivation. [37] − county-level poverty confers a greater risk of death from unintentional injury, and higher poverty areas have shouldered the burden of the recent national increases in unintentional injury mortality rates [38]
Household income	− lower income households [39] − income deprivation [35] − average income [40] − Having income below poverty line associated with higher rates of fire deaths [1] − no statistically significant association between household fire status and household income [41] − Poverty, defined as the percentage of persons whose incomes fell below the poverty line [36] − Percentage of families with annual incomes greater than $15,000; [36] − income - a significant drop in the fire rate as the income rises. [36] − In studies on children, younger children in families with least favorable occupational status have higher risks of burn injuries across UK, USA, Peru, South Africa [29] − presence of vehicles in the household [27] − the incidence of all fires decreased with rising rent [25] − fires caused by cigarettes were responsible for a larger share of fires among the high-rent tracts [25]

Vulnerability factor	General fire risk relationship
Employment status	− employment deprivation [35] − Unemployment [27]; [28] − employment ratio, and unemployment rate [40] − not worked for more than five years or have never worked [37]
Education	− Under-education, or the percentage of persons over the age of 25 who had fewer than eight years of schooling [42] − lower educational attainment [37] − secondary school level as highest [28] − 'Low levels' of education [36] − proportion with no high school education vs proportion with a university degree [40] − heads of fire households tended to have higher educational levels than heads of non-fire households. [41]
Ability to speak local language	− non- English speaking population [27] − Factors associated with poverty and elevated fire risk include the ability to speak English. [43]
Ethnicity	− identifying as Black [37] − ethnicity [27] − indigenous population [27] − Being either African-American or Black or Native American or Alaskan-American [1] − fire households were headed by relatively more Black or African Americans, American Indians, or Hispanic or Latin Americans. Fire households had relatively fewer White heads of households. However, the differences were not statistically significant. [41] − Ethnicity has also been found to be associated with rates of fire although it has been argued that this is the result of collinearity with poverty and deprivation [37] − Being born abroad [28] − Fire-related mortality and morbidity has previously been demonstrated to be significantly higher among Indigenous people in Canada. [33] [44] [41]
Inclusion in community	− expectations for the future of their neighborhoods [27] − residents as having a fatalistic attitude about fire translates into caring less about fire issue [25] − little sense of community [25] − feelings of alienation toward local government officials [25] − a previous study linked population movement with increased fire rate [25]
General fire statistics	− Number of intentional fires per 1000 inhabitants [28] − the incidence of all fires decreased with rising rent [25] − no statistically significant association between household fire status and type of dwelling, age of dwelling [41] − inadequate surveillance capabilities at abandoned workplaces [39]

Nonetheless, beyond general fire risks, this research scoping report is aiming to untangle deeper and more complex interactions between human vulnerability, fire risk, and the environment (i.e., housing and shelter) in which people live / reside. For this reason, the review of the literature also helped to identify shelter related categories that pertain to fire safety and explore the relevance of human vulnerability in such environments. Table 3 below shows a non-exhaustive summary of the results of such interactions.

It is evident that household income, poverty and family structure have been shown to translate to poor dwelling conditions with most certainty. However, it is also evident that many of the sociodemographic factors are not being explored beyond the 'general risks of fire'. For example, it has been largely unexplored in the sample of the reviewed literature, whether ethnicity, ability to speak the local language, employment status, gender, smoking and use of intoxicating substances bear relationship to any dwelling characteristics. These factors, however, all were shown to matter for general fire risks (as discussed above). Thus, the lack of evidence for specific sociodemographic factors and their relationship to dwelling characteristics limits our ability to understand diversity of insecurely and vulnerably sheltered populations in terms of age, gender,

inclusion in community and their income, and how this diversity interacts with fire risk. In addition, the dwelling characteristics are limited to those identified from the reviewed studies, which do not provide enough evidence for structure type, vacant buildings, or occupancy types, among, of course, other categories that exist but have not been identified in the reviewed literature. Furthermore, as homeless populations' dwelling conditions are not evidenced enough in the literature, nor is homelessness discussed as a vulnerability, more research is needed to uncover these relationships.

Table 3: Matrix of topics addressed by literature reviewed

Housing / shelter characteristic / Vulnerability factor	General Risks	Single individual households	Households with poor electrical appliances (e.g., for heating)[6]	Occupancy types disproportionately focus on single type of occupation	Older homes[7]	Fire safety maintenance	Dwelling neighbourhood characteristics	Tenure characteristics	Occupancy density	Vacant buildings	Structure type
Use of alcohol intoxicating substances	■										
Smoking	■										
Mental Health	■	■									
Physical disability	■	■			■						
Being Male	■										
Being Female	■										
Any age	■	■									
Older Age	■	■	■		■						
Younger Age	■			■							
Middle age	■										
Family structure	■	■	■			■			■		
Poverty	■	■	■		■		■	■	■	■	■
Household income	■		■			■	■				■
Criminal activity							■				
Employment status	■										
Education	■						■				
Ability to speak local language	■										
Ethnicity	■										
Inclusion in community	■										
General fire statistics	■										

[6] Seasonality's relationship to fire risk was identified by [102] which is likely due to fire incidents with heating/ chimeneas more likely in December/January, while cooking fires prevalent throughout the year [103]

[7] While the age of housing relationship to fire risk was found in a study by [33], it is also true that the age of housing on its own does not say much about how the building is kept up to standard for fire safety [1], including no significant differences in the distribution of the ages of housing for fire and non-fire households [47], nonetheless, the median age in housing units in the US has been getting higher [1], meaning managing burden of fire risk mitigation is increasing which may cause adverse consequences on fire safety over time.

3.4 Fire Risk Analysis

Fire risk analysis is the process of understanding and characterizing fire hazard(s), the unwanted outcomes (relevant losses or harm) that may result from a fire, and the likelihood of fire and unwanted outcomes occurring. [45] To help characterize fire risk, a number of questions need to be asked: [16] [46]

1. Who or what is exposed?
2. If it is people, what groups are exposed?
3. What is posing the risk?
4. What is the nature of the harm or loss?
5. What qualities of the hazard might affect judgments about the risk (e.g., voluntary / involuntary, known / unknown, etc.)?
6. Where is the hazard experienced?
7. Where and how do hazards overlap?
8. How adequate are the databases on the risks?
9. How much scientific consensus exists about how to analyze the risks?
10. How much scientific consensus is there likely to be about risk estimates? How much consensus is there among the affected parties about the nature of the risk?
11. Are there omissions from the analysis that are important for decisions?

In fire risk analysis, life safety, property protection, business continuity, the environment, and / or heritage are all potential foci. To determine how one or more of these focal points might be exposed, and to what specifically, fire hazard assessments are undertaken. To determine potential impacts from exposure, consequence analysis is used. Consequence analysis should consider how the impacts are valued by those exposed in setting risk tolerability / acceptability limits. To complete the risk analysis, evaluation of the likelihood of hazard events occurring, and the likelihood that unacceptable or intolerable levels of impact will occur, are needed to assess the potential that unacceptable or intolerable levels of risk will result.

Depending on the analysis that is desired / undertaken, the calculus can be 'total' risk (i.e., all components wrapped into a single expression of risk), or 'component' risk, which considers only the focal area of concern. It has been found that use of a 'total' risk value is often not well understood, for a variety of reasons (e.g., [47] [48]), in particular when very small numbers are used to encompass a complex problem. Also, such estimates can mean that important contributing factors are difficult to identify. For example, one can express 'fire risk' as the combination of fire occurring and resulting in death. One way in which to do this is to divide the total number of fire deaths (in a year, for example) by the total number of buildings (for example), which will result in an annualized individual risk of fire death in buildings of some very low number, such as $5x10^{-7}$. Such an approach does not take into account the numerous risk factors that may exist in the population of concern (e.g., [49] [36] [50] [30] [43]) or the building stock of concern (e.g., [51] [52]).

When data are sparse regarding both the population and the building, but characteristics of each are known, it can sometimes be helpful to consider conditional probability (risk) approach, in which one estimates the likelihood of an event or outcome (A), given that another (B) has already occurred. For example, estimating the conditional probability (or risk) of a fire death given that a fire has occurred. What this allows for is the ability to focus on comparing risk of death for different populations given a fire occurs, and on comparing efficacy of different fire prevention and protection measures on fire initiation and spread, which when taken independently can provide a

richer understanding of the problem as compared with combining all factors into a single the risk measure.

The conditional approach is essentially what is done in the 'relative' risk reporting by the United States Fire Administration (USFA), NFPA and others, which presents only the deaths (and injury) rates and comparisons (by state, age, etc.), without including any particular data about the building in which the fires occurred. Thus, while it is helpful on the one hand to know that the risk of dying in a fire in a particular state is 2.5 times higher than the national average, details that help understand why this may be the case are unknown (and unknowable from the statistic).

As such, for this work, we consider the problem of understanding fire risk and vulnerability of insecurely and vulnerably sheltered persons as being the product of two components – (a) the probability of credible fire event occurrence (a self-sustaining fire resulting from the confluence of a credible ignition source and available fuel), and (b) a measure of the possibility of death (or injury) to an occupant resulting from the occurrence of a credible fire event.

More important perhaps than the risk calculus, this approach allows for a deeper evaluation of attributes of the building, used as a shelter, which can lead to potentially dangerous fires, and the attributes of the population, which may make it more vulnerable to fire if it occurs, and how the combination of fire-vulnerable populations in fire-vulnerable shelters can be better understood and potentially addressed. In this regard, an understanding of fire protection features of shelters (or lack thereof), and fire hazard development given different levels of protection (vulnerability), is a major focus.

As reflected in the list of factors needed to characterize fire risk that is provided above, data is a key component. The following section explores the current situation regarding date for potential use in characterizing fire risk of the insecurely and vulnerably housed.

4 Data Insights

The collection of comprehensive data on insecure and vulnerable shelters and their populations is complicated, as is obtaining reliable data or estimates of the fire problem among insecurely and vulnerably sheltered populations. However, there are multiple existing data sources that offer potential for better defining the magnitude and nature of the problem.

4.1 National Data

There are several national-level databases that could potentially inform study of the fire problem among insecurely and vulnerably sheltered populations. These systems are primarily related to fire incidents, health, housing, and homelessness.

4.1.1 Fire Data

There are two principal data sources for fire incidents at the national level. These are the National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's annual survey of fire experience.

These existing data systems do not capture or define the socioeconomic circumstances of the property owner or occupant(s), the maintenance or upkeep status of the property (beyond vacancy), or characteristics of the environment (tent fire on a campground versus under a highway bridge). Information on a fire in an illegally subdivided apartment, for example, would

likely be indistinguishable from a code-compliant new dwelling. The lack of such data has required the use of neighborhood characteristics to make inferences about socioeconomic and building stock characteristics and fire risk within the literature. [27] The potential for collection of expanded data could greatly enhance our understanding of fire risk generally, and among insecurely and vulnerably sheltered populations.

NFIRS

The National Fire Incident Reporting System (NFIRS) is a voluntary federal database of fire and emergency incidents. The system consists of a basic module and includes several additional modules for different types of incidents, including fires, structure fires, wildland, hazardous materials, and civilian and fire service casualties. At present over 24,000 fire departments report to the NFIRS system, which represents about 75 percent of all fires in the US. [53]

Although it is a Federal Data System, local fire departments typically report their incidents of a periodic basis via the state fire marshal or similar office. The state fire marshal's use these data to assemble State-level reports and summaries and send their incidents to the US Fire Administration's National Fire Data Center. The reports from the system are typically done on an annual basis.

NFIRS is explicitly built around notions of property address or ownership. While these criteria may not exist for incidents involving all insecurely or vulnerably sheltered populations, the NFIRS structure fire module does have the capacity to capture information on vacant building fires. However, any potential casualty to civilians is not explicitly identified as people using the building for shelter. In contrast, homeless encampments do not have formal street addresses, undercutting the key identifier used within NFIRS. Further, the system is designed primarily to capture fires in structures and was not designed to anticipate fires involving informal shelters, such as tents, shacks, or vehicles.

The NFIRS system is designed to be used hierarchically, with the simplest incidents requiring one module. Additional modules, say for example, the structure fire module, may not be completed because a shelter such as a tent may not be regarded as a structure. The fire module does include "tent" as a structure type, but this field was not designed to capture camping tents often used by the homeless. In addition, the burden of completing additional modules may be perceived as unnecessary for what may be regarded as a low-consequence incident in economic terms.

The USFA produces and releases periodic guidance documents on coding of emergent incident types within the NFIRS System. Guidance has been provided for example, on e-cigarette fires, and hybrid or electric vehicles. These guidance documents are typically disseminated to a state point of contact, typically in the state fire marshal office, who in turn publicize this information to fire departments across their respective states. Consequently, NFIRS system administrators have limited direct impact on data quality and training issues, as these are largely delegated to the State-level lead agency, which in turn relies on each fire department to maintain quality and consistency of reporting.

At present, no guidance has been produced specific to capturing incidents of fire in homeless encampments, or fires originating with the possessions of people experiencing homelessness. Consequently, a fire originating in possessions of a person experiencing homelessness outside may even be coded incorrectly, such as an outside rubbish fire. Similarly, existing coding schemes are unable to distinguish between a fire in a vehicle being used as a residence from vehicle fires originating from other causes.

NFIRS does have the capacity for what are known as local use "plus-one" codes. These codes are defined as used by participating agencies to further define an existing code. When a State

agency creates such a code, it is subject to analysis by the USFA at the national level. However, codes created by an individual fire department are not designed for analysis at the national level. [54]

Thus, using NFIRS to develop estimates of the fire problem affecting insecurely and vulnerably sheltered populations is challenging. The large number of scenarios which could result in a fire, and the myriad ways in which they can be counted within the system would require considerable effort and additional research to produce a credible estimate.[8]

NFPA

NFPA conducts an annual survey of fire departments to develop national estimates of the fire problem. This mailed survey is an important part of understanding the nation's fire problem (https:www.nfpa.orgfireexperiencesurvey). This effort known as "Survey of Fire Departments for United States Fire Experience" is a stratified random sample of fire departments by community size. [55]

At present, the survey does not collect or ask for data relating to informal occupation of vacant or derelict structures, or the incidence or prevalence of structure fires involving insecurely or vulnerably sheltered populations, or homeless encampments, or vehicles being used as shelter for that matter. Given that this survey is conducted annually, and it is under the control of a single private organization, it could readily be adapted to begin collection of information that would better reflect and define the national problem.

4.1.2 Health Data

There are a number of health information systems that could assist in identifying the magnitude and characteristics of the fire problem affecting insecurely and vulnerably sheltered populations in the US. An important distinction with these data sources is that they are based upon the health status of the individual, as opposed to tracking a specific fire incident. Consequently, these health-related databases must usually be combined with fire incident data to reach definitive conclusions about circumstances surrounding fire injuries or deaths.

CDC data

The US Centers for Disease Control and Prevention (CDC) is a Federal public health agency. It maintains two data systems that are potentially useful in understanding the fire problem among insecurely and vulnerably sheltered populations. These systems are designed to track health characteristics of individuals – not fire related data *per se*. The two systems have limitations on data disclosure when small numbers of cases are involved, meaning that they are most useful at the major metro, statewide or national level. The two systems are as follows:

WISQARS™ (Web-based Injury Statistics Query and Reporting System)

This system is an online database that provides information on fatal and nonfatal injuries, violent deaths, and cost of injury data. It has the ability to provide summaries of deaths by fire burn (which includes fatal injuries from smoke inhalation). [56] Fatal injury data is derived from death certificates. Injury data are national estimates of injuries treated in U.S. Hospital emergency

[8] The USFA also produces an ongoing tally of press accounts of residential fire deaths which is publicly accessible.[112]

departments derived from the National Electronic Injury Surveillance System[9]. The system maintains separate databases for fatal and nonfatal injuries.

CDC WONDER (Wide-ranging Online Data for Epidemiologic Research)

WONDER is a query tool for multiple CDC data sets. [56] Among its data sets is mortality data drawn from death certificates. With regard to fires, a category for "exposure to uncontrolled fire" exists for both "in a building or structure" and "not in a building or structure."

The WONDER system also has the ability to examine multiple causes of death, which may be useful in cases where a fire-related injury may not be the primary cause of death. This system shows promise as a means to capture deaths and reconcile them with fire reports to better identify the fire risk among the insecurely and vulnerably housed.

NEMSIS

The National Emergency Medical Services Information System (NEMSIS) is a national incident system for (prehospital) emergency medical services (Home – NEMSIS). NEMSIS is administered by the National Highway Traffic Safety Administration (NHTSA). The system was endorsed by 52 states and territorial EMS Directors. By 2018, the system received over 20 million submissions. The data are collected in near-real-time.

NEMSIS is the *de facto* standard for the patient care reports completed by EMS Systems. Interestingly, the system does have the built-in ability to collect poverty data, although this is only indirectly based on zip code of the incident.

NEMSIS does collect data on "barriers to patient care" but these data do not reference characteristics about shelter or housing, except for a physical barrier preventing access to a patient. [57] (p.26)

Many fire departments also operate EMS transport services, so the NEMSIS database could be an important ancillary source of data to better understand injuries, illness, and other effects associated with fires involving the homeless or vulnerably sheltered.

4.1.3 Data on Homelessness

There is a clear relationship between homelessness, insecure and vulnerable shelter, and heightened fire risks. It is therefore relevant to consider homeless populations in this study, and to consider national statistics of homelessness. The definition of 'homelessness' itself is an area of inquiry and further research is needed to explore data sources and gaps, especially at sub-national levels.

The US Department of Housing and Urban Development (HUD) annual homeless assessment report for Congress provides a high level overview of the scale and nature of homelessness in the US. [58] In 2020, the headline finding of this report was that homelessness was increasing even prior to the Covid-19 pandemic; 2020 was the fourth consecutive year of increases in homelessness. On a single night in 2020, roughly 580,000 people were experiencing homelessness in the United States (about 18 of every 10,000 people in the country); 61 percent of people experiencing homelessness were sheltered, meaning they were staying in emergency shelters, transitional housing programs, or safe havens. The remaining 39 percent of people experiencing homelessness were 'unsheltered', which according to HUD, refers to a person's

[9] The NEISS-AIP is an extension of data collected by the US Consumer Product Safety Commission and the CDC.

primary nighttime location being a public or private place not designated for, or ordinarily used as, a regular sleeping accomodation for people (e.g., streets, vehicles, parks). This rise in homlessness has been driven mainly by an increase in the unshleterd homeless population. Furthermore, the majority of people experiencing homelessness (58.9 percent) were in urban areas, whereas nearly a quarter (23.6 percent) of people experiencing homelessness were in suburban areas, and the remaining 17.5 percent were in rural areas. More than half of all people experiencing homelessness were in four states – California, New York, Florida, and Texas. [58]

4.1.4 Data on Housing

Vacant and abandoned buildings provide diverse types of underregulated shelter. In 2011-2015, US fire departments responded to an estimated average of 30,200 structure fires per year in vacant properties. These fires resulted in an average of 60 civilian deaths, 160 civilian injuries, and $710 million in direct property damage per year. Many properties are vacant during changes of ownership / occupant and are not abandoned. Fires in vacant buildings are more likely to have been intentionally set and to spread beyond the building than are fires in other structures. They also cause a disproportionate share of firefighter injuries. [52]

However, the absence of universal definitions of vacancy and abandonment complicates efforts to assess the number of vacant and abandoned properties nationally. The best aggregate sources include the US Census Bureau and the US Postal Service, although these are not without limitations, such as the latest relevant data being from 2010-2011. Using these sources, the US Government Accountability Office (GAO) reported in 2011 that vacant residential units, not including those used seasonally or by migrant workers, increased from 7 million in 2000 to 10 million in 2010. The Joint Center for Housing Studies of Harvard University [20] reported that a subset of this category, homes vacant and not being marketed for sale or rent, reached a record high of 7.4 million in 2012, with increases concentrated in the high-foreclosure areas of the South and West. Although vacant homes can be found throughout the country, they tend to be concentrated; nearly 40 percent of the nation's vacant homes are in just 10 percent of all census tracts. More than half of the census tracts with vacancy rates of 20 percent or higher were in just 50 counties, most of them in metropolitan areas. Wayne County in Michigan and Cook County in Illinois, for example, each have more than 200 high-vacancy neighborhoods. In addition to the many vacant and abandoned residential properties across the nation, estimates place the number of brownfields — idle former industrial properties with real or perceived environmental contamination — at approximately a half-million. [28]

4.2 Sub-National Data

Given the shortcomings of existing national data systems, studying state or local data is a productive avenue for inquiry. Federal databases such as NFIRS and mortality databases are built upward from local agencies reporting through state offices, which in turn send data to the federal agency.

4.2.1 State Data

Both fire and public health data is collected at the state level, irrespective of the particular data systems in use. We primarily limit this discussion to the fire related data, while possible existence of state health agencies that track homelessness as part of the injury or fatality data is an area for future inquiry.

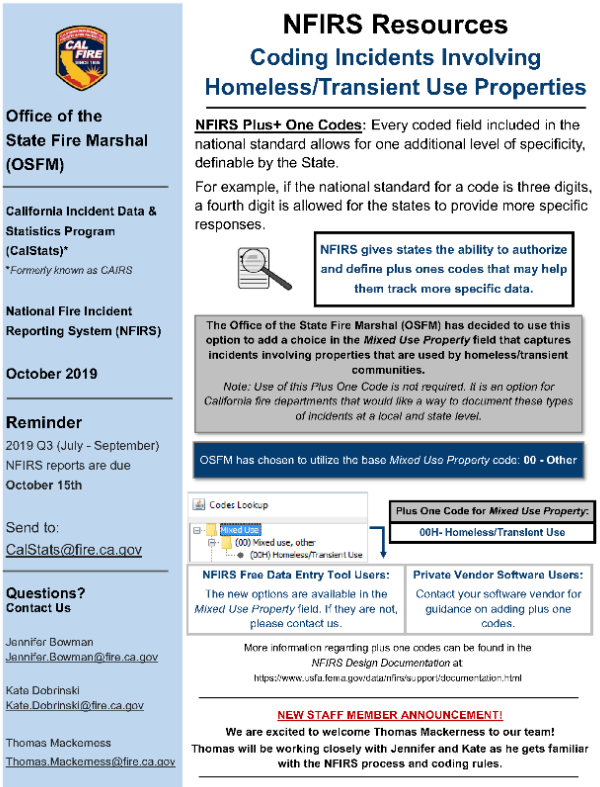
As indicated in the discussion of NFIRS, State Fire Marshal's Offices (or their equivalents) serve as an important player in identifying and measuring the fire problem among insecurely and vulnerably sheltered populations. These offices exert influence in several ways.

First, they oversee the training and data quality within the NFIRS reports coming into their agencies from individual fire departments. Second, they have an educational role in terms of promoting good practice and diligent completion of NFIRS reports by participating agencies and firefighters and officers on the front lines. Lastly, state agencies, through the ability to implement "plus-one" codes or other supplemental data collections, can create the possibility of gathering definitive data on the problem. A closely related capability that bears on this problem is the capacity to provide analysis of incident data to local fire departments, which will further encourage reporting.

As an example, the State of California Office of the State Fire Marshal developed guidance in October 2019 identifying the use of a "plus one" code specific to "homeless / transient use" as part of the Mixed Property Use code series within NFIRS' Basic Incident Report; see Figure 3.[10]

The Oregon State Fire Marshal's Office studied the problem and undertook a systematic analysis which examined both issues in coding incidents as well as trying to capture homeless incidents among existing incident types. Relying on major fire departments that captured their own data, they also studied the narrative portion of NFIRS incident reports. They found that causal information was also poorly characterized (a large proportion of "undetermined") which frustrates development of fire prevention messaging. [59]

[10] The reader is reminded that NFIRS is not a command-and-control system. Local agencies exercise considerable autonomy over training, quality control, utilization, and adoption of State-level coding schemes in most settings.



Office of the State Fire Marshal (OSFM)

California Incident Data & Statistics Program (CalStats)*
*Formerly known as CAIRS

National Fire Incident Reporting System (NFIRS)

October 2019

Reminder
2019 Q3 (July - September) NFIRS reports are due October 15th

Send to:
CalStats@fire.ca.gov

Questions?
Contact Us

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NFIRS Resources
Coding Incidents Involving Homeless/Transient Use Properties

NFIRS Plus+ One Codes: Every coded field included in the national standard allows for one additional level of specificity, definable by the State.

For example, if the national standard for a code is three digits, a fourth digit is allowed for the states to provide more specific responses.

NFIRS gives states the ability to authorize and define plus ones codes that may help them track more specific data.

The Office of the State Fire Marshal (OSFM) has decided to use this option to add a choice in the *Mixed Use Property* field that captures incidents involving properties that are used by homeless/transient communities.
Note: Use of this Plus One Code is not required. It is an option for California fire departments that would like a way to document these types of incidents at a local and state level.

OSFM has chosen to utilize the base *Mixed Use Property* code: **00 - Other**

Codes Lookup
Mixed Use
(00) Mixed use, other
(00H) Homeless/Transient Use

Plus One Code for *Mixed Use Property*:
00H- Homeless/Transient Use

NFIRS Free Data Entry Tool Users:
The new options are available in the *Mixed Use Property* field. If they are not, please contact us.

Private Vendor Software Users:
Contact your software vendor for guidance on adding plus one codes.

More information regarding plus one codes can be found in the *NFIRS Design Documentation* at
https://www.usfa.fema.gov/data/nfirs/support/documentation.html

NEW STAFF MEMBER ANNOUNCEMENT!
We are excited to welcome Thomas Mackerness to our team!
Thomas will be working closely with Jennifer and Kate as he gets familiar with the NFIRS process and coding rules.

Figure 3: State-level creation of NFIRS Coding to Identify Homeless-Related Incidents

We were not able to complete a systematic review for potential existence of other state-level data systems on homelessness as part of this scoping study.

4.2.2 Local Data

Other opportunities for data collection include locally collected data. Fire services in some communities may undertake supplemental data collection to track and understand the fire problem facing insecurely and vulnerably sheltered populations.

Given the limitations of data at the national and state level, local fire services can be a valuable source of information on the scope and magnitude of the fire problem among insecurely and vulnerably sheltered populations. To date, no systematic effort has been undertaken to collect this local data or to attempt to create national estimates based on this information. This is clearly an area of great promise given the challenges in identifying these incidents using national systems.

While a small but significant number of fire departments are collecting information on fires involving insecurely and vulnerably sheltered populations, they are doing so using locally derived definitions and adapting local data collection strategies. Consequently, data on the problem from different departments is not necessarily consistent nor is it directly comparable.

Nonetheless, such data appears to be the best available information at the present time. Illustrative examples below show the potential for identifying the magnitude and scope of the problem.

Seattle, Washington

The Seattle Fire Department, like many other west coast departments, has been at the forefront of the rapid growth of homeless encampments within the city. They noticed an increase in these incidents and reported that in August 2021 they implemented a change within their computerized dispatch and records systems to enable units in the field to radio a report to dispatch which results in a notation on the incident to indicate involvement of homeless individuals for fire and EMS responses. This formalization of recordkeeping has escalated the number of incidents, which increased markedly from 2019.

Other Examples

These fire departments and many others are actively engaged in risk reduction and outreach efforts for homeless settlements.

- St. Louis estimated that above that in 2018, 40 percent of their emergency fire calls involved vacant buildings [6]
- Los Angeles estimated that fires involving homeless encampments increased from 7 per day (2,555 annually) in 2018 to more than 25 per day in 2021 [69]
- Portland, Oregon reported over 2,000 fires related to homeless encampments in a year. They have an aggressive outreach campaign [70]
- New York City's Transit Authority announced that a sweep identified 29 encampments within subway tunnels [71]

As we have seen in this section, this problem is of great concern and is clearly in need of additional efforts to better quantify the toll that these fires are taking in terms of injuries, life loss, property damage, and disruption or damage to critical infrastructure within communities. A casual review of press accounts shows that the problem is widespread with regard to both geography and community size.

5 Fire Safety

Fire safety can be considered as *"the set of practices to prevent or avert occurrence of fire and manage growth and effects of accidental or intentional fires while keeping resulting losses to an acceptable level." (p.2)* [60]

5.1 Socioeconomic and Political Context

There are a number of factors that make fire safety interventions among insecurely and vulnerably sheltered populations a challenge.

As a commodity, housing is developed for profit. Market conditions contribute to homelessness and subpar living conditions in various housing / sheltering situations. Broader economic, policy, organizational, and political considerations are also important. Institutional actors including finance and insurance, real estate, and government play important roles. The insecurely and vulnerably sheltered population in the US is not static, and its size and characteristics vary over time and from community to community.

The problem of homelessness, and insecure and vulnerable housing is widespread, with 2.7 percent of students enrolled in public elementary or secondary schools reporting homelessness, doubling up, use of hotels, or being unsheltered at some point during the school year. [61] Public attitudes and institutional responses are affected by popular misconceptions and biases. A survey taken in Oregon in 2016 revealed that 23 percent of respondents felt "personal choice" was among the three main causes of homelessness within the State. Slightly less popular were "mental illness" and "substance abuse". [62] Meanwhile, advocacy groups cite statistics showing a stronger connection between low income or unemployment, lack of affordable housing, and economic trends such as the mortgage crisis [57] (p.3).

Attitudes and misperceptions are also reflected in the lack of political power and influence among the poor generally, and homeless populations in particular. [63] Additionally, political ideology can be indifferent or even hostile to the plight of the homeless. From a political economy perspective, fire services are enmeshed in institutional and political power structures as issues such as code enforcement or greater advocacy conflict directly with power, influence, and profit attendant to property ownership. Indeed, the opposition of groups such as the National Association of Home Builders to enhanced fire safety provisions is but one recurring example. [64] Similarly, real estate interests enjoy close relationships and support of many elected officials. [65] [66]

It is with this backdrop of misconception, invisibility, and lack of political power that fire services are confronting diverse fire problems facing insecurely and vulnerably housed populations. Communities in which issues of homelessness resonate with those in political power may take more proactive approaches, while absent this support, an attitude of ambivalence may prevail. [2] Of course, sheer demand on local fire resources is driving many fire departments to engage more deeply.

The complex nature and diverse challenges of fires among insecurely and vulnerably sheltered populations will require a high level of collaboration with organizations that may not be traditional partners with the fire service. Ensuring safety will also require confronting entrenched patterns and a more expansive view of fire prevention efforts from the fire service.

The fire service culture is dominated by firefighting – at the expense of preventive efforts, [49] [67] [68] (pp. 151-157) and only relatively recently are organizations adopting sustained, meaningful, targeted, and measurable efforts related to fire prevention. These efforts, falling under the banner of community risk reduction, are gaining in popularity, but much work remains.

5.2 Building Regulatory System in the US

There is no federal building safety regulatory scheme in the U.S. Instead, each state, or in some cases local government, is responsible for developing and enforcing its own requirements. As such, the requirements and enforcement of building and fire codes, and their very use, varies significantly across the country. These variations reflect differences in climate, predominate natural hazards (e.g., earthquake, hurricane, tornado, etc.), history of building and fire code development and implementation, and political attitudes toward regulatory practices. According to the Federal Emergency Management Agency (FEMA), given this patchwork regulatory

environment, more than half of U.S. states apply out of date building codes or have removed key provisions that improve safety and resilience of the built environment.

Like the variation in building regulatory systems, the overall resilience to fire varies across the country. However, as discussed in Section 4 of this report, the extent and quality of the FEMA supported National Fire Incident Reporting System (NFIRS) data limit visibility into the factors that affect building fire performance. These factors include the fire performance of aging buildings and the different vulnerabilities of building occupants.

State governments, and local governments where applicable, rely on their general remit of police powers to enact and enforce building, planning, and zoning regulations. Over time, these systems have emerged from public health and welfare laws put in place throughout the nineteenth and early twentieth centuries.[11] Typically, state legislatures have delegated the responsibility of developing and promulgating building, fire, and related codes to specialized boards or commissions that include representation from the public and stakeholders involved in construction and related industries. Rather than developing unique codes and standards, state laws generally incorporate nationally developed consensus codes and standards by reference, which the commissions than modify to reflect the interests raised by participants in the code promulgation process.

As used in this report, the term 'building regulatory system' encompasses the wide range of public and private sector components that impact the regulation and performance of buildings. While the emphasis of this report is fire and life safety, that is only one part of the overall regulatory system. The World Bank's 2015 report, *Building Regulation for Resilience* provides a robust framing of the building regulatory system components and their relationship to each other. [69] The report identifies three basic components that form the core of any building regulatory regime:

- An appropriate legal and administrative framework
- An adequate building code development and maintenance process
- Implementation of building and land use regulation at the local level

Around these core components is an extensive building regulatory infrastructure. This framing is illustrated in Figure 4.

[11] While some states, like Vermont, reserve all rulemaking power over building regulations to the states, in others, this power is reserved for local governments. In these Home Rule, or Dilon's Rule, states, like Texas, cities and counties are responsible for all aspects of building regulations, including whether to promulgate any laws or regulations at all.

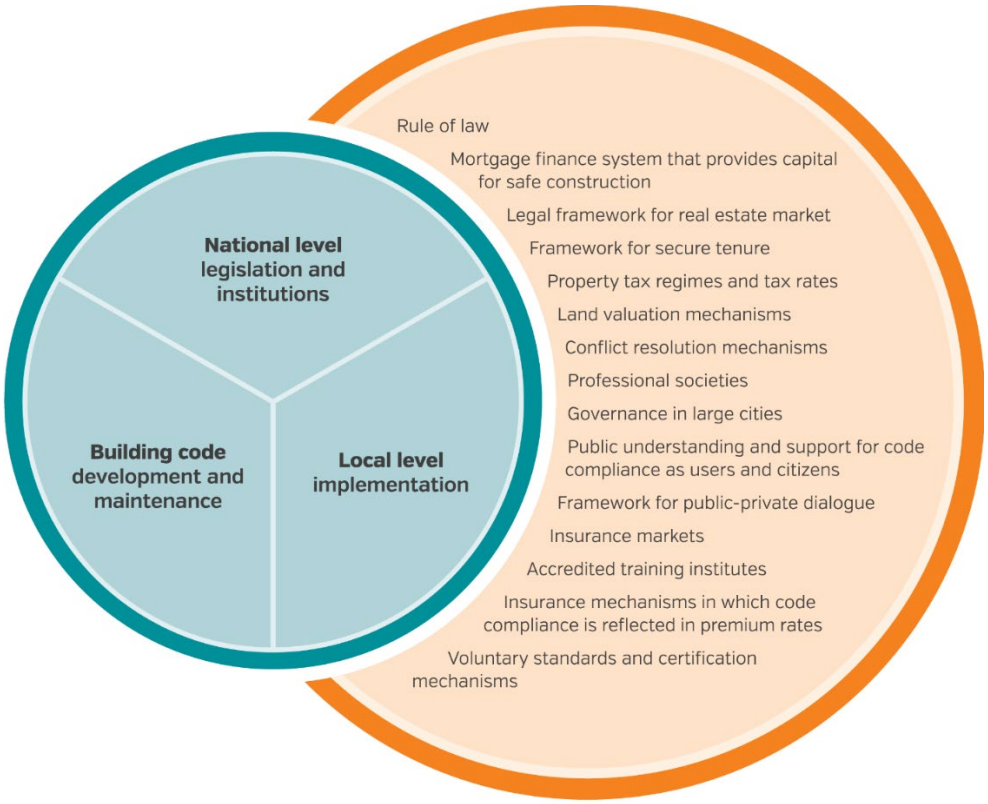

Figure 4: Building Regulatory Ecology [69]

A comprehensive discussion of building regulatory system strengths, weaknesses, and gaps ideally addresses each of the components in Figure 4. The focus of this report is largely on the core components, legislation, codes and standards, and their implementation, which are integrally linked to building regulation in the US. The focus is further narrowly centered on fire and life safety performance of buildings, and the core components that support them. In the US, this includes building, fire, planning and zoning codes, as well as related codes and standards that impact design, construction, operation and maintenance of buildings. Under this narrower framing, the NFPA's Fire & Life Safety Ecosystem [70] lens is helpful as well, in particular, the components of Government Responsibility, Development and Use of Current Codes, Referenced Standards, Code Compliance, and Investment in Safety.

The building regulatory system in the US is prescriptive, complex and unlike the building regulatory system in most countries.[12] There is no federal requirement for building regulation. There is no federal agency responsible for building regulation. There is no national building code. There can be significant variation in building code requirements, application, and enforcement from one part of the country to another. There is no federal system because states have the constitutional right to regulate for the health, safety, and welfare of their citizens, which includes building and fire regulation and enforcement. There can be wide variation between states due to climatic conditions, and the history of building code development and implementation across the US. Most state and local building codes are based on "model" building codes and 'consensus' standards, which are developed by the private sector and adopted into law at a state and local

[12] Other countries with federal-type systems, including Australia, Austria and Canada, have some challenges similar to the US in terms of regulatory development, adoption, implementation and enforcement.

level, with or without modification. This decentralization of regulatory power, coupled with private sector development of model codes and standards, results in several complex issues, including: a complex interaction of state and local laws and ordinances; separate building and fire codes; numerous reference standards and non-regulatory design guidelines; requirements for registration and licensing of professionals; and government enforcement. This complexity makes it difficult to understand fire issues at a national scale.

Figure 5: Fire & Life Safety Ecosystem [70]

5.2.1 Codes and Guidance for Existing Buildings

In many jurisdictions, it is not required that buildings, once constructed and the certificate of occupancy has been issued, continually meet the most recent building and fire code requirements. While this is not always the case, many jurisdictions only require that buildings be brought up to current standards in cases of significant renovation, modification or extension to a building, or in the case that the use of the building changes (e.g., from a warehouse to an apartment building).

The specific triggers for modification, and to what level of safety an existing building if renovated, modified or extended, may be specified in the local building code, or may be specified in a separate code for existing buildings. The ICC, for example, publishes the *International Existing Building Code* (IEBC), which is available for adoption. NFPA 5000, *Building and Construction*

Safety Code, contains provisions for rehabilitation of existing buildings, as well as for new construction. [71]

However, it is generally expected that existing buildings be maintained to meet the requirements imposed at the time the certificate of occupancy was issued, even if no change is made to the building. While this make sense, it can be difficult to enforce without promulgation of a property maintenance code. The aim of a property maintenance code is to require that existing buildings be properly maintained, and that critical systems, such as for fire and life safety, are regularly inspected and tested. The ICC publishes the model International Property Maintenance Code (IPMC) for adoption and use by jurisdictions. [72] Where adopted and enforced, the IPMC is intended to apply *"to all existing residential and nonresidential structures and all existing premises and constitute minimum requirements and standards for premises, structures, equipment and facilities for light, ventilation, space, heating, sanitation, protection from the elements, a reasonable level of safety from fire and other hazards, and for a reasonable level of sanitary maintenance; the responsibility of owners, an owner's authorized agent, operators and occupants; the occupancy of existing structures and premises, and for administration, enforcement and penalties."*

Unfortunately, one can only enforce a property maintenance code if adopted. As discussed in the ICC's *Building Safety Journal*, as of 2021, the ICC's International Property Maintenance code (IPMC) was mandatory statewide in only four states: New York (except New York City), Tennessee, Rhode Island and Maryland. [73] However, it is also required in West Virginia, South Dakota and Maryland unless the local community opts out, and it is adopted at the statewide level in Virginia, Georgia and West Virginia, where local adoption and enforcement is up to local governments. In another 32 states, the code is used at the local level. Furthermore, there are many challenges with inspections of existing buildings, and *"communities are seeking better guidance for inspections and feel that more accountability is necessary."*[37] These data and insights were learned from a national survey on existing building maintenance inspections that received 397 responses from 48 states, the District of Columbia, and one tribal community. It is noteworthy that only twenty percent of authorities having jurisdiction (AHJ) which responded stated that they have a periodic inspection safety program for existing buildings. This represents just one-third of responding AHJs who adopt a property maintenance code.

There are also various research and advocacy groups which aim to help provide guidance for existing buildings. NCHH, for example, has published with the American Public Health Association (APHA) a *National Healthy Housing Standard*. [74] The specific focus of this standard is the over 100 million existing homes in the US, which present the most significant opportunity to protect public health and reduce health disparities.

Tools such as the Verisk Building Code Effectiveness Grading Schedule (BCEGS®) [75], which assesses community building codes and their enforcement, can also be helpful. While the BCEGS® focuses on mitigation of losses from natural hazards, it can be a helpful measure of how well the building regulatory system is working in a jurisdiction. The grading tool considers a range of criteria associated with the adopted codes, plan review staffing and inspection staffing.

While history has shown the most effective way to improve fire safety in the built environment is the implementation of fire safety technologies through mandated codes and standards [1], not everyone enjoys the fire safety benefits of fire safety regulations, especially people living in under-regulated and unregulated housing / shelters, or in non-sheltered living conditions.

5.3 Towards Compliance of Under-Regulated Buildings

There are significant impediments to effectively address the myriad fire safety challenges with under-regulated buildings. As discussed earlier, many jurisdictions have not promulgated property maintenance codes. Even if they exist, many low-income occupants lack the means to maintain their dwellings in a fire-safe manner. Furthermore, there are numerous situations in which the use of a building is changed without informing the appropriate regulatory and enforcement bodies. If proper application for a building permit has not been submitted for a change to an existing building, the jurisdiction may be unaware of the safety of the building. While the fire service can enter a building if an imminent fire threat is suspected, they must first become aware of the problem.

While all stakeholders in the process play a role, the public often looks to enforcement officials to do more. This can be impractical if jurisdictions are under-resourced. If they lack staff, reporting systems, and other necessary resources, it is impossible to expect that they can inspect every building. This is understood, and several entities have explored how the system might be modified to help. [76] [77] [78] [79] Resources are of course needed but changing the way the process works can be helpful as well.

One approach advocated by the Vacant Property Research Network (VPRN) is what they call Strategic Code Enforcement,[62] which seeks to proactively address problem properties to further the wellbeing of residents, neighborhoods, and the broader community.

It requires six essential program elements:

1. Real property information and data systems
2. Inspection and investigation
3. Regulations and permitting
4. Enforcement and compliance actions
5. Case tactics/selection of remedies
6. Performance measurements and evaluation

While elements one expects to see in any jurisdiction, a major attribute to this approach is a systems-based and community-oriented approach. Having a deeper understand of socio-economic dynamics at the neighborhood level enables code enforcement to function as a system within that complex environment, and taking a systems approach instead of a program approach, code enforcement agencies, managers, and staff can facilitate communication and coordinate actions across sister departments and agencies.[62] In this approach, data must underpin the decision-making processes, collaboration is needed within and between local government departments and agencies that have compliance and enforcement responsibilities over properties, buildings, and neighborhoods, and care should be taken that the impacts and outcomes of its programs, policies, and interventions do not disproportionately impact vulnerable communities, families, and individuals.

This concept of strategic code enforcement, in which collaboration with other government departments and agencies, community and other stakeholders, is supported by others.[63,64] Weinberg[63], for example, suggests that *"strategic code enforcement brings together different areas of law, policy, and regulation to create a holistic plan that targets those who need help the most without over-zealously enforcing the code in a way that hurts low-income tenants. Code enforcement is part of a larger housing ecosystem, and partnerships with public health officials, medical professionals, community organizations, tenants, and landlords are crucial to the success of that ecosystem. Code enforcement agencies do not need to reinvent the wheel; rather, they*

need to coordinate with other actors already involved in the same work and unify efforts to provide a more informed and targeted solution."

House[64] delves into the underlying issues, exploring different approaches used by jurisdictions and some the challenges faced, concluding that *"code enforcement poses a variety of challenges as cities grapple with how to design and implement equitable, efficient, and responsive regimes that balance the needs of tenants, neighbors, property owners, and communities."* It is noted that there is a *"wide range of approaches that jurisdictions take to manage important tradeoffs: focusing enforcement attention and resources at the neighborhood or building level; taking a more proactive or reactive approach to code inspections; and striking a balance between punitive and collaborative measures to bring landlords into compliance."* The diversity of approaches of and resourcing available to jurisdictions makes single solutions difficult to envision.

The Urban Institute, in looking at the vacant building issues, identifies five elements, several of which are common with those outlined above:[65]

1. Comprehensive property data and information infrastructure.
2. Resources for land banking.
3. Strategic code enforcement.
4. Public and private resources.
5. Civic infrastructure and community stewardship.

With respect to data, echoing concerns of others, it is noted that *"no one knows how many vacant properties are in the US, and few communities have comprehensive and accurate data on their vacant properties. A few cities, such as Detroit, Cleveland, and Memphis, have conducted periodic, block-by-block property condition surveys to get a general idea of the vacant property type, its location and physical conditions, and basic ownership information. Though such inventories require resources and time, they are critical to determining the appropriate course of action for each property (which must then be and paired with neighborhood markets, revitalization strategies, and relevant social and educational services). Beyond these inventories, communities need reliable and consistent information infrastructure to harvest and analyze the multiple national, county, and city real property databases and share information with local officials, civic leaders, and residents."*

Similarly, conclusions related to resourcing of code enforcement echo the need for more support, *"Communities need technical capacity to prevent existing properties from becoming vacant. Local government code enforcement agencies, as the first responders to substandard housing and vacant properties, often lack sufficient capacities to proactively address the legal and policy complexities surrounding vacant properties. Under the rubric of strategic code enforcement, more communities are testing new techniques, data capacities, and legal remedies."*

However, punishment alone does not achieve code compliance or risk reduction. Procedural justice and legitimacy are critical factors to support compliance. *"…studies show that threats of punishment are a driver of compliance, but not a decisive one… Compliance driven by threats and deterrence is expensive…Research has consistently shown that the degree to which regulated subjects find authorities and rules legitimate is one of the strongest drivers of compliance. Provisions for open participation and fairness in the regulatory process, often referred to as "procedural justice," are the foundation of legitimacy and the most important driver of voluntary compliance… A major benefit of this approach is that it helps in developing long-term, self-sustaining drivers of compliance—and in reducing the need to increase a more traditional and costly type of police enforcement."*

The World Bank's 2015 report, *Building Regulation for Resilience,* emphasizes the importance of advisory services to promote compliance rather than relying solely on police enforcement, citing positive experiences from post-disaster reconstruction programs. This report advocates for institutionalization of a supportive, advisory approach coupled with a rigorous inspection regime. The advisory element focuses on increasing compliance with minimum safety standards in relation to specific building practices and local hazards, through strong communications aimed at building trust and confidence amongst stakeholders. [69]

5.4 Fire Safety outside a Regulatory Context

Fire safety in underregulated and unregulated housing / shelters is limited, and appears to primarily consists of the following:

- **Fire Services Response.** The fire services respond to fire incidents in homeless encampments, vacant buildings, and other underregulated and unregulated shelter on a regular basis. However, their ability to respond effectively may be severely hampered by unique and often unknown local conditions.

  The International Association of Arson Investigators, Inc. (IAAI) with a grant from the United States Fire Administration (USFA) undertook a project to develop materials to assist public officials in dealing with vacant or abandoned buildings within their jurisdictions. [80] Materials developed as part of the project were targeted toward the safety of fire suppression forces involved in fighting fires in vacant or abandoned buildings and the reduction of incendiary fires involving these properties. Nonetheless, that challenges remain daunting.

- **Public Education**. Most fire safety public education efforts by the fire services, schools, or non-profit organizations don't target, or may struggle to reach insecurely and vulnerably sheltered / housed populations, and may not be contextually appropriate (e.g., fire safety education messaging about an electric stove may be provided when someone may use an open flame to cook food) or sensitive to competing needs, wants, and risks faced by this population (e.g., need to secure warm shelter prioritized over fire safety).

- **Emergent Community-Based Fire Safety Practices.** Research from South Africa and Bangladesh indicate that communities that are highly vulnerable to fire may develop local practices and systems for fire prevention, mitigation, and preparedness. Additional research is needed in the US to learn more about existing capacities and capabilities for fire safety within insecurely and vulnerably sheltered / housed populations, and the networks of formal and informal social service providers that engage with and support these populations.

International research has also indicated that institutions often produce barriers to improving fire safety in these contexts, e.g., lack of legal recognition of homeless encampment prevents trash collection. Policy instruments which enable, rather than disable, emergence of fire safety should be prioritized so the benefits of fire safety regulation can extend to all.

As discussed in Section 5.3, promoting compliance by technical assistance and support for voluntary compliance can go a long way in terms to expand access to the benefits of the building safety and regulatory processes. *"This is particularly true for efforts to expand regulatory service delivery toward the informal sector. This report argues that understanding behavioral drivers, and*

the set of values upon which an effective regulatory system should be established, is crucial. In concrete terms, an effective reduction in risk requires more innovative and nontraditional regulatory approaches (such as guidance and educational effort typically deployed in reconstruction programs), which should be adopted and institutionalized in the mainstream permanent regulatory system for an effective reduction of risk." [69]

5.5 Cross-category comparison

The aim of this work is to understand the relationship between fire vulnerability of shelters, fire safety vulnerability of persons in those shelters, the extent to which regulation (construction, operation, and maintenance) impacts the fire resilience of the shelter, and how these factors interact.

In Figure 6, we consider fire risk as an indicator of the likelihood of a credible (self-sustaining) fire occurring, fire resilience as a reflection of the robustness of a shelter given a potentially harm-inducing fire (inverse of vulnerability), and the resulting risk to life from fire of occupants of the shelter.

On the left (Y) axis is fire risk, which decreases from left to right indicating unregulated shelters are exposed to higher levels of fire risk than other shelter categories. In other words, as formality, regulated nature, and maintenance of shelters increases (X) axis, fire risk decreases. On the right (Y) axis is fire resilience, which increases from left to right, being the lowest for unregulated shelters and the highest for vulnerability-protected shelters.

The 'non-sheltered' category is not shown in this graph because fire risk exposure is driven more by interactions with the surrounding environment than by shelter characteristics. Not to be confused with the non-sheltered category in this study, HUD refers to someone as being 'unsheltered' if a person's primary nighttime location is a public or private place not designated for, or ordinarily used as, a regular sleeping accomodation for people (e.g., streets, vehicles, parks). In relation to this study's shelter categorization, this means populations referred to as 'unsheltered' by HUD may seek refuge in shelters which are considered *unregulated* or *under-regulated*, or sleep in the open as per the *non-sheltered* category in this report.

The blue line indicates risk to life from fire, which decreases from left to right indicating unregulated shelters are exposed to the higher levels of risk to life from fire than the other shelter categories. There is a strong relationship between risk to life from fire and fire risk - they are interrelated. Regulatory mechanisms that prioritize life safety drive fire safety investments therefore reducing fire risk overall. Vulnerability-protected shelters go beyond regulatory requirements and include features that provide additional protection for one or more vulnerability attributes (e.g., could be enhanced fire protection features, enhanced evacuation features, care givers, etc.).

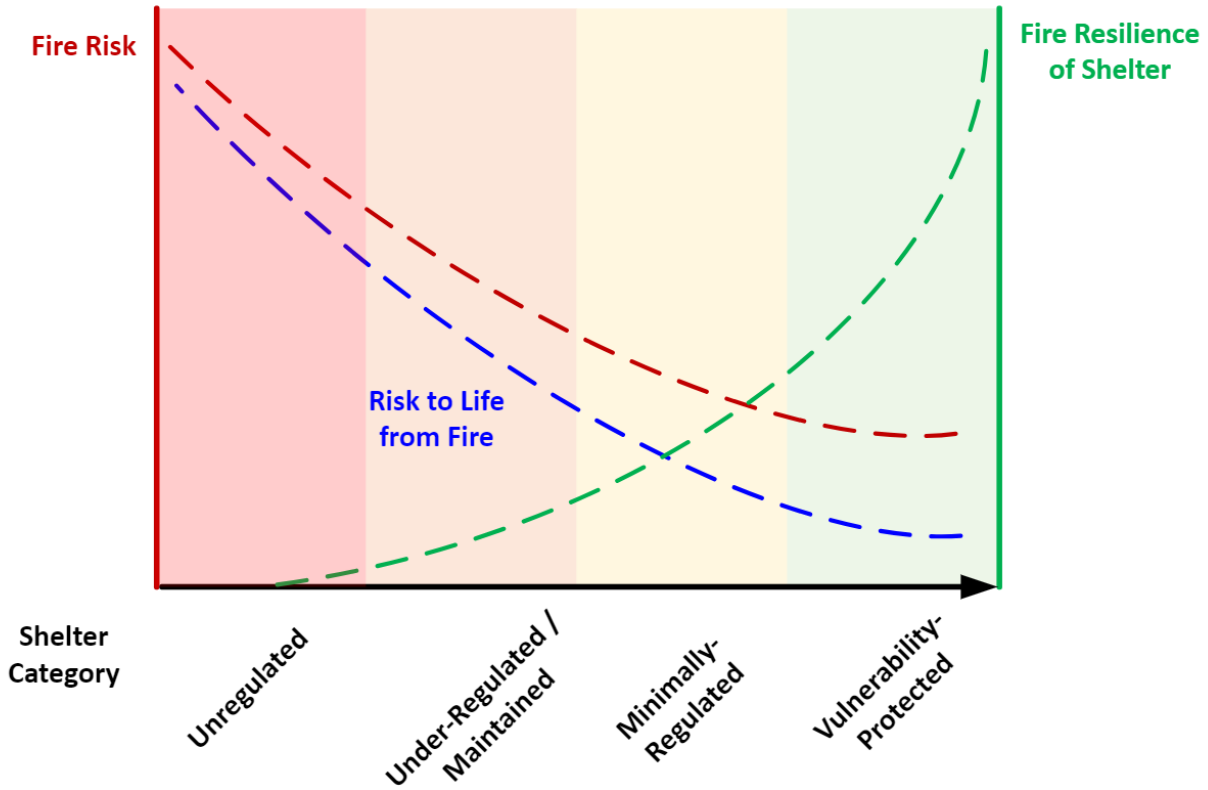

Figure 6: Fire Risk – Risk to Life from Fire – Fire Resilience curves as a function of shelter categories

Much is known and published on risk to life from fire associated with minimally regulated (i.e., code-compliant buildings, since building and fire regulations are minimum standards) and vulnerability-protected spaces. Some is known about risk to life from fire in some under-regulated, including under-maintained shelters (e.g., older, formal, once minimally regulated construction), but not other areas. Very little is known about risk to life from fire associated with unregulated and non-sheltered populations which should be the focus of further inquiry.

6 Gaps

This report has identified gaps in research, policy, and action pertaining to fire safety of insecurely and vulnerably sheltered populations in the US. It emphasizes that fire disproportionately affects populations in under-regulated, unregulated, and non-sheltered living conditions, despite significant challenges quantifying and describing fire risks and consequences on a national level – hence it is termed here the invisible US fire problem. Playing off this imagery of invisibility, an illustration of an iceberg is used to describe known and unknown dimensions of these fire problems.

The image (Figure 7) illustrates two parts of the iceberg. The tip of the iceberg represents the known areas of fire safety in regulated housing and in unregulated shelter that are commonly engaged with in research, policy making and are present in the news media and activism. These are the 'known' areas that support our thinking about fire safety currently. The illustration of the iceberg extends under-the-water, to the 'known unknowns', to illustrate research, policy making and activism gaps in relation to what is currently known about fire safety in insecure and vulnerable shelters. Currently, no consolidated effort exists to tackle these issues in an integrated, transdisciplinary way, where multiple research objectives converge. The water represents

'unknown unknowns', factors that may affect fire safety in these settings, but have not yet been identified.

As shown in Figure 7, several gaps and challenges exist:

- Lack of data on shelter vulnerabilities
- Lack of data in fire incidence concerning homeless populations
- Insufficient policies and interventions that address under-regulated, unregulated, and non-sheltered typologies
- Lack of strategies for fire risk reduction
- Lack of data on social vulnerabilities of vulnerably and insecurely housed populations
- Lack of fire risk characterization and analysis methods

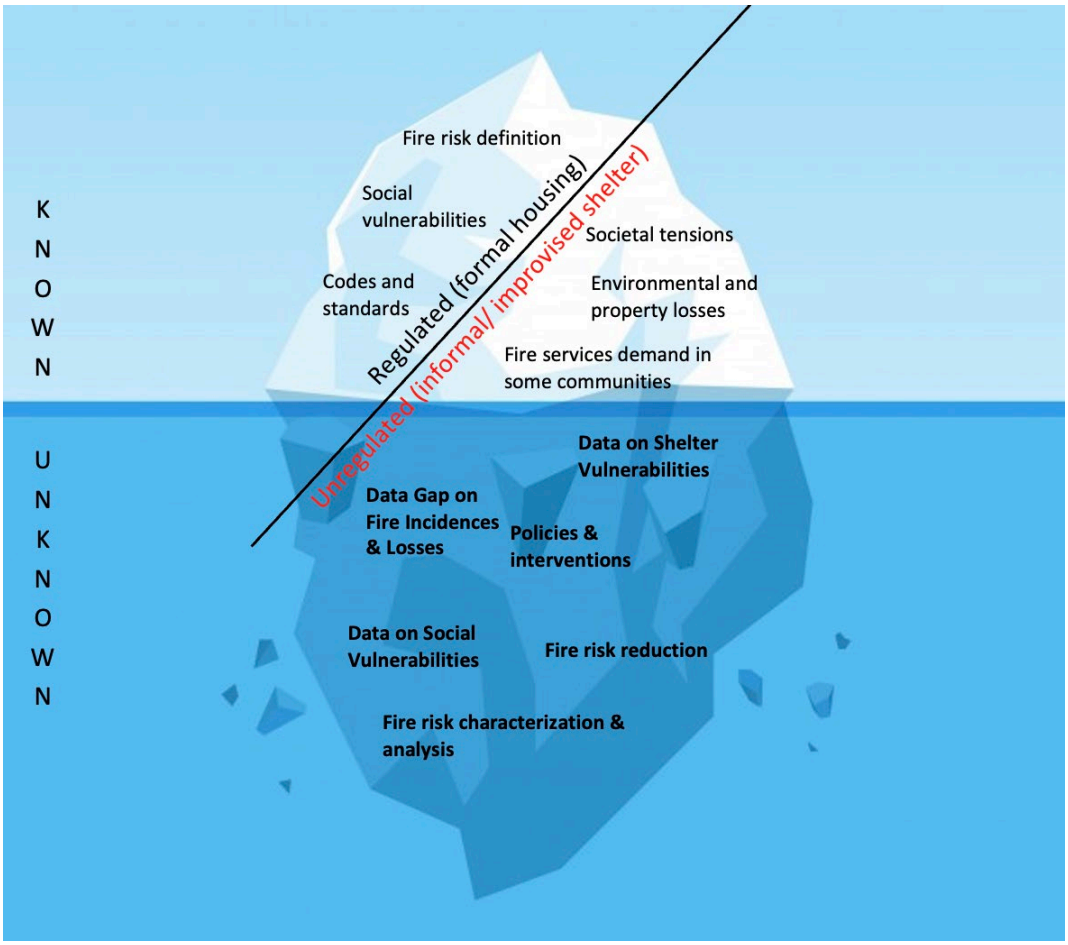

Figure 7: Research gaps under the water

While the iceberg illustrates the juxtaposition of fire safety in regulated versus unregulated settings, it does not describe the nuanced grey areas of under-regulated housing. Therefore, Table 4 is provided to identify the main fire safety gaps associated with under-regulated buildings and their impacts.

Table 4 Challenges, gaps and impact of under-regulated buildings used as shelter.

Category	Challenge / Gap	Impact
Under-Maintained	Lack of state/local adoption of code for existing buildings	Lack of legal authority to require safety upgrades to buildings when major changes are made
	Lack of state/local adoption of property maintenance codes	Lack of ability to require / force building fire safety maintenance
	Lack of enforcement capacity to inspect / enforce property maintenance codes	Lack of ability to conduct regular inspections, even if legal authority exists
	Extra-regulatory modifications, such as energy retrofits, may not be reviewed for fire compliance	Possibility of increased fire risks due to combustible insulation, photovoltaic systems, energy storage systems, …
	Limited ability of fire service to determine imminent hazard from outside of buildings	Lack of ability to identify potentially at risk buildings / occupants
	Limited capacity of fire service to conduct inspections inside buildings	Lack of ability to identify potentially at risk buildings / occupants
	Limited resources to low-income households to maintain building fire safety features	Lack of ability to maintain fire-safe buildings and/or to upgrade if needed
	Presence of landlords who do not maintain building fire safety features	Increased fire risk to occupants
	Nuisance alarms lead occupants to ignore real fire warnings	Increased risk of death or injury when fire actually occurs due to delay in evacuation
Under-the-Radar	Owners renting space in residential building, but without permits and adequate fire safety (e.g., egress from basement or attic, smoke alarms, …)	Lack of knowledge by enforcement officials of situation; increased fire risk to occupants, especially if also under-maintained
	Owners renting space in non-residential building, without permit, upgrades for change or use, and therefore inadequate fire safety (e.g., egress, fire alarms, sprinklers, …)	Lack of knowledge by enforcement officials of situation; increased fire risk to occupants, especially if also under-maintained
Vacant	Occupants in vacant residential building, with inadequate fire safety (e.g., egress, fire alarms, sprinklers, …)	Increased fire risk to occupants
	Occupants in vacant non-residential building, with inadequate fire safety (e.g., egress, fire alarms, sprinklers, …)	Increased fire risk to occupants
	Unknown structural and fire performance capacity of building	Significant risk to firefighters should fire occur – impact on fire response
	Unknown contents	Significant risk to firefighters should fire occur – impact on fire response
	Unknown whether transient occupants	Significant risk to firefighters should fire occur if search and rescue is needed, especially given above factors

7 Research Needs

By defining and framing these matters, this work aims to discover the breadth and depth of research and action needed to understand and ultimately address fire safety issues of insecurely and vulnerably sheltered populations[13] in the US.

To tackle holistically and urgently the identified gaps and improve fire safety across insecurely and vulnerably shelter contexts, stakeholders need to collaboratively engage with this 'invisible' fire safety problem through research, policy and action that addresses the full spectrum of economic, social, and technical issues.

The roles of public health data services, social services engaging with homeless populations, firefighters, fire engineers and academics among others are significant. Convergent transdisciplinary action research is needed.

The needs and actions identified in this section should be viewed as a starting point, and not an exhaustive list. It is important to engage with multiple stakeholders to address challenging and emerging fire safety gaps in these settings.

It is suggested that workshops should be held with relevant stakeholders, such as NFPA, DHS/USFA, HUD, code enforcement entities, the Urban Institute, Vacant Property Research Network, Center for Community Progress, Joint Center for Housing Studies of Harvard University, to develop more specific strategies and to identify funding opportunities for research and action.

Based on the gaps discussed in Section 6, areas have been identified for future research (Table 5). Extensive data collection and analysis is a priority to better understand the problem, enabling substantial progress.

[13] i.e., populations living in under-regulated, unregulated, or non-sheltered conditions; see Section 2.

Table 5 Research Needs, Type of Work, Required Actions and Stakeholders

Research Need	Type of work required	Actions
Fire Incidences & Losses	National guidance and local implementation on collecting fire incidence data in informal settings should include injuries, fatalities, property losses, fire service costs, emergency services costs, and other direct and indirect costs	
	Modifications to national fire incidence data collection could be done using NFIRS & NFPA survey	NFIRS and NFPA to consider potential changes
	Numbers of casualties among insecurely and vulnerably sheltered populations should be collected	
	Data on fire incidence and losses that does not rely on ownership and property address and thus would not exclude tent encampments, recreational vehicles, and other improvised housing	
	The extent to which homelessness related fires cause property damage, and disruption or damage to critical infrastructure within communities should be identified	Collect the evidence on the past events and their effects on infrastructure
	Guidance specific to capturing incidents of fire in homeless encampments, or fires originating with the possessions of people experiencing homelessness should be developed	Researchers and regulatory bodies should work together to identify develop guidance
	Life safety impact(s) or outcome(s) should be identified, and quantified in terms of intolerable temperatures, CO levels, smoke, etc. for insecurely and vulnerably populations	Researchers to hypothesize and simulate conditions related to vulnerable housing contexts
Data on Social Vulnerabilities	Socio-economic and demographic data should be captured more extensively	Researchers to consider cross-sectional analyses of insecurely and vulnerably sheltered populations, e.g., homelessness often affects families, and so consideration should be given for disaggregated data to by researchers
	Social vulnerabilities' relationship to informal housing fire risks should be identified	Carry out community-based research efforts and inquire into the living conditions of people residing in informal housing; mapping and identifying potential fire risks that are currently unknown to stakeholders, such as firefighters or policy makers
	Socio-demographic characteristics and their relationships to fire risks should be identified	Initiate intersectional research efforts to consider the relationships between socio-demographic characteristics and fire risks across the spectrum of shelter / housing typologies identified herein
	Socioeconomic conditions' relationship to fire safety should be identified	Research the effects of poverty, access to public resources, coping capacity based on resources, access to healthcare, fragile livelihoods', lack of social and financial safety nets, lack of tenure, etc. in relation to fire risk
Data on Shelter Vulnerabilities	Further development of shelter typologies	Carry out field work to observe and map diverse shelters; categorization of shelter typologies that highlight specific fire risk factors and support prioritization of fire safety improvements.
	Scale and nature of unregulated (i.e., abandoned, illegally subdivided / converted homes) shelters need to be better understood; and national data collection should be developed	Predict the effort required to review and implement fire safety measures by mapping exercise and a database to record these types of buildings, and projections should be made of the possible changes over time to reasonably scale up the required work.
	Housing system analysis should be performed	Conduct housing system analysis.
	Data on levels of fire protection of shelters should be collected	Collect data on levels of fire protection of shelters.
Fire risk characterization & analysis	Social and shelter vulnerabilities should be mapped	Conduct research describing in detail the shelter vulnerabilities and relating it back to intersectional any socio-demographic factors that might influence increased fire risk.
	Risk definitions should be agreed on	Agree with broad group of stakeholders appropriate definitions.
	Fire protection features of shelters (or lack thereof) should be understood	Develop common understanding of fire protection features of shelters.
	Fire hazard development given different levels of protection (vulnerability) should be understood	Fund and conduct research that investigates diverse housing conditions across the spectrum of compliance, identifying the potential for fire hazard development, ideally using simulation tools.
Fire risk reduction	Potential risk reduction measures in relation to life safety in case of a fire event should be identified	Organize workshops and focus groups involving fire safety experts and communities at risk from fire
	Study social valuation of fire risk reduction investments	Fund research the fire safety interventions and outcomes in communities, for example using randomised controlled trials, to determine what interventions had positive social outcomes when reducing risks and saved lives.

Research Need	Type of work required	Actions
	Cost-benefit analyses of potential risk reduction measures	Fund research that looks at the potential savings from implementing risk reduction measures across under-regulated buildings
Policies & interventions	Risk perception of fire across stakeholders including insecurely and vulnerably housed populations should be researched in more detail	Establish a fund for research available to grassroots organizations, where the stakeholders identify clear goals and priorities in the aim to understand risk perception of fire and potential interventions to bridge the gap between the subjective and objective perceptions of risk.
	The extent to which regulation (construction, operation, and maintenance) impacts the fire resilience of the shelter, and how this interact with social vulnerability of the individuals in the shelter should be better understood	Research the different types of housing and their design should in relation to socio-demographic factors of individuals occupying such housing, relating it back to fire incidences and fire risk
	The effects of housing supply-demand, related deficiencies in regulatory system (leading to under-regulated stock), and increases in fire risk should be identified	Fund research that looks across the historical and projected housing supply-demand, identify the regulatory loopholes that contribute to inefficient built environment outcomes and relate it to fire risks, hypothesizing that lack of regulation across built environment produces risks to life among vulnerable people.
	Consideration should be given to the development of a robust sociotechnical building regulatory systems framework that more appropriately takes into consideration the interactions of actors, institutions, and technologies, which if properly combined, can better address risk and deliver on more equitable fire safety for all	Build upon nascent sociotechnical systems building regulatory systems frameworks and assessment methods to facilitate sociotechnical systems review of the building regulatory systems.
Cross cutting research areas	Universal definitions of vacancy and abandonment should be developed to understand the scope of the issue and support collection of data	Create a panel of experts on social issues, urban development and policy makers who would be able to competently debate and mutually agree on the definitions, promoting their use across related sectors.
	Fire incidence, shelter vulnerabilities, and social vulnerabilities should be integrated in a holistic approach	The grant-giving bodies funding research projects, academic research in fire incidence and fire safety and engineering, policy makers initiating policy changes regarding housing and safety, and urban development practitioners supporting government housing goals should take into account the three interrelated aspects of people, shelter, public health, and fire risk.
Building Regulatory System	**Under-Maintained**	
	State/local adoption of code for existing buildings	Advocate for code adoptions
	State/local adoption of property maintenance codes	Advocate for code adoptions
	Enhance enforcement capacity to inspect / enforce property maintenance codes	Implement Smart Code Enforcement principles; enhance resources to enforcement entities
	Require fire review of all energy retrofits / energy efficiency upgrades	Implement Smart Code Enforcement principles; enhance resources to enforcement entities
	Implement multi-stakeholder strategic enforcement to assist fire service knowledge of imminent hazards	Implement Smart Code Enforcement principles; enhance resources to enforcement entities
	Implement multi-stakeholder data collection systems for all existing buildings in jurisdiction	Facilitate resources for data management, collection and analysis at local/state level
	Provide resources to low-income households to maintain building fire safety features	Facilitate HUD and other sources to provide interest-free loans to building fire feature maintenance
	Penalize landlords who do not maintain building fire safety features	Modify codes/ordinances to increase penalties
	Implement nuisance alarm reduction programs and increase fire response and evacuation training	Community risk reduction; provide smoke alarms; train occupants on fire safety and evacuation
	Under-the-Radar	
	Owners renting space in residential building, but without permits and adequate fire safety (e.g., egress from basement or attic, smoke alarms, …)	Modify codes/ordinances to increase penalties; see also above strategies
	Owners renting space in non-residential building, without permit, upgrades for change or use, and therefore inadequate fire safety (e.g., egress, fire alarms, sprinklers, …)	Modify codes/ordinances to increase penalties; see also above strategies
	Vacant	
	Unknown structural and fire performance capacity of building	Increase community resources to identify and address vacant buildings; see also above strategies
	Unknown contents	Increase community resources to identify and address vacant buildings; see also above strategies
	Unknown whether transient occupants	Increase community resources to identify and address vacant buildings; see also above strategies

8 Conclusions

This scoping paper has shown that the US fire problem is not solved. Certain groups of people suffer disproportionately from fire and evidence indicates people experiencing homeless are particularly vulnerable to fire, as are those living in insecure and vulnerable shelter more generally.

These fire problems seem ‘invisible’ at the national level, but they are plaguing American cities, undermining the lives and livelihoods of affected populations, and having negative impacts beyond those directly affected (such as the fire services and neighbouring communities).

There is a need for research, policy, and action to better understand and address these highly emergent and local fire problems.

The "invisible" fire problem is multidimensional, and will require collaboration of researchers, advocates, and practitioners across many domains. Funding opportunities should recognize this as an important component of broad disciplines of fire safety, urban planning, social services, and public health.

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