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Short communication

# IAFSS agenda 2030 for a fire safe world

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A B S T R A C T

The International Association of Fire Safety Science (IAFSS) is comprised of members from some 40 countries. This paper presents the Association's thinking, developed by the Management Committee, concerning pressing research needs for the coming 10 years presented as the *IAFSS Agenda 2030 for a Fire Safe World*. The research needs are couched in terms of two broad Societal Grand Challenges: (1) climate change, resiliency and sustainability and (2) population growth, urbanization and globalization. The two Societal Grand Challenges include significant fire safety components, that lead both individually and collectively to the need for a number of fire safety and engineering research activities and actions. The IAFSS has identified a list of areas of research and actions in response to these challenges. The list is not exhaustive, and actions within actions could be defined, but this paper does not attempt to cover all future needs.

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## 1. Introduction

The world is facing enormous challenges in terms of access to resources, increasing and diverifying population, and climate change impacts, including extreme weather events. Concurrently, technology is rapidly advancing, cities are growing larger and denser, and the population is aging. These challenges are recognized by countries around the world, across all levels of income, with varying capacity to address them. One important area that is currently often missing in discussions of societal grand challenges, is the impact of *fire* on health, safety, climate, community resilience, and the economy.

This is problematic, since the global impact of fire is considerable. The World Health Organisation (WHO) estimates global burn deaths at 180 000 annually, the vast majority of these in low and middle-income countries, with fewer fire safety regulations or provisions [1]. The situation in developed countries is troubling as well. Within Europe, more than 3500 people are killed annually in fires based on a five-year average [2]. The number of injuries is approximately 20 times the number of fatalities, resulting in at least 70 000 injuries per year in the EU alone. The losses in the USA are similar in absolute terms [3].

In most developed countries the cost of fire is estimated to at least 1% of the Gross Domestic Product (GDP). Indeed, the total annual cost of fire in the USA has been estimated at USD 328.5 billion (2014), which was 1.9% of the U.S. GDP [4]. Global loss due to wildand fire is presently greater than at any time in the past. SwissRe has reported that the combined insurance losses from all wildfires worldwide in 2017 were USD 14 billion, the highest ever in a single year [5]. According to Allianz, fires and explosions in the built environment accounted for 59% of 1807 business interruption claims globally, according to data analysed over a five-year period, with losses in 2015 in the billions of US dollars [6].

The International Association of Fire Safety Science (IAFSS) views the current and future outlook on the growing fire problem as an issue that urgently needs to be addressed. For more than 30 years, the IAFSS has played a significant role in advancing fire safety science and engineering worldwide. As an association of scientists, engineers and others focused on advancing fire safety through research, IAFSS is a global leader in advancing fire safety through science by facilitating fire research and education, and by fostering dialogue and exchange between fire safety scientists, engineers, governments and the public. The IAFSS currently includes members from some 40 countries, and seeks to expand collaboration and fire research in and between even more countries in the future.

In a recent open letter to the European Commission, it was noted that "Without a better understanding of fire safety technologies needed to protect our citizens we cannot provide a safer life to our citizens and to those who live among us or just visit Europe." [7] Indeed, if fire safety is to keep pace with the changing needs of modern society we face growing gaps in fire research. In response to the need for fire research globally, the IAFSS has produced this Agenda to highlight fire research needs that address broad Societal Grand Challenges. This document should be taken as a snapshot in time – reflecting the needs as viewed in 2019 – and will need to be updated as conditions and situations evolve going forward.

## 2. Societal grand challenges that fire research can help address

Societal Grand Challenges are more than isolated research topics or research priorities, of which there are as ready an abundance as there are researchers. Rather, Societal Grand Challenges should be viewed as a set of difficult but important challenges that have the potential to impact on society as a whole and capture the interest of multidisciplinary teams globally [8]. The list of Grand Challenges can be made long, and definitions are dependent on the perspective of the authors, and this paper is no different. However, IAFSS believes that the biggest impact can be made by undertaking fire research that addresses these broadly identified and agreed Societal Grand Challenges. As such, this paper presents two broadly defined Grand Challenges for which research in fire safety science and engineering can significantly help in addressing recognized societal needs.

The Societal Grand Challenges identified as being where fire safety science and engineering research can most significantly contribute in the near term are (1) climate change, resiliency and sustainability, and (2) population growth, urbanization and globalization. In addition, the ability to harness new technology, e.g. Artificial Intelligence and Big Data, and activities relating to Higher Education have been identified as

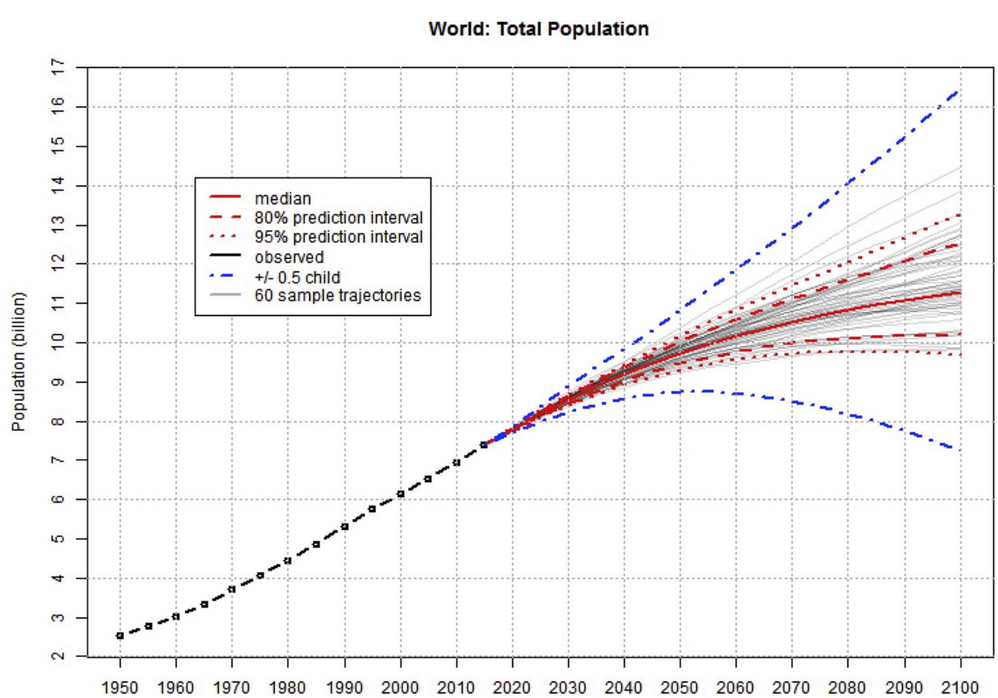


**Fig. 1.** Estimated world population growth. Source: United Nations, Department of Economic and Social Affärs, Population Division (2017).

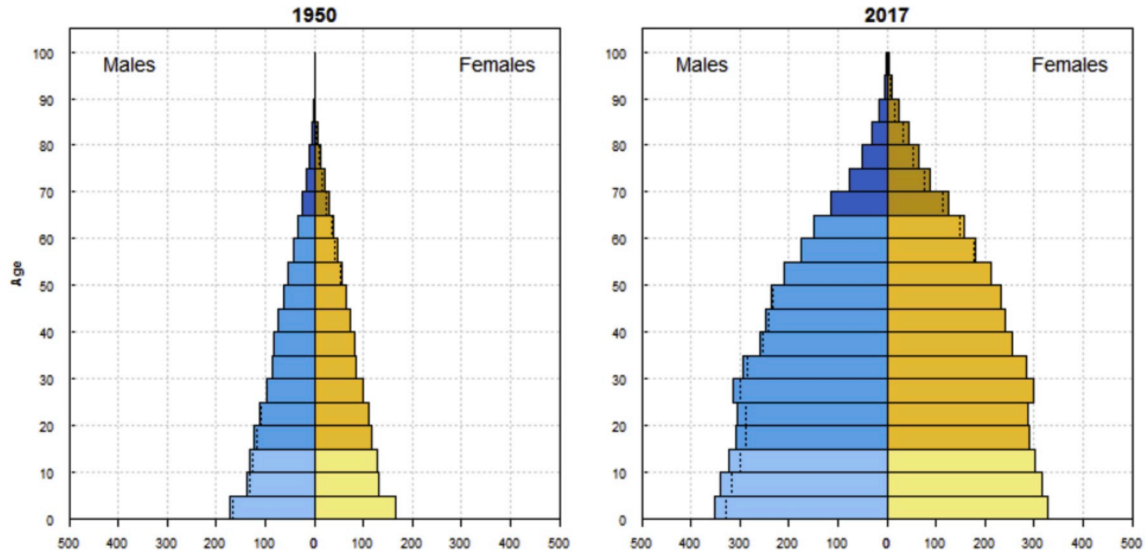


**Fig. 2.** Distribution of age of population, male in blue and female in yellow between 1950 and 2017. The dotted line indicates the excess male or female population in certain age groups. The x-axis represents millions of population for each age group. Source: United Nations, Department of Economic and Social Affärs, Population Division (2017). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

a cross-cutting Grand Challenge that are essential to solve many of the activities associated with the two challenges listed above. The rationale behind each challenge is given in more detail below.

### 2.1. Climate change, resiliency and sustainability

We live on a planet with finite resources and limited resilience, i.e., a limited capacity to recover to change. The concept of planetary boundaries as developed by Rockström et al., 2009 [9] and extended 2015 [10], defines a set of intrinsic processes that regulate the stability of the globe as a system. Two core boundaries have been identified, of which climate change is one, with the potential to single-handedly drive the earth's systems into a new state should they be significantly compromised. The key messages of the 5th Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) [11] are that:

- human influence on the climate system is clear;
- the more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts; and
- we have the means to limit climate change and build a more prosperous, sustainable future.

Even if it is possible to achieve the goal of no more than 2 °C mean temperature increase relative to 1850–1900 levels (something which is much debated), the additional risk of extreme weather events is seen to be high. As such, societal resilience to extreme weather events is crucial. In 2017 and again in 2018, increased global temperatures have facilitated drier conditions, resulting in widespread and significantly destructive wildland fires. Increasing the resiliency of society and the built environment to wildland fires as well as fires resulting as a trickle down effect from other climate events is crucial.

In 2016, the United Nations adopted their Sustainable Development Goals (SDGs) as part of The 2030 Agenda for Sustainable Development (A/Res/70/1). The UN Agenda 2030 is a plan of action which seeks to strengthen collaboration through a common understanding of what needs to be done. The rapid adoption of this framework is almost certainly due to the almost universal recognition of the need for common views and definitions of sustainability. Within the built environment, steps towards achieving increased sustainability include reducing materials, energy and waste, and utilizing more renewable resources. Strategies for these include increased use of timber, increased thermal insulation, and increased passive ventilation. Each of the areas identified by the UN to foster sustainability can create potentially competing objectives with respect to fire. These fire safety challenges must be understood and solutions developed that support sustainability.

### 2.2. Population growth, urbanization and globalization

In 1950 the global population was approximately 2.5 billion. The latest estimate according to the United Nations from 2017 shows the population at 7.6 billion and rising [12]. Conservative estimates suggest that globally population could begin to decline some time between 2050 and 2100, see Fig. 1 showing a probabilistic projection of population growth until 2100. Interestingly, this implies that children born today may live to see the peak in global population and ensuing decline opening opportunities for improved sustainable use of our limited resources.

Meanwhile, the demographic distribution globally has changed significantly over the past almost 70 years, see Fig. 2, corresponding to an aging society. In the developed world this distribution has the beginnings of a top-heavy "kite" distribution with an increasing number of citizens past their active working life.

With increasing population comes increased urbanisation. Already, more people live in urban areas than in rural areas. It is estimated that some 55% of the world's population presently live in urban areas. This should be compared to approximately 30% in 1950 and a projected 68% in 2050 [13]. A large portion of the population growth and urbanization is taking place in developing countries where regulation of fire safety is poor or emergent.

Increasing population, aging populations, and rapid urbanization all increase risks associated with fire. Rapid population growth can result in the need for quickly-constructed buildings, some of which may not provide adequate fire safety. This is seen particularly in low- and middle-income countries, where rapid urbanization is happening concurrently. In some of these cases, informal settlements and 'regulated' buildings and neighborhoods abut. With no fire protection in informal settlements, this places both communities at risk. This is further complicated by increased numbers of elderly persons, who may be unable to evacuate on their own in the case of fire and are more susceptible to fire incidents. Related to this, the increase in obesity in the western world increases the number of people with reduced mobility in fire situations. These related issues all warrant significant attention.

Globalization is not isolated to economic processes but includes the flow of people, products and politics. Global trade has lead to a five fold increase in per capita Gross Domestic Product (GDP) since 1980 [14]. In 1990, more than one third of the worlds population lived in extreme poverty, over 50% of these were in East Asia and the Pacific. By 2013 just 10% of the worlds population lived in extreme poverty with the greatest improvements happening in East Asia and the Pacific [15]. While economic development is taking place at a higher rate in the underdeveloped world than the developed world, the wealth gap continues to rise. Based on 2015 statistics of world wealth from Credit Suisse, Oxfam stated that the richest 1% of the world now hold as much as the wealth of the rest of the world combined [16]. This wealth gap is the basis for international instability and fertile soil for the development of inequality. Data shows that lower income populations are at a higher risk for fire incidents so an increase in wealth gap will also increase the safety gap. Combining these challenges with the rapid urbanization, substandard building construction and related issues noted above, the need for fire safety research is clear.

In addition, globalization leads to increased international dependencies, which increase vulnerability to, for example, cyber attack. Such vulnerability can be used as a means to cause fires and explosion, through cyber attack on critical safety systems. This was seen in the attack on safety systems at a Saudi Arabian refinery in 2017. Protection of critical infrastructure from fire and explosion becomes all the more important under these conditions.

## 3. Fire safety science and engineering fields of research and actions

The Societal Grand Challenges outlined in the previous section include significant fire safety components, that lead both individually and collectively to the need for a number of fire safety and engineering research activities and actions. The IAFSS has identified a list of areas of research and actions in response to these challenges. The list is not exhaustive, and actions within actions could be defined, but this paper does not attempt to cover all future needs. The focus of this paper is to identify those research areas and actions that the fire safety community, through the lens of IAFSS, has identified as most pressing in the short term.

### *3.1. Wildland fires and wildland-urban interface*

The summer of 2018 was the hottest on record globally [17]. Abatzoglou and Williams [18] noted in 2016 that over 50% of increased forest fuel aridity (directly relevant for the risk of wildland fires) since 1970 across the US, is due to climate change. Society faces immediate challenges in light of climate change causing increased weather volatility. There is a clear risk of increasing frequency and size of wildland fires, in part due to historical efforts to reduce wildland fire frequency leaving buildup of natural fuels together with the encroachment of buildings into wildland areas [19]. There is also spread to locations not typically seen in recent history, including the Nordic countries. It is important to continue efforts to model and understand wildland fire spread in order to develop modern preventative and mitigation methods. Understanding wildland fire spread will also provide valuable input to pre-planning and hazard and risk assessment. It is important to expand efforts to devise wildfire resilient structures. It is critical to have appropriate forecasting and communication to the exposed public. It is important to better understand the long-term impacts of fire suppression over other methods. Large scale wildland fires also present unique challenges for first responders and incident management. A large scale wildland fire can require the mobilisation of a large number (100's to 1000's) of personnel over large areas for long periods of time. More research is needed to optimize incident management in support of enhancing resilience in the face of large events.

Further, in light of increased urbanization broadening the extent of urban areas, the impact of fires in the wildland-urban interface (WUI) is critical. Understanding the complexity of the wildland-urban interface and how it impacts on the risk of wildfires is critical. Efforts are needed to further understand how WUI Communities can become more resilient, e.g. through hardening structure, community initiatives, codes and standards. Programs are available, for example the initiative described by Stein et al. [20], lessons learned internationally should be shared to ensure heightened awareness globally.


**Fig. 3.** Interplaying phases of incident response. Source: modified from Peng et al. [24].

### *3.2. Societal resilience*

There are numerous definitions of resilient and resiliency, many of which depend highly on the context within which they are used. At the root is the concept of being able to quickly return to an ideal "original", or at least acceptable, form or operation following some type of impact or event. The concept is applicable to individuals, communities, society, ecologies, economies, physical infrastructure and more. In looking at disaster resilience, the U.S. National Academies define resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." [21]. The *100 Resilient Cities* program defines urban resilience as "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience." [22,23] With the increasing extreme weather events, rapid urbanization resulting in increasing urban density, and changing demographics noted above, steps need to be taken to increase societal resiliency in the context of the types and magnitude of potential events, the ability of people to be protected in place or safely evacuated, and enhancing the capabilities of first responders.

This should be done in recognition of the interplay between pre-incident, incident and post-incident response as represented in Fig. 3, adapted from Peng et al. [24]. There is a need to further understand incident management for large scale incidents with the potential for one event to lead to a cascading escalation of the incident. Further, the interplay between different phases of incipient response in support of resilience need to be understood both in terms of fire events and fires as one part of a larger incident.

### *3.3. Fire safety and sustainability*

There is a pressing need to expand our present understanding of the intersection of fire safety and sustainability. Holistic models that

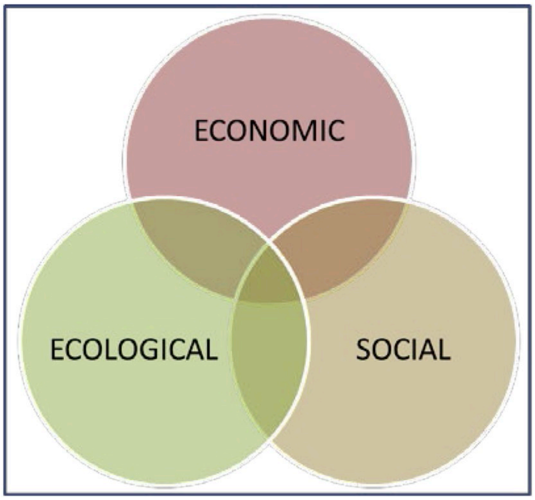


**Fig. 4.** The three dimensions of sustainability.

consider sustainability and fire safety from all dimensions, i.e., economic, ecological and social, are necessary, see Fig. 4. These are needed at the building system level (e.g., façade system performance, renovation), the object level (e.g., use of combustible but renewable resource, timber, new energy carriers and energy storage), and the community level (e.g., densification and conflagration potential, role of first responders, implementation of social housing). Models have been developed to incorporate these various dimensions of sustainability into a single global model [25] but they have yet to be applied to fire science. How will climate change increase fire risks? How will the use of new materials, new building practices and the emergence of new products and services in support of energy and resource sustainability change the nature and magnitude of fire risk?

We know that new building materials and technologies are being developed at a rapid pace to satisfy demands for sustainability and/or energy efficiency. However, a full understanding of the fire performance of these new materials and technologies is lacking. Research is needed to better understand fire performance of materials, products and systems. More holistic fire test methods are needed to help assure new materials and systems meet societal expectations, both in terms of fire safety and sustainability. We need to move away from pass-fail tests to performance based tests that provide engineering parameters. More integrated fire engineering analysis methods are needed to support design.

Traditional fire science has relied heavily on an understanding of heat transfer and fire dynamics supplemented by emissions data for toxicity. Data is sadly lacking for establishing the ecological and economic impact of fire safety, including emissions from accidental fires and environmental costs of replacing damaged installations. The community in general needs to think more holistically, in a multidisciplinary sense, about performance of materials, systems and overall building and infrastructure performance.

Economic sustainability requires a balancing of risks, benefits and costs in meeting fire safety and other objectives. Efforts are needed to consider performance and cost at the building safety level, the response and recovery level, and the community level. Cost-benefit analyses are part of any building project, but need to be optimized across all critical performance objectives. Return on investment is a essential factor in business decisions, whether capital costs on the building or life cycle impacts. Increasingly, return on investment is becoming part of policy decisions as well. Calculating the savings that the fire service provide to the economy and considering those savings in the comparison between expenditures and losses would enable fire departments to quantify and communicate their actual value to the public and to the policymakers. Calculating the effectiveness of expenditure in fire protection would make it possible for building designers to justify increased spending on fire protection and for policymakers to draft policies that allocate budget/resources based on effectiveness levels in addition to the conventional equity considerations. The cost of fire has traditionally been focused on the cost of the fire service, fatalities, injuries and property damage. The total cost of fire in the U.S. was analysed. It was found that lack of adequate data on indirect losses makes it difficult to quantify the actual economic impact of fire. It was also found that the calculation of fire protection part of building construction expenditure needs to be updated. A more holistic approach to economic analysis is needed.

### 3.4. Globally-consistent regulations, standards, and guidelines

An increasing population, rapid urbanization, enormous wealth disparity, integration of dissimilar cultures, and an increasing number of aged create significant firesafety challenges. A large portion of the population growth and urbanization is taking place in developing countries where regulation of fire safety is poor or emergent. Indeed a large portion of (but not all) fire deaths take place in developing countries with an urgent need for improved fire regulations and practices.

Increased regulation and standardisation of building or product fire performance requirements has been the standard response to lessons learned from historic fires, creating solutions to the problems that are known, but not effectively addressing or preventing emerging threats. Furthermore, there can be significant differences in the regulations and guidance from one country to the next. In many juristictions changes to codes and regulations are scrutinised for their potential economic impact. Therefore guidelines on what should be included in such calculations need to be developed internationally. In the current global environment, where movement of goods and labor between countries is significant, and not always well controlled, there is a risk that the fire performance of building components and systems, and of buildings, does not meet societal expectations. Also, application of complex building regulatory systems and structures into low- and middle-income countries could increase risks instead of reducing them, especially if knowledge of fire performance in country specific contexts, and the educational and training components are lacking.

In recent decades, the adoption of performance-based (or functionally-based) building regulations in numerous countries has supported the adoption of novel construction solutions. However, data on performance of materials, people and more are lacking. Further, large scale validation data needs to be generated to reflect new materials, building design and urban development.

Historically, regulations have been developed in response to large fire incidents, e.g. the great fire of London, the Triangle Shirtwaist Company fire, the fire on-board the Scandinavian Star and others. Data is only available in a distributed sense and fire statistics are typically collected and collated in different ways in different countries. In order to learn more from the past and the systematise the information gained it is important to create a common database of information, publicly available. The European Union recently started an initiative to foster communication of fire data, *The Fire Information Exchange Platform* (FIEP), with the aim to establish collaboration on:

- a common terminology and fire statistics;
- the application of fire prevention principles;
- dealing with new products (e.g. integrated photovoltaic panels) and high-rise buildings;
- the exchange of experience from fire accidents; and
- the use of a fire engineering approach in building regulations.

This initiative is a starting point for future work on international fire data and regulations and should be expanded to include non-European initiatives.

### 3.5. Tall buildings and urban development

Increased urbanisation and higher urban populations translate into increasing numbers of tall buildings with their commiserant fire safety challenges. These include internal and external fire spread, occupant protection and safe evacuation, and fire fighting at high elevation above street level, and the development of relevant building regulations, standards and guidelines that take into account all essential characteristics such as structural integrity, fire safety, energy performance, health and environmental impact, etc, while compromising none. Couple this with an aging population and more mobility-challenged population, and a societal shift to the care of elderly in their homes, and the fire safety risks in high-rise buildings increase significantly. Research is needed to understand the evolving changes in demographics, society, materials, and systems in high-rise buildings, how this changes fire risks, and how they can be suitably mitigated while achieving other societal goals and expectations in urban environments.

Higher residential density in urban communities also places challenges on accessibility for first responders. New materials and building design is developing in response to the need to house more people in a small area. It is important that models be developed to ensure that fire safety is not compromised in the race to provide inexpensive accommodation or in the effort to meet aims of heightened sustainability. We know that the success of fire suppression tactics in buildings depends highly on the type and arrangement of fuels burning, and the geometry and ventilation conditions within the spaces and buildings where the fire is burning. More research is needed concerning the interactions and influences between geometry, contents and tactics on fire performance, for use in fire safety design.

### 3.6. New technology, Artificial Intelligence and Big Data

A wealth of data is available from smart buildings, building energy management systems, CCTV cameras in public places, social media and other sensor sources. The rapid emergency of ground-based and aerial robotics provides means to collect additional data during and after fire events. These data represent a veritable gold mine that could be used both to provide input to first responders and a means of communication with the public during on-going incidents. The development of real time models could also allow the prediction of an emergent incident and the risk of escalation. It is essential that fire safety research taps into the emerging understanding of artificial intelligence as a means to identify risks and mine data for timely and appropriate design, management, and response.

There is an ongoing “digital transformation” where digital information is fundamental to much of global building design, construction and management. Fire safety engineering design, analysis tools, and fire protection systems need to fit become a part of this digital transformation to ensure that the fire safety research and engineering communities do not fall irreparably behind progress. Finally, new materials, new building practices, new energy carriers and energy storage and new services all require the development of relevant data for modelling of fire safety and sustainability function.

### 3.7. Higher Education

Fire science is by its very nature multidimensional. There is a need to include input from engineering, chemistry, physics, toxicology, ecotoxicology, psychologists, physiologists, sociologists and more. A common understanding of this field is important, not just in national settings but also internationally. Higher education has long been the preferred method to ensure that new professionals speak the same language and have a common understanding of their field. In the case of Fire Safety Engineering there is myriad approaches to education in different countries around the world. The approach to developing new fire safety professionals varies from formal undergraduate programs to masters programs and doctoral programs, as well as professional masters courses and continuing professional development courses. Some of these programs may lack the breadth of understanding needed to adequately prepare professionals for addressing emerging fire impacts associated

**Table 1**
Summary of fire science and engineering actions.

| Societal Grand Challenge | Fire Science and Engineering Fields of Research and Action | Research Activities |
|---|---|---|
| Climate Change, Resilience and Sustainability | Wildland Fires and Wildland-Urban Interface | • Fundamentals of Wildland Fire Ignition and Spread,<br>• Understanding and Management of Wildland-Urban Interface,<br>• Wildfire Resilient Buildings, Human Behavior in Wildland Fire,<br>• Wildfire Control, Suppression,<br>• Wildfire Incident Management |
| | Societal Resilience | • Resilience of buildings, communities and society<br>• Incident Management<br>• Risk for cascading/escalating incidents |
| | Fire Safety and Sustainability | • Low Environmental Impact Fire Safe Materials<br>• Fire Safe Energy Storage/ Energy Saving Materials<br>• Environmental Impact of Fire<br>• Economic impact of fire including cost of fire protection, savings due to fire service and indirect losses from fires<br>• Toxicity of Materials to Environment<br>• Fire Test Methods<br>• risk-based fire safety engineering |
| Population growth, urbanisation and globalisation | Globally-Consistent Regulations, Standards, and Guidelines | • Global Consistency<br>• Internationally-consistent Regulations<br>• Standards and Guidelines for Fire Safety, Human Behavior in Fire<br>• Universal data collection, collation and management<br>• Improved exchange of data and learning from real incidents both in terms of performance requirements and response tactics |
| | Tall Buildings and Urban Development | • Social, Psychological and Physiological Response to Fire of Aged Persons and of Persons of Different Abilities<br>• Safety in Place/Evacuation<br>• Fire fighting tactics<br>• Fire dynamics in the built environment |
| Cross-cutting | New Technology, Artificial Intelligence (AI) and Big Data | • Data mining<br>• Smart Buildings for Fire Safety,<br>• Smart Firefighting Technology<br>• Forecasting of Fire for Evacuation and Fire Service Response<br>• New and improved models for extrapolation from fire tests to real life performance<br>• Identification of At Risk Persons and Buildings |
| | Higher education | • International agreement on relevant curriculum and qualifications<br>• International exchange<br>• Multidisciplinary education |

with the Grand Societal Challenges. Furthermore, the move from largely prescriptive design and approval practice to risk-informed performance-based design and approval demands somewhat higher levels of competency of fire safety engineers. Efforts should be made to improve cross-national efforts to define what is necessary in terms of knowledge and experience to define a fire safety engineer or practitioner. Exchange programs, not only within one global region, should be established to develop and safeguard this common understanding. In addition, guidance around competencies, qualifications and accreditation of fire safety professionals should be developed to support such exchange.

## 4. Summary and conclusions – a call to action

This paper represents a call to action from the IAFSS to the fire science and engineering community concerning common Societal Global Challenges and their implication for fire safety research and innovation needs. The findings can be summarised in Table 1.

In light of the fields of research and action identified, the IAFSS calls fire scientists and engineers globally to open necessary dialogue in their regions and beyond to make regulators, funding agencies and fellow scientists and engineers aware of what needs to be done to move towards a fire safe world 2030. The IAFSS will continue to work to raise awareness, foster multidisciplinary collaboration, develop new models, methods, data and education in support of this vision.

The fire safety research and engineering community cannot live on its own island – it must be integrated with other disciplines, and with society, to make the impact that is needed. We need the help of others to help us break out of our silos and embrace a much wider understanding of societal needs, and of the role of fire safety science and engineering on building and infrastructure design, construction, and management. We invite all who are willing to partner with us to contact the Association (www.iafss.org) and support the IAFSS Agenda 2030 for a Fire Safe World.

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