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WUI state of the art and regulatory needs in Europe

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Abstract	The document summarizes the state of the art of the regulations relevant to WUI in Europe, providing an organized set of references to the specific regulatory documents. It is focused on three main relevant topics: *i)* fuel-reduced fringes; *ii)* Building codes and standards; *iii)* Wildland-Industrial Interface. Current regulations are analysed and compared, leading to the identification of important needs and limitations of the current European regulatory framework.

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1. Introduction

On many European countries, the forest continuity growth due mainly to rural abandonment and the wildland-urban-interface (WUI) increase are exposing entire communities and rendering them vulnerable to major fire events. As the climate steadily evolves towards warmer scenarios, hot and dry seasons in southern countries are lengthening and wildfires are showing extreme behaviour with huge intensities and enormous destructive potential (EEA, 2017). Climate change is also causing the WUI in northern countries to be progressively located in emergent fire-prone zones (Hagelin & Cluzel, 2016), whose policies and communities are not adapted nor designed to deal with large and destructive wildfires. In addition, human pressure in European natural areas is continuously growing with an increase of ignitions and man-built structures in the WUI (Wigtil et al., 2016). The affected constructions include not only homes and other community structures but also industrial facilities, which may eventually involve technological and economic risks associated to the presence of hazardous materials (e.g. chemical and petrochemical industries, oil and gas facilities, nuclear plants, etc.) and the potential loss of revenue (Johnston & Flannigan, 2018).

Forest fires affecting WUI areas have recently lead to tremendous consequences in Europe (see *WUIVIEW D 5.1. "Inventory of pattern scenarios"* for an in depth analysis of past events). In 2016, wildfires blazed Madeira Island spreading through the old quarter of the capital Funchal; almost 2000 people were evacuated in two WUI fires in Valencia with fire jeopardizing dozens of touristic developments; the Rognac-Vitrolles fire devastated 300 ha at the interface with Marseille, one of the most crowded cities in France. In this incident, the fire also threatened critical infrastructure (i.e a petrochemical complex, a water treatment plant and the Marignane International airport). In 2017, Portugal experienced the deadliest WUI fires in its history, with more than 110 deaths, and thousands of affected structures, including industrial facilities. And more recently (July 2018), fires in Greece killed around 100 people, trapped and burned inside their houses, cars or a few meters away from the beach. Just in 2017, the global wildfire impact involved 1.2 million ha burnt, 127 people killed and 10 billion € of economic losses (San-Miguel-Ayanz et al., 2018).

These hard facts reveal that the design and implementation of a common strategy for the defence and prevention of forest fires in Europe is utterly needed. In the meantime, the European Union as a whole, and the Member States in particular, are belatedly articulating new and appropriate regulations and implementing policies for the protection of WUI areas against forest fires. Indeed, there is a clear will of achieving some degree of coordination through the EU member states in forest fires-WUI fires related protocols and regulations. As illustrating examples, up to now particular EU harmonized tools and systems can be mentioned as a result of EU legislation like the Copernicus Emergency Management Service (which provides reliable information on fire danger and fire monitoring at European level) or the Civil Protection Mechanism supported by the Emergency Response Coordination Centre (ERCC, created to ensure a rapid and effective assistance in disasters). However, although fairly recommended (Ribeiro et al., 2015), a completely harmonized system through EU is far from being a reality due to several critical issues. To begin with, the definition of WUI and WUI fire related terms is still vague and not common to all the countries (Modugno et al., 2016). In addition, current WUI national safety management policies are highly intricate involving a complicated multi-level structure (i.e. from national to municipality level), with provisions differing significantly between countries, and with an overall low degree of compliance.

There is hence a clear need to address the WUI fire policy analysis and improvement at national level as European mechanisms are not harmonized nor standardized. Yet, it is focussing on local realities (in terms of landscape, ecosystems, meteorological conditions, socio-economic systems, land use, etc.) that solutions for the WUI fire global problem have to be found. These necessarily involves improving the knowledge base on WUI fire behaviour and risk at local scale, which will then be channelled into scientific-based recommendations for policy improvement.

2. WUI characteristics at European level

2.1. Types of interfaces with the wildland

Depending on the intensity of the interaction between the human settlements and its environment it is possible to describe two types of interfaces: the wildland-urban interface (Figure 1a) and the wildland-urban intermix (Figure 1b). Following Mell et al. (2010) approach, the wildland-urban interface can be described as where structures directly abut wildland fuels with a clear line of demarcation between structures and fuels, while the wildland-urban intermix is described as where structures are scattered throughout a wildland area, without a clear line of demarcation between structures and fuels. Subsequently, other definitions of interfaces based on the kind of activities supported in these areas have appeared. For example, Johnston & Flannigan (2018) have described the wildland-industrial interface as where industrial values meet with or are dispersed within wildland vegetation (e.g. power plants, LPG storage services or gas pipelines) and the wildland-infrastructure interface as where infrastructure values meet with or are dispersed within wildland vegetation (e.g. roads, railways or power lines).

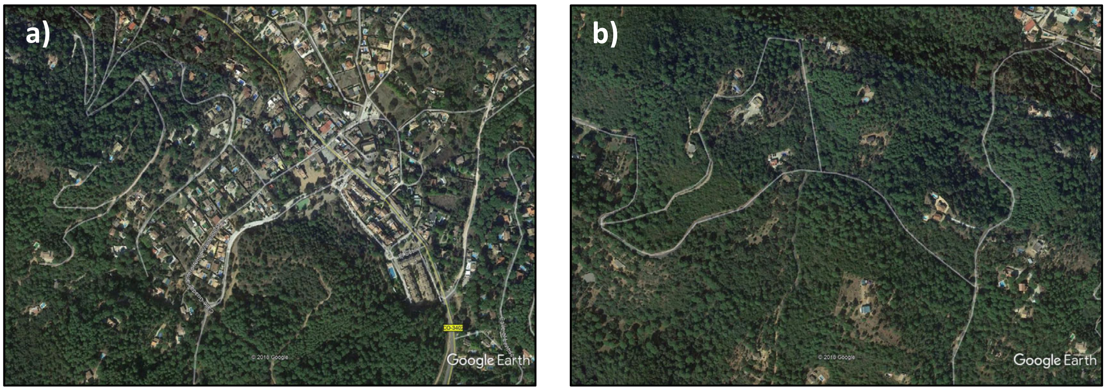

Figure 1. Examples of (a) wildland-urban interface and (b) wildland-urban intermix in Santa María de Trassierra, Córdoba (Spain). Source: Google Earth.

Regarding the wildland-urban interface, there are several configurations identified in Mediterranean Europe according to housing and vegetation density and type (Caballero et al., 2007). The ones with higher risk are *i)* scattered houses in developed areas, without any type of landscape planning, some of them in illegal or in lawless condition. This type of WUI hardly has common infrastructure and administrative organization; *ii)* isolated houses in wildlands where forest exploitation has progressively been abandoned. In these cases, flames can reach structures very easily; and *iii*) dense housing with a rambling road network, with residential fuel continuity, typical from the Mediterranean coast touristic developments.

2.2. Building characteristics

Constructive components, methods and practices are shared in most Mediterranean buildings. Bricks and concrete are the materials commonly used to erect walls and structures, and clay tiles for the roofing, so the vulnerability is significantly lower when compared to areas where wood or other combustible materials are primarily used (e.g. northern European countries, North America or Australia). It is worth noting that many areas in northern Europe, with availability of natural constructive components (i.e. wooden structures) are facing emergent fire prone conditions that are increasing the risk of WUI fires (e.g. Sweden or Finland).

As analysed in previous WUIVIEW D.5.1, openings in the buildings are one of the major weak points of houses when facing a forest fire. Forensic analyses of burned dwellings show that some points in the building such as vents, windows and doors left opened in the evacuation process, allowed the entrance of firebrands and hot gases compromising the whole structure (Ribeiro et al., 2018).

Opposite of what is observed in other areas (e.g. United States), houses affected by wildfires in Mediterranean Europe may stand erect, and even recoverable and reusable to some extent, after the fire event. In this sense, five levels of impact may be considered, according to the observed damage and likelihood of re-usage afterwards, namely: (*i)* No damage. There is no appreciable effect on the exterior elements, structure and interior are unaltered; (*ii)* Light damage. Some non-structural elements are affected, mostly external components frequently made of plastic. Some annexed service buildings may be affected; (*iii)* Moderate damage. A section of the house has been partially burned down, such as a room or part of the roof, some windowing and maybe annexed buildings are also affected. The structure is unaltered and fully reusable without major recovering works; (*iv)* Severe damage. The roof probably has collapsed entirely, most of the rooms are burned down and there are evidences of complete internal burning and fire propagation. Major reconstruction is required, but the main structure of the house is still safe to be reused. Major works need to be undertaken. Recovery of the house is frequently a matter of balancing the associated costs of recovery vs. demolition and rebuilding; (*v)* Complete destruction. The structure is irrecoverable as it presents significant cracks, displacements and other evidences of serious damages. Demolition is advised.

It is interesting to underline that this fact also provides opportunity for the post-fire investigation and the gathering of evidences, so to derive valuable lessons, as wooden houses frequently burn down to ashes giving very few evidences. According to the experience in past fires, the level (*iv)* is frequently perceived by owners and authorities as 'totally destroyed' while it is still recoverable. This type of classification should be adopted by insurance companies, but also to be used in the studies and mapping of house affections so to consistently derive lessons learnt.

Apart from interfacing wildland fuels (forests, shrublands or grasslands), WUI communities include also residential fuels (natural or non-natural), present in the exterior of the house in the garden, under porches, piled in the backyard, etc. whose hazard is in general poorly characterized and frequently disregarded by residents. These fuels are exposed to firebrands either generated by a wildfire or by burning structures. They can also be ignited by flame contact from the main fire front in cases where wild fuels are too close to communities. Ornamental trees or hedges, wood piles, pruning waste, wild fuel in undeveloped lots, fences, hydrocarbon storage bottles and tanks, gas canisters, garden furniture, outbuildings (e.g. storage sheds, pet houses, gazebos), etc. usually create fuel continuity through which the fire can easily percolate and may involve high heat loads in case of ignition. Furthermore, industrial interface is also present in Mediterranean Europe, particularly in the most active regions.

2.3. WUI fire management challenges

As in all WUI fire-prone areas, WUI fires in Mediterranean Europe pose enormous management challenges in terms of civil protection and fire mitigation. These fires often exceed the capacities of fire-fighters, who have to respond simultaneously to wildfire suppression, community evacuation and structures protection. The presence of smoke and firebrands, as in other parts of the world, complicates scenarios and frequently entails dilemma whether to evacuate or shelter in place. In fact, extended legal obligation to primarily defend people and properties, causes an unbalanced amount of firefighting resources into the urban area at the expense of the wildfire. In addition, many regions present a separation in fire services, making a distinction between forest firefighters and urban firefighters, being none of them completely prepared (in terms of equipment and training) for interventions in WUI scenarios.

Besides, the forecasted trend for most Europe in the coming years involves the concurrence of: *i)* an increase of WUI-fire prone areas due to the continued urban sprawl interfacing wildlands; *ii)* the upsurge of new fire regimes due to climate change leading to more frequent and intense fires; and *iii)* an increase of fuel accumulation contributing to the fire power, due to sustained rural abandonment and lack of efficient fuel management programs (Armero et al., 2009; Castellnou, 2018; Galiana, 2012).

For all these reasons, in the coming years self-protected communities will be the first priority over fire suppression, entailing more and best prepared WUI scenarios grounded on solid and sound guidelines and legislation. Actions like WUIVIEW are already pointing at this direction and will help to achieve such degree of safety. WUIVIEW will contribute to characterize fire hazard, will give insights on structures and materials fire behaviour and will deliver knowledge to disseminate through WUI communities and to inform policy makers in charge of WUI-specific standards/codes.

3. Legal framework

In most of the wildfire-prone European countries, there is a rather complex legal framework dealing with forest fire prevention and mitigation. According to the subsidiarity principle applicable in all EU member states, regional and local administrations are key actors co-responsible of forest fire prevention and defence in WUI areas. National laws are usually transferred to regions/provinces, which in turn have to articulate those laws issuing local regulation and guidelines, and ensuring compliance of provisions at municipal level. Despite the large amount of laws that this multi-level legal framework entails and the large impact that WUI fires are causing in Europe, legislation focused specifically on fire in WUI environments is still scarce. Furthermore, when available, it is nonspecific (i.e. it does not cover the large casuistry of influencing parameters related to weather, fuels and topography) and it is mainly grounded on rule-based methods resulting from observation and expert opinion.

Hardening communities exposed to wildfires can be approached by taking actions either addressed to *i)* minimize the fire heat load at which structures might exposed and *ii)* design structures more resistant to ignition. In countries with a higher degree of standardization dealing with the wildland-urban interface (e.g. Australia or United States), both approaches are usually covered by fuel treatment policies/recommendations and building codes/standards, respectively.

In the following sections (3.1 and 3.2) we summarize the findings of our literature survey concerning European regulation including fuel treatments and building/structures provisions. Moreover, we have enlarged our review by exploring regulations related to the wildland-industrial interface (section 3.3), as the presence of this type of interface in Europe has already been involved in serious WUI fire events.

3.1. European policies on fuel treatments

Fuel-reduced fringes are all those linear preventive structures where fuels are managed to avoid or hinder fire propagation. The most used are the fuelbreaks and the firebreaks. In fuelbreaks, vegetation is completely (or almost completely) removed, while in firebreaks fuels are partially and strategically removed. These two preventive structures are usually accompanied by transition zones, where a progressive reduction of the fuel from forestlands is performed.

The most common situation in legislative documents is to establish fixed safety distances for fuelbreaks around infrastructures, structures or settlements. As in many other topics, regulations on fuel-reduced fringes present a huge variability between European state members, and even between regions within a same country.

Spanish National acts give a general fixed value of 30 m for fuel-reduced fringes (BOE, 2013). Further development has been transcribed into regional regulations or recommendations in Galicia, Principado de Asturias, Catalunya, Extremadura and Comunitat Valenciana, where simple rules of thumb resulting from expert judgement have been set to consider meteorological conditions, slope or fuels when sizing fuel-reduced fringes (detailed information regarding Spanish policy can be found in Pastor et al., (2019)).

A similar situation is presented in France, with a general fixed value of 50 m for fuel-reduced fringes width around WUI communities, despite the specificity of local fire behaviour parameters (JORF, 2019). Some regions, such as Marseille, have considered further development, increasing this width up to 100 m or 200 m under mayor's decree or prefectoral orders.

Despite being one of the countries with the most severe wildfire events, Greece lacks an appropriate legal framework to deal with such large problem. However, some prescriptions can be found in its current legislation, regarding fuel treatments in high risk areas. Following the Civil Protection Plan to fight against forest fires (MIG, 2018), the distance to be treated is up to 100 meters, treating not just surface fuels but also prunning bottom branches to hinder transitions to crown fires.

Portuguese legislation changed after 2017 fire episodes, and it is expected to be further developed over the next few months. By now, provisions point at a minimum distance of 50 m to be fuel-treated in several settlements in rural areas, including industrial facilities. This distance can be further increased up to 100 m in case local fire prevention plans suggest so. Interestingly, Portugal has also developed provisions regarding the micro-scale. At home-owner level, a 1-2 m paved area around buildings and a 10 m buffer with no fuels (even residential fuels) around houses (20 m in high slope environments) is mandatory (DR, 2006). This information can be found in AFN (2011). Despite this degree of detail, it has been already acknowledged that the level of compliance in Portugal is very low (Ribeiro et al., 2015).

In Italy, fuel-managed fringes are specified according to regional provision. A guidance value of the distances specified in these Regional Plans regarding fuel-free surrounding fringes are 10 m for fuel-managed fringes around buildings and 3 m for strips at both sides of roads. (Ribeiro et al., 2015).

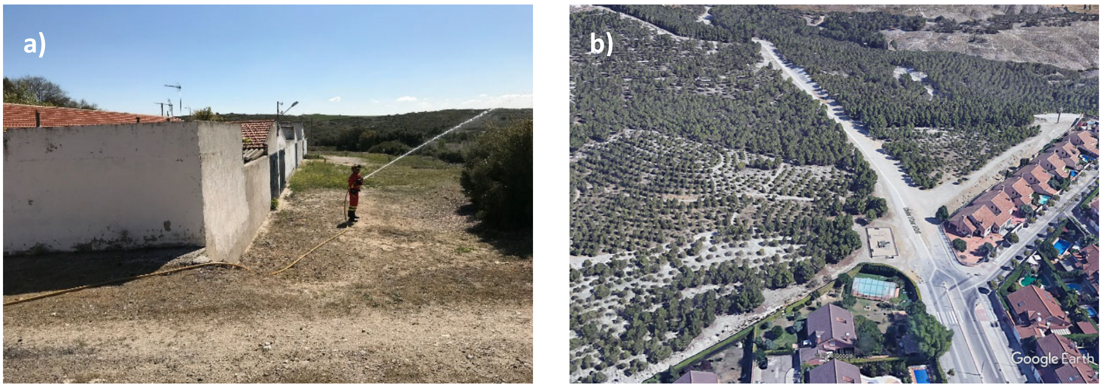

Figure 2. (a) Fuelbreak in Madrid (Spain). Cleared distance less than the minimum specified by legislation (30 m). Source: Ferran Dalmau Rovira. (b) Fuelbreaks around a neighbourhood in Rivas-Vaciamadrid (Spain). Different fuel treatments and safety distances at both sides of the road. Source: Google Earth.

3.2. Building codes

Construction practices and building materials are responsible, together with residential fuels, of vulnerabilities in WUI communities at home-owner scale. As it has been already commented in past WUIVIEW D 5.1, building materials commonly used in European countries are non-combustible, except for those used in northern countries, where wooden structures are more common. However, houses at the WUI always have weak elements to fire exposure (e.g. glazing and flooring systems, decks and verandas or eaves and gutters). This type of elements are responsible of vulnerabilities, either because they are made of materials sensitive to fire or either because their geometry enhances heat transfer. For example, ignition likelihood from embers might increase by re-radiation mechanisms in re-entrant corners (Manzello et al., 2017;

Manzello & Suzuki, 2017). Local turbulence and flame entrainment from residential fuels might be induced in angled and edgy façades, and semi-confined spaces (Leonard et al., 2018). Among them, some elements composing the building envelope, like vents, doors or windows, are particularly critical since they may allow the entrance of firebrands leading to ignition of the interior of the building.

In European countries, there are no codes dealing with the WUI fire problem, neither oriented to typical WUI areas (Mediterranean Europe), nor to emergent fire-prone zones in Northern Europe. In general, building codes in Europe do no add any particular provision in terms of characteristics, materials and dimensions in the design and construction of houses at the WUI.

On the contrary, there are some notable examples of building codes and standards issued in non-European countries to harden structures at the WUI. As an example, the American Standard NFPA 1144 (2018), the IWUIC Code (ICC, 2015) or the Australian Standard 3959 (AS, 2009) provide prescriptive regulations for the design and construction of buildings to reduce the potential of ignition from wildland fires. According to these codes, main construction requirements of different components (e.g. roofs, exterior walls, vents, eaves, exterior windows, etc.) require compliance with different standard testing methodologies (e.g. tests methods from ASTM, UL Standards, ICC and AS/NZS)

The huge contrast of the poor European legal framework when compared to different WUI realities together with the large impact of recent WUI fires and the forecasted trend for the coming years show evidence of an urgent need of WUI specific building provisions for Europe. Regulations on where and how buildings can be sited, designed and constructed to increase chances of building survival when exposed to wildfires are required. Moreover, countries in southern Europe have to take advantage of historical fire-resistant building materials to help reinforcing overall fire endurance of Mediterranean style homes in order to increase their sheltering capacity. Standards have to be developed to assess capabilities and adequacy of buildings acting as shelters. Spaces for programmed shelter in place could enormously benefit emergency management, minimizing the number of evacuations and facilitating overall fire-fighting actions.

3.3. Wildland-Industrial Interface

Forest fires can trigger industrial accidents giving rise to a natural-technological (Natech) emergency, which may pose tremendous fire management difficulties regarding fire suppression and civil protection. This particular type of domino effect is considered an emerging risk in Europe due to new fire regimes and growing industrialization. Management of Natech type of risks has been generally addressed through national legal frameworks for industrial accident prevention in Europe. The European Commission has already recognized the scarcity in guidance for Natech risk reduction supporting policy makers, being the lack of specific Natech risk-assessment methodologies and tools a priority research need (Krausmann & Baranzini, 2012).

No specific legislations for the wildland-industrial interface exist in European countries, and fire safety measures for industrial facilities are usually defined according to the developed activity (e.g. nuclear, chemical, oil and gas, etc.). Measures dealing with WUI scenarios, when present, are mainly related to fuel-reduced fringes characterization and sizing.

3.3.1. LPG tanks exposure to WUI fires

Smaller scale Natech scenarios have also been identified at home-owner level in WUI communities, mainly involving domestic LPG storage tanks and nearby vegetation (Pastor et al., 2018). Hydrocarbon tanks can be seriously threatened by a fire nearby, particularly in those cases where negligence or regulatory gaps allow a very close exposure of the vessels to flames coming from nearby fuels. In recent WUI fire events (e.g. Benitatxell, Spain, 2016; Madeira, Portugal, 2016; Calabassas, California, 2016, 2018) these type of LPG infrastructures were dangerously involved in the WUI fire emergency. Tanks were subjected to intense fire exposures, provoking loss of containment due to safety relief valves opening, giving rise to subsequent jet fires. Although in none of these cases major events were observed, the magnitude of the consequences in case of explosion could have been devastating, given the high population and asset density that usually characterize WUI areas.

In the European Union, the use and installation of LPG tanks is regulated by laws issued by each state member. For this reason, prescriptions specifying, among others, safety distances from the LPG supply unit to vulnerable elements, storage of flammable materials and sources of ignitions, may vary from one country to another. Regulations from France (JORF, 1979), Greece (ΦΕΚ, 1993), Italy (GUDRI, 2004) Portugal (DR, 2002), Spain (AENOR, 2008) and UK (HSE, 2016) are here taken into consideration. Figure 3 shows a comparison of minimum safety distances from domestic above-ground LPG tanks according to the legislation of the European countries listed above. Italy has the most conservative requirements, whereas Spain has the less restrictive ones. The Spanish regulation, for instance, indicates that for 1 to 5 m^3 tanks safety distances should be of 2 m from the walls of the tank (this distance can be reduced by a 50% for smaller tanks). For the same tank size, the Italian legislations prescribe a safety distance which is more than twice the one required in Spain. In general, it can be noted how prescriptions are not harmonized. Situations in compliance with a given standard may not be considered safe in a different country, even in the same European Union.

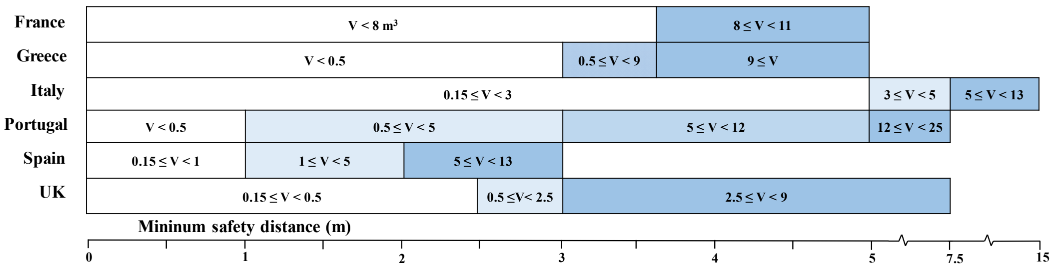

Figure 3. Minimum safety distance as a function of tank capacity (in m^3) for different European countries.

Another important aspect to be highlighted is that not all the standards in the different countries have explicit mention to the possible presence of vegetation in the proximity of the tank. The Greek regulation clearly states that "*the floor of the storage area must be kept clean and free of dry grass, grass and foreign objects*". Similarly, the HSE (UK) recommends that there should be no trees or shrubs within the safety distance reported in the standard. The Italian regulation requires that no vegetation is present in an area of 5 m around the tank. On the other hand, the Portuguese regulation has a more general statement, not allowing the presence of flammable products within such distance. The French regulation simply mentions that no storage of flammable material can be present in the area delimited by the safety distance. Clearly enough, such statement does not cover the case of ornamental vegetation commonly placed in WUI microscale and that might be ignited in case of wildfires. The Spanish regulation does not address the issue of the possible presence of fuels in the proximity of LPG tanks.

4. Concluding remarks

The presence and expansion of wildland-urban interface areas into existing and upcoming fire-prone zones in Europe is becoming a paramount concern for the protection of human life, homes, infrastructures and businesses against forest fires. In the years to come, **self-protected communities will be the first priority over fire suppression**, entailing more and best prepared WUI scenarios grounded on solid and sound guidelines and legislation.

As of today, the European Union is way behind this requirement, so do the Member States, which poorly have developed such regulations. **European standards are scarce and generally deficient** when addressing the factors and processes that take place in the destruction of communities and human life.

Furthermore, while the underlying WUI problem is a home ignition problem, most legislation deals with fuel management, but sets aside the structure itself. Reducing the vulnerability of structures against forest fires is a cornerstone to achieve a safer WUI, and it has to be achieved by **regulating on building practices and materials**. International examples mentioned in this document are available to serve as baseline for the European WUI reality.

The **wildland-industrial interface** and the industrial elements in the WUI (such as LPG tanks), have to be particularly prepared against forest fires due to their inherent hazard. The survey of regulations detailed in this deliverable provides evidence of a **lack of harmonization throughout European countries**. Moreover, important gaps have been highlighted in specific provisions, particularly those referred to the presence of fuels near domestic LPG tanks.

Finally, northern European countries have to be specially prepared for the forecasted scenario of a growing number of WUI fires, given the **greater vulnerability of their wooden traditional structures**.

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