European Program for Wildfire-Prepared Communities

FIREPRIME

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The FIREPRIME Program Toolkit

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Abstract	This document provides an overview of the tools and services developed by the FIREPRIME consortium for implementation in the pilot areas, including checklists, guidelines, and educational materials. It is structured into three main sections—one for each stream: homeowner fire safety, community engagement and education, and resilient infrastructure. It presents the general characteristics of all the tools, while the specific details on their testing, integration and implementation in the different pilot sites are provided in deliverables D4.1 (FIREPRIME pilot in SP), D5.1 (FIREPRIME pilot in SE), and D6.1 (FIREPRIME pilot in AT).

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1. Introduction and objectives

The current document is part of the FIREPRIME project that aims to develop the knowledge, tools and services needed to build and implement an integral program on risk prevention and preparedness across European WUI communities, with the focus on civil protection. These developments will be implemented and tested in local communities of 3 pilot areas: the province of Barcelona in Spain (Mediterranean Europe), Tyrol in Austria (Central Europe), and Gothenburg in Sweden (Northern Europe).

Therefore, the project seeks to increased wildfire risk knowledge and assessments, by considering specific wildfire risk components and its underlying drivers for a given region/area and to increase evidence-based public risk awareness, education and preparedness among the population for wildfires.

In particular, FIREPRIME will contribute to the achievement of these outcomes by:

- Developing and implementing risk assessment tools and guidelines to be applied at property level (households) and infrastructures.
- Developing and implementing risk awareness and education activities at community level in the pilot sites by producing educational and interactive material for the public, packaged for application beyond the pilot municipalities.

This deliverable belongs to WP3 “Program Development” and summarises results of tasks T3.1-3.3 whose main objectives were:

- To develop resources and services to empower homeowners and residents in wildfire preparedness.
- To design activities and tools to foster a fire risk culture and fire resilience within communities.
- To craft recommendations for infrastructures and critical entities in the WUI exposed to wildfires

This document is organized around the three FIREPRIME streams: homeowner fire safety, community engagement and education, and critical infrastructure. For each stream, the relevant tools are introduced and briefly described, addressing key questions in each subsection—what the tool is, who it targets, how it was developed, and how it will be piloted.

2. Homeowner fire safety stream

The FIREPRIME homeowner fire safety stream aims to empower WUI residents by providing tools and knowledge to help them creating defensible spaces and resilient homes. To this end, a pan-European quantitative risk assessment method including property-level risk mitigation guidelines has been developed gathering the expertise of the consortium. This method has then been implemented and made available as both a smartphone app—designed to be easy to understand and use—as well as in a non-digital format questionnaire (i.e., on paper).

Additionally, a training program for advanced home assessments has been developed for volunteers already involved in wildfire preparedness efforts, alongside the risk assessment method.

2.1. The FIREPRIME Smart Phone App for wildfire risk assessment at homeowner level

2.1.1. What is this tool, and who is it designed for?

This smartphone App, available for both Android and iOS, is designed to help smartphone-owning residents living in the wildland-urban interface across Europe assess the hazard and vulnerability levels of their property.

Using a simple, 25-question survey, users receive a quantitative risk assessment indicator along with personalized recommendations for improvement. The questions cover key factors such as building materials, maintenance practices, the presence of fuels within the home ignition zone, and their upkeep. To ensure clarity, the app provides examples and images customized to the specific pilot site, making the assessment process more intuitive and accessible. Language can be chosen between English, Catalan, Spanish, German and Swedish.

The system encourages homeowners to revisit the App, log improvements they have made or plan to implement, and track their progress through an updated risk score (Figure 1).

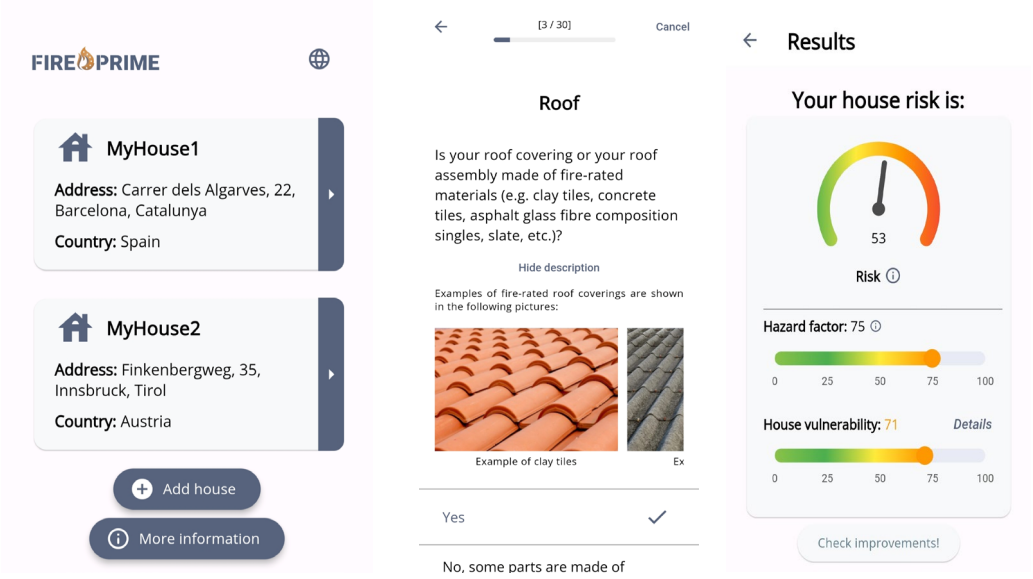

Figure 1. Screenshots of the FIREPRIME Smart Phone App

2.1.2. How was this tool developed?

The tool has undergone two parallel development processes: the development of the risk assessment method and the implementation of the smartphone app.

For the first, a wildfire risk assessment method has been specifically designed, leveraging the expertise of the consortium and incorporating a European perspective. This method considers the distinct characteristics of the three pilot sites—Mediterranean, Alpine, and Nordic regions—while building on insights from past and ongoing projects involving consortium members. The goal has been to enhance harmonization in wildfire risk assessment and mitigation while highlighting the added value of a European approach in sharing knowledge and expertise across Southern, Central, and Northern Europe.

Within the App, risk is defined as a function of both the hazard a property is exposed to and its vulnerability to wildfire. Hazard is determined locally using data from the EFFIS portal maps. Vulnerability is quantified through a fault tree analysis, which maps potential fire entry pathways into buildings in the WUI. The fault tree, developed based on scientific research on WUI fire ignition mechanisms, has been adapted to the specific conditions of each pilot site. Failure probabilities have been assigned to the fault tree's basic events through expert judgement, allowing for the calculation of fire entry probability.

The FIREPRIME app has modular and extensible architecture, allowing easy integration of new components. All processing occurs locally on the user's device, with cache-based communication ensuring functionality even with limited internet connectivity. The *House Management* component serves as the main entry point, managing the user's properties and initiating risk assessments. The *Risk Assessment* component coordinates the hazard and vulnerability Assessments. The hazard assessment retrieves hazard levels via a Web Map Service, currently integrated with Copernicus, and uses cached data when offline. The vulnerability assessment evaluates a house's vulnerability using the above-mentioned user questionnaire and fault-tree analysis. Once the risk is calculated, the *Recommender* module provides tailored, rule-based suggestions to help users reduce their home's risk. The app tracks anonymized user interaction data and stores it securely in the cloud to inform future improvements.

2.1.3. How will this tool be piloted?

The tool will be piloted using two different approaches: field testing and remote evaluation.

Field testing will be conducted in the SP pilot and will take place in two main phases. The first phase will involve testing the app in five homes within the "La Floresta" community and five more in "Sol i Aire". Residents will be carefully selected to ensure diversity in terms of building structures, risk levels, and socio-economic conditions. In the second phase, the app will be widely tested during a community event (Preparedness Day - October).

Remote evaluation will take place in SE and AT. In SE, the app's risk assessment algorithm will be tested on a set of homes in Berga municipality, leveraging data collected during the previous DG-ECHO WUIVIEW project. A second study area (Sundsvall municipality) will also be used for additional testing. In AT, the app will be showcased in the municipality of Haiming, where local stakeholders (the mayor, the heads of local firefighter volunteers) will provide feedback on its functionality and usability.

For further details on the testing process—including stakeholder involvement, timeline, and evaluation methods—please refer to deliverables D4.1, D5.1, and D6.1, which outline the implementation plans for the three pilot sites.

2.2. The FIREPRIME Homeowner Wildfire Risk Assessment Questionnaire

2.2.1. What is this tool, and who is it designed for?

This is the paper-based version of the app questionnaire, translated and adapted for the SP, AT, and SE pilot areas. It is intended for individuals who either do not have access to a smartphone or prefer not to use one to assess their wildfire risk.

2.2.2. How was this tool developed?

The consortium initially developed a standardized questionnaire primarily intended for use in Mediterranean countries. This core version was later adapted for pilot areas in Central and Northern Europe. Both the Austrian and Swedish partners revised certain questions and introduced new items to better reflect the specific conditions of their respective pilot regions. To enhance user understanding and contextual relevance, the questionnaire was illustrated with photographs from each pilot area. These images depict local architectural styles, distinctive building features, typical vegetation, and contextual elements such as the outdoor storage of combustible materials—helping users interpret the questions within their own environment. The questionnaire was translated into German, Catalan and Swedish.

2.2.3. How will this tool be piloted?

In CAT pilot, the questionnaire will be used as a complementary tool in those homes with elderly people and it will be used as training material for the volunteers being trained for the Advanced Home Assessment Program.

In AT pilot, the Homeowner Risk Assessment Questionnaire will be adapted in the local reality after discussing with the local stakeholders and be provided to the municipality as an alternative to the App for people that are not familiar to using Smart Phones.

As for the SE pilot, the questionnaire will be first tested against data and photos collected from a field trip in the village of Berga with a total of 71 properties bordering forested land. Thereafter, the questions will be also discussed during a workshop in Sundsvall municipality (April 3rd, 2025). In this workshop, the questions will be discussed through a number of examples from real incidents where buildings were ignited by wildfires.

2.3. The FIREPRIME advanced home assessment training

2.3.1. What is this tool, and who is it designed for?

The FIREPRIME project has developed a model to support residents through advanced home assessments conducted by trained local volunteers—either from municipal Civil Protection units or volunteer firefighting associations. These assessments can be carried out in two primary scenarios using the FIREPRIME app: (1) when residents lack the confidence or capacity to evaluate their wildfire risk independently, and (2) when municipalities or relevant authorities require property-level risk data to inform fire risk management strategies. This may include decisions related to horizontal confinement, evaluating the sheltering capacity of highly exposed communities, or other planning needs. To ensure consistency and reliability, FIREPRIME has developed a foundational training program to prepare volunteers for conducting these assessments.

2.3.2. How was this tool developed?

The basic training program was developed drawing inspiration from the FireSmart Advanced Home Assessment Program. It consists of a 3-hour interactive, in-person session in which volunteers are introduced to the risk model implemented in the FIREPRIME App. Special emphasis is placed on understanding the questions related to building vulnerability, the susceptibility of the surrounding environment to transmit fire to the structure, and the risk reduction recommendations generated by the App. This theoretical content is reinforced through two practical exercises: participants are provided with information on two different homes located in the wildland–urban interface, including building materials, location, and photographs of their surroundings. Volunteers are then asked to use the App to complete assessments for each property. Group discussions on the variability in answers and results help consolidate the theoretical concepts and promote critical thinking.

Following the classroom session, each volunteer is required to conduct two real-world assessments in collaboration with WUI residents. This hands-on activity involves using the App to evaluate the property, identify key vulnerabilities, explain the overall risk score, and provide guidance on possible mitigation actions.

2.3.3. How will this tool be piloted?

In the SP pilot, the advanced home assessment training program will be piloted with volunteers from the Civil Protection unit and the volunteer firefighting group (ADF – *Associació de Defensa Forestal*) of the municipality of Sant Cugat. The in-person training session is scheduled for April 5th and will be held at the Sant Cugat City Hall. The field-based assessments will take place the following week in the neighbourhoods of Sol i Aire and La Floresta.

A shorter version of the training will also be delivered in the AT pilot. The app will be presented at the mayor's office and installed on participants' smartphones. Each participant will receive a feedback

questionnaire. In a second phase, members of the general public may be involved. Local unions will be approached to act as multipliers for the App.

2.4. The FIREPRIME Homeowner Wildfire Risk Assessment Flyer

2.4.1. What is this tool, and who is it designed for?

This flyer is designed to help reduce vulnerabilities across wildfire-prone regions by raising awareness and promoting risk-reducing behaviours. While it conveys general messages applicable to all regions, it is also adapted to reflect the specific needs, risks, and cultural contexts of local communities. The flyer maintains a consistent visual identity and layout in line with FIREPRIME branding, ensuring coherence across all materials. However, each version includes community-specific content, such as tailored messages, practical advice, and targeted calls to action, allowing it to resonate more effectively with local audiences and address their unique wildfire challenges.

2.4.2. How was this tool developed?

The flyer has been conceived with a strong emphasis on the diverse realities already identified across Europe regarding wildfire risk. Recognizing that wildfire exposure, community preparedness, and public awareness vary significantly between regions, the flyer adopts a flexible, modular approach. While maintaining a consistent FIREPRIME visual identity and structure, its content is tailored to reflect the specific context, risk level, and communication needs of each pilot area. This ensures that the messages are not only technically sound but also culturally and socially relevant—whether by emphasizing structural vulnerability and fuel management in high-risk areas like Spain, fostering basic awareness and encouraging early community engagement in lower-risk regions like Austria, or promoting safety in traditional fire-use practices in contexts such as Sweden.

For the SP pilot, the flyer conveys synthesized messages derived from the overall risk assessment algorithm implemented in the App. It emphasizes two key priorities: managing vegetation and fuels around structures, and hardening buildings to improve their resistance to wildfire. The flyer includes simple, actionable messages that highlight practical steps WUI residents can take to reduce their risk. These messages are designed to be direct and easy to understand, encouraging immediate and feasible mitigation actions. For the AT pilot, the flyer stress on the need to increase risk awareness among population

For the AT pilot, the flyer focuses on raising wildfire risk awareness. The messages are designed to inform and sensitize residents about the potential for wildfire events, even in areas where such risks may not be immediately recognized. The flyer highlights the changing climate conditions, recent fire events, and the growing need for preparedness. It includes simple recommendations to help residents understand how their surroundings and daily activities could influence wildfire exposure, laying the groundwork for more proactive risk mitigation in the future.

For the SE pilot the flyer entails four key factors for protection of Swedish homes which have been singled out from a study of thousands of incidents in which vegetation fires have ignited Swedish buildings. The

flyer is an easy to understand sketch with very short take-home-messages. It constitutes a stand-alone product with no need for added information. It will, however, have a short (~2 page) text explaining the findings leading to the recommendation for those that are extra interested.

2.4.3. How will this tool be piloted?

The flyers will be distributed across the three pilot countries through tailored channels. In Spain, they will be shared within the municipality of Sant Cugat and officially presented during the second Preparedness Day in October 2025. In Austria, the flyer will be introduced to local stakeholders in Haiming, who will then take the lead in distributing it to residents. In Sweden, dissemination will be carried out on a national scale, with the flyer being sent to all 290 municipalities and 21 counties via the Swedish Civil Contingencies Agency.

3. Community engagement and education stream

The FIREPRIME community engagement and education stream is conceived to foster initiatives that encourage active community participation in risk management. This approach aims to empower citizens by involving them directly in various aspects of wildfire preparedness and prevention. In general terms, there are three types of tools within the community engagement and education stream: awareness and education, capacity building and collaborative partnership.

3.1. The FIREPRIME Preparedness Day

3.1.1. What is this tool, and who is it designed for?

The FIREPRIME Preparedness Day is a community event designed to raise risk awareness and planning actions to reduce wildfire risk (Figure 2). It brings together residents and local authorities to promote wildfire prevention, preparedness, and response strategies. In that sense, a preparedness day can host a wide range of different activities, for instance: educational workshops on home hardening and defensible space, receive hands-on training in wildfire risk assessment and emergency planning, get organized among the neighbourhood, and many others. Therefore, the main goal of a Wildfire Preparedness Day is to empower communities to take proactive measures in coordination with local authorities.

A factsheet with a FIREPRIME Wildfire Preparedness Day organization recommendations will be provided as a tool to assist civil protection authorities and local communities on the organization process.

Figure 2. Wildfire risk awareness door-to-door activity organized using a Preparedness Day format. Begur municipality, 2019.

3.1.2. How was this tool developed?

The Wildfire Preparedness Day is an initiative firstly launched in the United States by the National Fire Protection Association (NFPA) to promote preparedness and coordination between residents and civil protection authorities in facing wildfires in wildland-urban interface areas. It was initially planned as a

single-day activity to undertake a wide range of actions to promote risk management among involved stakeholders. Following its success in the U.S., the concept was adopted in other countries such as Canada, South Africa, and Italy, among others, achieving positive results worldwide.

As part of the FIREPRIME project, the Preparedness Day concept has been adapted to the Mediterranean Europe context, taking advantage of the FIREPRIME toolkit, in coordination with civil protection authorities and neighbourhoods.

At the end of the project, the factsheet tool will be produced, incorporating feedback from all related activities, and it will be made available in its final version at the FIREPRIME open repository.

3.1.3. How will this tool be piloted?

The FIREPRIME Wildfire Preparedness Day will be tested in Spain, through the Sant Cugat municipality pilot. It will consist on a morning event that will gather together local and regional authorities, as well as community neighbours. The event will be divided into three 1-hour blocks. The first one will be a round table of stakeholders to share and introduce all wildfire risk reduction actions undertaken during the last years. It will serve as a starting point so that everyone is at the same page to discuss during the following blocks.

The second block will be a focused discussions on three topics:

- Warning and Emergency Response Protocols
    - Who alerts the population in case of a wildfire, and how?
    - How can we ensure that everyone receives the information on time?
    - What can residents do to be better prepared?
- Sheltering and Evacuation
    - Preparing for sheltering in advance: What should be ready? Where should I take shelter?
    - How can sheltering information be improved to reduce uncertainty?
    - In case of evacuation, what is the procedure to follow? What needs to be prepared? How should it be done?
- The Role of Citizens in Self-Protection
    - What responsibility do communities have in risk management?
    - Self-protection groups: How can collaboration between residents and authorities be strengthened?
    - What self-protection initiatives have been implemented successfully?

The third block, taking as examples recommendations from US and Canada partners, will consist in a free time slot. The idea is to give free time to the attendees to discuss between them. In this slot, participants will have the opportunity to write risk reduction proposals for the future, to get coordinated and to check risk awareness and planning material.

A second Wildfire Preparedness Day will be organized after the fire season to discuss topics related to fire prevention, for instance, smart gardening, home ignition zone clean-up strategies, community infrastructure management.

After the two Preparedness Days a meeting with local authorities and communities will be organized in order to evaluate the performance.

Information about the organisation of such an event will be given to the heads of the voluntary Firefighters in the AT pilot. They can use this information to organise similar events to improve public awareness and risk perception.

3.2. The FIREPRIME Self-protection Field Guide

3.2.1. What is this tool, and who is it designed for?

It is a field guide designed for teenagers. The activity can be used in both formal education (schools) and non-formal education (extracurricular activities, hiking groups, etc.). It consists of a questionnaire that assesses the level of self-protection of a house through the visual evaluation of different factors.

The factors considered include the location of the house in the landscape, the condition of the surrounding vegetation, the home, and the garden. In the end, a score out of 10 is obtained. Based on the score, the guide provides recommendations to reduce risk.

The activity is designed to be self-sufficient, as the guide includes all the necessary explanations for teenagers to complete the test independently.

This guide provides practical knowledge about home wildfire risk and includes an interactive exercise that allows young participants to collectively assess the preparedness level of a home. By using this guide, teenagers can better understand wildfire risk and contribute to improving safety in their communities through informed decision-making and proactive measures.

3.2.2. How was this tool developed?

The self-protection field guide was developed by Pau Costa Foundation in 2024 with the collaboration of the Technical University of Catalonia and the support of the Catalan Government (Department with competencies on forestry).

The tool has been improved specifically for FIREPRIME, reinforcing the civil protection perspective of the field guide, lining the questionnaire for teenagers with the questionnaire for homeowners, and providing more details for the autonomy of the teenagers when answering the questions.

3.2.3. How will this tool be piloted?

The FIREPRIME Self-protection field guide will be piloted in Sant Cugat (SP pilot) through the local scouts group. A wildfire challenge race will be implemented and the field guide will be one of the challenges that the scouts will have to undertake. A member of the FIREPRIME team will be at the activity in order to explain it to scouts and supervisors and to check its effectiveness.

3.3. The FIREPRIME Landscape products game

3.3.1. What is this tool, and who is designed for?

This activity addressed to teenagers connects local products with wildfire risk reduction. Participants explore how different land uses, such as cultivated fields and managed forests, help prevent wildfire propagation. The exercise highlights how choosing local products promotes land management practices that reduce wildfire risk (Figure 3).

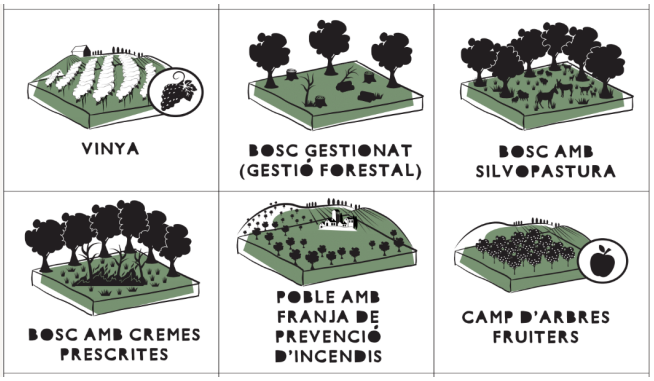

Figure 3. Example of some of the landscape products games tiles.

Participants are divided into two teams to play a game inspired by the traditional handkerchief game. Each team receives a set of tiles representing different landscape elements, such as cultivated fields, continuous forests, unmanaged forests, villages with or without fuel breaks, and others. The game is played as a relay race: one player at a time runs to a designated point, places a tile to build a collective landscape, and then runs back to allow the next team-mate to go.

In the second phase, participants analyse the landscape they have created. Using additional tiles, they identify the social benefits provided by each element, such as supporting the rural economy, offering protection, supplying food, providing energy and construction materials, or enhancing biodiversity. The team that accumulates the most benefits wins the game.

3.3.2. How was this tool developed?

The game was initially designed in 2024 with a landscape-focused approach to illustrate how food consumption influences landscape dynamics. By engaging participants in constructing different landscapes, the activity aimed to highlight the role of land use in shaping rural environments, agricultural practices, and biodiversity. Through the FIREPRIME project, the game has been adapted to emphasize the relationship between landscape management and wildfire risk, including more tiles, such as villages or fuel breaks. This new version introduces key concepts related to the wildland-urban interface, the impact of land use on fire behaviour, and the need for proactive management to reduce risk.

3.3.3. How will this tool be piloted?

The FIREPRIME landscape products game will be piloted in Sant Cugat (SP pilot) through the local scouts group. A wildfire challenge race will be implemented and the Landscape products game will be one of the challenges that the scouts will have to undertake. A member of the FIREPRIME team will be at the activity in order to explain it to scouts and supervisors and to check its effectiveness.

3.4. The FIREPRIME Fire Behaviour Game

3.4.1. What is this tool, and who is designed for?

The Fire Behaviour Game is a tool targeted to teenagers. Using a wooden board, matchsticks and cotton different fire behaviour scenarios can be demonstrated, including:

- The difference between fire spreading uphill or downhill
- The difference between crown fires and surface fires
- The effect of matchstick density on fire spread
- Effect of fuel breaks on buildings protection

Additional fire behaviour scenarios can also be explored.

The goal of this activity is to help young people learn and visually understand fire behaviour on a small scale. Ultimately, the game serves to better understand how home location and fuel management are critical factors influencing building damage, therefore, serving as a risk awareness exercise (Figure 4).

Figure 4. Fire behaviour game. The difference between a managed and unmanaged forest is clearly visible in the fire behaviour.

3.4.2. How was this tool developed?

Tool initially developed by YMCA of the Rookies association and adapted to Civil Protection purposes for FIREPRIME. The initial tool consists in a table with standing matchsticks and cotton in order to simulate

forest trees and shrubs. Using different scenarios, youngsters can easily understand different fire propagation and behaviour concepts.

This tool has been adapted for FIREPRIME including Wildland-Urban interface scenarios through a home toy model that is located in different scenarios such as with or without fuel-break, with or without forest management. Teenagers can see by themselves the importance of landscape management and fuel-breaks to ensure an appropriate home defence and avoid damages to properties.

3.4.3. How will this tool be piloted?

The FIREPRIME fire behaviour game will be piloted in Sant Cugat (SP pilot) through the local scouts group. A wildfire challenge race will be implemented and the fire behaviour game will be one of the challenges that the scouts will have to undertake. A member of the FIREPRIME team will be at the activity in order to explain it to scouts and supervisors and to check its effectiveness.

3.5. The FIREPRIME Wildfire Readiness Game

3.5.1. What is this tool, and who is designed for?

In this activity addressed to teenagers, participants are introduced to a certain wildfire scenario and must make decisions on how to respond based on official Civil Protection guidelines. They are given cards with different items or actions (Figure 5). Some of them are correct, while some others are incorrect. Participants must choose if they keep the card or not in order to overcome the situation. Afterwards, a review is conducted to discuss what was done well and what could have been improved. The goal is to help participants think critically about emergency response, self-protection during wildfires and community coordination.

Figure 5. Example of an action card from the Wildfire readiness game.

3.5.2. How was this tool developed?

This game has been specifically developed for FIREPRIME. It is based on official recommendations provided by civil protection authorities on what to do when a wildfire approaches an inhabited area.

To enhance the learning experience, the game includes both correct and incorrect action cards. These incorrect cards introduce a dynamic challenge where participants must critically assess each option and select the correct responses.

The cards have been carefully designed and formatted to improve clarity. Visual illustrations have been added to each card to provide hints about whether the action is correct or incorrect, making the game accessible to a wider audience.

3.5.3. How will this tool be piloted?

The FIREPRIME wildfire readiness game will be piloted in Sant Cugat (SP pilot) through the local scouts group. A wildfire challenge race will be implemented and the readiness game will be one of the challenges that the scouts will have to undertake. A member of the FIREPRIME team will be at the activity in order to explain it to scouts and supervisors and to check its effectiveness.

3.6. The Mediterranean Forest Fire and You Program

3.6.1. What is this tool, and who is designed for?

The Mediterranean Forest, the Fire and You (MeFiTu) is an environmental awareness initiative aimed at primary school students to educate them about the role of fire in the Mediterranean ecosystem and its relationship with humans. The initiative seeks to shift the perception of fire from being a natural disaster to understanding it as an essential ecological factor that has shaped landscapes.

The project emphasizes living with fire, focusing on prevention, self-protection, and sustainable forest management. It encourages students to understand the causes of fires, the effects of climate change, and the importance of citizen involvement in fire risk management.

MeFiTu includes interactive workshops and activities, such as:

- Audiovisual presentations explaining fire's role in history and its impact on forests.
- Origami workshops where students create trees to simulate managed and unmanaged forests and observe fire behaviour in both scenarios (Figure 6).
- Field trips to explore real-life fire-affected forest areas.

The project aims to empower students as active agents in fire prevention and self-protection, helping them to adopt a fire risk culture.

Figure 6. Controlled burn of the Mediterranean Forest Fire and You program.

3.6.2. How was this tool developed?

Mefitu first draft was created in 2005 by the Catalan Fire and Rescue Service. In 2011, the Pau Costa Foundation adopted the program, creating audiovisual content and rethinking the workshop. Through FIREPRIME, a replication guideline has been developed in order to encourage teachers and non-formal educators to use its contents to promote a risk culture among children.

3.6.3. How will this tool be piloted?

The MeFiTu will be piloted in Sant Cugat (SP pilot) through the local scouts group. The scouts group will take part of a wildfire challenge race that will equipped them with basic knowledge on fire behaviour and self-protection measures. Therefore, the teen scouts will be leading the MeFiTu activity with the younger members of the group, using the indications of FIREPRIME team. A member of the FIREPRIME team will be at the activity in order to supervise the well-functioning, as well as assessing its effectiveness.

3.7. The FIREPRIME Safe Burning Guideline

3.7.1. What is this tool, and who is it designed for?

Burning of grass litter and garden residues are common activities in Sweden and part of the rural tradition. These activities are the cause behind many of the incidents that damage buildings or injure people. The project therefore has produced flyers with five rules for safe burning practices aimed to the public and to be distributed by municipalities and the civil contingencies agency. The guidelines are also applicable to neighbouring regions with similar climate, landscapes and culture such as Norway, Finland and the Baltic states.

3.7.2. How was this tool developed?

The five rules in the guidelines are deduced from a study of thousands of incident reports with adverse consequences. The flyer is self-understood on its own but is also associated to a short document (~2 pages) explaining the background to the findings (same document as that mentioned in section 2.4.2.

3.7.3. How will this tool be piloted?

The flyer will be distributed to municipalities and county boards through the civil contingency agency. It will be also a part of the workshop in the SE pilot site in Sundsvall, where several real examples of burning activities leading to building ignitions will be discussed and disseminated.

3.8. The FIREPRIME community risk assessment checklist

3.8.1. What is this tool, and who is it designed for?

This is a checklist-based tool designed to support community-level discussions on the overall wildfire risk in their area. It takes into account key factors such as the surrounding landscape, type of wildland–urban interface, vegetation cover, topographic complexity, availability of preventive infrastructure, social vulnerabilities, and other risk-amplifying elements such as access limitations or the presence of critical or vulnerable infrastructure within the neighbourhood.

3.8.2. How was this tool developed?

This check-list has been developed based on the relevant indicators for WUI community risk assessment developed in the project WUICOM "Wildfire-resilient communities in Barcelona", executed by UPC, PCF, and UOF. It has also been inspired by similar materials from the FireSmart program

This checklist has been developed based on key indicators for WUI community risk assessment identified in the WUICOM project (*Wildfire-resilient Communities in Barcelona*), carried out by UPC, PCF, and UOC. It is also inspired by similar tools and methodologies from the FireSmart program.

3.8.3. How will this tool be piloted?

This tool will be piloted during the second Preparedness Day, scheduled for October, as part of the SP pilot in Sant Cugat. The tool will be tested by teams composed of both community members and local stakeholders, facilitating collaborative risk assessments. Its primary goal will be to enhance wildfire risk awareness among participants, while also fostering meaningful discussions and knowledge exchange within the community.

4. Resilient infrastructure stream

4.1 Wildfire risk assessments for critical infrastructures

The resilient infrastructure stream objective is to produce practical guidelines, inspired by active relevant guidelines and assessments outside Europe, that can inform and guide private companies in assessing and reducing wildfire risk to critical infrastructures in diverse European environments. To maximise the applicability of the guidelines produced, three different critical infrastructures were selected, one based in each FIREPRIME pilot site: a SEVESO industrial chemical plant in Spain, an electrical substation in Austria, and the railway system in Sweden. The selection of these infrastructure sites was conducted based on (1) industry types that are historically most closely related to wildfire damage or ignitions, (2) local relevance in the pilot sites in terms of the local wildfire risk or significant service provided to local community and (3) European relevance as all these infrastructures are common in the WUI of European countries.

The guidelines produced work on the basis of common objectives, adapted to the specific infrastructure vulnerabilities and local wildfire risk specifications. The three main objectives addressed by all wildfire risk assessments, and the information and actions included in the assessment to address those objectives, are summarised in Table 1. The guidelines are designed with a flexible format, which can be amended to be applied to a greater number of infrastructure typologies in the future, and with a European-focus, by referring to EU directives and open-source wildfire risk material developed for the European continent. The following parts of the document introduce, the general development methodology and final features that are common to all three guidelines, and then each produced assessment guideline individually.

Table 1: Wildfire Risk Assessment for Resilient Infrastructure: Objectives and Methods

Assessment Objectives	Information and Actions that support objectives
Increase the wildfire risk awareness of infrastructure managers	Provide relevant background on wildfire behaviour and wildfire ignition mechanisms.
	List the most common damage modalities due to wildfire, and wildfire ignition mechanisms for each infrastructure typology considered.
Identify wildfire vulnerabilities of their infrastructure sites	List the commonly accepted wildfire risk influencing factors for general infrastructure, and their specific infrastructure typology.
	Motivate users to obtain, score, and interpret information related to these influencing factors for their specific infrastructure location.
Provide general risk scores, and inform user on possible detailed quantitative risk analysis needs	Based on the users-defined scores for each individual wildfire risk influencing factor, a risk score using a risk matrix is provided.
	The risk scores inform the user how many of the general recommendations provided to implement, and on whether a detailed quantitative risk assessment for specific areas of their infrastructure is needed.

4.1.1 Development approach

The approach used to develop the different resilient infrastructure guidelines included reviewing existing guidelines and regulations for industry and the infrastructure typologies considered, choosing the most relevant ones for the FIREPRIME infrastructure wildfire risk assessment, communicating with the contact

persons at each infrastructure typology, and conducting specific research which informed of the relevant vulnerabilities of each infrastructure typology we considered. The information and resources considered were combined to create three separate and specialised wildfire assessments with guidelines for each infrastructure considered. Figure 7 shows the development process, with the specific aspects of the example resources considered that were selected to include in the final assessments and guidelines in a flowchart diagram.

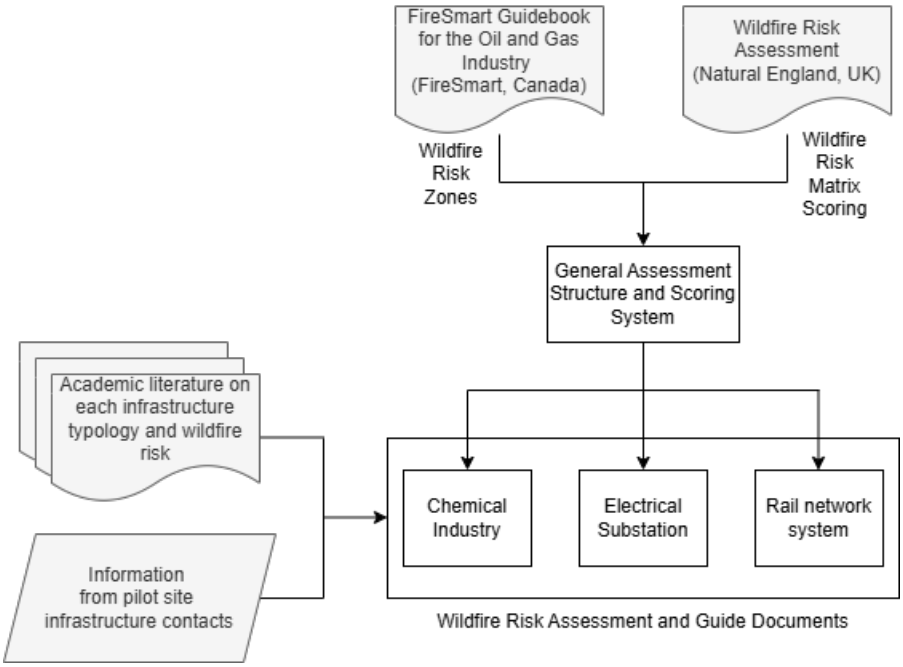

Figure 7: Flowchart outlining the development process for the wildfire assessment guidelines for the three resilient infrastructure typologies considered

In the initial stage of developing the assessment, existing guidelines and procedures to assess or reduce wildfire risk to similar types of infrastructures were identified and reviewed. Two practical and applied wildfire risk assessment resources were selected as the main inspiration for the FIREPRIME resilient infrastructure tools:

1. FireSmart Guidebook for the Oil and Gas Industry (Sustainable & Development, 2012)

   Active in: Alberta, Canada.

   Purpose: Provides a step-by-step process for assessing wildfire risks and implementing mitigation options to reduce threats and liability to the oil and gas industry. The guide is designed for industry planning engineers and safety program managers in the oil and gas sector, particularly those operating in Alberta's Forest Protection Area.

   Features implemented: Risk zoning and associated questions for some of the influencing factors.

2. Wildfire Risk Assessment and wildfire planning (Natural England, 2020)

Active in: England, UK

Purpose: Assist in identify and mitigate wildfire risk on heathlands and peatlands in England.

Features implemented: Wildfire Risk assessment methods which considers the wildfire likelihood factors and wildfire severity factors and scores the overall wildfire risk using a risk matrix.

After basing the main structure and scoring system of the wildfire risk assessments on these example resources, dedicated academic literature on the wildfire risk with each different infrastructure typology was reviewed. Furthermore, the pilot sites specific infrastructure locations were either visited, or interactions and questions to the contact person at each pilot site infrastructure location were organised. This secondary step was included to ensure to adapt the general format to include both the established infrastructure vulnerabilities to wildfire, and any specific vulnerabilities and conditions that we learned through the interaction with the pilot infrastructures considered in FIREPRIME.

The assessments produced also considered open-source European wildfire risk and industrial risk materials to further tailor the produced assessment and guidelines to the European context, and to leverage the existing research and work created for the European Union. This adaptation referenced the established European resources:

- The assessments require the use of EFFIS (European Forest Fire Information System) for wildfire risk rating calculations as one indicator question.
- The assessments, especially the one created for the chemical industry, references the Seveso III Directive (Directive 2012/18/EU) to define relevant hazardous substances identification.

4.1.2 Format of Assessments

The assessments are intended for direct employees of the infrastructure establishment, working as safety managers, safety officers, or personnel responsible for safeguarding infrastructure against various risks, particularly natural hazards like wildfires. The assessment framework aims to support users in understanding general wildfire risk and wildfire spread dynamics, assess their infrastructure site-specific vulnerabilities, and generally predict the most likely potential impacts. The assessments are designed to have a flexible format, in order to be used by a large number of different infrastructures, and therefore are limited in the level of detail and depth the assessments can provide. Recommendations provided are therefore general improvement suggestions, based on widely accepted wildfire risk-reduction measures, however each infrastructure should independently consider their potential need for quantitative risk assessments and investment in dedicated detection, protection, suppression, and reinforcement measures to address any medium and high-level wildfire exposure and vulnerabilities characteristics.

The general format of all wildfire risk assessments for the resilient infrastructures considered is illustrated in Figure 8. Each risk assessment includes two documents:

1. Guide to the Wildfire Risk Assessment – PDF with figures
2. The Wildfire Risk Assessment – Excel file with automatic calculation from the scores entered

The guide PDF document includes background information on wildfire propagation behaviour, and on the interactions between the infrastructure typology in questions and wildfire risk and damage, as well as guidance on how to fill in the assessment questions and background on how the assessment is scored,

and a summary of the recommendations provided. The assessment excel scoring includes all the relevant assessment questions, divided in four sections: two relating to estimating wildfire occurrence likelihood or probability, and two more related to estimate the potential wildfire effect severity.

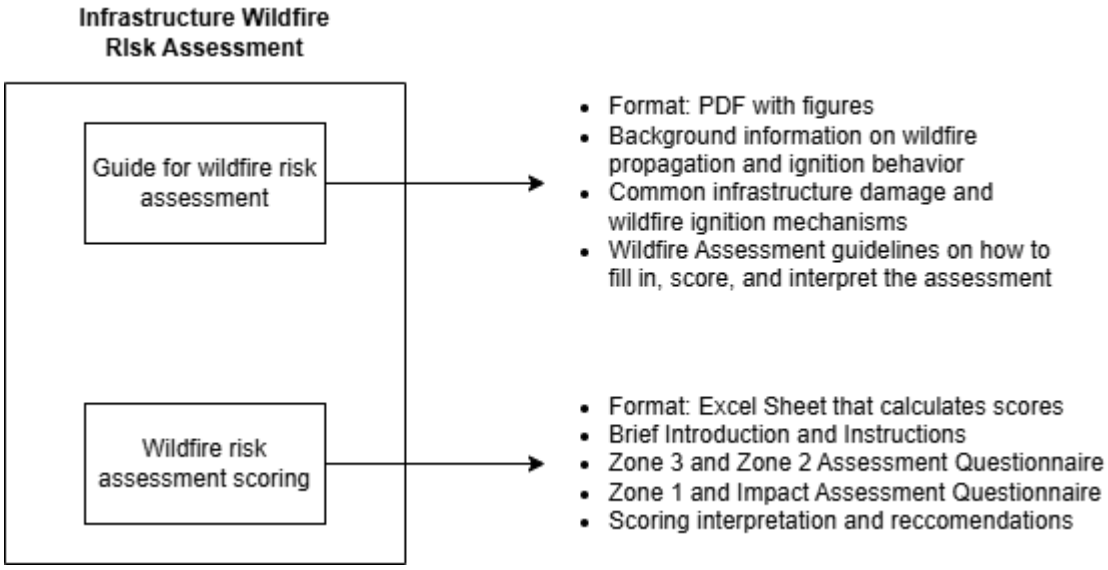

Figure 8: General format of the FIREPRIME Infrastructure Wildfire Risk Assessment

4.1.3 Scoring and Recommendations

The wildfire risk assessment procedure evaluates critical hazards and vulnerabilities within and around an industrial site. The assessment questions are divided into questions relating to four different risk-related aspects: three spatial zones related to wildfire risk and an impact section.

Wildfire Likelihood sections: The assessment classifications specified to assess the wildfire likelihood hazard in the general location are the same for the electrical substation, and the chemical industry assessment guides, and vary in the format they are applied to for the rail network infrastructure given the linear nature of train line network.

- **Zone 3:** This area covers locations more than 50 meters from the infrastructure perimeter. It includes extended environmental surroundings and wildfire ignition history, which are significant in determining the general likelihood of wildfire occurrence and intensity. The hazard calculation involves dividing the area into four quadrants surrounding the infrastructure and completing a respective table for each quadrant.
- **Zone 2:** This zone extends from 10 to 30 meters from the infrastructure perimeter. It evaluates the immediate environment's influence on the wildfire spread and related radiant heat exposure, thus influencing the probability of wildfire impact.

For point infrastructure (for example: the chemical industry, and electrical substation), the Zone 3 vulnerability is scored based on the procedure given in the FIRESMART guidelines, where the surrounding environment is divided in four quadrants, as illustrated in Figure 9, and each quadrant is assessed based on relevant characteristics and vulnerability indicators for the expected wildfire occurrence and severity. For These factors related to the presence and condition of possible wildfire fuel and possible ignition sources (vegetation, housing, and other industries). Alternatively, for linear infrastructure (rail network)

the zones distances are considered over the entire infrastructure network; relevant indicators in each zone need to be mapped out to the precision desired for the assessment and the assessment asks specific questions regarding the results of this mapping to assess wildfire risk. In the Zone 2 section of the assessment, questions refer to topographical vulnerability indicators (the slope magnitude and location of infrastructure relative to slope) and distance of the infrastructure to the forest.

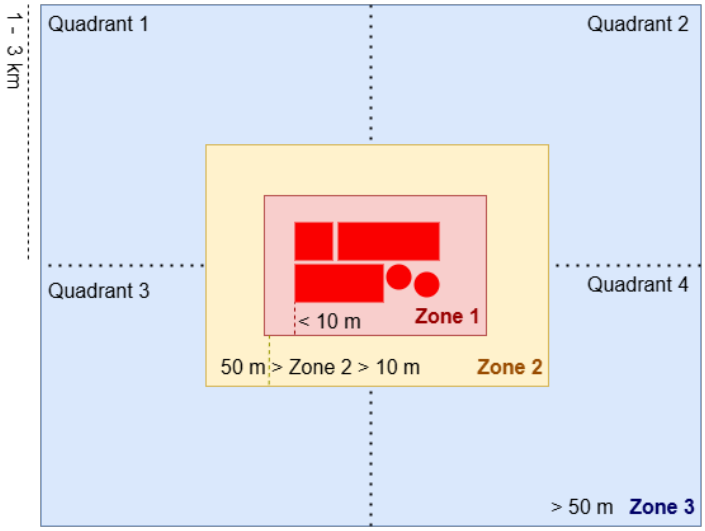

Figure 9: Diagram illustrating relative zones for assessment – adapted from (FIRESMART, 2012)

Wildfire Severity sections: The sections relating to assessing the severity of wildfire impact vary for each infrastructure typology considered as they contain specific questions relating to the infrastructure specific vulnerabilities.

- **Zone 1:** This area includes the infrastructure itself and the immediate surroundings within a 10-meter radius. The assessment focuses on the condition of the infrastructure and nearby vegetation to determine its vulnerability to ignition, influencing the severity of potential wildfire impact.
- **Impact Section:** Beyond the physical characteristics of the infrastructure and its surroundings, this section assesses potential impacts in terms of monetary losses and service disruption if a wildfire damages the infrastructure. Worst-case scenarios should be considered when answering questions in this section.

4.1.3.1 Scoring System

For each section there are specific questions relating to risk indicators that belong to each zone and three possible indicator characteristics relating to: low, medium, and high risk. The user scores each indicator based on these three descriptions which correspond to a risk score of 0, 1, or 2. Scores are summed, and normalised for each section. This results in overall scores ranging from 0 to 2 for each of the four sections described.

The scores for sections Zone 3 and Zone 2 are then added to estimate wildfire likelihood with a score ranging from 0 to 4. Similarly, the scores for Zone 1 and Impact sections are summed to evaluate factors

affecting the severity of the impact. These simple calculations are performed automatically within the Excel worksheet, and are also described in the PDF guide document in case the user wants to conduct them independently.

Once the Likelihood and Severity scores are established, they are plotted on a risk matrix to provide an overall risk interpretation. The matrix and accompanying scoring guidelines help determine the wildfire risk level and suggest appropriate mitigation measures. The risk matrix is provided in Figure 10 and the general recommendations related to the resulting overall risk scores are given in Table 2. The user is finally referred to a specific list of recommendations, classified by the subthemes of each vulnerability classification (the three zones, and impact).

		Severity (Zone 1 + Impact)			
		0 ≤ S < 1	1 ≤ S < 2	2 ≤ S < 3	3 ≤ S < 4
Likelihood (Zone 3 + Zone 2)	0 ≤ L < 1				
	1 ≤ L < 2				
	2 ≤ L < 3				
	3 ≤ L< 4				

Figure 10: Wildfire risk matrix to interpret scores for both wildfire likelihood and wildfire severity

Table 2: Wildfire risk matrix to interpret scores for both wildfire likelihood and wildfire severity

Overall Risk Score	Advice and suggestions on how to apply specific reccomendations
Low	Set up regular reviews (biannual or annual) to monitor the risk, and consider applying some reccomendations to specific sections which scored as medium or high risk.
Moderate	Set up regular reviews (biannual or seasonal) to monitor the risk, and apply reccomendations to specific sections which scored as medium or high risk.
Medium	Set up quaterly reviews to monitor the risk, apply all relevant reccomendations, consider conducting detailed wildfire risk assessments for your infrastructure site.
High	Set up quaterly reviews to monitor the risk, apply all relevant reccomendations, invest in conducting detailed widlfire risk assessments for your infrastructure site.

4.2 Wildfire risk Assessment for the Chemical Industry

4.2.1 What is this tool, and who is it designed for?

The wildfire assessment tool for the chemical industry, and piloted with the chemical storage plant located in the Spanish pilot site is created for general chemical industry plants and is heavily inspired by the

FIRESMART guidelines for the Oil and Gas Industries, developed by FIRESMART Canada. The general assessment tool is able to be used by any chemical industry, which may be classified as Seveso or not, with specific focus on the storage of hazardous substances, which is the most important vulnerability related to the potential impact of external fire ignition.

The sections of the assessment specifically tailored for the chemical industry assessment, which differ from the other infrastructure assessments, are:

Zone 1: Onsite fire spread propagation potential

Questions are tailored to the distance and amount of vegetation and thermally susceptible elements expected and likely to be found on a chemical industrial plant.

Zone 1: Onsite protection system

Chemical industries, especially if classified as Seveso establishments, all already need to comply with legislation that includes requirements of advanced fire protection systems. These questions are tailored to ask users to evaluate whether the existing protection systems are effective for wildfire exposure mechanisms.

Zone 1: Hazardous Substances and Zone 1: Hazardous Substance Storage

Sections dedicated to assess the level of hazardous substances are included in this assessment to consider the important vulnerability that hazardous and flammable substances pose to possible wildfire hazard threat.

Impact: Impact Assessment and Severity: Evacuation routes and plans

The impact assessment is tailored to the product supply disruption that is most relevant for these types of industries. Similarly, to the “Onsite protection system” section, the questions in the “Evacuation routes and plans” section are designed to ask users to think specifically to the possible impairment of their existing evacuation plans due to wildfire damage.

4.2.2 How was this tool developed?

The development of the wildfire assessment tool, in addition to the procedure described in section 1.1.1 is based on additional infrastructure-specific research and engagement.

Firstly, the tool builds upon previous research conducted at the UPC. In 2024, two wildland industrial interface (WII) fire risk workshops were conducted at Universitat Politècnica de Catalunya and Università di Bologna. The workshops’ objective was to connect professional and operational stakeholders with WII fire risk expertise to assess the WII fire risk perception and awareness in the field, and record stakeholders’ insights on key vulnerabilities, knowledge gaps, and potential approaches for effective risk assessment and mitigation. Participants included practitioners from the fire emergency services, industrial risk assessment consultancies, industrial plants, local government, and civil protection from both respective hosting regions (Catalonia, Spain and Emilia-Romagna, Italy). The information recorded from these workshops was used to inform the specific questions included in the assessment.

The development process involved a dedicated academic literature review of existing research and guidelines relevant to industrial safety. A review using Scopus and Google Scholar searching for wildfire-induced industrial Natech risk research identified a total of 14 resources - twelve academic articles specifically investigating wildfire risk to industrial installations or components, one practical best practice guideline for wildfire risk-reduction, and one policy report - published between 2012 and 2024; 85.7% of the resources were published after 2017, indicating the increasing concern of this topic. The main takeaways from this review are summarised in an accessible manner in the guide pdf document.

Additionally, a site visit was conducted, allowing for direct conversations and contact with the pilot infrastructure's safety manager and operators. This interaction provided valuable insights, further supported by a comprehensive review of their materials to ensure the tool's applicability and effectiveness.

4.2.3 How will this tool be piloted?

The infrastructure considered in the Spanish pilot site, which was consulted in the development phase and will be involved in the piloting and verification of the wildfire risk assessment, is called SVC Chemicals Storage Services S.L.U. The general details of the industrial company site operations are:

- Operations: Receival, storing, and dispatch of chemical products
- Classifies as high-tier establishment due to the type and quantity of hazardous substances it handles according to the Seveso III Directive, corresponds to RD 840/2015 in Spanish law

The piloting process will be divided in four steps:

1) **Initial meeting:** This step has been conducted on January 30th 2025. FIREPRIME researchers visited the pilot site, obtaining all necessary documentation regarding the pilot site safety plan, and hazardous substance documents and making first contact with the industry members. Based on the information retrieved, the initial wildfire assessment is developed and proposed. A general risk assessment for the industry location is also conducted by the UPC team to gain a general understanding of the wildfire risk and major vulnerabilities of the site.
2) **Sharing the assessment and testing ease of use:** The stakeholder contacts will be asked to try and apply the assessment, also the UPC team conducts the assessment separately based on the documents and information received. This ensures that relevant stakeholders understand the process and can provide initial feedback on its clarity and accessibility. It helps identify any immediate concerns before proceeding further.
3) **Evaluation of results:** The resulting scores obtained by the pilot contacts are compared with the results obtained by the UPC team. The identified vulnerabilities are presented and discussed with the pilot contacts to understand whether the identified vulnerabilities seem relevant, and if there are any vulnerabilities and threats identified that were not already identified by the standard risk assessment procedures for the industry. This step helps determine strengths and areas that may need improvement based on the assessment criteria.
4) **Discussion of applicability, improvements, and need for more in-depth analysis:** Finally, the usability of the assessment is discussed, along with the feasibility of implementing possible recommendations. Any necessary modifications are considered to enhance effectiveness. This step ensures continuous improvement and refinement of the assessment process as needed.

4.3 Wildfire risk Assessment for Electrical Substations

4.3.1 What is this tool, and who is it designed for?

The wildfire assessment tool for an electrical substation is designed for any electrical substation located in the WUI in Europe. The assessment differs from the other assessments presented by considering the most commonly identified vulnerable equipment and components in an electrical substation. Electrical substation-specific assessment questions are inspired by recommendations and found in the Utility Wildfire Mitigation Guide, created by Canadian Electricity Association (Canadian Electricity Association, 2020), and the Victorian State Government Powerline Bushfire Safety Taskforce: Final Report (Victoria State Government, 2011).

The sections of the assessment specifically tailored for the chemical industry assessment, which differ from the other infrastructure assessments, are:

Zone 1: Onsite protection system

The protection questions are inspired by the academic literature reviewed which suggests monitoring cameras as possible wildfire detection systems, especially as they relate to more isolated power grid transmission components in the wildlands.

Zone 1: Electrical Grid Component

This section includes specific questions on the electrical grid components materials and conditions which have been identified in the reviewed literature as vulnerable to wildfire hazard, as well as those common and usually present in the European Power Grid.

Impact: Impact Assessment and Severity: Evacuation routes and plans

The impact assessment is tailored to the electrical power grid, taking into account the number of households that power is provided to, and the possible need to replace fire damaged parts to start service again. The “Evacuation routes and plans” section is designed to consider the most likely number of employees and the specific challenges associated.

4.3.2 How was this tool developed?

The specific development of the electrical substation assessment involved two main actions focused on the electrical grid, and more specifically electrical substation components’ vulnerabilities to wildfire:

4.3.2.1 Review of existing tools and academic literature

A comprehensive overview of the academic literature considering the power grid vulnerabilities to wildfire, with specific focus on the already active and applied risk-reduction measures and general recommendations in affected countries was conducted.

Official recommendations from official taskforces relating to power grid wildfire were used as general guidance of possible implementable changes already to strengthen problematic power grid systems. The following are the main mitigation measure topics summarised from the Victorian Bushfires Royal

Commission Final Report (Teague et al., 2010), and the California Wildfire Mitigation Plans for public utility companies (Vazquez et al., 2022).

- **Grid design and system hardening**
  - Upgrading vulnerable components with more resistant options.
- **Vegetation management**
  - Defining safety zones around components, and vegetation management standards. Involving municipal safety plans in the utility's safety plans.
- **Asset inspections**
  - Setting inspection standards and timing: specific vulnerable equipment (e.g.: SWER, certain type of distribution lines of specific voltage levels) are set to be inspected repeatedly at a given time frame.
  - Improving training of the inspectors.
- **Situational awareness and forecasting**
  - Specific wildfire risk indexes considering the climate conditions are included in the utilities planning and safety considerations to inform grid operation and maintenance.
- **Public safety power shutoff (PSPS)**
- **Operational response**

Bandara et.al. (2023) analyse common power grid faults related to wildfires and recommend to conduct regular condition assessments of infrastructure**:** poles, crossarms, overhead cables, and other attachments, to identify potential defects More focused information relating to these grid components and their response wildfire exposure is collected to inform assessment questions.

Poles:
Damage modes due to wildfire: Poles can be damaged from approaching wildfire flames and high winds due to the thermal impact and possible falling.
Research on performance: Wildfire exposure tests conducted by Southern California Edison (SCE) at the Southwest Research Institute (SWRI) (Char et al., 2022):

- **Ductile Iron Poles:** No strength reduction; slight strength increase from annealing.
- **Concrete Poles:** Minor strength (23%) and deflection (17%) reduction.
- **Tubular Steel Poles:** No reduction in strength or deflection.
- **Fibre-Reinforced Polymer (FRP) Poles:** Composite materials that combine fibres (typically glass) with a polymer matrix.
- **Wooden Poles:** Highly vulnerable to combustion; rapid structural degradation unless treated with fire retardants.

Power Lines:
Damage modes due to wildfire:
Wildfire flame exposure can increase the conductor surface temperature, which can cause conductor sag and reduced safety vertical clearance. The resulting temperature increase can influence optimal power flow of the network and influences entire operation. In extreme cases the temperature increase can cause irreversible conductor annealing and loss of tensile strength.

Power Grid faults igniting wildfires:
Vegetation, animals, or lightning making contact with powerlines can cause improper electricity flow and generates sparks – this can occur due to vegetation falling or powerline sag to the point of contacting

vegetation. Conductor slap refers to wind causing powerlines to clash, generate molten particles or make contact with objects.

Research on performance: Experimental test of new aluminium stranded conductor steel reinforced (ACSR) 480 mm² wires, to flame exposure (direct contact, 10cm and 20cm distance from flames generated by propane gas torch) (Lee et al., 2011):

- Inner galvanized steel wires showed insignificant changes in tension load and extension rate, likely due to their internal positioning.
- The inner aluminium wires experienced minimal mechanical loss, the outer aluminium element wires showed decreased tension load and increased extension rates – by 2.68% (new wire) to 5.60% (fire-deteriorated wire).
- Results indicate proximity to heat significantly influences structural integrity.

Sayarshad and Ghorbanloo (2023) solve an optimal power flow problem incorporating the heating and cooling and conductors, coupled with wildfire spread models considering relevant landscape factors and find the following relating to power line conductors (Sayarshad & Ghorbanloo, 2023):

- The breakdown voltage reduces by up to 14% for an 11 m increase in line height.
- The breakdown voltage decreases by up to 28% for a 15 m increase in wildfire distances from power lines.
- The aging failure probability for an aluminum conductor increases over time by up to 7% when the temperature exposure increases by up to 150ºC.

Transformers:
Damage modes due to wildfire: Heat transfer from wildfire flames to transformers can induce common transformer faults, the most severe of which is transformer explosion.

Power Grid faults igniting wildfires: Transformer explosion is a known common power grid fault that has been found to ignite wildfires due to improper surrounding vegetation managements (Arab et al., 2021).

4.3.2.2 Cooperation among FIREPRIME Partners

A collaborative partnership between the UPC and BOKU FIREPRIME partner groups played a central role in the development of the risk assessment. Researchers from each institution worked closely and regularly, combining their expertise from two distinct research groups, one specialised in wildfire exposure and management (UPC) and one on natural hazard risk assessments and vulnerability assessments (BOKU). This collaboration allowed for the integration of diverse knowledge areas, leading to a more comprehensive and refined final product. By pooling their insights, the team was able to improve the assessment materials, identify additional reference sources, and incorporate both risk-based approaches and physical vulnerability considerations into the final product.

4.3.2.3 Interview of Electrical Substation contact persons

Once a preliminary draft of the assessment was completed, it was translated and shared with the pilot site contacts. This exchange provided valuable feedback on the assessment's usability, practical utility, and the general perception of risk among local stakeholders. Insights from this feedback helped inform the refinement of the assessment. Further details on this process are provided in the piloting section.

4.3.3 How will this tool be piloted?

This tool will be piloted in the Austrian study area. In Haiming (Tyrol, Austria) there are three substations (Tiwag, ÖBB and APG). Our focus is the largest of these substations (APG, Figure 11) which is located in the little pine forest (Forchet) which is in the centre of the municipality. Although no wildfire incident has been recorded in the substation, its location and importance at the local, regional and international scale makes it the right pilot for this tool.

Figure 11. The Westtirol Substation in Haiming (Tyrol, Austria) (Source: APG)

The pilot process will be divided in the following steps

1) Initial visit to check the locality and the surroundings of the substation (August 2024)
2) Collection of information regarding substations and wildfire risk assessment, similar guidelines and information regarding the specific substation in Austria (Autumn 2024)
3) Working on drafts of the guideline and assessment form together with the FIREPRIME partners (February-April 2025)
4) Meeting with the contact person of the Substation to discuss the first draft of the Guideline (Interview-April 2025)
5) Integration of feedback in the guideline and general improvements (Planned for May-June 2025)
6) Presentation of the guideline the substation contacts (planned for July 2025)
7) Finalisation of the guideline (August-September 2025)
8) Translation in German and distribution to the contacts of the substation and other interested parties

4.4 Wildfire risk Assessment for Rail Networks

4.4.1 What is this tool, and who is it designed for?

The wildfire assessment tool for the train rail network system is specifically designed for railway lines infrastructure located within the WUI; currently with a few questions specified for the temperature Europe vegetation based on stakeholder interaction, which can be easily modified for other vegetative regions in Europe. The specification to this region of Europe is due to the mention of specific flammable

vegetation of the region (flammable moss) this can be modified to be applied to vegetation in Southern Europe as well.

Unlike assessments created for other types of infrastructure, this tool considers the linear nature of railway systems and the specific vulnerabilities associated with railway tracks and surrounding vegetation. The assessment is informed by key resources Forzieri et al. (2018) on the climate-induced risks to European critical infrastructure, and the study by Nezval et al. (2022) on vegetation fires along the Czech rail network.

Given the linear and expansive layout of the rail network, the assessment is structured to evaluate risk across mapped sections of rail infrastructure. Questions related to the spatial location of infrastructure to wildland vegetation are therefore posed by prompting the user to calculate the percentage of rail length (out of the total rail length considered) where certain wildfire risk conditions are met, using a scoring system based on thresholds. An example illustrating how this is applied in the assessment, is instead of asking whether the infrastructure is located within 50m of a coniferous forests, the user is asked for what percentage of the tracks are there coniferous forests located within 50 meters. The risk scores are assigned depending on the proportion of the rail track that fits the question conditions. In the given example case the lowest risk score is given if the proportion of tracks is 0, the medium risk score of 1 is given if the proportion of tracks is under or equal to 30%, and if it is higher than 30% the highest risk score is given. This structure allows for quantifiable risk analysis across large spatial areas, capturing both the environmental and infrastructural context of railway systems in wildfire-prone zones.

In addition to the structural adaptation of the assessment questions, several key content areas have been modified to reflect the specific characteristics of the rail transport system, the nature of employees typically present along rail lines, and the potential impact on both rail customers and society at large. The updated sections include:

Zone 1: Fire Spread Potential, focusing on vegetation proximity and potential fuel loads along the railway corridor

Zone 1: Rail Infrastructure Vulnerabilities, which assesses the resilience of tracks, and conditions of trains associated with wildfire ignition

Impact: Evacuation, tailored to rail staff, maintenance crews, and passengers in isolated or high-risk areas

Impact: Impact Assessment and Severity, Addressing broader service disruption, societal dependency on rail transport, and the cascading consequences of rail system shutdowns due to wildfire events.

4.4.2 How was this tool developed?

Similarly, to the development of the electrical substation assessment, the development of the rail network assessment involved the same two development process actions, only focused on train rail vulnerabilities to wildfire and potential to ignite wildfires:

4.4.2.1 Review of existing tools and academic literature

Although a less number of academic and operational resources were identified regarding train rail wildfire safety compared to power grid wildfire safety, the following resources were identified: (Baranovskiy et

al., 2021; Mulholland and Feyen, 2021; Nezval et al., 2022; Transport Canada, 2022; Jonatan Gustafsson, 2023; Torvanger et al., 2024).

The most relevant information is summarised below, as well as in the wildfire assessment guide.

Wildfire Damage to Trains
Wildfires can cause severe damage to railway infrastructure and disrupt train operations. Key impacts include:

- **Track Buckling:** Extreme heat exposure can cause steel rails to expand and buckle, compromising track integrity and leading to potential derailments.
- **Sagging Overhead Power Lines:** For electrified train tracks, elevated temperatures can cause power lines to sag, resulting in electrical faults or power outages that disrupt rail services.
- **Reduced Visibility:** Smoke from wildfires can impair visibility, making train operations hazardous and increasing the risk of accidents.
- **Service Disruptions:** Wildfires often lead to shutdowns and delays across rail networks, significantly impacting passenger services, freight operations, and overall network reliability.

Potential Wildfire Ignitions by Trains
Trains can also act as ignition sources, particularly in dry, fire-prone areas. Key ignition mechanisms include:

- **Sparks from Braking Mechanisms:** Certain trains, especially those using cast iron brake blocks, can generate sparks due to friction between the brake block and the steel wheel. These sparks can easily ignite dry vegetation near the tracks.
- **Vegetation Contact with Power Lines:** Fires near electrified tracks can occur when vegetation makes contact with power lines due to fallen trees or branches landing on power lines, or high winds causing power lines to sway and make contact, producing molten particles that can ignite dry vegetation.
- **Exhaust Particles and Hot Surfaces:** Diesel locomotives and other rail vehicles with hot exhaust systems or undercarriage components can ignite dry plant matter on contact.

Mitigation Strategies
The assessment will provide detailed strategies for mitigating wildfire risks associated with train operations. The following are some general mitigation measures:

- **Regular Track Inspections:** Ensuring tracks are inspected and maintained regularly to detect heat-induced deformations.
- **Vegetation Management:** Clearing brush and vegetation along tracks to reduce the risk of fire ignition.
- **Use of Modern Brake Systems:** Transitioning from cast iron brake blocks to composite materials that reduce spark generation.
- **Improved Monitoring Systems:** Deploying sensors and monitoring systems to detect excessive heat, track buckling, and potential ignition sources promptly.

4.4.2.2 Cooperation among FIREPRIME Partners

A collaborative partnership between the UPC and RISE FIREPRIME partner groups played a central role in the development of the wildfire risk assessment tool for the railway network system. Researchers from each institution combined knowledge of the situation of wildfire behaviour and wildfire risk in Sweden, especially related to the train rail network – related wildfire risk, and knowledge and experience on wildfire behaviour and risk assessment development.

4.4.2.3 Interview of Train Rail contact persons

Direct contact with the train rail operators in Sweden, as well as access to a database of train rail-caused ignitions in Sweden were consulted throughout the development process. This exchange allowed local stakeholders to provide practical feedback on the tool's applicability, clarity, and relevance to their day-to-day operations. Their insights contributed significantly to refining the assessment questions and structure, ensuring that the tool was both usable and contextually appropriate. Further details on the piloting process and outcomes are available in the corresponding piloting section.

4.4.3 How will this tool be piloted?

The tool will be discussed in a joint meeting with the Swedish transport administration and the Civil contingencies agency in which this tool will be presented and compared to the existing (possibly informal) methods used today. This meeting will also highlight further actions for either background work or implementation in current systems.

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